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Influence of clipping and water stress on growth performance and nutrient value of four range grasses

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Abstract. The paper examines the effect of water stress and clipping treatments on growth behaviour and nutrient value of 4 grasses, viz., *Lolium perenne*, *Poa pratensis* (both C_3 plants), *Chloris gayana* and *Panicum coloratum* (both C_4 plants).

Biomass, net production, relative growth rates were affected more markedly and adversely in the two C_4 species due to water stress. The effect of clipping varied with species and was generally more marked and adverse in two C_4 species. The C_3 plants developed higher R:S ratio under water stress. Water stress resulted in a greater decline of total non-structural carbohydrate and protein content in the two C_4 species. Clipping affected adversely the non-structural carbohydrate content and again the effect was more marked in the two C_4 species. On the other hand, protein content in shoots of all plants increased due to clipping.

Keywords. Clipping; water stress; growth performance; total non-structural carbohydrate; protein content.

1. Introduction

Under conditions of water stress growth of plants is usually reduced (Bassiri *et al* 1977; Yegappan *et al* 1982). The decrease is evidently due to decline in net assimilation brought about by the decreased water potential in the leaves (De Puit and Caldwell 1975). The effect of water stress varies with species (Brown and Blaser 1965). Further C_3 and C_4 plants respond differentially to water stress.

Defoliation is another factor affecting the persistancy of grass plants. Yield, vigour and total non-structural carbohydrate (TNC) levels of plants are drastically reduced by intensive defoliations (Trlica and Singh 1979).

In the present investigation the following 4 grass species were tested for their comparative resistance/susceptibility to water stress and defoliation (clipping treatments): *Lolium perenne* L. and *Poa pratensis* L. (C_3 plants) and *Chloris gayana* Kunth and *Panicum coloratum* L. (C_4 plants). The former two species occur naturally in this area while the latter two are being tested for introduction.

2. Methods of study

Uniform sized tillers of *L. perenne* and *P. pratensis* were collected in July, 1977 from a native sward, while those of *C. gayana* and *P. coloratum* were obtained from the experimental farm of Indo-German Agricultural Development Association (IGADA) where they had been grown for about 10 years. The tillers were transplanted into polyethylene pots filled with a 3:1 mixture of soil and farmyard manure and grown in a glass house at Naini Tal from July-November.

Temperature in the glass house ranged between 13°C and 25°C. Naini Tal is located at 2050 m above mean sea level (29°24′ N lat., 79°28′ E long.) and experiences a monsoon temperate climate (Pandey and Singh 1980).

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 period soil water content in one set of pots for each species was maintained at field capacity (1FC) while in the other set the soil was allowed to dry to a level as close as possible to half field capacity ($\frac{1}{2}$FC). Under both conditions pots were weighed every third or fourth day and soil water was brought to the desired level (i.e. 1FC and $\frac{1}{2}$FC) by adding the required amount of water. In addition to the regular weighing, soil water content was monitered gravimetrically at frequent intervals. For each species 72 pots (one plant per pot) were maintained under 1 FC and 72 under $\frac{1}{2}$FC. The variation in gravimetric water content within treatments was small (Pande and Singh 1981).

Thereafter, under each water condition, plants of each species were divided into 4 sets (18 pots per set). One set of 18 pots in each case was treated as control (unclipped). Out of the remaining 3 sets, one set each was subjected to weekly, fortnightly and monthly clipping treatments. First clipping was identified as time zero. 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. The clipping height from the base of the tiller was: *L. perenne* 6·6 cm, *P. pratensis* 7·0 cm, *C. gayana* 7·0 cm and *P. coloratum* 9·6 cm. The clipped material was oven-dried and weighed on each treatment date.

Three plants from each treatment were selected at random for harvest at time zero and subsequently at 15-day intervals for about 80 days. The harvested plant material was separated into component parts (leaf, stem, crown and root), oven dried at 80°C and weighed. Crown in each tiller represented a 5 cm long segment (from the point of rooting upwards) in *C. gayana* and *P. coloratum* and a corresponding 3 cm long segment in *L. perenne* and *P. pratensis*. The significance of separating crown lies in the fact that these basal parts of grass tillers often serve as storage organs. In this paper shoot weight in *L. perenne* and *P. pratensis* was the sum of cumulative leaf weight and crown weight, while the same in *C. gayana* and *P. coloratum* was the sum of cumulative weights of leaf and stem plus the weight of crown. The weight of the material clipped between the sampling dates s_1 and s_2 was added to the shoot weight for the sampling date s_2. Relative growth rates were calculated following Evans (1972).

TNC of shoots, roots and crowns were determined following Smith (1969). The nitrogen content was determined for shoots only, following Piper (1944). Protein content was then calculated by multiplying N content by 6·25. Chemical analysis of plant material was done at I, IV and VI harvests. Each analysis was replicated thrice. For chemical analysis, shoot refers to leaves in *L. perenne* and *P. pratensis* and to leaves + stem in *C. gayana* and *P. coloratum*.

3. Results and discussion

3.1 *Plant biomass*

Total biomass tended to increase with time attaining the highest value at final harvest (figure 1). Water stress had an unfavourable effect on it in all cases. Generally, the

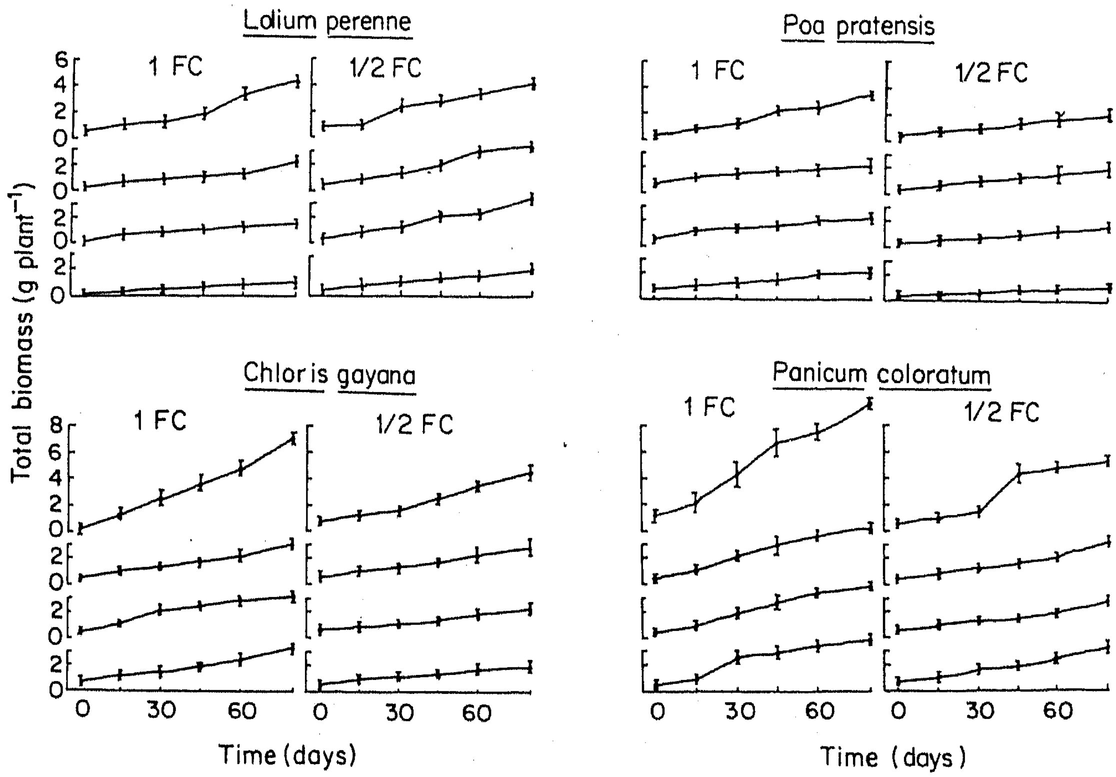

Figure 1. Cumulative dry matter yield of whole plant of four grass species subjected to various clipping treatments under two soil water conditions. In each case the curves from top to bottom represent respectively; unclipped, monthly clipped, fortnightly clipped and weekly clipped plants. Vertical bars represent ± 2 SE (total length of bar = 4 SE).

reduction in biomass was maximum for weekly clipped plants followed by fortnightly clipped, monthly clipped and unclipped plants.

Table 1 indicates the degree to which water stress affected the cumulative total biomass and biomass of different organs. The adverse effect of water stress on total biomass of unclipped, monthly clipped and fortnightly clipped plants was comparatively greater in magnitude in two C_4 species followed by *P. pratensis*, while in weekly clipped plants, the maximum reduction occurred in *C. gayana* followed by *P. coloratum*. *L. perenne* either showed least reduction in total biomass (unclipped) or increased biomass (all clipping regimes) under ½FC. Water stressed, monthly clipped plants of *P. pratensis* also accumulated greater biomass on the final harvest compared to 1 FC. This suggests that the two C_4 species were more severely affected by water stress than the two C_3 species. Similar results were obtained by Carrol (1943) and Boyer (1970).

Shoot biomass, in general, was most adversely affected by water stress in *P. coloratum* while the root biomass was most adversely affected in this species and in *P. pratensis* (table 1). In *L. perenne*, with the exception of unclipped plants, the root biomass was higher under ½FC. This was perhaps due to some stimulation of root growth by slight moisture stress as has been reported for certain other species (Eaton 1942; Jarvis 1963).

Table 2 shows the adverse effect of clipping on biomass. The reduction in biomass in all organs became sharper with increasing clipping frequency, particularly in *L. perenne* and *P. coloratum*. In the two C_3 species the reduction in biomass due to clipping was greater under 1 FC compared to ½FC, while in the C_4 species the reduction was almost

Table 1. Per cent reduction or increase (values prefixed with + sign) in total biomass and biomass of different organs in the 4 species under different clipping regimes, due to water stress. Values are calculated as $\frac{1\,FC - \frac{1}{2}FC}{1\,FC} \times 100$.

Species	Clipping treatment	Total biomass	Shoot	Root
L. perenne	Weekly clipped	+159	+116	+586
	Fortnightly clipped	+ 82	+ 56	+258
	Monthly clipped	+ 54	+ 46	+ 88
	Unclipped	11	5	18
P. pratensis	Weekly clipped	51	53	40
	Fortnightly clipped	27	22	58
	Monthly clipped	+ 2	3	+ 44
	Unclipped	41	29	58
C. gayana	Weekly clipped	55	50	+ 38
	Fortnightly clipped	35	42	+ 93
	Monthly clipped	8	11	+ 16
	Unclipped	39	45	+ 7
P. coloratum	Weekly clipped	39	41	15
	Fortnightly clipped	51	51	44
	Monthly clipped	43	46	37
	Unclipped	48	46	54

The effect of species and treatments (water level and clipping) was significant ($P < 0{\cdot}01$) in all cases.

Table 2. Per cent reduction or increase (values prefixed with + sign) in biomass of different organs in the 4 species under two water conditions, due to clipping frequency. Values are calculated as $\frac{\text{Unclipped} - \text{clipped}}{\text{Unclipped}} \times 100$.

		1 FC			½FC		
Species	Clipping treatment	Total biomass	Shoot	Root	Total biomass	Shoot	Root
L. perenne	Weekly clipped	82	71	96	48	44	69
	Fortnightly clipped	65	45	90	29	10	56
	Monthly clipped	50	27	79	13	+14	52
P. pratensis	Weekly clipped	44	18	85	50	46	75
	Fortnightly clipped	42	22	75	30	24	75
	Monthly clipped	44	21	82	5	+ 7	37
C. gayana	Weekly clipped	53	50	78	58	54	73
	Fortnightly clipped	60	56	83	57	53	69
	Monthly clipped	59	58	63	47	33	61
P. coloratum	Weekly clipped	46	35	82	37	28	67
	Fortnightly clipped	43	31	81	47	25	77
	Monthly clipped	32	20	69	26	17	58

equal under the two water conditions. Under 1 FC, *L. perenne* was most susceptible to clipping followed by *C. gayana*, *P. pratensis* and *P. coloratum*. In contrast, under ½FC the C_3 plants were more resistant to clipping compared to C_4 plants. In all 4 species clipping affected the root system more adversely compared to shoot system. It was suggested that frequent clipping and consequent recovery allows little time for the manufacture of surplus photosynthate, hence downward translocation is limited. This results in the reduction of root growth (Bokhari and Singh 1974). Detling *et al* (1979) and Painter and Detling (1981) also observed that increased frequency of clipping reduces root yield.

In all 4 species under both water conditions the root: shoot ratio (R:S ratio) of unclipped plants was generally higher than of clipped ones during most of the experimental period (figure 2). In *L. perenne* and *C. gayana* (also in *P. pratensis* except for the last 3 samplings) water stress resulted in a relatively greater accumulation of dry matter in roots. In *P. coloratum* the effect of water stress on R:S ratio was not marked. However, at most harvests the clipped plants had a higher R:S ratio under ½FC. Several workers reported an increase in R:S ratio under water stress (Black 1968; Struk and Bray 1970). According to Loomis *et al* (1971), the water stress slows shoot growth more and sooner than it does root growth. Increasing clipping frequency under both water conditions tended to reduce the R:S ratio. Evidently clipping suppressed root growth more than the shoot growth.

Unclipped C_3 plants had a greater R:S ratio compared to the unclipped C_4 plants (figure 2). The higher R:S ratio is thought to be conducive to drought tolerance (Maximov 1929; Parker 1968).

3.2 *Net production*

The mean values for net production (cumulative dry weight at the final harvest minus the initial dry weight) are given in table 3. In *L. perenne* the total net production of water stressed plants (in all clipping treatments) was greater than in 1 FC. In contrast in other species (monthly clipped plants of *P. pratensis* being an exception) it decreased due to water stress.

Generally, net production decreased by increasing clipping frequency (table 3). Compared to the unclipped plants, the clipped plants of all 4 species under 1 FC exhibited lower net production. The root production was comparatively more adversely affected by clipping compared to the shoot production. In the water stressed C_3 plants the reducing effect of clipping was of a smaller magnitude. In contrast, in the two C_4 species, generally, the clipping frequency affected net production to the same degree under both water conditions. For example, total net production of weekly and fortnightly clipped plants in *C. gayana* under 1 FC was reduced by 62% and 65% and under ½FC by 61% and 64% respectively.

3.3 *Relative growth rate*

The relative growth rate on shoot (R_SGR) and root (R_RGR) in all species fluctuated considerably with no consistent temporal pattern except for the fact that in majority of cases the rate declined towards the end of the experimental period.

The mean values of R_SGR (table 4) indicate that the water stress had an adverse effect on the two C_4 species. In the two C_3 species the water stress tended to induce the R_SGR

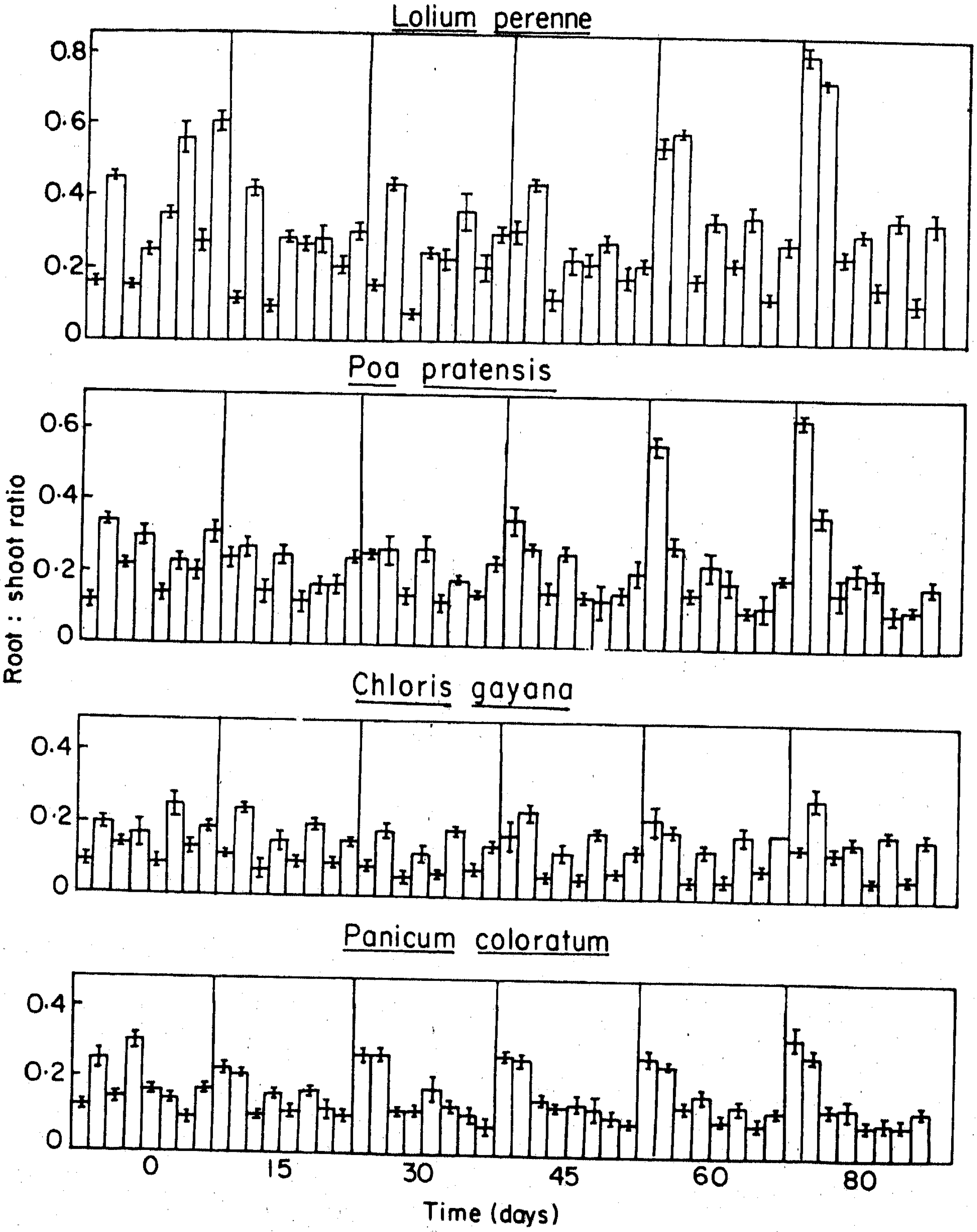

Figure 2. Root: shoot ratio of four grass species subjected to various clipping treatments under two soil water conditions. For each harvest, the bars from left to right represent: unclipped under 1 FC, unclipped under ½FC, monthly clipped under 1 FC; monthly clipped under ½FC, fortnightly clipped under 1 FC, fortnightly clipped under ½FC, weekly clipped under 1 FC and weekly clipped under ½FC. Vertical bars represent ± 1 SE (total length of bar = 2 SE).

Table 3. Net production of different species during the experimental period under different treatments (g plant^{-1}).

	1 FC			½FC		
	Shoot	Root	Total	Shoot	Root	Total
L. perenne						
Weekly clipped	0·48	0·02	0·50	1·17	0·31	1·48
Fortnightly clipped	1·04	0·10	1·14	1·70	0·52	2·22
Monthly clipped	1·38	0·35	1·73	2·10	0·65	2·75
Unclipped	1·83	1·82	3·65	1·75	1·34	3·06
P. pratensis						
Weekly clipped	1·19	0·08	1·27	0·53	0·04	0·57
Fortnightly clipped	1·14	0·26	1·40	1·06	0·08	1·14
Monthly clipped	1·27	0·15	1·42	1·39	0·28	1·67
Unclipped	1·79	1·32	3·11	1·24	0·46	1·70
C. gayana						
Weekly clipped	2·49	0·11	2·60	1·17	0·18	1·35
Fortnightly clipped	2·23	0·11	2·34	1·08	0·17	1·25
Monthly clipped	2·16	0·26	2·42	1·78	0·28	2·06
Unclipped	5·85	0·84	6·69	2·65	0·80	3·45
P. coloratum						
Weekly clipped	4·31	0·39	4·70	2·37	0·28	2·65
Fortnightly clipped	4·72	0·41	5·13	2·01	0·19	2·20
Monthly clipped	5·57	0·70	6·27	2·97	0·36	3·33
Unclipped	6·43	2·33	8·76	3·53	1·08	4·61

except for unclipped plants of both species, and weekly clipped plants of *P. pratensis*. The effect of clipping was not consistent and marked.

Water stress had a stimulatory effect on the mean R_RGR of all clipped plants of *L. perenne* and in weekly clipped plants of *C. gayana* (table 4). In other plant treatments it reduced the R_RGR. Increasing clipping frequency also reduced the mean R_RGR in all cases.

In general, the R_SGR : R_RGR ratio indicated that clipping shifted the balance between shoot and root growth so as to favour the former more strongly. This is in conformity with the observations of other workers such as Kleinendorst and Brouwer (1969) and Davies (1974). This tendency was more strongly realised under 1 FC and more markedly in *L. perenne* and *C. gayana*. Although there was no equanimity in the response of different components to water stress, the RGR at the whole plant level (R_WGR) was reduced except for clipped plants of *L. perenne* and the fortnightly and monthly clipped plants of *P. pratensis*, in the latter cases water stress stimulated the R_WGR (table 4). Thus growth rates of the C_4 plants were more severely affected by water stress. Clipping treatments generally reduced the R_WGR under both water conditions except for *P. coloratum*, where the effect of clipping was not consistent.

3.4 *Total non-structural carbohydrate*

In all species the unclipped plants continued to accumulate TNC throughout the study indicating storage of reserves as the plants mature (figure 3). These results agree with the earlier reports (Trlica and Cook 1972; Mooney 1972).

Table 4. Effect of water stress and clipping on relative growth rates (R_SGR, R_RGR and R_WGR) (as mean across all sampling intervals) of four grass species.

Species/clipping treatment	Mean relative growth rate of shoot (R_SGR; g g^{-1}day^{-1})		Mean relative growth rate of root (R_RGR; g g^{-1}day^{-1})		Mean relative growth rate of whole plant (R_WGR; g g^{-1}day^{-1})	
	1 FC	½FC	1 FC	½FC	1 FC	½FC
L. perenne						
Weekly clipped	0·016±0·005	0·021±0·010	0·004±0·001	0·013±0·003	0·014±0·004	0·019±0·006
Fortnightly clipped	0·022±0·010	0·026±0·009	0·011±0·003	0·019±0·005	0·020±0·009	0·024±0·007
Monthly clipped	0·020±0·006	0·024±0·005	0·025±0·006	0·027±0·009	0·015±0·005	0·020±0·005
Unclipped	0·021±0·008	0·020±0·011	0·040±0·009	0·025±0·007	0·026±0·007	0·022±0·010
P. pratensis						
Weekly clipped	0·012±0·004	0·012±0·002	0·007±0·003	0·005±0·003	0·013±0·004	0·011±0·002
Fortnightly clipped	0·014±0·006	0·020±0·005	0·018±0·004	0·010±0·002	0·015±0·006	0·019±0·004
Monthly clipped	0·017±0·008	0·023±0·005	0·012±0·004	0·019±0·006	0·016±0·008	0·022±0·006
Unclipped	0·021±0·008	0·019±0·006	0·042±0·012	0·021±0·004	0·028±0·007	0·021±0·006
C. gayana						
Weekly clipped	0·021±0·005	0·019±0·009	0·011±0·004	0·017±0·005	0·018±0·004	0·019±0·009
Fortnightly clipped	0·024±0·011	0·016±0·006	0·017±0·009	0·012±0·005	0·023±0·010	0·015±0·006
Monthly clipped	0·024±0·006	0·020±0·006	0·018±0·007	0·018±0·005	0·023±0·006	0·019±0·006
Unclipped	0·041±0·016	0·021±0·004	0·049±0·010	0·024±0·009	0·041±0·015	0·021±0·007
P. coloratum						
Weekly clipped	0·028±0·012	0·022±0·007	0·029±0·015	0·015±0·004	0·028±0·010	0·021±0·006
Fortnightly clipped	0·034±0·012	0·019±0·005	0·029±0·012	0·016±0·008	0·033±0·011	0·019±0·005
Monthly clipped	0·035±0·011	0·026±0·005	0·033±0·010	0·017±0·007	0·035±0·012	0·024±0·004
Unclipped	0·028±0·008	0·026±0·010	0·042±0·014	0·038±0·017	0·034±0·009	0·028±0·012

The effect of species and treatments (water level and clipping) was significant at $P < 0·05$ in all cases.

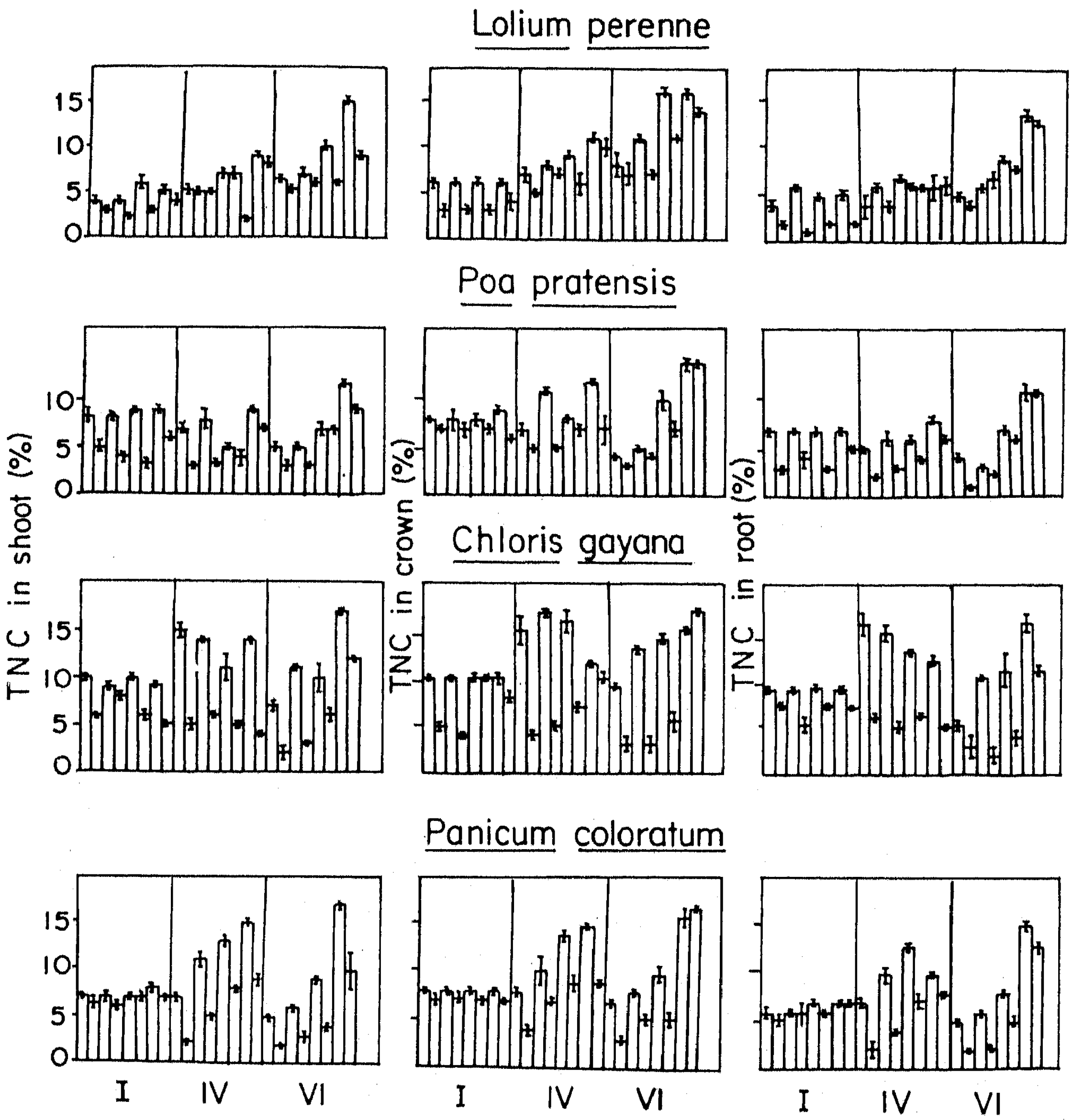

Figure 3. TNC content of different organs of 4 species subjected to various clipping treatments under two soil water conditions. For each harvest the bars from left to right represent: weekly clipped under 1 FC, weekly clipped under ½FC, fortnightly clipped under 1 FC, fortnightly clipped under ½FC, monthly clipped under 1 FC, monthly clipped under ½FC, unclipped under 1 FC and unclipped under ½FC. Vertical bars represent ± 1 SE (total length of bar = 2 SE).

The clipping treatments interfered with this general pattern and the clipped plants did not have as much opportunity to replenish their reserve by the end of the growth cycle as the unclipped plants. Under 1 FC root, shoot and crowns of clipped plants of the two C_4 species exhibited an initial increase in the TNC content followed by a decline. Similar trend was observed in big sagebrush (*Artemisia tridentata*) by Coyne and Cook (1970). In other cases such as root and shoots of monthly clipped plants of *P. pratensis* under 1 FC the TNC content declined initially and thereafter, these organs replenished the reserve. According to literature reviewed by Jameson (1963), early decline in carbohydrates in perennial plants is apparently caused by their utilization in the production of new leaves. Another temporal pattern was observed in severely clipped plants of the C_4 species under $\frac{1}{2}$FC and *P. pratensis* under both water conditions; the TNC content tended to decline rapidly with time.

Table 5 indicates that generally, water stress adversely affected the TNC content of different organs. The decline in TNC content due to water stress was much more marked in the two C_4 species than in the two native C_3 species and in severely clipped plants than in moderately clipped plants. The effect of water stress on carbohydrate reserves depends upon the species involved, the growth stage and the environmental factors (Bokhari and Dyer 1974). Perhaps a lesser decrease in TNC due to water stress in C_3 compared to C_4 plants indicates greater adaptability of the former to water stress conditions.

Clipping also caused a reduction in the TNC level (table 5). The reduction was greater in severely clipped compared to moderately clipped plants. Clipping caused more reduction in the TNC levels of water stressed plants. Generally, again the water stressed C_4 plants suffered the adverse effect of clipping on TNC more than the water stressed C_3 plants. The level of reduction due to severe clipping was greater for crowns and roots than for shoots. Evidently the amount of assimilates produced by the remaining leaf

Table 5. Effect of water stress (per cent decrease in TNC content relative to 1 FC value at the final harvest) and clipping (per cent decrease in TNC content relative to unclipped value at the final harvest) on TNC accumulation of 4 grass species.

Species/ clipping treatment	Effect of water stress			Effect of clipping: 1 FC			Effect of clipping: $\frac{1}{2}$FC		
	Shoot	Crown	Root	Shoot	Crown	Root	Shoot	Crown	Root
L. perenne									
Weekly clipped	15	17	26	57	50	62	42	53	70
Fortnightly clipped	14	35	0	53	31	60	36	49	50
Monthly clipped	40	28	15	34	2	35	36	20	40
Unclipped	37	12	7	–	–	–	–	–	–
P. pratensis									
Weekly clipped	43	39	76	61	70	62	69	81	91
Fortnightly clipped	27	20	25	62	66	71	62	72	77
Monthly clipped	6	29	21	43	28	35	26	47	45
Unclipped	28	4	5	–	–	–	–	–	–
C. gayana									
Weekly clipped	73	68	49	60	42	66	83	86	75
Fortnightly clipped	77	81	78	36	11	33	77	87	78
Monthly clipped	42	60	63	46	8	29	52	71	62
Unclipped	35	0	34	–	–	–	–	–	–
P. coloratum									
Weekly clipped	57	57	60	72	54	69	77	88	86
Fortnightly clipped	53	30	65	68	51	62	74	69	86
Monthly clipped	56	44	40	52	40	49	63	71	65
Unclipped	42	0	14	–	–	–	–	–	–

TNC content in different organs of 4 species varied significantly with time, water level and clipping frequency ($P < 0.01$).

area on severely clipped plants may be sufficient only for stimulated shoot growth. This will leave very little to be translocated to crowns and roots (Bokhari and Singh 1974). Perry and Chapman (1974) and Ogden and Loomis (1972) also indicated a severe depletion of carbohydrate reserves following clipping in basin wild rye (*Elymus cinerus*) and intermediate wheatgrass (*Agropyron* sp.), respectively.

Generally, crowns had greatest TNC content in all 4 species in this investigation. Sosebes and Wiebe (1971) believed that increased accumulation of reserves in perennating organs such as crowns might be an effective survival mechanism, allowing plants to utilize reserves for increased growth when environmental conditions improved.

3.5 *Crude protein*

Protein content in shoots of 4 grass species under two soil water conditions and various clipping regimes is given in figure 4. Water stress also had a depressing effect on protein content of shoots in all four species (table 6). Bonner (1950) argued that water stress may induce proteolysis in leaves. Protein hydrolysis has also been reported in other plants subjected to water stress (Kemble and Macpherson 1954; Parker 1969).

Mall and Singh (1977) reported that increasing clipping frequency increased the protein content of *Themeda triandra.* According to them, frequent clipping which prevents plants from becoming overmature, increases the protein content at the expense of yield. In the present study also protein content in shoots of all 4 species increased in clipped plants (table 6). This increase was pronounced in the severely clipped compared to the moderately clipped plants. Further, the water stressed plants subjected to severe clipping accumulated more protein compared to the water stressed unclipped plants. The behaviour of protein content was thus reverse of TNC content. Besides increasing the protein content, clipping also resulted in greater relative leaf weight in mature plants. In table 7 the mean leaf weight as per cent of total plant dry weight in unclipped and weekly clipped plants of the 4 grasses are compared at final harvest. It is evident that the proportion of leaves was much more in the clipped plants compared to the unclipped plants. Thus the plants which underwent defoliations had relatively more leafy material rich in protein. Thus clipping also increases the potential growth period of the plant if no other factor is limiting because of the stimulated new leaf initiation and growth (Bokhari and Singh 1974).

4. Conclusions

It may be concluded from the above that the overall performance of C_3 species was much superior compared to C_4 plants. The present C_3 species were shown to develop a greater amount of water saturation deficit (WSD) and showed a comparatively greater amount of leaf rolling under conditions of water stress compared to C_4 plants (Pande and Singh 1981). The two C_3 plants were thus able to withstand the stress of water and clipping in a much better way than the C_4 plants. These results are in contrast to the general belief that the C_4 species have a greater drought resistance than C_3 species (see Singh *et al* 1980). Perhaps the C_4 plants possess a competitive advantage over C_3 plants only under conditions of high temperature and intermittent water stress (Doliner and Jolliffe 1979), while in a low temperature region at high altitudes, such as Naini Tal,

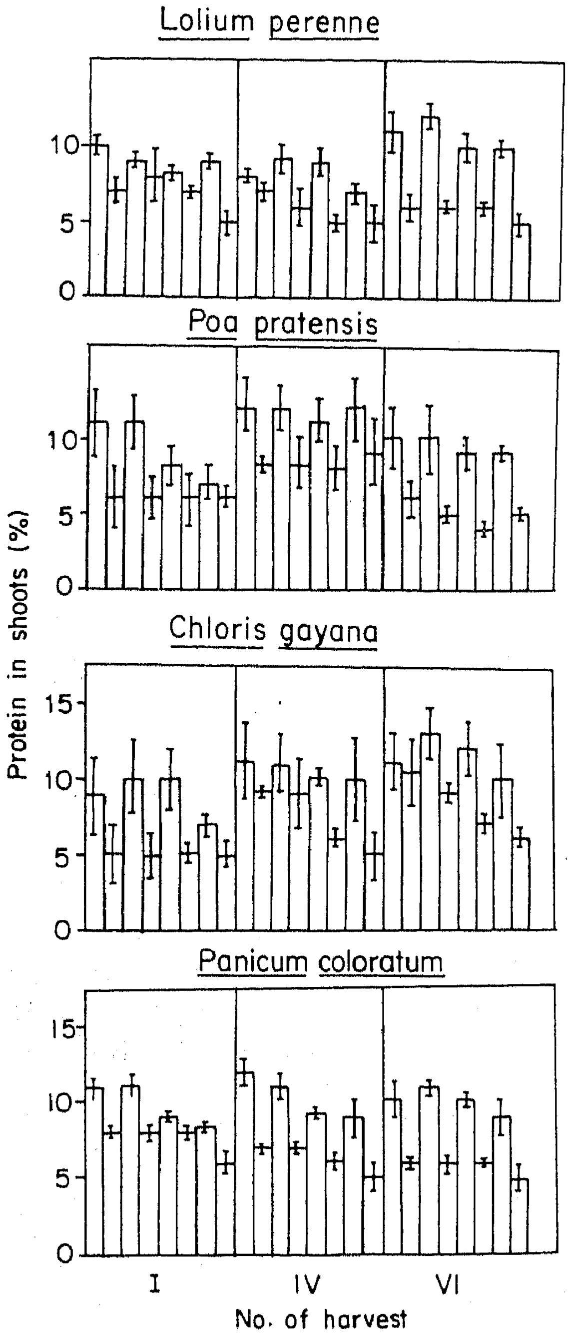

Figure 4. Protein content of shoots of 4 grass species subjected to various clipping treatments under two soil water conditions. For rest of the explanation see figure 3.

the C_3 plants are better at resisting drought. Sims and Singh (1983) found for the North American grasslands that communities dominated by cool season species (C_3) were comparable to or more efficient in energy capture and water use than the communities dominated by warm season (C_4) plants.

Table 6. Effect of water stress (per cent decrease in protein content relative to corresponding 1 FC value at the final harvest) and clipping (per cent increase in protein content relative to unclipped value at the final harvest) on protein accumulation in shoots of 4 grass species

Species/clipping treatment	Effect of water stress	Effect of clipping	
		1 FC	½FC
L. perenne			
Weekly clipped	43	7	31
Fortnightly clipped	49	8	31
Monthly clipped	41	0	23
Unclipped	54	–	–
P. pratensis			
Weekly clipped	38	12	40
Fortnightly clipped	47	8	16
Monthly clipped	59	0	0
Unclipped	51	–	–
C. gayana			
Weekly clipped	6	14	87
Fortnightly clipped	28	28	62
Monthly clipped	39	21	33
Unclipped	43	–	–
P. coloratum			
Weekly clipped	44	15	30
Fortnightly clipped	47	15	23
Monthly clipped	42	11	30
Unclipped	50	–	–

Total protein in shoots varied significantly in all 4 species with water level, clipping frequency and water level × clipping frequency interactions (all at $P < 0{\cdot}01$)

Table 7. Leaf dry weight as per cent of total plant dry weight at final harvest.

Species	1 FC		½FC	
	Weekly clipped	Unclipped	Weekly clipped	Unclipped
L. perenne	80	44	66	47
P. pratensis	83	44	73	49
C. gayana	71	48	52	37
P. coloratum	72	43	73	50

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