Maize silage and winter crop options to maximise drymatter and energy for NZ dairy systems

R.J. DENSLEY[1], G.M. AUSTIN[1], I.D. WILLIAMS[1], R. TSIMBA[1] and G.O. EDMEADES[2]
[1]*Genetic Technologies Ltd., P.O. Box 105 303, Auckland*
[2]*43 Hemans St., Cambridge*
rdensley@genetic.co.nz

Abstract

Trade-offs in dry matter (DM) and metabolisable energy (ME) between combinations of three maize silage hybrids varying in maturity from 100-113 CRM and six winter forage options were investigated in a Waikato farmer's field over 2 years. Winter crops were triticale, cut once; oats grazed 1-2 times; and Tama and Feast II Italian ryegrass, each cut or grazed 2-3 times. Greatest DM and ME production (38.9 t/ha; 396 GJ/ha) was from a 113 CRM hybrid followed by a single-cut triticale crop. The most economical sources of DM and ME were obtained from a 100 CRM maize hybrid plus grazed oats (11.8 c/kg; 1.12 c/MJ), while the cheapest ME source among cut winter forages was a 113 CRM maize hybrid + triticale (1.18 c/MJ). Reliable annual silage production of 30 t DM/ha and 330 GJ ME/ha (or 3000 kg MS/ha) is possible using a late maturing maize hybrid combined with a winter forage crop such as triticale, although the low feed value of the triticale may limit its use as feed for milking cows.

Keywords: Italian ryegrass, oats, maize silage, supplements, triticale, winter forage crops

Introduction

Dairy farm production per hectare has increased by around 20% over the past decade (LIC 2005). This trend towards intensification continues as farmers strive for greater economic efficiency by breaking the feed barrier of around 15 t dry matter (DM)/ha/yr imposed by pasture forage supply (Deane1999; Densley *et al*. 2001; Kolver *et al.* 2001). Maize silage is now well established as a high energy supplement on dairy farms, where, compared with pasture, it provides a moderate to high yield of metabolisable energy (ME) but is low in crude protein (CP) (Densley *et al.* 2005). It serves to extend lactation length, increase carrying capacity and boost milksolids (MS) production by increasing energy intake (Thomson *et al*. 1998). By international standards New Zealand's maize silage yields are high, averaging 22.3 t DM/ha when assessed across 294 strip plot or small plot trials (Densley *et al.* 2005).

There is currently a growing interest in developing 12 month cropping systems using maize silage followed by a winter forage crop. The Comparative Relative Maturity (CRM) system generally ranks maize hybrids according to heat units required to reach harvest maturity. Farmers are interested in determining the combination of maize hybrid CRM and winter crop that gives maximum annual DM and ME yields at the lowest unit costs.

The aims of the present study were to evaluate the production of winter forages following a summer maize silage crop, to establish the trade-offs in DM yield, quality and cost between long vs. short season maize hybrids and the following winter forage crop and to maximise 12-month-crop gross margins in a dairy farm context.

Materials and Methods

The experiment was repeated twice in the period 2003-2005 on a well-drained Maeroa ash soil in the same area of a commercial farmer's field near Te Awamutu.

Maize silage

In Year 1, an exploratory trial was established consisting of an unreplicated strip of 16 rows, 0.76 m apart and 72 m long, of each of three maize hybrids differing in maturity. In Year 2, three replicates (16 rows x 26.5 m long) were established within each maize strip. Hybrids were sown with a commercial vacuum planter at a planting population of 110,000 plants/ha on 23 September (Year 1) and 2 October (Year 2). Maize hybrids consisted of late (112-114 CRM; 33J56 or 33G26), intermediate (109 CRM; 34K77) and early (100 CRM; 36H36) maturity comparisons. Soil samples were collected prior to ground cultivation using a 150 cm core and fertiliser requirements were calculated using an Excel spreadsheet (Densley 2002). Nitrogen was applied at 264-277 kg/ha in each year, along with adequate levels of P, K, S and Mg. Weeds were controlled by standard herbicides Roundup Xtra ® (3 L/ha) with Harmony® (20 g/ha) applied prior to planting; Roustabout® (3 L/ha) and atrazine (3 L/ha) applied pre-emergence in Year 1; and by spot spray application of dicamba (1 L/ha) in Year 2. Individual hybrids were harvested at 35% whole plant dry matter using a small plot silage chopper. Samples for DM analysis were collected during harvest and fresh weights per plot measured on site.

Winter crops

In both years, winter forage crops were sown 2 d after

Table 1 Annual yields of winter forage and of the combined (maize + winter forage (WF) system) for DM, ME and CP over Years 1 and 2, and quality characteristics of the final harvest of winter forages in Year 2. Predicted milk solids production, valued at $4/kg, and crop production costs are used to estimate gross margins.

		Winter forage (WF)			Annual forage system output				
Maize hybrid DM (t/ha)	Winter forage treatment	DM t/ha	ME MJ/kg	CP %	Maize + WF DM t/ha	Maize + WF ME GJ/ha	Milk solids kg/ha	Crop cost $/ha	Gross margins $/ha
Late	Triticale cut	9.5	8.9	8.1	38.9	396	3597	4665	9725
(29.3)	Oats grz	4.0	11.3	16.3	33.3	356	3232	4004	8925
	Tama grz	2.6	11.4	12.7	31.9	340	3095	4022	8356
	Tama cut	3.2	11.2	9.3	32.5	346	3147	4215	8374
	Feast II grz	2.8	11.6	14.5	32.2	344	3126	4066	8438
	Feast II cut	3.2	11.3	9.7	32.5	346	3150	4259	8339
Mean		4.2	10.9	11.8	33.5	355	3225	4205	8693
Inter.	Triticale cut	9.8	8.3	7.3	37.1	370	3363	4551	8901
(27.2)	Oats grz	5.3	10.6	14.5	32.5	344	3130	3875	8647
	Tama grz	3.4	12.4	15.0	30.6	331	3009	3892	8144
	Tama cut	4.2	11.1	10.0	31.5	336	3051	4150	8055
	Feast II grz	4.1	11.3	14.9	31.4	336	3051	3936	8269
	Feast II cut	5.1	11.1	14.2	32.3	345	3138	4247	8306
Mean		5.3	10.8	12.7	32.6	344	3124	4109	8387
Early	Triticale cut	10.1	8.3	9.7	36.9	368	3344	4541	8837
(26.8)	Oats grz	5.7	10.2	12.7	32.6	343	3116	3848	8617
	Tama grz	3.5	11.8	16.1	30.3	325	2957	3865	7965
	Tama cut	4.3	11.2	10.8	31.1	332	3017	4102	7966
	Feast II grz	4.6	11.2	13.3	31.4	336	3051	3910	8293
	Feast II cut	5.3	11.7	11.1	32.1	346	3150	4232	8366
Mean		5.6	10.7	12.3	32.4	342	3106	4083	8341
All	Triticale cut	9.8	8.5	8.4	37.6	378	3435	4586	9154
(27.8)	Oats grz	5.0	10.7	14.5	32.8	348	3160	3909	8730
	Tama grz	3.2	11.9	14.6	31.0	332	3020	3926	8155
	Tama cut	3.9	11.2	10.1	31.7	338	3072	4156	8132
	Feast II grz	3.9	11.4	14.3	31.6	338	3076	3971	8333
	Feast II cut	4.5	11.4	11.7	32.3	346	3146	4246	8337
Mean		5.0	10.8	12.2	32.8	347	3151	4132	8474
S_d hybrid		0.68	0.17	1.02	1.06	11.1	101		
S_d winter forage		0.25	0.21	1.42	0.25	2.6	23.3		
S_d hyb. x wint. forage		0.68	0.38	2.46	0.93	9.6	88		
P hybrid		NS	NS	NS	NS	NS	NS		
P winter forage		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		
P hyb. x wint. forage		NS	0.046	NS	NS	0.004	0.004		

the maize harvest in three replications established on each maize strip. In Years 1 and 2, sowing dates differed, respectively by 17 and 20 d between the early (12 March) and late (1 April) hybrids. Crops were sown using a small plot planter in 15 cm rows. Six winter forage crop systems were established. These were: 1) triticale cv. Monster, cut; 2) oats cv. Massif, grazed; 3) Italian ryegrass cv. Tama grazed or 4) cut; and 5) Italian ryegrass cv. Feast II grazed or 6) cut. Sowing rates (kg/ha) were: triticale 140, oats 60, Tama ryegrass 40, and Feast II ryegrass 25. Triticale was cut once, oats were cut or grazed twice in Year 2 but only once in Year 1 due to a lack of regrowth. All ryegrass treatments were cut or grazed three times (Year 1) and two times (Year 2). Final winter crop harvest date was 8 September (Year 1) and 9 September (Year 2), and was determined by maize planting date for a 12 month cropping system. Grazed plots were 7.2 m wide x 6 m long, while cut plots were 2.4 m wide x 6 m long. Weeds following maize were negligible. No additional nutrients were applied to the winter forage crop because of the risk of high nitrate levels, and one grazing of oats in Year 1 was discarded because nitrate levels exceeded those considered safe as a sole feed source. DM available on grazed plots was assessed from a strip of 1.2 x 6 m cut prior to grazing. Cutting to 4 cm height was by sicklebar mower, and forage was sampled for DM before being weighed fresh on site. Dry Friesian cows were used for the grazing treatment. A 1 kg sample from the final harvest in Year 2 was analysed for nutritional composition (Corson *et al*. 1999).

Data analysis

Total annual production of DM, ME and CP was estimated by adding components of each from maize and winter forages. Maize silage ME content of 10.6 MJ ME/kg, and CP values for late, intermediate and early hybrids of 7.6%, 7.3% and 7.7% were assumed (Kolver *et al*. 2001, 2003). Quality data from the last harvest of 2005 was applied to all winter forage data, and MS production was calculated assuming 110 MJ ME/kg MS. Statistical analyses (REML, GenStat v.8.1) considered reps and years as random effects and all other factors as fixed.

Results and Discussion

Maize silage yields

In across year comparisons, REML estimates of means indicated that late, intermediate and early hybrids averaged 29.3, 27.2 and 26.8 t DM/ha (P<0.001; s_d=0.26 t/ha). Yields in Year 1 (30.7 t/ha) and Year 2 (24.9 t/ha) differed mainly because of an unusually cool spring and a very hot summer in Year 2. Mean yields increased with hybrid maturity at a rate of 0.17 t/ha/unit CRM, a rate similar to that derived from other reports (e.g. Densley *et al*. 2001).

Winter forage DM yields

There were few significant differences in DM yield between the years (Year 1: 4.80 t/ha; Year 2: 5.26 t/ha) since the two winters were quite similar. Yields of winter forages were similar to those reported elsewhere (e.g. Hughes & Haslemore 1984; de Ruiter *et al*. 2002). While there was a trend for higher forage yields for crops planted after an early maturing hybrid, differences due to hybrid were significant only at P=0.10 (Table 1). Cut triticale (9.81 t/ha) significantly outperformed all other treatments, and was followed by grazed oats (4.98 t/ha) and cut Feast II (4.50 t/ha). These in turn significantly outyielded the other three treatments. The strong performance of triticale can be attributed to its single harvest, whereas all others were cut or grazed 2-3 times, resulting in periods when leaf area was well below optimal for radiation interception. Annual DM production was greatest for late maize + triticale (38.9 t/ha) and least for the early hybrid + grazed Tama (30.3 t/ha). The contribution of the winter crop to annual DM production averaged 15% and varied from 27% (early hybrid + triticale) to 8% (late hybrid + grazed Tama). Annual DM production averaged across hybrids was dominated by triticale, and this out-yielded the next best, oats + cut Feast II, by almost 5 t DM/ha (P<0.001).

Variation in annual DM production for each year was more strongly associated with variation in maize yields (r = 0.75, P<0.01) than with winter forage DM yield (r = 0.53, P<0.01; 34 df). Across years, the trend (NS) in winter forage yield was -0.09 t/ha/unit CRM, or approximately half that for maize yields. When triticale data were excluded because of its low quality, the regression of winter forage DM yield on maize DM yield (Forage DM = 21.9 - 0.61(Maize DM); N=15; R^2=0.51; P=0.003) showed that the increase in forage yields accounted for only 61% of the losses incurred by the maize component as maize CRM decreased. Annual DM production is therefore maximised by utilising an adapted late maturing hybrid, even in unfavorable years.

Forage quality

Nutritive samples were collected from winter crop treatments at the last harvest in Year 2 only. The laboratory results showed significant differences in nutritive quality between winter crops (Table 1). Triticale was cut only once 2-3 weeks prior to the planned maize planting date. Ideally harvest should have occurred later but was brought forward to represent typical on-farm practice where maize planting date determines winter crop harvest date. As a consequence, in all measures of quality, triticale was significantly poorer than all other winter forages, often by >8 x s_d values for the trait. Its predicted digestibility, CP and ME contents were 57%, 8.4% and 8.5 MJ/kg vs. a mean of 70%, 15.9% and 11.3 MJ/kg for the other five winter systems. Digestibilities of less than 60% can pose problems in ruminant nutrient intake (Blaxter *et al*. 1961), and silage of this quality should not be fed to lactating cows. Grazed Tama forage was superior in ME and digestibility, while grazed oats was inferior to the ryegrass options in quality, and may have levels of nitrate that endanger stock. Grazing regimes generally resulted in a higher CP percentage than cut regimes.

Unfortunately this trial did not include any nutritional analysis of maize. Maize ME was assumed to be the same for all hybrids which is reasonable given that New Zealand data show an average DM digestibility difference of just 1.8% between long and short maturity hybrids (Kolver *et al.* 2003). The actual value used (10.6 MJ ME/kg DM) was the average for maize silage samples (N=477) submitted to FeedTech in 2002 (Dean Corson pers.comm.) which may be slightly low when compared to the ME achieved under good management (Kolver *et al.* 2001).

Annual ME production from maize + winter forage systems differed significantly between years because of large differences in maize yields, but there was no significant effect of hybrid on this trait (Table 1). Production of ME at 396 GJ /ha/yr for the late hybrid +

Table 2 Cost per unit DM and ME by cropping system component and as an annual cropping system when averaged A) across cropping systems, or B) by hybrid maturity.

	Costs (cents) per					
	kg DM maize	kg DM WF	kg DM annual	MJ ME maize	MJ ME WF	MJ ME annual
A: Across hybrids by winter cropping systems						
Triticale cut	13.5	8.6	12.2	1.27	1.01	1.21
Oats grazed	13.5	3.4	11.9	1.27	0.32	1.12
Tama grazed	13.5	6.0	12.7	1.27	0.51	1.18
Tama cut	13.5	11.1	13.2	1.27	1.00	1.24
Feast II grazed	13.5	6.2	12.5	1.27	0.54	1.17
Feast II cut	13.5	11.5	13.1	1.27	1.01	1.23
B: By hybrid across winter cropping systems						
Late	13.1	8.9	12.6	1.23	0.82	1.19
Intermediate	13.6	7.3	12.6	1.28	0.70	1.19
Early	13.7	7.2	12.6	1.29	0.68	1.20

triticale was significantly greater than that for any other combination, while that of the poorest, early hybrid + grazed Tama, was 18% less. Mean ME production over hybrids for triticale was 9% greater ($P<0.01$) than the next best options, oats and grazed Feast II. The greatest CP yields came from combinations of maize with triticale or oats (data not shown). Variations in annual ME and CP production for both years were again more closely related to variation in ME and CP yields of maize (ME: $r = 0.86$, $P<0.01$; CP: $r = 0.69$, $P<0.01$) vs. those of winter forage (ME: $r = 0.31$NS; CP: $r = 0.48$, $P<0.01$). These data support the assertion of Kolver *et al*. (2003) that variation in DM yields is a more important determinant of ME and CP yield than variation in quality parameters *per se*.

Performance of ryegrass cultivars

Feast II outyielded Tama under both grazing and cutting by 19% ($P<0.001$). Cutting resulted in a 20% greater ($P<0.001$) forage production over grazing, presumably because of treading damage under grazing. Yields of ME followed a similar pattern, and yields of CP were 27% greater ($P<0.001$) for Feast II, but were unaffected by harvest method.

Economic analysis

Costs of maize growing, harvesting, storage and feeding, based on yields from this study, were calculated using partial budgeting techniques (Genetic Technologies Ltd 2005). Costs for each of the winter forage options, including cultivation, seed, sowing, and, where applicable, harvesting, stacking, and feeding, or break fencing for grazing, were estimated. No allowance was made for storage or feed-out wastage in any of the cut treatments.

Economic analysis was calculated assuming 110 MJ ME/kg MS. This translates to a milk response of 96 g MS/ kg DM (assuming a maize ME of 10.6 MJ/kg DM). Maize silage is commonly used to extend lactation. Waimate West Demonstration trial data showed seasonal responses to maize silage up to 179 g MS/kg DM (Deane 1999).

Greatest gross margins ($9725/ha) were from late maize + triticale, and the least ($7965/ha) from early maize + cut or grazed Tama (Table 1). Cheapest unit sources of DM and ME were from grazed winter forage options, the lowest priced option being early maize + grazed oats (11.8 c/kg) (Table 2). Among the cut options, the cheapest source of DM was late maize + triticale (12.0 c/kg), and the most expensive was early maize + Tama (13.4 c/kg). Across hybrids, treatments with maize ranked by cost/kg DM as: grazed oats < triticale < grazed Feast II < grazed Tama < cut Feast II < cut Tama, though grazed options provided cheaper ME sources that cut winter forage treatments. The cheapest sources of ME (and MS) were early maize + grazed oats (1.12c/MJ), while late hybrid + triticale (1.18c/MJ) was the lowest priced cut option. Late hybrids generally resulted in lower unit costs of DM and ME because of their greater yields (Table 2).

Conclusions

Annual production levels of more than 30 t DM/ha and 330 GJ ME/ha are possible using maize-based cropping systems combined with a winter forage crop. Winter forage crops contribute an average of 15% and up to 27% of total annual DM yield. Despite the rapid decline in forage quality in triticale, maximum annual ME production (396 GJ/ha) was from late maize + triticale, although the low digestibility of triticale at maturity may restrict its use as silage for lactating dairy cows. Unit costs of DM and ME were lower for grazed vs. cut winter forage options, with the cheapest option being early maize + grazed oats. For cut and ensiled options, we recommend a late maize hybrid + single-cut triticale or oats. These alternatives will double the annual DM production of pasture, and generate forage sufficient to produce > 3000 kg MS/ha/yr in a commercial setting.

REFERENCES

Blaxter, K.L.; Wainman, F.W.; Wilson, R.S. 1961. The regulation of food intake by sheep. *Animal Production 3*: 51-61.

Corson, D.C.; Waghorn, G.C.; Ulyatt, M.J.; Lee, J. 1999. NIRS: Forage analysis and livestock feeding. *Proceedings of the New Zealand Grassland Association 61*: 127-132.

Deane, T. 1999. The profitable use of supplementary feeds in pasture based dairy farm systems. *Proceedings of the Ruakura Farmers Conference 51*: 64-77.

Densley, D.W. 2002. Fertiliser recommendations for forages using soil tests and an Excel spreadsheet. pp 389-395. *In*: Proceedings of the Dairy Farm Soil Management Workshop. Massey University.

Densley, R.J.; Miller, D.; Kolver, E.S. 2001. Breaking the feed barrier using maize silage. *Proceedings of the New Zealand Grassland Association 63*: 289-293.

Densley, R.J.; Kolver, E.S.; Miller, D.B.; Williams, I.D.; Tsimba, R. 2005. Comparison of conventional and leafy maize silage hybrids in New Zealand dairy farm systems. *Proceedings of the New Zealand Grassland Association 67*: 163-168.

de Ruiter, J.M.; Hanson, R.; Hay, A.S.; Armstrong, K.W.; Harrison-Kirk, R.D. 2002. Whole-crop cereals for grazing and silage: balancing quality and quantity. *Proceedings of the New Zealand Grassland Association 64*: 181-189.

Genetic Technologies Ltd. 2005. Farming for more success. Pioneer® brand forage products for 2005-2006. Auckland, New Zealand (http://www.pioneer.co.nz).

Kolver, E.S.; Roche, J.R.; Miller, D.; Densley, R. 2001. Maize silage for dairy cows. *Proceedings of the New Zealand Grassland Association 63*: 195-201.

Kolver, E.S.; Densley, R.; Miller, D.; Williams, I.; Sapienza, D.A. 2003. Ranking maize hybrids for silage quality and milk production in pasture-based dairying. *Proceedings of the New Zealand Society of Animal Production 63*: 101-106.

LIC 2005. Dairy Statistics 2004-2005. Livestock Improvement Corporation Ltd, Hamilton, New Zealand. pp7.

Thomson, N.A.; Davis, K.L.; McGrath, J.M.; Hainsworth, R.J.; Clough, J.C. 1998. Impact of feeding maize silage on dairy production. *Proceedings of the New Zealand Grassland Association 60*: 51-55.