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CHEMICAL FEATURES OF *CHIONOCHLOA* SPECIES IN RELATION TO GRAZING BY RUMINANTS IN SOUTH ISLAND, NEW ZEALAND

Summary: *Chionochloa* species vary in the degree to which they are grazed by introduced ruminants. This is presumed to reflect the relative nutritive value and/or palatability of the forage provided by these indigenous grasses. Data are presented here on silicon content, in *vitro* organic matter digestibility (OMD), metabolisable energy (ME), crude protein and total nutrient mineral (TNM) contents of mature leaves of eleven *Chionochloa* species in southern New Zealand. Silification in all species is low, possibly as an evolutionary consequence of the absence of native mammalian herbivores in New Zealand. OMD determinations indicate a generally low nutritive value for these tussock grasses. Species characteristic of oligotrophic peats (c. *acicularis* and C. *crassiuscula* ssp. *torta)* produced very low values (20-25%) but others *(C. pallens* ssp. *cadens,* C. *macra* and C. *ovata)* approached OMD levels of medium quality pasture (50-60%). Crude protein values are also in the poor to moderate range (4.13% in C. *acicularis* to 8.34% in C. *ovata)*. The values for total nutrient mineral content largely parallel those for protein. The results are discussed in relation to the apparent relative palatability of each species in the field, and the vulnerability to grazing of some species with restricted distributions.

Keywords: *Chionochloa;* silicon; organic matter digestibility; protein; grazing; ruminants.

Introduction

The *Chionochloa* grasslands in the southern regions of the South Island of New Zealand have been extensively grazed by introduced ruminants since the 18508. In areas east of the Southern Alps sheep *(Ovis aries* L.), cattle *(Bos taurus* L.) and a smaller number of goats *(Capra hircus* L.), occupy tall tussock grasslands dominated by C. *rubra,* C. *rigida* ssp. *rigida* and C. *macra* at a wide range of altitudes. In the alpine zone along the Main Divide and in Fiordland, red deer *(Cervus elaphus scoticus* Lonnberg) are the main ruminant grazers of a variety of grassland types formed by different *Chionochloa* species. Chamois *(Rupicapra rupicapra* Couturier), thar *(Hemitragus jemlahieus* Smith), and wapiti *(Cervus elaphus nelsoni* Bailey) also use these grasslands, but their effects are probably localised regionally because of their limited distribution.

All these introduced herbivores show strong preferences in their choice of forage, with certain *Chionochloa* species being consistently selected over others. This is inferred from field observations on the relative use made of (or damage caused to) the different *Chionochloa* species by these grazers. For example in Fiordland, counts of red deer faecal pellets in grassland plots indicate a relative use: *C. rigida* ssp. *Amara*[1] (formerly *C. flavescens)* > *C. pallens* ssp. *cadens* > *C. crassuiscula* ssp. *torta* > *C. teretifolia* (Mills and Mark, 1977). Rose and Platt (1987) confirm the high preference shown for *C. rigida* ssp. *amara* and *C. pallens* ssp. *cadens,* and the latter species responds dramatically to deer removal (Mark, 1989). Other Fiordland species which are favoured by deer are *C. ovata* and *C. spiralis* (Lee and Lavers, 1990). *C. acicularis* and C. *crassiuscula* ssp. *torta* are consistently less favoured (Wardle *et al.,* 1970; Evans, 1972). For domestic livestock in the eastern regions of the South Island, preference is shown for *C. flavescens,* with C. *macra* intermediate, and *C. rubra* the least favoured (Connor, Bailey and O'Connor, 1970). In a laboratory food-choice experiment Macrae and O'Connor (1970) demonstrated that sheep favour *C. macra* more than *C. rubra* > *C. rigida* > *C. flavescens*.

The basis for these preferences is assumed to be the relative nutritive value of the different species since the most heavily grazed species characteristically occur on the most fertile soils, and have the highest levels of minerals in their tissues (Lee and Fenner, 1989). Young foliage that arises after burning of tussocks is highly preferred by stock to that on unburnt tussocks, possibly on account of its high concentrations of mineral nutrients, low lignin content and high concentrations of soluble

[1] Nomenclature follows Connor (1991)

carbohydrates (Williams and Muerk, 1977). However, mineral nutrient content may be only one of many factors determining the acceptability of the herbage for ruminants. Organic matter and protein content, digestibility, degree of silification (Brizuela, Delling and Cid, 1986), leaf strength (Connor and Bailey, 1972), and even accessibility in the field, may influence preference.

In this study we examine a number of chemical characteristics in eleven southern *Chionochloa* species and discuss (a) their relationship to preferences of introduced ruminants found in the field; (b) how they compare with introduced pasture species; and (c) the particular vulnerability to grazing of certain *Chionochloa* species with restricted distributions.

Methods

The species

The eleven species sampled are given in Table 1. They include all of the species and subspecies which occur in the southern half of South Island, New Zealand. Collectively the species occupy a wide range of altitude, soil types and habitats. From the alpine zone, three of the species are characteristic of oligotrophic peats (*C. acicularis, C. crassiuscula* ssp. *torta* and *C. teretifolia). C. pallens* ssp. *cadens* in contrast is found on young fertile mineral rich soils in this zone. Also from high altitudes, *C. ovata* is found on flush zones around exposed bluffs, and *C. oreophila* in sheltered hollows with persistent snow-lie in the spring. *C. rigida* ssp. *amara* (formerly included in *C. flavescens)* occurs on more mature soils at lower altitudes. *C. rigida* ssp. *rigida* occupies a range of dry soils, mostly in the low-alpine zone, but extending to lower altitudes on suitable sites. At higher altitudes it may be replaced by *C. macra*. *C. conspicua* is a forest edge species, extending in altitude to the tree line. *C. rubra* ssp. *cuprea* has a wide tolerance of different soil types, but occurs on poorly-drained sites from lowland to subalpine zones. *C. spiralis* is unique in being the only calcicole species, and is confined to limestone cliff ledges in eastern Fiordland. All these species are subject to at least intermittent grazing, those in the alpine zones mainly by red deer, and those at lower altitudes by sheep and cattle.

Sampling and analysis

Samples of the eleven species were collected in the Murchison Mountains and Key Summit, Fiordland, and the Remarkables Range, Otago, in late summer (9-14 March 1987), each from a single representative location. The sites were chosen as consisting of vegetation in which the relevant species was either dominant or was a major component. For *C. rigida,* two subspecies were sampled (*C. rigida* ssp. *amara* and *C. rigida* ssp. *rigida)*. For *C. rubra* ssp. c*uprea,* samples at two contrasting sites were collected because of its wide edaphic tolerance in Fiordland. Table 1 lists the sites, with map references, altitudes, aspect, slope and brief descriptions of the soil types.

At each site two representative non-flowering tussocks of the species were selected. Two samples, each consisting of between 10 and 50 tillers (depending on plant size) were taken from each tussock. All dead leaf sheaths were removed from the bases of the tillers, which were then washed and air dried. The tillers were separated into their green and non-green parts. The former consisted of the leaf blades plus all green leaf sheath material present. The latter consisted of the base of the shoots below the sheath/blade junction of the outermost leaf plus all withered leaf tips. Only the green tissues were used in this study, being the fraction most attractive to and eaten by the grazing ruminants. All samples were oven-dried at 80°C.

Silicon determinations were carried out by X-ray fluorescence spectrometry (Hutton and Norrish, 1977). Ash content was measured by incinerating samples in a muffle furnace to constant weight at 550°C.

Silica-free ash is calculated by subtracting silica content from ash. Organic matter digestibility (OMD) was measured by the technique of Tilley and Terry (1963) and Minson and McLeod (1972). Metabolisable energy (ME) in MJ kg^{-1} dry matter was calculated by %OMD x %OM x 0.00163 (Fennessy, *unpubl. data)*. Chemical analysis for concentrations of the nutrient minerals (nitrogen, phosphorus, potassium, calcium, magnesium, iron, sulphur and sodium) were carried out according to the methods given in Payton *et, al*. (1986). Values for the individual elements in this material are given in Lee and Fenner (1989). Here, the data for the individual elements are summed to give total nutrient minerals (TNM) as percent of dry matter. The mineral content of the material is given here as total nutrient minerals, silica-free ash, and ash, all expressed as percentages of tissue dry weight.

Results

Table 2 gives the values for the various chemical features measured. The silicon levels averaged 0.74%, with only one species, *C. conspicua,* over 1 %. The

Table 1: *Details of sampling sites for chemical analysis of* Chionochloa *species from locations* in *the South Island, New Zealand. Grid references from NZMS1 series.*

Species Sampled	Place name and map reference	Alt (m)	Aspect (°)	Slope (°)	pH	Soil and site description
C. acicularis	Plateau Creek S140 594 402	1040	340	22	4.5	Black moderately decomposed peat with loamy component
C. conspicua ssp. *conspicua*	Key summit S122 078 949	20	315	40	5.6	Dark reddish brown fibrous peat in upper IOcm with very dark greyish brown silty peat below
C. crassiuscula ssp. *torta*	Takahe Valley S140 673 371	1160	170	31	4.8	Very dark brown loamy fibrous peat in top 4 em, with peaty sandy loam below
C. macra	Rastus Bum S132 688 680	1580	315	15	5.1	Dark grey sandy loam, weakly weathered with clean sand grains
C. oreophila	Takahe Valley S140 673 373	1310	160	32	5.0	Very dark greyish brown sandy loam
C. ovata	Plateau Creek S140 585 411	1280	180	52	5.7	Very dark brown fibrous peat with sandy loamy component
C. pallens ssp. *cadens*	Takahe Valley S140 671 371	1160	150	46	5.2	Very dark greyish brown gritty sandy loam
C. rigida ssp. *rigida*	Rastus Bum S132 677 702	1220	45	28	5.0	Dark grey sandy loam with about 5% gravel
C. rigida ssp. *amara*	Takahe Valley S140 672 369	1130	70	25	4.6	Black silty peat
C. rubra ssp. *cuprea* (Fertile site)	Takahe Valley S140 699 365	890	0	0	5.4	Very dark greyish brown coarse sandy loam; aspect and slope level
C. rubra ssp. *cuprea* (Poor site)	Takahe Valley S140 708 350	890	340	22	4.5	Very dark brown fibrous peat of low bulk density with patches of yellowish brown *Sphagnum*
C. spiralis	Takahe Valley S140 725 342	1070	360	15	7.1	Dark greyish brown gritty sandy loam
C. teretifolia	Takahe Valley S140 673 370	1130	110	31	4.7	Black silty peat

Table 2: *Chemical features of eleven species of South Island* Chionochloa *species. Percents are of dry weight. Means are of two samples. [1]Crude protein = % nitrogen x 6.25. [2]Silica-free ash = total ash - silica.*

Species	Silicon (%)	Organic matter digestibility (%)	Metabolisable energy (MJ kg^{-1})	Crude Protein[1] (%)	Total nutrient minerals (%)	Silica-free ash[2] (%)	Ash (%)
C. acicularis	0.246	24	3.8	4.1	17.3	2.1	2.6
C. conspicua ssp. *conspicua*	1.274	34	5.2	6.6	26.7	3.4	6.2
C. crassiuscula ssp. *torta*	0.614	22	3.5	5.4	20.5	2.7	4.0
C. macra	0.541	53	8.1	4.3	20.1	4.1	5.3
C. oreophila	0.771	47	7.3	6.4	33.4	3.1	4.7
C. ovata	0.709	51	7.9	8.3	36.9	4.1	5.6
C. pallens ssp. *cadens*	0.766	59	8.9	7.9	32.5	5.0	6.6
C. rigida ssp. *rigida*	0.819	39	6.1	5.0	22.7	2.3	4.1
C. rigida ssp. *amara*	0.879	44	6.9	6.2	23.0	1.9	3.8
C. rubra ssp. *cuprea* (Fertile site)	0.822	32	5.8	6.0	22.2	2.6	4.4
C. rubra ssp. *cuprea* (Poor site)	0.765	37	5.1	4.5	19.0	2.1	3.7
C. spiralis	0.884	37	5.5	6.8	40.5	6.0	7.9
C. teretifolia	0.583	38	5.9	5.1	18.6	2.9	4.1

silicon levels here do not correlate with any of the other chemical properties.

The figures for organic matter digestibility (%OMD) range from less than 25% (*C. acicularis* and *C. crassiuscula* ssp. *torta)* to more than 50% *(C. ovata. C. macra* and C. *pallens* ssp. *cadens).* Crude protein levels range from less than 4.5% (*C. acicularis* and *C. macra)* to more than 8% (*C. ovata).* There is a highly significant (P<0.01) positive correlation between protein content and digestibility, if the anomalous *C. macra* is excluded from the regression. This species combines a low protein content with a relatively high digestibility. Metabolisable energy provides an estimate of the utilisable energy content of the herbage. The ME values here closely parallel those of %OMD. *C. acicularis* and *C. crassiuscula* ssp. *torta* had the lowest values (<4 MJ kg^{-1}), while *C. pallens* ssp. *cadens* and C. *macra* (>8 MJ kg^{-1}) had the highest metabolisable energy values. *Chionochloa spiralis, C. ovata. C. oreophila* and *C. pallens* ssp. *cadens* (all highly palatable species) have nutrient mineral contents of more than 3.0%. At the other end of the scale, *C. acicularis* and *C. teretifolia* have nutrient minerals of less than 2.0%. Silica-free ash provides an approximate measure of nutrient minerals in plant tissue. As expected, it is strongly correlated (P<0.01) with total nutrient minerals. Both measures show *C. spiralis* to have a remarkably high ash content, in spite of a low silicon level. This is due to the accumulation of calcium in the leaves of this species (nearly 1.5%; Lee and Fenner, 1989).

Discussion

Amongst the *Chionochloa* species there is a considerable range in herbage quality regardless of which measures of nutritive values are used. With the exception of the silicon levels (which show no consistent relationship with other chemical features) the various measures are broadly consistent with each other, though with some notable exceptions. Two species stand out as being the most nutritious. *C. pallens* ssp. *cadens* has the highest metabolisable energy, the second highest protein levels, and the fourth highest nutrient mineral content. *C. ovata* has the highest protein levels, second highest mineral content and third highest metabolisable energy. Both these species are known to be highly sought after by ruminants (Mills and Mark, 1977; Lee and Lavers, 1990). At the other end of the scale, *C. acicularis* has the lowest or second lowest levels of protein, nutrient minerals, and metabolisable energy. *C. crassiuscula* ssp. *torta* also scores poorly on all these features. Both these species are notably less favoured by ruminants in the field. *C. spiralis* and *C. conspicua* have high levels of protein and nutrient minerals, but have notably low metabolisable energy contents whereas *C. macra* shows the opposite pattern with a high metabolisable energy, but low protein and nutrient mineral content. Among the remaining intermediate species, *C. oreophila* and both subspecies of *C. rigida* are moderately nutritious, while *C. rubra* and *C. teretifolia* are rather less so. Again this broadly reflects preferences by livestock.

Compared with introduced northern hemisphere pasture grasses, *Chionochloa* as a group provide poor quality herbage. Both protein (4.1 to 8.3%) and metabolisable energy (3.5 to 9.2 MJ kg^{-1} dry matter) are very low compared with values of 15% and 10% for protein and metabolisable energy respectively in well managed New Zealand pastures (Ulyatt *et al.,* 1980).

Silicon contents in all the species of *Chionochloa* measured here are consistently low in comparison with other grasses. The mean level here of 0.74% (range 0.25 to 1.27%) contrasts with 2.5% (range 1.26 to 4.53%) for grass forage in New Mexico rangelands (Smith, Nelson and Boggino, 1971), and 1-4% for South Dakota prairie species (Brizuela *et al.,* 1986). For East African savanna grasses Dougall and Drysdale (1964) give a mean of 2.31 % (range 0.74 to 8.43%), and McNaughton *et al.* (1985) give levels of 6 to 9%. The low values recorded here are similar to those given by Connor *et al.* (1970), with the exception of our lower value for *C. macra* (0.54 versus 1.92%). Since silica (SiO_2) in plant tissues confers on them abrasive and indigestible qualities (Brizuela *et al.,* 1986), and since high values are found in regions which have a long history of grazing pressure (McNaughton *et al.,* 1985), it is often argued that its role is defensive. The historic absence of native mammalian grazers in New Zealand may account for the low silification found in these species. A survey comparing the silicon levels in New Zealand grasses generally with those of related species which evolved under grazing pressure would test this hypothesis.

Four of the species considered here have very restricted distributions, and so are potentially under threat from overgrazing by introduced ruminants. *C. acicularis,* though localised in its distribution in south Westland and Fiordland (Connor, 1991), is probably the least at risk because of its low nutritive value and poor digestibility. It is generally agreed to be one of the species for which ruminants show least preference. *C. teretifolia* also has a highly localised distribution (in Southland and Fiordland). The chemical analyses for this species show that it has low levels of nutrient minerals and protein and is also somewhat indigestible, but whether these features are sufficient to protect it from over-grazing is unknown. The evidence for the degree of preference shown by ruminants is less clear-cut than in the case of C. *acicularis*. Faecal pellet counts of red deer in plots dominated by different *Chionochloa* species suggest these ruminants show a low preference for C. *teretifolia* (Mills and Mark, 1977), and Lee and Lavers (1990) also list it as one of low palatability. In contrast, faecal pellet data of Wardle *et al.* (1970) and Evans (1972) indicate this species may be favoured by deer. However these latter results may reflect the small number of plots (10) in *Chionochloa teretifolia* communities and their occurrence in a region of very high pellet densities generally.

C. ovata is confined to Fiordland where it occurs typically on damp sites at the bases of rocky bluffs at high altitudes. Its combination of restricted distribution and high palatability may put it at risk from over-exploitation by deer. It has responded well in the last decade to reductions in deer numbers (Lee, *pers. obs.).* Its tissues are high in protein, nutrient minerals, and metabolisable energy and field observations indicate it is highly sought after by grazers (Lee and Lavers, 1990). It may be that surviving populations are ones which are relatively inaccessible, or that they are sufficiently extensive to have survived by chance. This species is potentially vulnerable and merits monitoring for conservation purposes.

The rarest of the four restricted species is *C. spiralis,* known only from three sites in Fiordland, mainly on ledges of limestone cliffs. Deer show a high preference for this species in spite of its low digestibility and metabolisable energy. Its attraction may be the exceptionally high levels of calcium in its tissues, an element which may be in short supply for large mammals in Fiordland. The highly specialised ecological requirements of this species reduce the extent of its potential habitat within its geographic area, and its attractiveness to grazers renders it vulnerable to over-exploitation. Its population has already been considerably reduced by deer, as is indicated by the number of dead and damaged tussocks on accessible sites. *C. spiralis* fully merits its inclusion in the Red Data Book for New Zealand (Williams and Given, 1981). The main factor ensuring the current survival of this species may be the extreme inaccessibility of the remaining populations.

Overall, the various measures of nutritive value for all the species considered here go some way to explaining the relative preferences shown by the introduced ruminants. Controlled comparative experiments, such as those of Macrae and O'Connor (1970), in which the relevant herbivores are provided with choices of the various species, would provide a better indication of relative palatabilities than diverse field observations. However, chemical analyses on their own can give important clues to feeding behaviour. Minson (1987) showed that laboratory measures of digestibility related closely to voluntary intake by sheep in trials with different cultivars of *Panicum maximum.* The other chemical data, such as protein and mineral content can then be used as indicators of the quality of what is ingested.

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