Nutritive value of chicory and plantain herbage under grazing

ABSTRACT

The use of forage chicory (*Cichorium intybus* L.) and English plantain (*Plantago lanceolata* L.) in the NE USA may help achieve acceptable forage productivity during the entire summer grazing. However, their reproductive habit may negatively affect the nutritive value of pure stand pastures. We evaluated several cultivars, compared them with 'Pennlate' orchardgrass (*Dactylis glomerata* L.), and assessed if and how different grazing strategies influenced their nutritive value in two grazing experiments during 3 years. Pre-grazing herbage samples were analyzed for crude protein (CP), neutral detergent fiber (NDF) content, and *in vitro* true digestibility of dry matter (IVTDMD). In Exp.1 and 2, average CP content of all entries was 180 to 200 g kg^{-1}, but generally not significantly higher than orchardgrass; whereas their NDF content was 300 to 400 g kg^{-1}, and always lower than orchardgrass. The IVTDMD of chicory cultivars in both experiments was between 850 - 950 g kg^{-1}; Forage Feast and Puna chicory had higher IVTDMD than Pennlate orchardgrass (on average 866 g kg^{-1}). Low IVTDMD was observed for Lancelot plantain compared to orchardgrass. In Exp. 1, nutritive value was affected by the frequency of grazing. In Exp. 2, herbage composition differed significantly among seasons and cultivars, nevertheless continuous reproductive development did not directly affect nutritive value. Our previous recommendations to utilize a plant-based grazing strategy to maximize yield and persistence of Puna chicory and Lancelot plantain, does not compromise their nutritive, and overall, Puna chicory could be a good complement to Pennlate orchardgrass in grass-based feeding systems.

Abbreviations: CP, crude protein; NDF, neutral detergent fiber; IVTDMD, *in vitro* true digestibility of dry matter; DM, dry matter; SEM, standard error of means.

Maintaining acceptable forage productivity and quality during the grazing season can sometimes be difficult, particularly in areas where cool-season pasture species are predominantly grown. A solution may be in the use of alternative forage species and varieties to increase forage production during the summer; crops such as chicory and English plantain are being considered for this purpose (Jung et al., 1996; Holden et al., 2000; Foster et al., 2002; Sanderson et al., 2003ab; Belesky et al., 2000, 2001, and 2004). Research suggests that forage chicory can complement and even improve seasonal dry matter productivity of pastures in the northeastern USA (Sanderson et al., 2003a; Labreveux et al., 2004). Tolerance to winter temperatures of available cultivars of forage plantain needs improvement (Skinner and Gustine, 2002), nevertheless this species has the potential of improving digestibility, average animal performance, and micronutrient balance of pastures (Belesky et al., 2001; Sanderson et al., 2003b)

The chicory cultivar "Grasslands Puna" released in 1985 has been frequently used in the USA, and is reported to have good summer productivity (Jung et al., 1996; Volesky, 1996). Reportedly, this cultivar can have similar or higher digestibility than perennial ryegrass (*Lolium perenne* L) and white clover (*Trifolium repens* L) mixtures (Hoskin et al., 1999), and birdsfoot trefoil (*Lotus corniculatus* L.) (Fraser and Rowarth, 1996; Min et al., 1997). In addition, its faster rumen degradation and rates of passage improved voluntary feed intake and growth rate of deer (*Cervus elaphus*) grazing chicory (Kusmartono et al., 1997). Forage chicory has also been recommended to improve summer and fall energy levels and increase growth potential of red deer calves (Stevens and Corson, 2003). Other chicory cultivars, such as Forage Feast and INIA Lacerta, have become available; however, there is little information on their nutritive value or performance in the USA (Belesky et al. 1999; Foster et al., 2002; Sanderson et al., 2003ab)

Plantago species are widely represented in grasslands around the world (Kuiper and Bos, 1992; Scehovic and Jeangros, 1994; Tracy and Sanderson, 2004). Only recently were two cultivars developed for use as forage; Grasslands Lancelot (New Zealand, Pastoral Agriculture Research Institute Ltd., 1996) and Ceres Tonic (Pyne Gould Guinness Ltd., 1996). These cultivars were selected for their upright growth habit and larger leaves from naturally occurring types. Leaves of plantain cultivars are reported as highly palatable to animals and to have a similar digestibility to perennial ryegrass and birdsfoot trefoil pastures (Fraser and Rowarth, 1996; Stewart, 1996; Rumball et al., 1997).

A draw back to the use of chicory and plantain in grazing systems is their ability to produce flower stalks during most of the growing season, which may have a lower nutritive value than leaves. As opposed to haying and mowing situations where pasture species can be compared under regular cutting intervals and uniform cutting heights, grazing animals generate areas of less uniformly grazed and rejected patches that could greatly affect the nutritive value of the pasture (Griffiths et al., 2003). Adjustments to the grazing strategies could aid at controlling the canopy structure of the pasture and potential nutritive value (Garcia et al., 2003). In our previous research, we concluded that a plant-based grazing strategy was more useful than a fixed schedule in terms of herbage yield and plant persistence (Labreveux et al, 2004). In the current study we assessed how these grazing strategies influenced the nutritive value of chicory and plantain cultivars.

MATERIALS AND METHODS

Two grazing experiments were conducted at the Pennsylvania State University Haller Farm Beef Research Center near State College, PA. The soil at the experimental site was a Hagerstown silt loam (fine, mixed, mesic Typic Hapludalfs).

Experiment 1

Chicory cultivars Forage Feast, Grasslands Puna and INIA LE Lacerta, plantain cultivars Grasslands Lancelot, Ceres Tonic, and Pennlate orchardgrass were seeded in pure stands in May 1997. Chicory was seeded at 4.5 kg ha^{-1}. Plantain and orchardgrass were seeded at 11 kg ha^{-1}. Soil tests to a 150-mm depth in March 1998 indicated a pH of 6.3 and 93, 489, and 256 kg ha^{-1} of P, K and Mg, respectively. No fertilizer was added at planting. Urea was applied on 10 April and 15 June 1998 at 50 kg ha^{-1} N. A total of 60 and 120 kg ha^{-1} of P and K, respectively, was applied in April. Mowing controlled weeds during the year of establishment.

A randomized complete block (four replicates) design with a split plot arrangement of treatments was used with cultivars randomly assigned to subplots within the grazing treatment main plots. Subplot size (cultivars within grazing treatment) was 12 by 14 m, resulting in a main plot size of 72 by 14 m and a block size of 72 by 56 m. The grazing treatment consisted of all combinations of frequency (3- and 5-wk rest period) and intensity (50- and 150-mm stubble residue) of grazing. The grazing treatments were based on Li et al. (1997) in New Zealand and Volesky (1996) in Oklahoma where rest periods of 4 and 5 wk were more productive than those 1 or 2 wk long. All cultivars (subplots) within a grazing treatment (main plot) and block were grazed at the same time. The number of animals per paddock at each grazing event (12 to 14 cow-calf pairs) was adjusted to minimize the grazing period (no longer than 36h) and avoid pasture damage. Grazing began on 5 May and ended 9 September 1998. Herbage mass was collected from all subplots before grazing from four 0.1m^2 quadrats cut to ground level with electric shears. One of four pre-grazing herbage samples was separated into seeded and non-seeded species. All material was oven dried at 55 °C for 48 h and weighed to estimate DM yields (reported separately in Labreveux et al., 2004).

Nutritive value data were statistically analyzed using the MIXED procedure in SAS (SAS Institute, 1998). Within each harvest date, data were compared with planned orthogonal contrasts (Steel et al., 1997). Planned cultivar comparisons were Forage Feast chicory vs. Pennlate orchardgrass (Penn), Lacerta chicory vs. Penn, Puna chicory vs. Penn, Tonic plantain vs. Penn, and Lancelot plantain vs. Penn. Grazing treatment by cultivar means were compared for the effect of grazing treatment within each cultivar. Planned grazing treatment comparisons were frequently (3-wk interval) vs. infrequently (5-wk interval), severely (50-mm stubble height) vs. lightly (150-mm stubble height), and the interaction of grazing frequency and intensity.

Experiment 2

Grasslands Puna chicory, Grasslands Lancelot plantain and Pennlate orchardgrass were seeded on August 1999 in a different field with similar soil type at the Haller Beef Research Farm. Soil tests before planting indicated a pH of 6.5; P, K and Mg levels of 89, 325, and 205 kg ha^{-1}, respectively. Before seeding, weeds were controlled with glyphosate [*N*-(phosphono-methyl) glycine]. Seeding rates were the same as those used in Experiment 1. Mowing controlled weeds during establishment.

Nitrogen fertilizer was applied in May and August at a rate of 40 kg ha^{-1}. The experimental site was approximately 2.2 ha and each experimental unit was 0.09 ha. A split block design (four blocks) was used. Two grazing intensity treatments developed based on the yield and persistence results from Experiment 1 (Labreveux et al., 2004) that were defined by the post grazing stubble height left during spring and summer. The 'severe' treatment plots were always grazed to an average canopy height of 50 mm, while the 'severe-moderate' plots were grazed to a 50 mm stubble height in spring and 100 mm in summer. The grazing cycle was defined by the time required to reach a canopy height of 250 mm for orchardgrass and chicory and 200 mm for plantain. Residual height was measured once or twice during the occupation period. Two canopy height measurements were taken during the rest period to establish time to grazing.

Pre-grazing herbage samples were taken from a 2-m section of one row and separated into leaves, flower stalks, dead leaves, stubble and weeds. All samples were oven dried at 55°C for 48h and weighed.

The MIXED procedure with repeated measures over years was used to perform the statistical analyses (SAS Institute, 1998). A compound symmetry covariance structure was selected as the one that best fit the data. Replicates (blocks) and interactions with replicates were considered to be random effects while years were considered as fixed effects. Guidelines for analysis of data were based on Steel et al. (1997) and Littel et al. (1996, 1998). Planned orthogonal contrasts were used to compare means (Steel et al., 1997). Cultivar comparisons were Puna chicory vs. Pennlate orchardgrass and Lancelot plantain vs. Pennlate orchardgrass. Grazing effect was tested on summer data using the contrast 'severe' vs. 'severe-moderate'. Planned contrast for year comparison was 2000 vs. 2001.

Nutritive Value Analysis

Herbage was ground to pass a 2-mm screen in a shear mill and then a 1-mm screen in an impact mill. Ground samples were analyzed for CP (N X 6.25), NDF, and IVTD by near infra-red spectroscopy by the Crop Quality Laboratory at Penn State University. Calibration samples (100 from each experiment) were analyzed for N with the Dumas combustion method Carlo Erba NA15000 Elemental Analyzer (Horneck and Miller, 1998), and for NDF and IVTDMD by the Ankom filter bag methods (Ankom Technology, Fairport, NY). Ruminal fluid was collected from one cannulated cow offered orchardgrass and alfalfa hay.

Calibration statistics for CP estimation were SECV = 1.07, Bias = -0.20, SEC(C) =1.07, RSQ = 0.959 (where SECV is the standard error for cross validation, SEC(C) is the standard error for calibration uncorrected for bias). Calibration statistics for NDF_Ankom estimation were SECV = 2.76, Bias = -0.75, SEC(C) =2.62, RSQ = 0.94. Calibration statistics for IVTD_Ankom estimation were SECV = 1.85, Bias = negligible, SEC(C) =1.85, RSQ = 0.94.

RESULTS AND DISCUSSION

Herbage nutritive value of different chicory and plantain cultivars. Experiment 1

Differences in nutritive value between cultivars of chicory, plantain and Pennlate orchardgrass were observed both in the year of establishment and in the subsequent year (Table 1). The differences in CP content were more apparent at the beginning than at the end of the grazing season with an average 20% higher CP content in the forbs than the grass. In May 1998, the chicory cultivars had an average CP content of 217 g kg^{-1} whereas orchardgrass had 173 g kg^{-1} ($P < 0.05$). Of the plantains, only Tonic had a higher CP than Pennlate orchardgrass (210 vs. 173 g kg^{-1}, respectively, $P < 0.05$). For the remainder of the grazing season, the differences observed were not significant. However, a slight increase in CP was observed in all cultivars from October 1997 onwards that was most probably related to our fertilization schedule.

Jung et. al (1996) also found no overall differences in the CP content of Puna chicory and Pennlate orchardgrass herbage when grazed frequently over a two year period (230 g kg^{-1} for both species averaged over 1992 and 1993) with N fertilization rates ranging between 165 – 330 kg ha^{-1}. Belesky et al. (2000) reported N concentrations of Puna chicory herbage ranging from 22 to 35 g kg^{-1} at fertilization levels of 0 to 480 kg ha^{-1} N. These values correspond to CP contents of 137 and 219 g kg^{-1}, respectively, which suggests that the N fertilization rate of 100 kg ha^{-1} yr^{-1} used in this study was sufficient to obtain adequate content of CP in Puna chicory. Accordingly, increasing N fertilization rates on chicory pastures has no added benefit, but may rather be detrimental to plant density, as reported by Belesky et al. (2000) and Collins and McCoy (1997).

The NDF content in chicory and plantain herbage was significantly lower than that of Pennlate orchardgrass in the year of establishment and the following year (Table 1). Average NDF contents of 260 g kg^{-1} were observed in October 1997, but increased to values above 300 g kg^{-1} in the following year. This increase was most probably related to their reproductive habits, since a low percentage of plants flowered within the year of establishment (data not shown). The highest values were observed in May when the average fiber content of chicory, plantain and orchardgrass was 381, 391 and 545 g kg^{-1}, respectively.

In their study comparing Puna chicory and Pennlate orchardgrass under different cutting management, Holden et al. (2000) reported NDF values of 207 g kg^{-1} and 506 g kg^{-1} for the chicory and the grass, respectively. The authors suggested that even though the lower NDF content of Puna chicory should allow for higher DM intakes, these levels could be too low to reach adequate rumen health. In our studies both under cutting (Sanderson et al., 2003) and the one being reported, NDF contents were in all cases higher than those reported by these authors.

The IVTDMD of the three chicory cultivars was on average between 4 to 6% higher than that of Pennlate orchardgrass in May and October 1998 (896 and 905 vs. 863 and 853 g kg^{-1}, respectively, $P < 0.05$; Table 1). In August 1998 however, their IVTDMD did not differ (894 vs. 885 g kg^{-1}, respectively), which was due to a more negative effect of infrequently and lightly grazed treatments on the IVTDMD of Puna chicory and Lancelot plantain (793 and 769 g kg^{-1}, respectively) than orchardgrass' (858 g kg^{-1}, complete data set not shown). Information presented by McCoy et al. (1997) suggests that, at least for Puna chicory, these results may be related to differences in IVTDMD of pasture strata.

The IVTDMD of the plantain cultivars was not higher than that of Pennlate orchardgrass in any of the harvest dates (857 vs. 867 g kg^{-1} average over the year, respectively). Reported IVTDMD values for naturally occurring plantain species are 804 g kg^{-1} (Derrick et al., 1993), but no reports have been found concerning the nutritive value of *Plantago* sp. under grazing conditions.

Nutritive value as affected by grazing strategies in Experiment 1

Only in Exp. 1 (Table 2) did grazing treatment have a significant effect on nutritive value. The frequency and intensity of grazing combination used in Exp.1 had a significant effect on the CP content and the IVTDMD in herbage grown during August and October 1998. The frequency with which the pastures were grazed in August had a more prominent effect on the CP content of herbage than did the intensity. The difference between grazing every 3 wk or every 5 wk was almost 20% (229 vs. 189 g kg^{-1}, $P<0.01$), a much higher difference than the one or two percentage points observed in our parallel studies under cutting conditions (Sanderson et al., 2003). Holden et al. (2000), also found that the more frequently clipped plots exhibited a higher CP content than the less frequently harvested (225, 166 and 149 g kg^{-1} on the frequent, moderate, less frequent harvest, respectively; average over 1992 and 1993). However, and as observed in the current study, the authors did not observe a significant effect of management level on NDF content.

The slower grazing frequency also negatively affected IVTDMD of chicory, plantain and orchardgrass, particularly when the plots were grazed to a 150-mm stubble height. The average IVTDMD of frequently grazed plots was 890 g kg^{-1}, four percent higher than the IVTDMD of infrequently grazed pastures ($P < 0.05$).

Herbage nutritive value of Puna chicory and Lancelot plantain Experiment 2

Results for herbage CP content for Exp. 2 (Table 3) were slightly different than what was observed in Exp. 1 (Table 1). The CP contents of Puna chicory and Lancelot plantain in May (average over both years of study) were similar to those of orchardgrass (174, 161 and 165 g kg^{-1}, respectively). In August, the CP content of Puna chicory was higher than orchardgrass (191 vs. 179 g kg^{-1}, $P < 0.05$). Lancelot plantain did not differ from orchardgrass in CP. The CP contents observed in 2001 were slightly lower than those observed in 2000, and, even though no attempts of statistical comparison between experiments should be made, 1998 values were also numerically higher (182.5, 165, and 199 g kg^{-1}, average of shared entries for 2000, 2001, and 1998, respectively). Jung et al. (1996) proposed potential CP values for Puna chicory and Pennlate orchardgrass greater than 250 g kg^{-1}, and related lower values to floral stem production.

As observed in Exp. 1, in Exp. 2 the NDF contents of the forbs was always lower than for orchardgrass (383, 375 and 484 g kg^{-1} for Puna chicory, Lancelot plantain and Pennlate orchardgrass, respectively, $P < 0.001$ for both comparisons). Finally, IVTDMD of Puna chicory herbage in May (898 g kg^{-1}) and August (919 g kg^{-1}) 2000 was slightly higher, than that of Pennlate orchardgrass (858 and 845 g kg^{-1} May and August, respectively), however no differences were observed in 2001. In both years and sampling seasons the IVTMD of Pennlate orchardgrass was higher than that of Lancelot plantain (740 and 773 g kg^{-1} average of May and August 2000 and 2001, respectively). Furthermore, and as observed for CP contents, NDF and IVTDMD of herbage differed considerably between May 2000 and 2001 (Table 4, $P < 0.0001$), and may have been either affected by the drier weather conditions in 2001 and/or the proportion of leaf in relation to stem as it is discussed in the next section (Table 5).

Nutritive value as affected by reproductive stages - Experiment 2

Comparisons of the nutritive value of herbage between 2000 and 2001 (Table 4) can be related to the developmental stage of the pastures and, to a lesser extent, to weather conditions being more stressful during 2001(Labreveux et al., 2004). However, there was no year by species interaction suggesting that regardless of the differences in herbage composition between years and seasons, the relationship between species remained the same. It was observed that in May the nutritive values of the three species in 2001 was lower than in 2000 (CP: 183 vs. 150 g kg^{-1}, $P < 0.01$; NDF: 392 vs. 435 g kg^{-1}, $P < 0.05$; IVTDMD: 846 vs. 804 g kg^{-1}, $P < 0.05$; on 2000 and 2001, respectively). In August however, these differences disappeared.

Leaf to stem ratios (Table 5) of Puna chicory and Lancelot plantain herbage in spring 2001 were one half the ratio in 2000 (2.94 for both species in 2000 and almost 1.5 in 2001, $P < 0.001$ for year comparison). In August, the leaf to stem ratio of Puna chicory was less than a quarter in 2001 of what was observed in 2000 (3.8 vs. 14.3 over 2001 and 2000, respectively $P < 0.05$), while the corresponding ratio for plantain herbage between years was similar (10.6 on average between 2000 and 2001). The composition of the herbage of Pennlate orchardgrass in May was also different between years, but the relation was opposite. The proportion of leaves over stems was 4.4 in 2000 and 25.0 in 2001 ($P < 0.05$), while in August the herbage was composed of leaves only.

The nutritive values of most forage species vary over time. This variation can be associated to reproductive stages, maturity of plant parts (Buxton et al., 1985), and effects of grazing animals caused by treading, dung and urine depositions (Matches, 1992). Reproductive stages of Pennlate orchardgrass are early in the spring while chicory and plantain may flower later in the spring and summer (Castellano-Cantero, 1997; Stewart, 1996). It is possible that differences in the timing to reproductive development are associated with nutritive values observed since most differences occurred in May between the forbs and orchardgrass. However, the impact of continuous reproductive development of chicory and plantain do not limit the nutritive value of the forage produced when the pastures are grazed aggressively during the spring. In the case of forage chicory it may even help prevent effective fiber deficiencies when the pastures are grazed by high yielding lactating cows.

CONCLUSIONS

Results of three years of study of chicory and plantain cultivars under different grazing conditions suggest that most of the tested cultivars have acceptable nutritive values, similar to that of Pennlate orchardgrass. It was also found that our recommendations to utilize a plant-based grazing strategy to maximize yield and persistence of Puna chicory and Lancelot plantain, does not compromise their nutritive value. As opposed to what could be deduced from the literature, the impact of continuous reproductive development of chicory and plantain did not directly affect the nutritive value of the forage produced when the pastures are grazed aggressively during the spring. Overall, Puna chicory could be a good complement to Pennlate orchardgrass in grass-based feeding systems.

REFERENCES

Belesky, D.P., J.M. Fedders, K.E. Turner, and J.M. Ruckle. 1999. Productivity, botanical composition and nutritive value of swards including forage chicory. Agron. J. 91:450-456.

Belesky, D.P., K.E. Turner, and J.M. Ruckle. 2000. Influence of nitrogen on productivity and nutritive value of forage chicory. Agron. J. 92:472-478.

Belesky, D.P., K.E. Turner, J.M. Fedders, and J.M. Ruckle. 2001. Mineral composition of swards containing forage chicory. Agron. J. 93:468-475.

Belesky, D.P., J.M. Ruckle, and W.M. Clapham. 2004. Dry-matter production, allocation, and nutritive value of forage chicory cultivars as a function of nitrogen. J. Agron. Crop Sci. 190:100-110.

Buxton, D.R., J.S. Hornstein, W.F. Wedin, and G.C. Marten. 1985. Forage quality in stratified canopies of alfalfa, birdsfoot trefoil, and red clover. Crop Sci. 25:273-279.

Castellano-Cantero, F.U. 1997. [Aspects related to seed production of the chicory (Cichorium intybus L) cultivar INIA Lacerta].(In Spanish.) Tesis Ingeniero Agrónomo. Univ. de la República, Facultad de Agronomía, Montevideo, Uruguay. 61p.

Collins, M., and J.E. McCoy. 1997. Chicory productivity forage quality, and response to nitrogen fertilization. Agron. J. 89: 232–238

Derrick, R.W., G. Mosely, and D. Wilman. 1993. Intake by sheep and digestibility of chickweed, dandelion, dock, ribwort, and spurrey compared with perennial ryegrass. J. Agric. Sci. 120:51-61.

Foster, J. G., J.M. Fedders, W.M. , J.W.Robertson, D.P. Bligh,K.E. Turner. 2002. Nutritive value and animal selection of forage chicory cultivars grown in Central Appalachia. Agron. J. 94:1034-1042.

Fraser, T.J., and J.S. Rowarth. 1996. Legumes, herbs *or* grass for lamb performance? Proc. NZ Grassl. Assoc. 58:49–52.

García, F., P. Carrère, J.F. Soussana, and R. Baumont. 2003. How do severity and frequency of grazing affect sward characteristics and the choices of sheep during the grazing season. Grass Forage Sci. 58:138-150.

Griffiths, W.M., J. Hogdson, and G.C. Arnold. 2003. The influence of sward canopy structure on foraging decisions by grazing cattle. I. Patch selection. Grass Forage Sci. 58:112-124.

Holden, L.A., G.A. Varga, G.A. Jung, and J.A. Shaffer. 2000. Comparison of 'Grasslands Puna' chicory and orchardgrass for multiple harvests at different management levels. Agron. J. 92:191-194.

Horneck, D.A., and R.O. Miller. 1998. Determination of total nitrogen in plant tissue. In Y.P. Kalra (ed.) Handbook and Reference Methods for Plant Analysis. CRC Press, NY.

Hoskin, S.O., T.N. Barry, P.R. Wilson, W.A.G. Charleston, and J. Hogdson. 1999. Effects of reducing anthelmintic input upon growth and faecal egg and larval counts in young farmed deer grazing chicory (Cichorium intybus) and perennial ryegrass (Lolium perenne)/white clover (Trifolium repens) pasture. J. Agric. Sci. 132:335-345.

Jung, G.A., J.A. Shaffer, G.A. Varga, and J.R. Everhart. 1996. Performance of ‘Grasslands Puna’ chicory at different management levels. Agron. J. 88:104-111.

Kuiper, P.J.C., and M. Bos (eds.). 1992. Plantago: a multidisciplinary study. Springer-Verlag, Berlin Heidelberg.

Kusmartono, A. Shimada, and T.N. Barry. 1997. Rumen digestion and rumen outflow rate in deer fed fresh chicory (*Cichorium* intybus) or perennial ryegrass (*Lolium* perenne). J. Agric. Sci. 128:87-94.

Labreveux, M., M.H. Hall, and M.A. Sanderson. 2004. Productivity of chicory and plantain cultivars under grazing. Agron. J. 96:710-716.

Li, G.D., P.D. Kemp, and J. Hogdson. 1997a. Regrowth, morphology and persistence of Grasslands Puna chicory (*Cichorium intybus* L.) in response to grazing frequency and intensity. Grass Forage Sci.52:33-41.

Littel, R.C., G.A. Miliken, W.W. Stroup, and R.D. Wolfinger. 1996. SAS System for mixed models. SAS Institute Inc., SAS Campus Drive, Cary, NC.

Littel, R.C., P.R. Henry, and C.B. Ammerman. 1998. Statistical analysis of repeated measures data using SAS procedures. J. Anim. Sci. 76:1216-1231.

McCoy, J.E., M. Collins, and C.T. Dougherty. 1997. Amount and quality of chicory herbage ingested by grazing cattle. Crop Sci. 37:239-242.

Min, B.R., T.N. Barry, P.R. Wilson, and P.D. Kemp. 1997. The effects of grazing chicory (Cichorium intybus) and birdsfoot trefoil (Lotus corniculatus) on venison ad velvet production by young red and hybrid deer. NZ J. Agric. Res. 40:335-347.

Matches, A.G. 1992. Plant response to grazing: A review. J. Prod. Agric. 5:1-7.

New Zealand, Pastoral Agriculture Research Institute Ltd.1996. Variety: 'Grasslands Lancelot'. Application no: 96/016. Plant Varieties J. 9:39-40.

Pyne Gould Guinness Ltd. 1996. Variety: 'Ceres Tonic' syn 'PG 30'. Application no: 96/017. Plant Varieties J. 9:39.

Rumball, W., R.G. Keogh, G.E. Lane, J.E. Miller, and R.B. Claydon. 1997. "Grasslands Lancelot" plantain (*Plantago lanceolata* L.). NZ J. Agric. Res. 40:373-377.

Sanderson, M.A., M. Labreveux, M.H. Hall, and G.F. Elwinger. 2003 a. Forage yield and persistence of Chicory *and* English plantain. Crop Sci. 43:995-1000.

Sanderson, M.A., M. Labreveux, M.H. Hall, G.F. Elwinger. 2003b. Nutritive value of chicory *and* English *plantain* forage**.** Crop Sci. 43:1797:1894.

SAS institute, Inc. 1998. SAS User's Guide: Statistics. 7th ed. SAS Inst., Inc., Cary, NC.

Scehovic, J., and B. Jeangros. 1994. A new index for assessing the effects of the botanical composition of permanent pastures on forage quality. (In French with English abstract.) Revue Suisse d’Agriculture 26:167-170.

Skinner, R.H., and D.L. Gustine. 2002. Freezing tolerance of chicory and narrow-leaf plantain. Crop Sci. 42:2038-2043.

Steel, R.G.D., J.H. Torrie, and D.A. Dickey. 1997. Principles and procedures of statistics. A biometrical approach. 3rd ed. The McGraw-Hill Companies, Inc., New York, NY.

Stevens, D.R., and I.D. Corson. 2003. Optimizing calf growth of red deer in summer and autumn. Proc. NZ Soc. Anim. Prod. 63:218-221.

Stewart, A.V. 1996. Plantain (Plantago lanceolata) - a potential pasture species. Proc. NZ Grassl. Assoc. 58:77-86.

Tracy, B.F., and M.A. Sanderson. 2004. Forage productivity, species evenness and weed invasion in pasture communities. Agric. Ecosys. Environ. 102:175-183.

Volesky, J.D. 1996. Forage production and grazing management of chicory. J. Prod. Agric. 9:403-406.

Table 1: Nutritive value of chicory, plantain and orchardgrass under grazing in the year of establishment and during 1998 (Experiment 1).

	1997	1998		
	October	May	August	October
	--------------------------- dry matter (g kg^{-1}) ------------			
Species / Cultivar †	Crude Protein			
Forage Feast Chicory	160	212	211	216
Lacerta Chicory	143	221	201	169
Puna chicory	166	214	207	220
Lancelot plantain	150	179	216	188
Tonic plantain	131	210	219	203
Pennlate (Penn) orchardgrass	155	173	198	197
Contrasts ‡				
Feast vs. Penn	NS	*	NS	NS
Lacerta vs. Penn	NS	*	NS	*
Puna vs. Penn	NS	*	NS	NS
Lancelot vs. Penn	NS	NS	NS	NS
Tonic vs. Penn	NS	*	NS	NS
SEM	4.9	5.5	12.9	11.6
	Neutral Detergent Fiber			
Forage Feast Chicory	255	399	321	277
Lacerta Chicory	240	384	350	371
Puna chicory	251	361	328	291
Lancelot plantain	284	391	347	288
Tonic plantain	264	390	312	283
Pennlate (Penn) orchardgrass	538	545	510	529
Contrasts				
Feast vs. Penn	*	*	*	*
Lacerta vs. Penn	*	*	*	*
Puna vs. Penn	*	*	*	*
Lancelot vs. Penn	*	*	*	*
Tonic vs. Penn	*	*	*	*
SEM	5.8	11.0	18.4	16.3
	In Vitro True Dry Matter Digestibility			
Forage Feast Chicory		892	922	935
Lacerta Chicory		892	878	847
Puna chicory		905	882	932
Lancelot plantain		849	795	870
Tonic plantain		872	873	884
Pennlate (Penn) orchardgrass		863	885	853
Contrasts				
Feast vs. Penn		*	NS	*

Lacerta vs. Penn	*	NS	NS
Puna vs. Penn	*	NS	*
Lancelot vs. Penn	NS	*	NS
Tonic vs. Penn	NS	NS	NS
SEM	7.9	21.3	19.2

* Significant at the 0.05 probability level.
† Data are average of herbage yield over four grazing treatments and 4 replicates (n=16)
‡ Planned orthogonal contrasts.

Table 2: Herbage nutritive value as affected by grazing treatment in three different dates during 1998 (Experiment 1).

Grazing treatment †	May 1998	August 1998	October 1998
	-----------------dry matter (g kg^{-1}) -----------------		
	Crude Protein ‡		
Frequently severely	206§	236	203
Frequently lightly	201	221	172
Infrequently severely	199	189	212
Infrequently lightly	200	189	208
Contrasts §			
Frequently vs. infrequently	NS	**	*
Lightly vs. severely	NS	*	*
Frequency* Intensity	NS	NS	NS
SEM	9.5	16.3	8.2
	Neutral Detergent Fiber		
Frequently severely	415	351	318
Frequently lightly	404	345	356
Infrequently severely	424	361	333
Infrequently lightly	405	387	351
Contrasts			
Frequently vs. infrequently	NS	NS	NS
Lightly vs. severely	NS	NS	NS
Frequency* Intensity	NS	NS	NS
SEM	11.3	15.1	12.5
	In Vitro True Dry Matter Digestibility		
Frequently severely	878	890	901
Frequently lightly	884	890	858
Infrequently severely	872	868	884
Infrequently lightly	881	841	898
Contrasts			
Frequently vs. infrequently	NS	*	NS
Lightly vs. severely	NS	*	NS
Frequency* Intensity	NS	NS	*
SEM	6.5	17.3	15.4

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
† Frequently and infrequently treatments correspond to 3- and 5-wk grazing intervals. Severely and lightly treatments correspond to 50- and 150-mm post grazing stubble heights.
‡ Data are averages of chicory, plantain and orchardgrass cultivars, and four replicates (n=24).
§ Planned orthogonal contrasts.

Table 3: Herbage nutritive value of grazed Puna chicory, Lancelot plantain and Pennlate orchardgrass during 2000 and 2001(Experiment 2).

Cultivar	2000		2001	
	May	August	May	August
	------------------------- dry matter (g kg^{-1}) ------------			
	Crude Protein			
Puna chicory	187	200	161	196
Lancelot plantain	177	170	144	164
Pennlate (Penn) orchardgrass	184	177	146	180
Contrasts †				
Puna vs. Penn	NS	*	NS	0.10
Lancelot vs. Penn	NS	NS	NS	NS
SEM	6.5	11.7	8.6	13.1
	Neutral Detergent Fiber			
Puna chicory	369	318	396	357
Lancelot plantain	344	336	406	339
Pennlate (Penn) orchardgrass	464	502	505	492
Contrasts				
Puna vs. Penn	****	****	****	****
Lancelot vs. Penn	****	****	****	****
SEM	17.0	15.1	20.6	17.2
	In Vitro True Dry Matter Digestibility			
Puna chicory	898	919	845	879
Lancelot plantain	782	792	698	755
Pennlate (Penn) orchardgrass	858	845	870	884
Contrasts				
Puna vs. Penn	*	****	NS	****
Lancelot vs. Penn	****	***	****	****
SEM	13.9	13.6	17.6	11.7

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
**** Significant at the 0.0001 probability level.
† Cultivar mean planned orthogonal contrasts against Pennlate ($P < 0.05$).

Table 4: Variability of herbage nutritive value of grazed chicory, plantain and orchardgrass cultivars over a two year study (Experiment 2).

	May			August		
	CP†	NDF	IVTDMD	CP	NDF	IVTDMD
	---------- g kg^{-1} ----------					
Year						
2000	183‡	392	846	184	386	852
2001	150	435	804	180	396	839
Contrast §						
2000 vs. 2001	****	****	****	NS	NS	****
SEM	4.8	10.4	9.6	7.4	9.3	8.3

**** Significant at the 0.0001 probability level.
NS, Not significant at the 0.05 probability level.
† CP, crude protein; NDF, neutral detergent fiber; IVTD, in vitro true dry matter digestibility. Data are average of chicory, plantain and orchardgrass cultivars.
‡ Data are average of herbage yield of Puna chicory, Lancelot plantain and Pennlate orchardgrass, two grazing treatments, four replicates and two (spring) or three (summer harvest).
§ Planned orthogonal contrasts.

Table 5: Leaf to stem weight ratio of Puna chicory, Lancelot plantain and Pennlate orchardgrass under grazing during 2000 and 2001 (Experiment 2).

	May			August		
	Puna chicory	Lancelot plantain	Pennlate Orchardgrass	Puna chicory	Lancelot plantain	Pennlate † orchardgrass
Leaf-stem ratio ‡						
2000	2.94	2.94	4.4	14.3	10.0	--
2001	1.52a§	1.43a	25.0b	3.8	11.1	--
Contrast ¶						
2000 vs. 2001	***	***	*	*	NS	--
SEM	0.5	0.5	1.9	0.5	0.5	

* Significant at the 0.05 probability level.
*** Significant at the 0.001 probability level.
NS, Not significant at the 0.05 probability level.
† No reproductive stems were observed in Pennlate orchardgrass in the summer.
‡ Data are average of two grazing intensity treatments, severe / severe treatment grazed to 50 mm over both seasons, and severe/moderate intensity grazed to 100 mm over the summer.
§ Different letters within years denote significant differences between species (orthogonal contrast chicory vs. orchardgrass or plantain vs. orchardgrass, $P < 0.05$).
¶ Planned orthogonal contrasts.