Photosynthetic characteristics of perennial ryegrass and red fescue turf-grass cultivars

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Abstract

The photosynthetic characteristics of eleven commercial perennial ryegrass (Lolium perenne L.) and nine red fescue (Festuca rubra L.) turf-grass cultivars were evaluated. In general, perennial ryegrass had a faster growth, with higher net photosynthesis and quantum efficiency and lower dark respiration (Rd) than red fescue. Among the perennial ryegrass cultivars two major groups were observed: the first one with slow growth, high light compensation point (Ic) and low Rd and the second one with fast growth, low Ic and high Rd. A similar ranking was evident for the red fescue cultivars tested. The chewings fescue (F. rubra ssp. commutata) cultivars belonged to the first group, whereas the strong creeping red fescue (F. rubra ssp. rubra) cultivars were classified into the second group. Slender creeping red fescues (F. rubra ssp. trichophylla) had intermediate features. These variations make it possible to use some of these characteristics in breeding programmes for turf-grasses.

Introduction

In recent decades there has been an increasing demand for amenity grasses for ornamental lawns, grasslands, green areas in parks and for sports turf. In almost all situations where lawn grasses are used, they are subjected to conditions of stress. Therefore, tolerance to cutting and drought and resistance to wear are important selection criteria, besides reduced growth, persistence, sward density, winter hardiness, disease resistance, fineness of the leaf, leaf colour and coloration of cut areas (Feuerstein, 1994). One of the future challenges for the breeders of turf-grass is the development and use of cultivars with superior shade resistance. In sporting arenas shade is a significant factor in the problems associated with the loss of grass cover to the turf and with algal invasion (Newell, 1997). In parks and ornamental lawns, shade is most frequently combined with drought stress as a result of competition with trees and shrubs.

At low irradiance, common adaptive morphological responses (increased leaf area ratio, increased shoot-to-root ratio, decreased leaf thickness, reductions in mesophyll cell number and stomatal density) and a decreased photosynthetic capacity are frequently observed in grasses (Boardman, 1977; Woledge, 1977; Prioul et al., 1980; Schnyder and Nelson, 1989; Allard et al., 1991a;b; Kephart et al., 1992). Most of these studies on grass canopy photosynthesis have been related to forage grasses and optimization of dry-matter production and forage quality (Woledge et al., 1992; Kephart and Buxton, 1993), whereas physiological studies in turf grass are, as far as we know, rather limited. However, for the development of shade tolerance in turf-grass, photosynthetic characteristics (e.g. low light compensation point and high quantum efficiency) will be an important additional selection in addition to those characters mentioned above.

Therefore, the objectives of this research were to study the physiology of turf grasses and to evaluate the possible use of photosynthesis and chlorophyll a fluorescence measurements for breeding shade-tolerant turf-grass cultivars. As a first step to achieve this goal, existing commercial cultivars of perennial ryegrass and red fescue were screened in order to get a better insight into the variation of the photosynthetic characteristics among cultivars and species.

Materials and methods

Plant material

Eleven commercial cultivars of perennial ryegrass (Lolium perenne L.) and nine of red fescue (Festuca rubra
Table 1 The perennial ryegrass (Lolium perenne L.) and red fescue (chewings fescue: Festuca rubra L. ssp. commutata; strong creeping red fescue: F. rubra ssp. rubra; slender creeping red fescues: F. rubra ssp. trichophylla) cultivars used in the experiments. (Cultivars indicated with an asterisk are not commercially available.)

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Species</th>
<th>Company/institute</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bardessa</td>
<td>Lolium perenne L.</td>
<td>Barenbrug Holland</td>
<td>the Netherlands</td>
</tr>
<tr>
<td>Livonne</td>
<td>Lolium perenne L.</td>
<td>Deutsche Saatveredelung</td>
<td>Germany</td>
</tr>
<tr>
<td>RvP71245*</td>
<td>Lolium perenne L.</td>
<td>DvP</td>
<td>Belgium</td>
</tr>
<tr>
<td>Oxi*</td>
<td>Lolium perenne L.</td>
<td>DvP</td>
<td>Belgium</td>
</tr>
<tr>
<td>Renoir</td>
<td>Lolium perenne L.</td>
<td>Cebeco Zaden</td>
<td>the Netherlands</td>
</tr>
<tr>
<td>Lorina</td>
<td>Lolium perenne L.</td>
<td>Saatzucht Steinach</td>
<td>Germany</td>
</tr>
<tr>
<td>Kelvin</td>
<td>Lolium perenne L.</td>
<td>VanderHave Grasses</td>
<td>the Netherlands</td>
</tr>
<tr>
<td>Ohara</td>
<td>Lolium perenne L.</td>
<td>DvP</td>
<td>Belgium</td>
</tr>
<tr>
<td>Mervue</td>
<td>Lolium perenne L.</td>
<td>DvP</td>
<td>Belgium</td>
</tr>
<tr>
<td>Juventus</td>
<td>Lolium perenne L.</td>
<td>DLF-Trifolium</td>
<td>Denmark</td>
</tr>
<tr>
<td>Vigor</td>
<td>Lolium perenne L.</td>
<td>DvP</td>
<td>Belgium</td>
</tr>
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<td>Enjoy</td>
<td>Festuca rubra L. ssp. commutata</td>
<td>Cebeco Zaden</td>
<td>the Netherlands</td>
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<tr>
<td>Samt</td>
<td>Festuca rubra L. ssp. commutata</td>
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<td>Darwin</td>
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<td>Nevski*</td>
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</tr>
<tr>
<td>Cindy</td>
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<td>the Netherlands</td>
</tr>
<tr>
<td>Gardeoz</td>
<td>Festuca rubra L. ssp. rubra</td>
<td>KWS Kleinwanzlebener Saatzucht</td>
<td>Germany</td>
</tr>
<tr>
<td>Barskol</td>
<td>Festuca rubra L. ssp. trichophylla</td>
<td>Barenbrug Holland</td>
<td>the Netherlands</td>
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<tr>
<td>Marker</td>
<td>Festuca rubra L. ssp. trichophylla</td>
<td>Cebeco Zaden</td>
<td>the Netherlands</td>
</tr>
<tr>
<td>Barlander</td>
<td>Festuca rubra L. ssp. trichophylla</td>
<td>Barenbrug Holland</td>
<td>the Netherlands</td>
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L.) (Table 1) were sown in May 1995 in two different plots (2 m × 1 m) at the Department of Plant Genetics and Breeding (DvP), Melle, Belgium (50°59’N, 3°49’E), on a sandy-loam soil. After establishment, plots were mown weekly at a height of 3 cm. Fertilizers were applied on 15 March (0·50 of total amount), 15 June, 1 August and 15 September, with an annual rate of 150 kg ha⁻¹ N and 100 kg ha⁻¹ P₂O₅ and 75 kg ha⁻¹ K₂O. During 1996 and 1997 turf quality and colour were visually scored four times a year (in March, June, August and October) on a scale from 1 to 5 (5 = best quality or dark green). To determine turf quality an overall assessment of each plot was made that took into account sward density, fineness of the turf, regrowth after cutting and homogeneity of the plot.

For photosynthesis and fluorescence measurements, four randomly placed 15-cm-diameter cores were taken (two per plot) of each cultivar in 1997 and transplanted into plastic pots. Before measurements, these pots were maintained in a controlled environment chamber (Weiss, Balingem-Frommern, Germany) at a day/night temperature of 20/16°C. Cool, white fluorescent lamps and incandescent bulbs provided a photosynthetic photon flux density (PPFD) of 150 μmol m⁻² s⁻¹ at plant level and a 16-h photoperiod. Pots were arranged in a randomized, complete-block design with four replicates. After 1 week of acclimatization, plants were cut to a height of 3 cm above soil level and allowed to regrow. Four and 8 days after cutting, the leaf length was measured. From these data average daily growth rates (mm d⁻¹) were calculated. Photosynthesis measurements were made when the grass canopy was about 7 cm tall.

Photosynthesis measurements

Photosynthesis, at canopy level, was measured using an infrared gas analysis system, consisting of four clear acrylic (Plexiglass) cuvettes and operating in an open differential mode as described in detail by Lootens and Vandecasteele (1998). Each cuvette measured 0·41 × 0·19 m (height × diameter) (11·6 l). The air flow entering each cuvette was about 11 l min⁻¹, depending on the cuvette. The CO₂ concentration of incoming and outgoing air was continuously monitored by using an infrared gas analyser (IRGA, MK3, Analytical Development, Hoddesdon, UK). Air temperature (20°C), CO₂ concentrations (380 μl l⁻¹) and relative humidity (65%) in the cuvettes remained constant during the measurements, whereas light intensity depended on the measurements. Signals from the IRGA, thermocouples and quantum sensor (Li-Cor, Lincoln, USA) were fed to a data logger (DL-2, Delta-T, Cambridge, UK) connected to an IBM-compatible computer, which enabled the program-controlled logging of these parameters.

For the measurements, whole pots with the turf-grasses were placed in each cuvette. Dark respiration
Table 2  Summary of visual observations of turf quality during 1996 and 1997 (on a 5-point scale; 5 = best quality), leaf colour (on 5 point scale; 5 = dark green; mean of observations in 1996 and 1997) and fluorescence ratio (Fv/Fm) in 1997 for different perennial ryegrass cultivars. Data are means ± s.e. (n = 8, except for Fv/Fm, n = 4).

Table 3  Summary of visual observations of turf quality during 1996 and 1997 (on a 5-point scale; 5 = best quality), leaf colour (on 5 point scale; 5 = dark green; mean of observations in 1996 and 1997) and fluorescence ratio (Fv/Fm) in 1997 for different red fescue cultivars. Data are means ± s.e. (n = 8, except for Fv/Fm, n = 4).

Photosynthetic characteristics of turf-grass cultivars

(Rd) and photosynthesis at different PPFDs (50, 100 and 400 µmol m⁻² s⁻¹) were determined. Before measurements were taken, plants were allowed to adapt during a 30-min period at every PPFD. Afterwards, all leaf material was removed and the pots were placed in the cuvettes to determine soil respiration. The harvested leaves were dried at 80°C for 24 h before dry weight (DW) was measured. For each cultivar four different pots were measured. Dark respiration and net photosynthesis were calculated, taking into account the corrections for soil respiration, and expressed on a DW basis. Light compensation point (Lc) and quantum efficiency (Φ) were calculated by linear regression analysis using the data for dark respiration and net photosynthesis at 50 and 100 µmol m⁻² s⁻¹ (R² varied between 0·96 and 0·99) (Masarovicova, 1997).

Fluorescence measurements

Chlorophyll a fluorescence was measured with a pulse-amplitude modulation fluorometer (Model PAM-2000, Walz, Effeltrich, Germany). Minimal fluorescence (F₀) was determined after 15 min of dark adaptation, whereas maximal fluorescence (Fm) was measured after a saturation pulse of about 2300 µmol m⁻² s⁻¹ with a halogen lamp (8V/20W, Bellaphot, Osram, Munich, Germany). The fluorescence ratio Fv/Fm, with the variable fluorescence Fv = Fm − F₀, was then calculated (van Kooten and Snel, 1990).

Statistical analysis

Analysis of variance was conducted on all data using STATGRAFICS (STSC, 1987). When significant differences occurred, means were separated according to the least-significant difference LSD (P = 0·05) method.

Results

Tables 2 (perennial ryegrass) and 3 (red fescue) give the results for turf quality and leaf colour for the cultivars tested. In general, turf quality was scored higher for most cultivars in 1996 than in 1997. Among the perennial ryegrass cultivars, ‘Ohara’, ‘Mervue’, ‘Juventus’ and ‘Vigor’ were consistently evaluated with lower scores (Table 2), whereas among the red fescues the strong creeping cultivars (‘Nevski’, ‘Cindy’ and ‘Gardez’) generally had lower scores (Table 3). ‘Juventus’
(perennial ryegrass) and ‘Gardez’ (red fescue) had the darkest leaf colour of all the cultivars tested (Tables 2 and 3).

Compared with red fescue, perennial ryegrass (for turf-grass use) has a significantly higher (0.60) daily growth rate (Table 4). This was reflected in a higher quantum efficiency and net photosynthesis measured at 400 μmol m⁻² s⁻¹ and fluorescence ratio (Fv/Fm) for perennial ryegrass (L. perenne) and red fescue (F. rubra) turf-grass (data are means of all cultivars tested in the experiment ± s.e.).

Within each species significant differences between the cultivars were observed for all the variables measured, with the exception of Fv/Fm (Tables 2 and 3, Figures 1–4). In perennial ryegrass significantly higher growth rates were observed for ‘Vigor’, ‘Mervue’, ‘Ohara’ and ‘Juventus’ (Figure 1), whereas for the red fescues highest growth rates were seen in the strong creeping cultivars ‘Nevski’, ‘Cindy’ and ‘Gardez’ (Figure 1).

Based on light compensation point and dark respiration, ‘Vigor’, ‘Mervue’, ‘Ohara’ and ‘Kelvin’ were

![Table 4](image_url)

### Table 4

<table>
<thead>
<tr>
<th>Species</th>
<th>Mean ± s.e.</th>
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<th>Mean ± s.e.</th>
<th>Mean ± s.e.</th>
<th>Mean ± s.e.</th>
</tr>
</thead>
<tbody>
<tr>
<td>L. perenne</td>
<td>7.3 ± 0.25</td>
<td>0.97 ± 0.036</td>
<td>–13.3 ± 1.18</td>
<td>14 ± 1.25</td>
<td>240 ± 6.7</td>
<td>0.805 ± 0.0017</td>
</tr>
<tr>
<td>F. rubra</td>
<td>4.6 ± 0.20</td>
<td>0.75 ± 0.027</td>
<td>–8.2 ± 0.80</td>
<td>11 ± 1.14</td>
<td>180 ± 8.2</td>
<td>0.813 ± 0.0013</td>
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<td><strong>ANOVA</strong></td>
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</tbody>
</table>

**Note**: Daily growth was measured under controlled environmental conditions: 16 h photoperiod, photosynthetic photon flux density of 150 μmol m⁻² s⁻¹ and day/night temperature of 20/16°C.

NS, Non-significant; *significant at P = 0.05; **P < 0.01, using analysis of variance.
classified as cultivars with low $I_c$ and a high $R_d$, whereas the other perennial ryegrass cultivars tested had high $I_c$ and low $R_d$ values (Figure 2). A similar classification could be made for red fescue. Here the chewings fescues (‘Samt’, ‘Enjoy’ and ‘Darwin’) had the highest $I_c$ and lowest $R_d$, whereas the strong and the slender creeping red fescue cultivars were characterized by low $I_c$ and a high $R_d$ (Figure 2). For both perennial ryegrass and red fescue a negative relationship between $I_c$ and $R_d$ was observed (Figure 2).

For both species, fewer significant differences were observed for $a_c$ (Figure 3) and net photosynthesis measured at 400 $\mu$mol m$^{-2}$ s$^{-1}$ (Figure 4). Among the perennial ryegrass cultivars tested, ‘Vigor’, RvP71245 and ‘Bardessa’ had the highest $a_c$ (Figure 3) and net photosynthesis was measured at 400 $\mu$mol m$^{-2}$ s$^{-1}$ (Figure 4). For the red fescue cultivars, highest net photosynthesis was measured for ‘Samt’, ‘Enjoy’ and ‘Gardez’ (Figure 4), whereas ‘Enjoy’, ‘Marker’ and ‘Cindy’ had the highest quantum efficiency (Figure 3).

Discussion

Fluorescence measurements revealed that during the experiment all plants were in good condition, as was indicated by an $F_v/F_m$ value of about 0.8 for all cultivars, which is typically in the range of 0.75–0.85 for non-stressed plants (Bolhar-Nordenkampf et al., 1989). The growth of red fescues was generally slower than that of perennial ryegrass (Figure 1), which was also reflected in a lower quantum efficiency (Figure 3) and lower net photosynthesis (Figure 4). This is in agreement with observations in official turf-grass trials (The Sports Turf Research Institute, 1998).

In this study, values for $a_c$ of 0.97 mmol m$^{-2}$ mol$^{-1}$ g$^{-1}$ for perennial ryegrass and 0.75 mmol m$^{-2}$ mol$^{-1}$ g$^{-1}$ for red fescue (Table 4) were found. In the literature specific leaf weights (SLWs) between 30 and 60 g DW m$^{-2}$ are given for different grass species (Wilhelm and Nelson, 1985; Allard et al., 1991b; Kephart et al., 1992). SLW was not measured in our experiments, but if the range of SLWs between 30 and 60 g DW m$^{-2}$ is applied to our data then $a_c$ in our experiments varies between 29 and 58 mmol of CO$_2$ fixed per mol of incident PPFD for perennial ryegrass and between 22 and 45 mmol mol$^{-1}$ for red fescue. These figures are similar to those reported by Osborne and Garrett (1983) and Allard et al. (1991b). Also, values found for net photosynthesis at a PPFD of 400 $\mu$mol m$^{-2}$ s$^{-1}$ were in agreement with previous results (Wilhelm and Nelson,
Light saturation (PPFD between 1200 and 1500 μmol m⁻² s⁻¹) was not measured in our experiments, because we were mainly interested in the characteristics of grass cultivars at low light intensities.

The perennial ryegrass cultivars could be separated into two distinct groups based on dark respiration and light compensation point. ‘Vigor’, ‘Mervue’, ‘Ohara’ and ‘Kelvin’ had a high Rd and low Ic (Figure 2). Apart from ‘Kelvin’, these cultivars had also a strong growth (Figure 1), and turf quality was scored low (Table 2). The other cultivars all had low Rd and high Ic values (Figure 2). These cultivars, with the exception of ‘Juventus’, were slower growing ones (Figure 1) and the turf quality was scored higher (Table 2).

From all the perennial ryegrass cultivars tested, ‘Kelvin’ seems to have the most promising characteristics for selection for shade-tolerant turf-grass: a combination of good turf quality (Table 2) with the potential of good growth in shade as is expressed in a low Ic (Figure 1). The other cultivars with a low Ic (‘Vigor’, ‘Mervue’ and ‘Ohara’) scored significantly lower on turf quality (Table 2). These results are also in agreement with the fact that ‘Vigor’ was first selected as a forage grass with a fast growth and high dry-matter production, but because of its high persistency it has been used as a turf-grass for a long time (GEVES, 1997).

For the red fescue cultivars tested in our experiments the ranking, based on dark respiration and light compensation point, was generally similar. This classification was also closely linked with the subspecies to which one cultivar belonged. The three strong creeping cultivars, ‘Gardez’, ‘Cindy’ and ‘Nevski’, had a low Ic and high Rd (Figure 2) in combination with a strong growth (Figure 1), whereas the chewings fescue cultivars, ‘Enjoy’, ‘Sant’ and ‘Darwin’, had a high Ic and a low Rd (Figure 2) with a slow growth (Figure 1). These observations are in agreement with official turf-grass trials in England in which strong creeping red fescues tend to grow faster and to form a more open sward than chewings and slender creeping red fescues (The Sports Turf Research Institute, 1998). Intermediate characteristics were observed for the slender creeping red fescues.

The lower Ic found for most red fescues than that for perennial ryegrass cultivars indicates a better adaptation of red fescue to lower light intensities.

Our results also show that sufficient genetic variation in photosynthetic characteristics was available in both perennial ryegrass and red fescue for selection and

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Figure 3 Quantum efficiency (αc; mmol m⁻² mol⁻¹ g⁻¹) for different perennial ryegrass (open symbols) and red fescue (closed symbols) cultivars in relation to dark respiration (Rd; nmol CO₂ g⁻¹ DW s⁻¹). Values are means ± s.e. (n = 4).
breeding purposes. Previously, similar conclusions were made for tall fescue (*Festuca arundinacea*), and it was found that the heritability of these characteristics were large enough to facilitate progress by recurrent selection (Asay *et al.*, 1974; Wilhelm and Nelson, 1985). It will be necessary in a future approach to screen at individual plant level, instead of canopy level, in order to select turf-grass clones with the desired photosynthetic characteristics for growth in shade, namely a high $\alpha_c$ and low $I_c$. This selection on physiological traits in combination with the evaluation of field performance of the preselected clones can enhance breeding programmes for shade-tolerant turf-grass cultivars.

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**References**


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