Matter production of bentgrass (*Agrostis palustris* Huds.) and manilagrass (*Zoysia matrella* Merr.) turfs

2. Comparison of photosynthetic characteristics in both turfs under the intensive mowings

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Introduction

Frequent mowings are requisite to maintain the uniformity and high density of turf grasses. Particularly, the mowing frequency in golf course green comes up to more than one hundred times in seven months of growing period in the northern part of Kyushu Island14). High tolerance and specific growth responses to severe mowing stresses are suggested for turf grasses.

AGATA et al2). reported that canopy photosynthesis in zoysiagrass (*Zoysia matrella* Merr.) green was higher than that of bentgrass (*Agrostis palustris* Huds.) green; the former was measured in summer and the latter was measured in autumn. There were seasonal changes of aboveground dry matter production of both two species grown under the intensive mowing3). Also, the seasonal changes of canopy photosynthesis, which are the basis of dry matter production, are considered in both greens.

In this study, photosynthesis of these turfs were periodically measured for six and seven months during the growth periods, and the differences between their responses to mowing were discussed in relation to climatic factors: light intensity and air temperature.

Materials and Methods

This study was conducted at the experimental field of Kyushu University (Fukuoka, Japan) in 1990. Materials used were creeping bentgrass (*Agrostis palustris* Huds. cv. Penncross; Bentgrass), a cool season turf grass and manilagrass (*Zoysia matrella* Merr.), a warm season turf grass. The establishment and cultivation of both turfs were made by the same manner shown as in a previous paper3).

1. Measurement of photosynthesis and dark respiration

Core samples were taken up with hole cutter (10.6 cm in diameter) from turf on the pre- and post-mowing occasions every month. After soil part (2 to 3 cm in height) of the core sample was sealed with vinyl, photosynthesis and dark respiration were measured by an open system chamber method1). Metal-halide lamp was used for light source. In the first measurement, chamber temperature was adjusted at five levels from 15°C to 30°C for bentgrass and from 15°C to 35°C for manilagrass at a light intensity of 1830 μmol m⁻² s⁻¹. Dark respiration was measured immediately after measurement of photosynthesis at each temperature. In the following measurement, light intensity was changed in six steps from 1830 μmol m⁻² s⁻¹ to darkness at a constant chamber temperature at 20°C for bentgrass and 30°C for manilagrass, respectively.

2. Aboveground dry matter weight (DMW) and chlorophyll content (CHL)

After measuring photosynthesis and dark respiration, the aboveground plant part of core sample was cut with scissors and 0.3 g
(fresh weight of clippings) was used for measurement CHL. For determination of CHL Arnon method\(^4\) was used. The remnants of clippings were dried at 80°C for 48 hours in a forced-air drier to determine DMW.

Measurements of photosynthesis and growth parameters were done from February to August for bentgrass and from May to October for manilagrass. The temperature and light responses of gross photosynthesis (\(P_g\), net photosynthetic plus dark respiration rate) at pre- and post-mowing were statistically compared using the mean values calculated from all the data measured during the growing period.

3. Approximation of light response curve

Light response pattern of \(P_g\) was made an approximation with the following equation:

\[
P_g = \frac{B}{1 + A \cdot I}
\]

A and B are constant and I is the photosynthetic active radiation (PAR, \(\mu\) mol m\(^{-2}\) s\(^{-1}\)). The initial slope (Q) was obtained by differentiating \(P_g\) with respect to I.

\[
Q = \frac{dP_g}{dI}(I \to 0)
\]

Maximum \(P_g\) (\(P_{g_{\text{max}}}\)) was also defined as follow:

\[
P_{g_{\text{max}}} = \lim_{I \to \infty} P_g
\]

4. Calculation of relative efficiency of light utilization (RELU)

The multiplying Q and I is a theoretical maximum gross photosynthetic rate (\(P_g \geq 0\)) at light intensity I. RELU was estimated as the ratio of net photosynthetic rate (\(P_n\)) to \(P_g\), (RELU \(\leq 1\)).

Results and Discussion

In this experiment, canopy photosynthesis and dark respiration of turf were estimated from CO\(_2\) absorption and evolution using core sample. The response of gross photosynthetic

![Fig. 1 Effect of temperature on gross photosynthetic rate (\(P_g\)) at pre- (●, ■) and post-mowing (○, □) in bentgrass (●, ○) and manilagrass (■, □) turfs. Each plot is the meanvalue calculated from all the data measured values from February to August for bentgrass and May to October for manilagrass turfs. Obtained regression equations are as follows:

●, \(Y = -2.41 + 1.94 \cdot X - 0.038 \cdot X^2\) \(r = 0.981^{**}\)

■, \(Y = -4.90 + 1.41 \cdot X - 0.017 \cdot X^2\) \(r = 0.999^{***}\)

○, \(Y = -10.34 + 2.53 \cdot X - 0.050 \cdot X^2\) \(r = 0.980^{**}\)

□, \(Y = -9.30 + 1.60 \cdot X - 0.025 \cdot X^2\) \(r = 1.000^{***}\)

** and *** show significant level at 1% and 0.1%, respectively.
rate (Pg) per unit ground area to temperature differed greatly between bentgrass and
manilagrass turfs (Fig. 1). Like other C₄ plants°), the optimum temperature for Pg was
higher in manilagrass turf (over 30°C), while in the case of bentgrass turf (C₃ plant), it was
about 25°C. The Pg at temperature over 35°C was higher in manilagrass turf than in bent-
grass turf.

Generally, by mowing, Pg is supposed to
decrease accompanying with decreasing of
leaf area index (LAI). Table 1 shows the
mean value of dry matter weight (DMW) and
chlorophyll content (CCA) in aboveground
part at pre- and post-mowing. It was obvious
from Fig. 1 that mean decreasing ratio of Pg
by mowing had almost the same value (around
23%) at every temperature in bentgrass turf.
DMW and CCA also decreased by 22.86% an
24.20% by mowing respectively. Furthermore,
there were significant relationships between
CCA and maximum Pg (Pg_max) or dark res-
piration rate (RES) in bentgrass turf (Fig. 2).
Canopy photosynthesis is usually estimated by
the structural factors (such as leaf area and
coefficient of light extinction) and the produc-
tive capacity of a single leaf. However, be-
cause direct and accurate measurement of leaf
area is very difficult for turf grasses,
chlorophyll index (CI) has been used for anal-
ysis of their matter productivity°,°,°°. Accord-
ingly, these results of bentgrass turf support
that CI can be used as an index for showing
the influence of mowing to photosynthesis.

On the other hand, mean decreasing ratio
of CCA (46.84%) in mowed manilagrass turf
was higher than those of DMW (Table 1)
and Pg (Fig. 1). The optimum temperature
differed between pre- and post-mowing, and
the differences of Pg between pre- and post-

Table 1 Mean values of aboveground dry matter weight (DMW) and chlorophyll content (CCA and CCB°) at pre- and post-mowing in bentgrass and manilagrass.

<table>
<thead>
<tr>
<th></th>
<th>DMW (g·m⁻²)</th>
<th>CCA (g·m⁻²)</th>
<th>CCB (mg·g⁻¹)</th>
<th>Decrease of DMW (%)</th>
<th>Decrease of CCA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentgrass</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Pre-mowing</td>
<td>211.47±92.22</td>
<td>1.46±0.66</td>
<td>6.90±1.66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-mowing</td>
<td>166.05±80.34</td>
<td>1.12±0.53</td>
<td>6.72±1.36</td>
<td>22.86a°</td>
<td>24.20a</td>
</tr>
<tr>
<td>Manilagrass</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Pre-mowing</td>
<td>254.43±23.06</td>
<td>1.15±0.11</td>
<td>4.52±0.48</td>
<td></td>
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</tr>
<tr>
<td>Post-mowing</td>
<td>177.06±18.07</td>
<td>0.60±0.14</td>
<td>3.41±0.70</td>
<td>29.50a</td>
<td>46.84b</td>
</tr>
</tbody>
</table>

1) CCA, per unit ground area; CCB, per unit dry matter weight.
2) Decrease ratio by mowing.
3) *, **, *** show significant difference at 5%, 1% and 0.1% level between pre- and
   post-mowing for each turf grasses, respectively. NS shows non-significant.
4) The same letter shows non-significant difference at the 5% level.
5) ** and *** show significant difference at 1% and 0.1% level between bentgrass and
   manilagrass, respectively. NS shows non-significant.
mowing became large with increasing of temperature (Fig. 1). This indicated that it was impossible to confirm the influence of mowing on Pg by CCA (Fig. 2).

Light response patterns and the related parameters are shown in Fig. 2 and Table 2. There were no significant differences in the initial slope (Q) and RES in both turfs between pre- and post-mowing. Although the differences of Pg between pre- and post-mowing depended on light intensity, mean decreasing ratio of Pg max by mowing was around 39.8% in bentgrass and 31.8% in manilagrass turfs. In manilagrass turf, Pg max and CCA were decreased by mowing, but the decrease ratio was higher in CCA. In this experiment, the maximum relative efficiency of light utilization (RELU max) was not significantly different between pre- and post-mowing, but the light intensity at which the maximum efficiency was shown was lower at post-mowing in manilagrass turf. It has been suggested that photosynthetic response to light intensity differed between pre- and post-mowing and also photosynthetic capacity was higher at post-mowing, because of the better light-interception and high RELU max in manilagrass turf. This suggestion can be supported by the fact that Pg per chlorophyll content in manilagrass turf increased by mowing, whilst that in

![Fig. 2](image_url)

*Fig. 2* Correlations of maximum gross photosynthetic rate (Pg max, A and C) and dark respiration rate (RES, B and D) to chlorophyll content of bentgrass (A and B) and manilagrass (C and D) turfs in every month. *** and NS show significant level at 0.1% level and nonsignificant, respectively. Symbols and measuring periods are the same as those in Fig. 1.
Table 2 The parameters which consist of light-photosynthesis response curve at pre- and post-mowing in bentgrass and manilagrass turfs.

<table>
<thead>
<tr>
<th></th>
<th>Q</th>
<th>$P_{g_{\text{max}}}$</th>
<th>RES</th>
<th>$\text{RELU}_{\text{max}}$</th>
<th>$\text{PAR}_{\text{opt}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bentgrass</strong></td>
<td></td>
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<tr>
<td>Pre-mowing</td>
<td>0.028±0.005</td>
<td>60.61±31.49</td>
<td>8.47±3.53</td>
<td>0.41±0.04</td>
<td>1071.6±146.8</td>
</tr>
<tr>
<td>Post-mowing</td>
<td>0.028±0.002</td>
<td>33.24±11.61</td>
<td>8.22±2.89</td>
<td>0.26±0.04</td>
<td>1156.2±223.6</td>
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<tr>
<td></td>
<td>NS$^1$</td>
<td>*</td>
<td>NS</td>
<td>**</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Manilagrass</strong></td>
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<tr>
<td>Pre-mowing</td>
<td>0.030±0.009</td>
<td>42.74±9.46</td>
<td>10.52±1.87</td>
<td>0.27±0.09</td>
<td>1396.4±123.0</td>
</tr>
<tr>
<td>Post-mowing</td>
<td>0.023±0.010</td>
<td>26.80±7.74</td>
<td>8.51±1.92</td>
<td>0.23±0.08</td>
<td>1251.1±97.9</td>
</tr>
<tr>
<td></td>
<td>NS</td>
<td>*</td>
<td>NS</td>
<td>**</td>
<td>NS</td>
</tr>
</tbody>
</table>

All values are shown as mean±standard deviation.

1) * and ** show significant differences at 5% and 0.1% level between pre- and post-mowing for each turf. NS shows non-significant.

2) ** and NS show significant difference at 1% level and non-significant between bentgrass and manilagrass turfs, respectively.

Fig. 3 Relationships between photosynthetic active radiation (PAR) and mean gross photosynthetic rate. Symbols and measuring periods are the same as those in Fig. 1.
bentgrass turf was independent of mowing (Fig. 3).

Incidentally, mowing and artificial defoliation induce not only decrease in LAI\(^8,12,19\) but also suppress on root growth\(^5,10,11,18\). Photosynthesis of leaves are not independent of suction force and nutrient uptake intensity relating to the expanding of root system. In addition, regrowth of aboveground parts after mowing depends on the reserve nutrient in runner and stubble of plants\(^9\). As manilagrass used here has excellent water stress tolerance and avoidance\(^7\), the high productivity even under the severe mowing stress in summer can be sustained with vigorous growth of stolon and rhizome.

Reference

10) Harrison, C. M. (1931) Plant. Physiol. 6

Fig. 4 Effect of temperature on mean gross photosynthetic rate per chlorophyll content of bentgrass and manilagrass turfs. Obtained regression equation are as follows:

- ●, \( Y = -23.82 + 7.98X - 0.157X^2 \) \( r = 0.972^* \)
- ○, \( Y = -57.35 + 11.24X - 0.224X^2 \) \( r = 0.933^* \)
- ■, \( Y = -15.08 + 4.43X - 0.053X^2 \) \( r = 0.999^**** \)
- □, \( Y = -66.74 + 10.20X - 0.154X^2 \) \( r = 0.999^**** \)

* and **** show significant level at 5% and 0.1%, respectively. Symbols and measuring periods are the same as those in Fig. 1.
Creeping bentgrass (Agrostis palustris Huds.; Bentgrass) and manilagrass (Zoysia matrella Merr.) were grown under turf condition mowed at 8 mm in height. Photosynthesis, dark respiration and the growth parameters in both turfs were periodically measured from February to August for bentgrass and from May to October for manilagrass in 1990, respectively. The differences of photosynthetic characteristics between both turfs in relation to climatic factors and mowing treatment were discussed. Turf photosynthesis and dark respiration were determined by the open system chamber method with core samples taken up from turfs. The results are as follows:

Gross photosynthetic rate (Pg) in bentgrass turf decreased accompanying with decreasing of dry matter weight (DMW) and chlorophyll content (CCA) of aboveground plant part by mowing. There were significant relationships between CCA and maximum Pg or dark respiration rate in bentgrass turf. Consequently, it was possible by growth parameters to know the response of photosynthesis to mowing.

On the other hand, the decreasing ratio of Pg by mowing was less than that of CCA, and Pg per unit chlorophyll content was higher at post-mowing in manilagrass turf. This is supposed to be caused by improving light-interception with the high relative efficiency of light utilization of turf at post-mowing, indicating high adaptability of manilagrass to intensive mowing than that of bentgrass.

Key words: Core, Creeping bentgrass, Manilagrass, Mowing, Photosynthesis
ペントグラス（Agrostis palustris Huds.）とコウシュンシバ（Zoysia matrella Merr.）ターフの物質生産

2. 高頻度低刈り栽培された両種の群落の光合成能力の比較

要約

クリーピングペントグラス（Agrostis palustris Huds.；以下ペントグラス）とコウシュンシバ（Zoysia matrella Merr.）を芝地条件下で栽培管理し、ターフからサンプリングしたコアを用いて光合成速度を測定した。測定には、通気式同化箱法を用いた。ペントグラスでは、1990年2月から8月、コウシュンシバについては5月から10月にかけて測定を行い、両群落の光合成速度に対する気象要因および刈取り処理の影響について比較検討した。材料の栽培条件は、前報と同じである。以下に結果を示す。

刈取りによるペントグラス群落の総光合成速度（Pg）の低下率は、地上部の乾物重（DMW）やクロロフィル含量（CCA）の減少率と同じであった。Pgの最大値とCCAおよび暗呼吸速度との間には、有意な相関関係が認められ、光合成速度を植物体の生長パラメーターで予測することが可能であった。

一方、刈取りによるコウシュンシバ群落のPgの低下率は、CCAの減少率に比べて小さかった。コウシュンシバ群落では、刈取り後も高い相対光利用効率を示したことから、葉面積やクロロフィル含量は減少するが、植物体は刈取り後も有利な受光態勢にあることが推察された。さらにコウシュンシバでは、DMWやCCAの季節変動が小さいことから、生育期間を通じて芝地の生産態勢は安定した状態にあるものと考えられる。

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