Certain Leaf Characteristics for Four Range Grasses as Affected by Water Stress and Clipping Treatments

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Effects of water stress and clipping frequency on certain leaf characteristics of four grass species were studied at 2050m altitude at Nainital. Leaves of C₄ plants were more sensitive to water stress at this altitude as indicated by greater reduction in their biomass, total leaf area, specific leaf area, relative growth rate, leaf weight ratio, leaf area ratio and pigment concentration. Clipping frequency reduced leaf biomass more markedly in the two C₄ species. In contrast, clipped plants of all species showed greater specific leaf area, leaf weight ratio, leaf area ratio and pigment concentration under both water conditions.

Key Words: Biomass, Clipping, Leaf characteristics, Range grasses, Water stress

Introduction
Area of the leaves and pigment concentration significantly affect the photosynthetic output, which plays a key role in ecosystem functioning. The yield of plants ultimately depends upon the photosynthetic efficiency and the extent of photosynthetetic areas. According to Misra et al. (1967) and Whittaker and Garfune (1962), growth rate and dry matter production are related to total leaf area and chlorophyll content in a number of species. The present investigation was conducted to assess the influence of water stress and clipping, on certain leaf characteristics of two C₃ grasses (Lolium perenne L. and Poa pratensis L.) and two C₄ grasses (Chloris gayana Kunth. and Panicum coloratum L.) at National. (aat 2050m above mean sea level 29°24'N 79°28'E).

Material and Methods
Tiller of four species were transplanted into polyethylene pots in the beginning of July 1977 and were grown under glasshouse conditions from July to November 1977. The water holding capacity of the pot mixture was determined (Piper 1966) before the start of the experiment and after tiller transplantation. For the first two weeks the pots were watered regularly to maintain the soil water at the level of maximum field capacity. After this, soil water content in one set of pots for each species was maintained at field capacity (1 FC) while in the other set the soil was allowed to dry to a level as close as possible to half field capacity (1/2 FC). Under both conditions pots were weighed every third or fourth day and soil water was brought to the desired level (i.e. 1 FC, 1/2 FC) by adding the required amount of water. In addition to the regular weighing, soil, water content was monitored gravimetrically at frequent intervals. Pande and Singh (1981) gave further details on water conditions.

Under each water condition, plants of each species were divided into four sets (18 pots per set). One set of 18 pots in each case was treated as control (Uncipped). Out of the remaining three sets, one set each was subjected to weekly, fortnightly and monthly clipping treatments. The height of clipping varied from species to species and was fixed so as to remove 80% shoot by volume, from each plant on the basis of predetermined height volume relationships. Sampling was done fortnightly. Details of the experimental design and sampling are given in Pande and Singh (1981, 1985). Leaves from clipped and unclipped plants were collected and
divided into two equal halves by fresh weight. Of these, one half was used to determine dry weight, while the other was used for chlorophyll determination. Chlorophyll was extracted at 80% acetone and the optical density was read at 630, 645, 652 and 665nm in a spectrophotometer (Pande & Singh 1981). Total leaf area was determined by using a planimeter. The specific leaf area (cm² g⁻¹) was calculated by dividing the leaf area by leaf dry weight. The following expressions, based on Evans (1972) were used for calculating different growth analysis parameters:

i) Relative growth rate of leaf (g g⁻¹ day⁻¹)

\[
\frac{\log_{10} W_2 - \log_{10} W_1}{T_2 - T_1}
\]

where, \( W_1 \) and \( W_2 \) are dry weights (g) at time \( T_1 \) and \( T_2 \) and \( T_2 - T_1 \) number of days in the sampling interval.

ii) Unit leaf rate (g cm² day⁻¹)

\[
\frac{W_2 - W_1}{T_2 - T_1} \times \frac{\log_{10} A_2 - \log_{10} A_1}{A_2 - A_1}
\]

Where \( W_1 \) and \( W_2 \) are dry weights (g) at time \( T_1 \) and \( T_2 \), \( A_1 \) and \( A_2 \), total leaf area (cm² plant⁻¹) at time \( T_1 \) and \( T_2 \) and \( T_2 - T_1 \), the number of days in the sampling interval.

iii) Leaf weight ratio = \( \frac{LW}{W} \)

Where, \( LW = \) total leaf dry weight (g) \( W = \) total plant dry weight (g)

iv) Leaf area ratio = specific leaf area × leaf weight ratio

Results and Discussion

Leaf Biomass

Analysis of variance on leaf biomass indicated that differences due to water level, clipping frequency and sampling dates and their interactions were significant at p<0.001.

The cumulative leaf biomass increased with time in each species figure 1. In L. perenne the water stress promoted cumulative leaf biomass with the exception of unclipped plants which accumulated greater dry matter under 1 FC compared to 1/2 FC. In P. pratensis, P. coloratum and C. gayana water stress had an unfavourable effect on leaf biomass. Degree to which leaf biomass was influenced by water stress differed from species to species. Relative decrease in biomass at the final harvest due to water stress was recorded in the following order (the values represent per cent reduction in biomass under 1/2 FC as compared to corresponding values under 1 FC).

Unclipped plants – C. gayana (55%) > P. coloratum (37%) > P. pratensis (33%) > L. perenne (4%).

Monthly clipped plants – P. coloratum (40% > C. Gayana (27%) > P. pratensis (5%).

Fortnightly clipped plants – C. gayana (54%) > P. coloratum (53%) > P. pratensis (22%).

Weekly clipped plants – C. gayana (61%) > P. coloratum (53%) > P. pratensis (22%).

In monthly, fortnightly and weekly clipped plants of L. perenne there was an increase in biomass under 1/2 FC.

It is apparent from the above that leaf biomass was most adversely affected by water stress in P. coloratum and C. gayana.

Clipping treatment had in general, an unfavourable effect on the yield of leaf dry matter. The reduction in biomass became sharper (with few exceptions) with increasing clipping frequency particularly in L. perenne and P. coloratum. In P. partensis and C. gayana under 1 FC, the biomass was reduced due to clipping but the effects was almost similar in magnitude in all three clipping regimes (table 1). In the two C₃ species the reduction in biomass due to clipping was greater under 1 FC compared to 1/2 FC, while in the two C₄ species

Table 1 Percent reduction or increase (Values prefixed with + sign) in leaf biomass of four grass species under two water conditions, due to clipping frequency. Values were calculated as unclipped-clipped × 100/unclipped

<table>
<thead>
<tr>
<th>Species</th>
<th>1 FC</th>
<th>1/2 FC</th>
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<tbody>
<tr>
<td></td>
<td>Weekly Clipped</td>
<td>Fortnightly clipped</td>
</tr>
<tr>
<td>Lolium perenne</td>
<td>71</td>
<td>45</td>
</tr>
<tr>
<td>Poa pratensis</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td>Chloris gayana</td>
<td>46</td>
<td>50</td>
</tr>
<tr>
<td>Panicum coloratum</td>
<td>32</td>
<td>27</td>
</tr>
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</table>
reduction was almost equal under two water conditions.

Under 1 FC leaves of *L. perenne* were most susceptible to clipping followed by *C. gayana, P. pratensis* and *P. coloratum*. In contrast, under 1/2 FC the leaves of C3 plants were more resistant to clipping compared to the C4 species.

**Specific Leaf Area (SLA) and Total Leaf Area (TLA)**

According to Evans (1972), SLA is influenced in a complex manner by various factors, including ontogenetic drift. The SLA of the present species responded differentially to water stress and clipping treatments. Water stress adversely affected the mean SLA of each species. At the same time increasing clipping frequency in *L. perenne* (under 1 FC), *P. pratensis* and *P. coloratum* (under both water conditions) tended to increase the SLA. In *C. gayana* the effect of differential clipping frequency was not very consistent and marked (table 2). On the whole, the mean SLA was greater in clipped plants compared to unclipped plants. This is understandable since clipping induces development of new leaf tissue having thin texture. In unclipped plants the number of leaves increased, they became tough and shading by upper leaves also influenced adversely the SLA. Similar results were obtained by Briggs et al. (1920).

Evans (1972) reported that total leaf area (TLA) generally, increases with time. In the present investigation all four species conformed to this finding (figure 2). Except for *L. perenne*, the TLA was adversely affected by water stress. According to Brouwer and De Wit (1969), water stress may often show leaf expansion even before affecting the photosynthesis. Increasing clipping frequency induced TLA in the two C4 species under 1 FC and reduced the same under 1/2 FC. This effect of clipping was consistent in the two C3 species.

**Relative Growth Rate of Leaf (R<sub>L</sub>GR)**

The RGR of leaf (R<sub>L</sub>GR) in the two C3 species was either not affected markedly (*P. pratensis*) or was induced (*L. perenne*) by water stress but that of C4 species was adversely affected. Increasing clipping frequency under 1 FC reduced the RGR in *L. perenne, P. pratensis* and *C. gayana* while this adverse effect of clipping in *P. coloratum* was evident only under 1/2 FC table 2.

**Leaf Weight Ratio (LWR), Leaf Area Ratio (LAR) and Unit Leaf Rate (ULR)**

Generally, mean leaf weight ratio was adversely affected by water stress. Under both water conditions, the LWR of clipped plants was generally higher than

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Figure 2 Total leaf area (TLA) of four grass species subjected to various clipping treatments under two Soil water conditions.

- ○ Weekly clipped, △△ Fortnightly clipped
- ■■ Monthly clipped ▲▲ unclipped
<table>
<thead>
<tr>
<th>Species</th>
<th>Clipping treatment</th>
<th>Mean Specific leaf area (cm² g⁻¹)</th>
<th>Mean relative growth rate (R_L GR g⁻¹ day⁻¹)</th>
<th>Mean leaf weight ratio (LWR)</th>
<th>Mean leaf area ratio (LAR)</th>
<th>Mean unit Leaf rate (ULR: g cm⁻² × 10⁻⁵ day⁻¹)</th>
</tr>
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<tr>
<td></td>
<td></td>
<td>1 FC</td>
<td>1/2 FC</td>
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Figure 3 Chlorophyll concentration of *Lolium perenne* and *Poa pratensis* subjected to various clipping treatments under two soil water conditions: Total Chlorophyll, Chlorophyll a, Chlorophyll b.
Figure 4 Chlorophyll concentration of *Chloris gayana* and *Panicum coloratum* subjected to various clipping treatments under two soil water conditions.
that of unclipped plants (table 2). Most of the changes in LWR were brought about by changes in SLA, i.e. leaf expansion (Hughes 1959).

Values of mean LAR were higher under 1 FC compared to those under 1/2 FC. Under 1 FC increasing clipping frequency increased LAR but under 1/2 FC this was not well marked (table 2).

ULR fluctuated considerably with time in each species but generally values declined towards the end of the experimental period indicating an ageing effect. Throne (1960) has also reported that RGR, ULR and LAR decreased with time. The mean values of ULR (table 2) indicated that water stress either had no marked effect (P. pratensis) or it stimulated the ULR (L. perenne) in C₃ species. On the other hand, ULR in the two C₄ species was reduced due to water stress. In each species clipped plants had lower ULR compared to unclipped ones. However, the effect of clipping was more marked in the two C₃ species. Thus, although under 1 FC and with no clipping the C₄ species had greater ULR as well as RGR, the imposed conditions of water stress and clipping mitigated this advantage and made these plants inferior to the C₃ ones.

Chlorophyll Concentration

Changes in the total chlorophyll, Chl a and Chl b of four grasses under varying conditions of water stress and clipping are presented in figures 3-4. In L. perenne and C. gayana, the concentration of pigments generally declined with age. Under 1 FC, weekly clipped and fortnightly clipped plants of L. perenne showed maximum concentration of pigments at II harvest and monthly clipped and unclipped at I harvest (chl-b in unclipped was greater at II harvest than I harvest). Under 1/2 FC all clipped plants had maximum concentration at III harvest while unclipped at II harvest. P. pratensis, on the other hand, exhibited a much fluctuating trend under both water conditions but here again, finally concentration declined. Under 1 FC, chl a and total chlorophyll of weekly clipped plants showed peak values during I harvest; chl b had two peaks, one at I and other at II harvest. Fortnightly clipped plants also had two peaks for all pigments (III and V harvest). Monthly clipped and unclipped plants showed maximum value (with the exception of chl a of unclipped plants) at I harvest. Under 1/2 FC all clipped plants, generally, showed maximum concentration during V harvest and unclipped at I harvest. In C. gayana, under 1 FC pigment concentration of weekly and fortnightly clipped plants was greatest during I harvest and monthly clipped and unclipped under 1 FC and all plants under 1/2 FC showed maximum concentration at the time of III harvest. In P. coloratum, under both water conditions (with the exception of monthly clipped under 1 FC and weekly clipped under 1/2 FC) greatest concentration was recorded at I harvest. In this

<table>
<thead>
<tr>
<th>Species</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Chl-a</td>
<td>Chl-b</td>
</tr>
<tr>
<td>Lolium perenne</td>
<td>Weekly clipped</td>
<td>2.17</td>
<td>2.02</td>
</tr>
<tr>
<td></td>
<td>Fortnightly clipped</td>
<td>2.98</td>
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<td></td>
<td>Monthly clipped</td>
<td>2.95</td>
<td>1.90</td>
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<tr>
<td></td>
<td>Unclipped</td>
<td>1.53</td>
<td>1.69</td>
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<tr>
<td>Poa pratensis</td>
<td>Weekly clipped</td>
<td>2.17</td>
<td>1.54</td>
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<tr>
<td></td>
<td>Fortnightly clipped</td>
<td>2.18</td>
<td>1.78</td>
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<tr>
<td></td>
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<td>2.50</td>
<td>2.05</td>
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<tr>
<td></td>
<td>Unclipped</td>
<td>2.35</td>
<td>1.55</td>
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<tr>
<td>Chloris gayana</td>
<td>Weekly clipped</td>
<td>2.39</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>Fortnightly clipped</td>
<td>2.83</td>
<td>1.64</td>
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<td>1.85</td>
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<tr>
<td></td>
<td>Unclipped</td>
<td>2.17</td>
<td>1.90</td>
</tr>
<tr>
<td>Panicum coloratum</td>
<td>Weekly clipped</td>
<td>3.62</td>
<td>2.28</td>
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<tr>
<td></td>
<td>Unclipped</td>
<td>2.40</td>
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species although there was a general tendency (with some fluctuations) for pigment concentration to decline with time, this decline was marked after IV harvest in all conditions. In water stressed plants the decline after the IV harvest was much more compared to plants under 1 FC. Bokhari (1975) also observed a decline in pigment concentration with time in Western Wheatgrass and blue-grama.

Mean chl-a, chl-b, total chlorophyll and chl a/b ratios of different species under various conditions are given in table 3. It is apparent that the mean values in clipped plants (with few exceptions for pigment concentration) tended to be higher compared to those of unclipped plants. Besides, increasing chlorophyll concentration clipping also induces development of new leaf tissues rich in protein (Pande & Singh, 1985).

Rauzi Dobrenz (1970) reported that chl a was more abundant than chl b in western wheatgrass (Agropyron smithii Rydb) and blue-grama (Bouteloua gracilis). All four species in the present investigation conformed to this finding (except L. perenne under 1/2 FC). Bokhari (1975) showed that increasing the soil water increased the concentration of chlorophyll in blue-grama, a C₄ species and in western wheatgrass, a C₃ species. In the present investigation P. pratensis and two C₄ species showed a similar response (table 3). In L. perenne mean chl a and total chl of clipped plants were decreased due to water stress. Reverse was true for unclipped plants. Mean chl b also increased in each clipping treatment due to water stress.

Rauzi Dobrenz (1970) reported a higher pigment concentration in leaves of many C₄ species compared to C₃ plants. Bokhari (1975) on the other hand, found a higher concentration of pigments in western wheatgrass than in blue-grama. However, the chlorophyll did not differ markedly among the C₃-C₄ species in the present investigation.

All four species did not undergo a significant change in mean chl a/b ratio. Maximum chl a/b ratio was recorded for fortnightly and unclipped plants of C. gayana under 1/2 FC (1.93) and minimum for fortnightly clipped plants of L. perenne under 1/2 FC (0.90). These results show differences in photosynthetic efficiency in the different conditions. However, these differences are not very marked. Under 1 FC, lowest chl a/b ratio was recorded either for unclipped plants (L. perenne and C. gayana) or monthly clipped plants (P. pratensis and P. coloratum). Clipping induces development of new leaves having greater amount of chl a than chl b. In unclipped plants the leaves become mature and more rapid breakdown of chl a compared to chl b perhaps lowered this ratio. Under 1/2 FC, weekly clipped (C. gayana) or fortnightly clipped (in the remaining three species) plants showed lowest ratio. The more rapid breakdown of chl a compared to chl b under a variety of circumstances involving the decay of green plant tissue has been demonstrated by many workers (Strain 1949, Wolf & Wolf 1955, Goodwin 1958).

In conclusion, the leaves of two C₃ species were able to withstand the stresses of water and clipping in much better way than those of C₄ plants at the present altitude. There was a greater reduction in leaf biomass, relative growth rate, total leaf area, leaf area ratio, unit leaf rate and pigment concentration of two C₄ species due to water stress. Clipping frequency also reduced markedly the biomass of two C₄ species.

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