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Dairy cow performance on limpograss (*Hemarthria altissima*)

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ABSTRACT

Limpograss is a perennial subtropical grass which has the potential to produce a bulk of standing feed (34 t DM/ha/yr) for consumption by cattle during summer. To assess the value of limpograss for lactating dairy cows, two experiments were conducted comparing limpograss and mixed temperate pasture diets. In both experiments a four day adjustment period was allowed before milksolids yield was assessed on three of the following ten days. Forage samples were taken for nutritional value assessment.

During March 1994, two groups of six Friesian cows on once a day milking late in lactation were pen fed diets of freshly harvested limpograss (*Hemarthria altissima*) or temperate pasture at equal intakes of 13.1 ± 0.5 vs 13.5 ± 0.7 kg DM/cow/day. Temperate pasture was dominated by ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*). In limpograss levels of crude protein, phosphorus, calcium and sodium were below recommended levels for dairy cows. *In vitro* digestibility of limpograss (59.1-65.3%) was also low. Mean daily milk yield (7.8 ± 0.4 vs 8.5 ± 0.3 litres/cow, for limpograss and temperate pasture respectively) was not significantly different, but milk fat yield (0.35 vs 0.41, ± 0.02 kg/cow; $P<0.05$), protein yield (0.27 vs 0.31, ± 0.01 kg/cow; $P<0.05$) and total milksolids (0.62 vs 0.72, ± 0.03 kg/cow; $P<0.05$) were lower in cows consuming limpograss. Animals consuming temperate pasture had elevated rectal temperatures (39.0 vs 40.0, ± 0.1 °C; $P<0.001$). Clinical animal health problems (heat stress and ryegrass staggers) were observed in animals fed temperate pasture.

During March 1995, a grazing trial compared two groups of ten Friesian cows grazing either limpograss or temperate pasture. Mean intakes assessed from pre- and post-grazing harvests were slightly lower in limpograss (13.4 ± 1.8 vs 15.1 ± 1.9 kg DM/cow/day), but were not statistically different. Unadjusted mean daily milk yield (13.3 ± 0.4 vs 12.6 ± 0.3 litres/cow), milk fat yield (0.60 vs 0.65, ± 0.02 kg/cow), protein yield (0.43 vs 0.43, ± 0.01 kg/cow) and total milksolids (1.03 vs 1.07, ± 0.03 kg/cow) were not significantly different ($P>0.05$). Cows on both treatments lost liveweight during the trial, but liveweight losses were not statistically significant. Rectal temperatures (38.3 vs 38.3, ± 0.01 °C) were not significantly different and no animal health problems were observed on either treatment.

Results indicate that limpograss would need to be used in conjunction with supplements or other feeds to achieve milk production equivalent to that from mixed temperate pasture. Providing quality can be maintained, limpograss may offer an alternative to mixed temperate pasture or annual crops during periods of drought stress and animal health challenge.

Keywords: limpograss; milksolids; quality.

INTRODUCTION

Summer and autumn feed deficits often constrain dairy production in northern New Zealand. Miller (1980) showed that existing forage crops had a profitable role in Northland dairy systems, and suggested that research and development on grazing forages preferably perennial, pasture type forages would bring greatest rewards in the short term. Providing adequate soil moisture and nitrogen is present, warm temperatures during summer and autumn favour subtropical (C_4) grass growth. Small plot experiments have identified the potential of limpograss (*Hemarthria altissima*) to overcome feed deficits during this period (Rumball and Lambert, 1981; Taylor *et al.*, 1976b; Davies and Hunt, 1983), fulfilling a role similar to lucerne, maize or sorghum crops. Once established, limpograss has the ability to produce a bulk of reasonable quality feed for cattle consumption during summer and autumn.

Limpograss is a perennial subtropical grass originating in South Africa which can be used as a summer growing component of temperate pasture or as a special purpose forage. The species has undergone considerable development in Florida where it is used as a cattle forage, sometimes in association with legumes, on poorly drained acid soils. It requires vegetative establishment and is winter dormant. On an alluvial site at Kaikohe where 300 kg N/ha was applied, limpograss produced 14-15 t DM/ha/yr between November and April (Rumball, 1989). Mixed pasture digestibility was 68-72% and crude protein content 12-13%. During cooler months an additional 4-5 t DM/ha was produced, mainly from temperate species. Growth rates from January to March often exceeded 100 kg DM/ha/day. In Florida, optimum combinations of yield and quality were obtained with adequate N fertilisation (60-100 kg N/ha), 4-5 week cutting intervals in the summer and 6-8 week cutting intervals in the spring and autumn (Christiansen *et al.*, 1988).

Limpograss is used for beef cattle grazing in Florida (Kretschmer and Synder, 1979; Holderbaum *et al.*, 1991). Quality factors affecting beef cattle performance on stockpiled limpograss have been investigated (Holderbaum *et al.*, 1991; Quesenberry and Ocumpaugh, 1980 and 1982),

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but no work has been done with lactating dairy cattle. The objective of this study was to evaluate limpograss as a summer forage for lactating dairy cows.

MATERIALS AND METHODS

Forage establishment and management

Areas of limpograss were established on Waipu silt loam soil at the Kaikohe Research Station and Northland College during January 1992 and 1993. Stolon cuttings 20-30 cm in length were either hand or mechanically planted into cultivated soil. Before planting, basal fertiliser was applied at 700 kg/ha 30% potassic superphosphate. To assist establishment, irrigation was applied throughout summer and areas were lightly grazed during the subsequent winter. Adjacent areas of existing mixed perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) pasture were used to supply the temperate pasture used. To encourage vegetative growth and accumulate sufficient herbage for animal assessments, nitrogen was applied fortnightly to both limpograss and temperate pastures at 100 kg urea/ha/application from late October. Basal fertiliser of 700 kg/ha 30% potassic superphosphate was applied annually during November. Both forages were rotary slashed or cut for hay during December, and the regrowth used for subsequent experiments. Kikuyu (*Pennisetum clandestinum*) samples used for comparative quality and mineral content analyses were obtained from adjacent areas.

Animal performance

Pen feeding trial

During March 1994 two groups of six Friesian cows in outside enclosures were fed diets of limpograss or temperate pasture at equal daily allowances of 13 kg DM/cow/day. The limpograss pasture consisted of a mixture of the cultivars Bigalta and Floralta originally planted as a 50:50 mixture. All cows in the herd were herd tested and condition scored on 7 March 1994. Results were used to select pairs of high performing cows, which were then assigned to treatment groups of similar initial mean and variance. All cows were from a commercial herd on once a day milking, late in lactation. Forages were mown before being baled green, and transported to cows for immediate feeding from bins. Cows were fed weighed amounts twice daily. Each day, samples were taken from freshly harvested material for dry matter assessment by microwave during the day, and oven overnight. Oven dry matter assessments were used to estimate morning feed requirements. Microwave dry matter assessments (confirmed by a duplicate set of overnight oven dried samples) were used to calculate afternoon feed requirements, and thereby balance treatment allowances on a daily basis. Wasted material was raked up, weighed, subsampled and dried, and data taken into consideration when estimating daily allowances and intakes. Fresh forage samples were also taken for botanical dissection. A four day lead in, acceptance, and rumen adjustment period was allowed, before the experiment. Four herd tests were then conducted over the ensuing ten days ending 28 March 1994. Unfasted cow liveweights were regularly recorded throughout the trial, and rectal temperatures were taken 28 March 1994.

Grazing trial

During March 1995 two groups of ten Friesian cows were grazed on either Floralta limpograss or temperate pasture. All cows were herd tested on 15 January 1995 and again on 9 March 1995, immediately before the trial commenced. Liveweight and condition scores were also recorded. Results were used to select pairs of high performing cows, which were then assigned to treatment groups of similar initial mean and variance. All cows were from a commercial herd on twice a day milking, late in lactation. Cows were given access to fresh breaks after each milking, back fenced to include the previous break. Allowances and mean intakes were assessed three times per week from pre- and post-grazing harvests to ground level. Six quadrats were hand harvested from the same break before and after grazing. Post-grazing samples were washed before oven drying for dry matter determination. Remaining fresh material was bulked and a subsample

TABLE 1: Mean pre- and post-harvest herbage mass (kg DM/ha) and botanical composition (%) of forages harvested and pen fed to dairy cows during March 1994.

Limpograss								
			Botanical composition					
	mass	SEM	leaf	stolon	ogras†	legum†	weed	dead
Pre-harvest	34210	3326	31.0	57.0	4.6	Trace	1.4	5
Post-harvest	4577	760						
Utilisation	87%							
Temperate pasture								
			Botanical composition					
	mass	SEM	ryeg†	wclov†	ogras†	legum†	weed	dead
Pre-harvest	6825	426	28.1	15.5	14.5	Trace	2.5	39.6
Post-harvest	2073	153						
Utilisation	70%							

† Abbreviations: ogras = other grasses, legum = other legumes, ryeg = ryegrass, wclov = white clover

taken for botanical dissection. A five day lead in, acceptance, and rumen adjustment period was allowed before the experiment. Three herd tests were then conducted over the ensuing ten days ending with the morning milking on 23 March 1995. Milk samples were taken from two afternoon milkings for chilling overnight and taste panel comparison by a panel of three males. Unfasted cow liveweights and rectal temperatures were taken after each of the morning herd tests (approximately 9.00 am).

Statistical analysis

Statistical analyses of both forage and animal data were performed using a single factor analysis of variance procedure. Though treatment groups had the same initial mean and variance, standard errors of the mean were determined from individual treatment variances calculated from data collected as the trial progressed. Covariance analyses based on the limited pre-experiment data used to select cows were not performed.

RESULTS

Forage yield and quality

Weather conditions and management caused yield and composition differences between years. Pastures used for outside pen feeding were rotary slashed and closed to grazing from mid December 1993. Weather conditions were dry throughout the growing period (140.6 mm, January to March 1994). Accumulated yields of limpograss exceeded those of temperate pasture (Table 1). Limpograss pasture pen fed to cows contained 88% limpograss, of which 35% was leaf and 65% stem. Other species and dead material were a minor component of limpograss forage offered to animals. Limpograss pastures had lower dry matter contents than temperate pastures. Ryegrass was the main species in stockpiled temperate pasture which also contained a large amount of dead material. Crude protein content (Table 2) of limpograss pasture (7.3%) was below NRC (1989) recommended levels for lactating dairy cows, and was also lower than temperate pasture (20.8%) and kikuyu (22.7%). *In vitro* digestibility of limpograss pasture (59.1%) was lower than temperate pasture (77.2%) and kikuyu (71.3%). Neutral detergent fibre content of limpograss (74.7%) and ryegrass (74.2%) were similar. Levels of phosphorus (0.19%), calcium (0.35%) and sodium (0.10%) in limpograss were below NRC (1989) recommendations for lactating dairy cows. The mineral content of temperate pasture was above NRC (1989) recommended minimums for all elements analysed, but the level of phosphorus (0.29%) was marginal. Kikuyu pas-

TABLE 2: Comparative crude protein (CP%), *in vitro* organic matter digestibility (IVOMD), neutral detergent fibre (NDF%) and mineral contents (% of dry matter) of forages sampled on 9 March 1994, and subsequently pen fed to lactating cows.

	CP%	IVOMD	NDF%	P	S	Mg	Ca	Na	K
Limpograss pasture†	7.3	59.1	74.7	0.19	0.28	0.25	0.35	0.10	2.55
Limpograss leaf†	11.6	65.0	72.4	0.21	0.38	0.29	0.78	0.08	1.97
Limpograss stolon†	3.9	65.3	78.6	0.15	0.21	0.16	0.11	0.06	2.53
Temperate pasture	20.8	77.2	74.2	0.29	0.29	0.21	0.80	0.28	2.10
Kikuyu pasture	15.0	71.3	66.3	0.25	0.37	0.28	0.39	0.04	4.38
Kikuyu leaf	22.7	62.4	71.7	0.32	0.32	0.28	0.46	0.04	3.63
Kikuyu stolon	13.8	64.2	66.5	0.31	0.46	0.32	0.29	0.04	4.84
NRC recommended minimum for 8 l/day	12.0	63.0	28.0	0.28	0.20	0.20	0.43	0.18	0.90
NRC recommended minimum for 17 l/day	15.0	67.0	28.0	0.33	0.20	0.20	0.51	0.18	0.90

† Limpograss sampled was a mixture of the cultivars Bigalta and Floralta.

TABLE 3: Mean pre- and post-grazing herbage mass (kg DM/ha) and botanical composition (%) across all daily breaks of forages grazed by dairy cows during March 1995.

Limpograss								
			Botanical composition					
	mass	SEM	leaf	stolon	ogras†	legum†	weed	dead
Pre-grazing	11314	902	21.1	52.4	9.3	7.8	1.7	7.7
Post-grazing	7078	770	11.1	64.2	9.1	5.9	Trace	9.7
Utilisation	37%							
Temperate pasture								
			Botanical composition					
	mass	SEM	ryeg†	wclov†	ogras†	legum†	weed	dead
Pre-grazing	3748	127	53.6	8.8	10.0	0.3	3.5	23.8
Post-grazing	2007	104	46.9	6.6	10.6	0.9	0.9	35.0
Utilisation	46%							

† Abbreviations: ogras = other grasses, legum = other legumes, ryeg = ryegrass, wclov = white clover.

ture sampled from the same area had a higher mineral content than limpograss, but levels of phosphorus (0.25%), calcium (0.39%) and sodium (0.04%) were below NRC (1989) recommended minimums.

Pastures grazed by cows were cut for hay during mid December 1994 before regrowing. Weather conditions were dry during December (14.0 mm), but subsequent rainfall (434.2 mm January to March 1995) and warm temperatures provided good growing conditions. Accumulated yield of limpograss exceeded that of temperate pastures (Table 3), though yields were not as great as the previous year. Temperate pasture offered to cows contained more ryegrass and less dead matter than the previous year.

Animal performance

In the pen feeding trial (Table 4) mean daily milk yields were not significantly different. Milk fat yield, protein yield and total milksolids were lower from cows consuming limpograss than those fed temperate pasture ($P<0.05$). Liveweights did not differ significantly among forage treatments or between the start and finish of the trial. Rectal temperatures were elevated 1 °C in cows fed temperate pasture ($P<0.001$), on days when air temperature reached a maximum of 25.0 °C, minimum of 10.7 °C, with windrun of 157 km. One cow fed temperate pasture exhibited symptoms of ryegrass staggers, and another symptoms of heat stress. No symptoms of ill health were noted on limpograss. Mean intakes on both pastures were similar. Rejection and wastage of pen fed material was low at 8% and 7% of dry matter offered, for limpograss and temperate pastures respectively.

TABLE 4: Overall means from cows pen fed limpograss and temperate pasture during March 1994.

	Limpograss	Temperate pasture
Milk volume (l/cow/day)	7.8 ± 0.4	8.5 ± 0.3
Milk fat (kg/cow/day)	0.35 ± 0.02	0.41 ± 0.02
Protein (kg/cow/day)	0.27 ± 0.01	0.31 ± 0.01
Total milksolids (kg/cow/day)	0.62 ± 0.03	0.72 ± 0.03
Initial liveweight (kg)	519.3 ± 22.8	18.0 ± 29.4
Final liveweight (kg)	21.7 ± 25.9	498.0 ± 28.4
Rectal temperature (°C)	39.0 ± 0.1	40.0 ± 0.1
Intake (kg DM/cow/day)	13.1 ± 0.5	13.5 ± 0.7

TABLE 5: Overall means from cows grazing limpograss and temperate pasture during March 1995.

	Limpograss	Temperate pasture
Milk volume (l/cow/day)	13.3 ± 0.4	12.6 ± 0.3
Milk fat (kg/cow/day)	0.60 ± 0.02	0.65 ± 0.02
Protein (kg/cow/day)	0.43 ± 0.01	0.43 ± 0.01
Total milksolids (kg/cow/day)	1.03 ± 0.03	1.07 ± 0.03
Initial liveweight (kg)	506.4 ± 10.7	505.9 ± 9.7
Final liveweight (kg)	490.7 ± 11.5	488.3 ± 7.6
Rectal temperature (°C)	38.3 ± 0.01	8.3 ± 0.01
Intake (kg DM/cow/day)	13.4 ± 1.8	15.1 ± 1.9
Initial condition score	4.0 ± 0.2	3.8 ± 0.1
Final condition score	3.6 ± 0.1	3.4 ± 0.1

In the grazing trial (Table 5) mean daily milk, fat and protein yields, total milksolids, liveweights and rectal temperatures were not significantly different ($P>0.05$). Protein yield was sustained but milk fat yield declined in animals consuming limpograss, although this trend was not statistically significant. No animal health problems occurred on either treatment. Mean intakes were slightly lower in limpograss but were not significantly different.

No adverse aroma, flavours or taste differences were detected between unpasteurised milk samples from cows grazing limpograss or temperate pasture. A commercially available pasteurised milk sample was detected as different to taste.

DISCUSSION

Yields achieved indicate that when limpograss is successfully established a large quantity of feed can be produced during summer and autumn, when alternative feed stuffs are limited. Measured yields during summer from pure limpograss were comparable or higher than those previously reported in Northland (Taylor *et al.*, 1976b; Davies and Hunt, 1983; Davies and Hunt, 1989; Rumball, 1989) for limpograss in mixed pasture. However, the leaf content (35%) was considerably lower than figures recorded by Taylor *et al.*, (1976a) (69% leaf) and Rumball (1989) (56% leaf) using the same cultivars, and this would have detrimentally affected quality.

The supply of quality feed to stock during summer and autumn has been identified as a constraint to animal production in Northland. Stock-piling disadvantaged quality of both pastures used in this study. Stock-piled limpograss is known to decline in quality (Quesenberry and Ocumpaugh, 1980), and it is likely to be a major factor affecting the data reported here. The large amount of dead material in temperate pasture pen fed to cows reflected the dry summer conditions and effects of stock-piling feed. More regular harvesting or grazing of both pastures would improve quality by maintaining a leafy state with less stolon or stem and dead material present. To better utilise limpograss and maintain quality, feed conservation strategies such as hay and silage need to be developed, and compared to other options such as maize silage, or kikuyu hay and silage. When fed to steers, limpograss hay had the highest intake and digestibility of four subtropical grass hays grown in central Florida (Horton and Pitman, 1994).

Crude protein content of limpograss leaf (11.7%) and stolon (3.9%) material was lower than previously reported in Northland, and would have limited animal performance. Taylor et al., (1976a) and Rumball (1989) reported crude protein contents of 15.0-15.8% and 6.1-8.9% in the leaf and stolon of limpograss fertilised with nitrogen. Limpograss crude protein content has been improved by N fertilisation (Ruelke and Quesenberry, 1983), but responses tend to be short lived (Christiansen *et al.*, 1988). Sollenberger *et al.*, (1988) suggested that frequent N applications would be needed to maintain Floralta crude protein above levels limiting intake. Holderbaum *et al.*, (1991) suggested that feeding a corn-urea supplement may be effective in improving animal performance.

Legume-limpograss associations also have the potential to overcome crude protein deficiencies. In Florida, Rusland *et al.,* (1988) achieved superior animal performance from steers grazing limpograss and *Aeschynomene americana* pastures. Lotus (*Lotus pedunculatus*) and white clover (*T. repens*) have been grown with limpograss under Northland conditions (Taylor, *pers. comm.*; Rumball, 1989). Nitrogen fertilised limpograss suppressed legume growth during summer (Rumball, 1989), but legumes and temperate weed grasses have dominated limpograss areas during winter. Ruelke and Quesenberry (1981) investigated the use of cool season legumes with limpograss in Florida. Greatest clover yields were obtained from red clover (*T. pratense*), but some soils suitable for limpograss in Northland may be too poorly drained for red clover.

In vitro digestibility's for limpograss (59.1-65.3%) observed in this study were lower than those previously reported in Northland. Data obtained for separated leaf and stolon (65.0% and 65.3% respectively) were inconsistent with that for the limpograss pasture sample (59.1%). Similar inconsistencies were present in the limpograss data of Taylor (1976a). Taylor *et al.,* (1976a) and Rumball (1989) found digestibility's of leaf (66-73%) and stolon (66-77%) to be similar in tetraploid cultivars. Tetraploid forms such as Bigalta and Floralta used in this study are favoured over diploids because of higher *in vitro* organic matter digestibility, and although tetraploids appear stemmy, cattle readily eat both stems and leaves (Schank *et al.,* 1973).

Neutral detergent fibre content of both pastures were high and may have limited intake. Levels of phosphorus, calcium and sodium in limpograss pen fed to cows were below NRC (1989) recommendations for dairy cows, hence limpograss will need to be used in conjunction with supplements or other feeds containing higher amounts of these elements. Rumball (1989) found phosphorus and calcium to be below recommended levels but other major elements were adequate. Quesenberry and Ocumpaugh (1982) studied changes in the mineral composition of stockpiled limpograss. Potassium and phosphorus levels were below recommendations for ruminants. Calcium content frequently fell below recommended levels for lactating beef cows. Magnesium content did not fall below the recommended minimum. They concluded that mineral supplementation would be required for cattle feeding on 2-3 month old limpograss and suggested that soil fertility could have a significant effect on forage mineral composition.

Limpograss was readily consumed by lactating cows. Animal health problems noted in pen fed animals consuming temperate pasture may have been partially due to reduced ability to selectively feed, and to the presence of toxins in ryegrass. Field utilisation by mechanically harvesting material (87% and 70% for limpograss and temperate pasture respectively) for pen feeding was considerably higher than grazing in situ (37% and 46% for limpograss and temperate pasture respectively), regardless of year or stage of growth. Rejection and wastage rates of mechanically harvested pen fed material were low. Grazing animals had greater ability to select against eating dead or other undesirable material. Post-grazing botanical compositions (Table 3) indicated a higher proportion of stolon material present in residue.

Under grazing milk and protein yields on limpograss were maintained despite apparently lower intakes. Assessment of limpograss using pre- and post-grazing harvests may have provided a variable or inadequate intake estimate, due to interactions of plant morphology, growth and grazing variability. Greater sampling intensity using the existing trial design may have improved precision of both intake and animal performance estimates. Similarly, use of a replicated block design may have improved precision, but would have required greater resources than available.

CONCLUSION

Limpograss is capable of producing a bulk of feed for consumption by cattle during summer and early autumn. Economic means of reliable establishment are needed before the crop can be widely used by farmers. It offers an alternative to temperate pasture or annual crops during periods of drought stress or animal health challenge. Limpograss would need to be used in conjunction with other feeds or mineral supplements in order to achieve a balanced mineral intake and dairy production equivalent to that from temperate pasture. Management to maintain maximum quality is critical, and should include maintenance of high soil fertility, use of nitrogenous fertilisers, and harvesting or grazing frequencies to minimise excessive stock-piling. Further investigation of legume-limpograss associations under New Zealand conditions is warranted. Conservation strategies to better utilise the crop and assist in maintaining quality including the use of hay and silage making, require investigation. It may have potential as a summer growing forage on effluent disposal sites of dairy farms.

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REFERENCES

Christiansen, S.; Ruelke, O.C.; Ocumpaugh, W.R.; Quesenberry, K.H.; Moore, J.E. 1988. Seasonal yield and quality of 'Bigalta', 'Redalta' and 'Floralta' limpograss. *Tropical Agriculture* **65:** 49-55.

Davies, L.J.; Hunt, B.J. 1983. Growth of tropical grass introductions in mixed swards with ryegrass and clover under mowing. *New Zealand Journal of Agricultural Research* **26:** 415-422.

Davies, L.J.; Hunt, B.J. 1989. Evaluation of five introductions of the subtropical grass *Hemarthria altissima* at a frost-prone site in North–land. *New Zealand Journal of Agricultural Research* 32: 469-476.

Holderbaum, J.F.; Sollenberger, L.E.; Moore, J.E.; Kunkle, W.E.; Bates, D.B.; Hammond, A.C. 1991. Protein supplementation of steers grazing limpograss pasture. *Journal of Production Agriculture* 4: 437-441.

Horton, G.M.J.; Pitman, W.D. 1994. The nutritional value of selected tropical grass hays fed with concentrate. *International Journal of Animal Science* **10:** 205-206.

Kretschmer, A.E.Jr; Snyder, G.H. 1979. Production and quality of limpograss for use in the subtropics. *Agronomy Journal* **71:** 37-41.

Miller, C.P. 1980. Modelling the contribution of forage crops to production, profitability and stability of North Island dairy systems. *Proceedings of the New Zealand Society of Animal Production* **40:** 64-67.

NRC 1989. Nutrient requirements for dairy cattle. National Academy Press, Washington, DC.

Quesenberry, K.H.; Ocumpaugh, W.R. 1980. Crude protein, IVOMD, and yield of stockpiled limpograsses. *Agronomy Journal* **72:** 1021-1024.

Quesenberry, K.H.; Ocumpaugh, W.R. 1982. Mineral composition of autumn-winter stockpiled limpograss. *Tropical Agriculture* **59:** 283-286.

Ruelke, O.C.; Quesenberry, K.H. 1981. Topseeding winter clovers on limpograss, potentials and problems. *Soil and Crop Science Society of Florida, Proceedings* **40:** 162-164.

Ruelke, O.C.; Quesenberry, K.H. 1983. Effects of fertilization timing on the yields, seasonal distribution and quality of limpograss forage. *Soil and Crop Science Society of Florida, Proceedings* **42:** 132-136.

Rumball, P.J. 1989. Performances of three lines of limpograss (*Hemarthria altissima*) in mixed pasture. *New Zealand Journal of Agricultural Research* **32:** 151-155.

Rumball, P.J.; Lambert, J.P. 1981. Plant introduction trials. Performance of some subtropical grasses in Northland. *New Zealand Journal of Experimental Agriculture* **9:** 79-83.

Rusland, G.A.; Sollenberger, L.E.; Albrecht, K.A.; Jones, C.S.Jr.; Crowder, L.V. 1988. Animal performance on limpograss-*Aeschynomene* and nitrogen-fertilized limpograss pastures. *Agronomy Journal* **80:** 957-962.

Schank, S.C.; Klock, M.A.; Moore, J.E. 1973. Laboratory evaluation of quality in subtropical grasses: II. Genetic variation among *Hemarthrias* in *In Vitro* digestion and stem morphology. *Agronomy Journal* **65:** 256-258.

Sollenberger, L.E.; Ocumpaugh, W.R.; Euclides, V.P.B.; Moore, J.E.; Quesenberry, K.H.; Jones, C.S.Jr. 1988. Animal performance on continuously stocked 'Pensacola' bahiagrass and 'Floralta' limpograss pastures. *Journal of Production Agriculture* **1:** 216-220.

Taylor, A.O.; Haslemore, R.M.; McLeod, M.N. 1976a. Potential of new summer grasses in Northland. III. Laboratory assessments of forage quality. *New Zealand Journal of Agricultural Research* **19:** 483-488.

Taylor, A.O.; Rowley, J.A.; Hunt, B.J. 1976b. Potential new summer grasses in Northland. II. A further range of species. *New Zealand Journal of Agricultural Research* **19:** 477-481.