Yield and quality of cereals grown for silage

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Abstract

The whole crop forage yield and metabolisable energy content of three temperate cereals, >Omaka= barley, >Hokonui= oats and >Aranui= triticale and 7 maize hybrids were compared in a trial planted on the 1st of November 1998 at Massey University, Palmerston North. The maize hybrids included 1 specialised silage hybrid possessing the leafy gene (TF94), three dual purpose grain/silage hybrids (Janna, P3905, P3790), one flint type hybrid utilised in the food industry (Clint) and two non commercial hybrids (CF06, CF08). Forage yield and metabolisable energy content were measured at ear emergence and soft dough stages (standard silage maturity) for the temperate cereals and at standard silage maturity (50 % kernel milkline) for the maize hybrids. At silage maturity the temperate cereals generally produced significantly lower yields (11,527 kg DM/ha, 12,030 kg DM/ha and 14,651 kg DM/ha for the barley, oats and triticale respectively), than the maize hybrids, which produced yields ranging from 17,151 to 23,332 kg DM/ha. Harvest dates ranged from 19/1 to 29/1 for the temperate cereals and from 4/3 to 1/4 for the maize hybrids. Metabolisable energy content in the temperate cereals at the soft dough stage was significantly lower (8.9 to 9.7 MJ ME/kg DM) than in the maize hybrids (10.2 to 11.4 MJ ME/kg DM), but comparable at ear emergence. However, yields at this stage were poor (3,955 kg DM/ha, 6,356 kg DM/ha, 6,786 kg DM/ha for the triticale, barley and oats respectively). Triticale was the best of the temperate cereals achieving both high yield and high metabolisable energy content. Among the maize hybrids yield was positively associated with maturity (thermal time to 50 % silking). It is concluded that in regions with reliably good maize yields, the performance of spring sown temperate cereals makes them uncompetitive, however, where very early harvest is required they may be acceptable alternatives to maize.

Additional Key Words: metabolisable energy, maize, barley, oats, triticale, leafy hybrids

Introduction

Whole plant maize silage is a major source of supplementary feed in New Zealand dairy systems combining a high forage yield and good nutritive value compared to traditional supplementary feeds such as pasture silage and hay (Ulyatt *et al.,* 1980). However cool tolerant (temperate) cereal species such as barley and oats are increasingly being planted as alternatives to maize (Bailey, 1997), particularly in regions marginal for maize because of limited seasonal thermal time accumulation and short frost free period, but also in regions suitable for maize despite lower yield potential. Typically maize silage is harvested during early to mid autumn whereas harvesting of temperate cereal crops normally occurs in early to mid summer. Later harvesting with maize may be a disadvantage for farmers wanting to ensure that new pasture is sown prior to the onset of cool autumn weather.

Maize is an ideal crop for ensiling because it is high yielding and nutritive value, which increases during maturation, is also high. This allows harvesting to occur when dry matter accumulation is nearly complete. Usually, silage maize is harvested just prior to kernel blacklayer (maximum kernel dry weight) when the kernel milkline is midway down the face of the kernel, whole crop dry matter is around 35 %, metabolisable energy content is stable at between 10 and 11 megajoules (MJ)of metabolisable energy (ME) /kg of dry matter (DM) and DM accumulation has reached 90 to 95 % of potential. In contrast, the nutritive value of small grain cereals is strongly influenced by stage of maturity. During the vegetative growth stages nutritive value can be high (12 MJ ME/kg DM) but it declines after the onset of reproductive growth to less than 9 MJ ME/kg DM by harvest maturity (Hughes and Haselmore, 1981), making stage of maturity at harvest an important management decision. Temperate cereal silage crops generally produce lower yields than maize silage crops.

Maize hybrids marketed for silage in New Zealand have usually been grain hybrids possessing traits which make them useful for silage, such as high grain % and good stay-green (Anon. 2002). However, maize hybrids developed specifically for silage are now being marketed in New Zealand (Anon. 2000). These hybrids utilise the so called >leafy gene= first identified in the late 1970's. Hybrids possessing the leafy gene produce 2 to 4 additional leaves above the cob compared to hybrids of similar maturity. The result of overseas studies on the merits of leafy hybrids is inconsistent (Kuehn *et al.,* 1999). Temperate cereal cultivars utilised for silage have, in the past, typically been cultivars originally selected for grain production. However, the use of specialised forage cultivars is increasing in New Zealand.

The objective of this study was to compare three temperate cereal species and a range of commercial and experimental maize hybrids for yield and nutritive value and identify any relationships between nutritive value, grain content and plant architecture in the maize hybrids.

Materials and Methods

Treatments

Treatments consisted of seven maize hybrids and 1 cultivar each of barley, oats and triticale (Table 1). The maize hybrids included three Pioneer brand hybrids marketed by Genetic Technologies Ltd as dual purpose grain/silage hybrids, one hybrid (Mycogen brand) marketed by Corson Grain Ltd as a specialised silage hybrid (TF94) and three New Zealand hybrids (CF08, CF06 and Clint) developed by the Institute for Crop and Food Research Ltd at Palmerston North. A Crop and Food breeding programme has being combining Mexican and Peruvian Highland germplasm with genetic material from a range of sources in an attempt to develop hybrids with greater cool tolerance (Eagles and Hardacre, 1989). Of the New Zealand hybrids only Clint has been commercialised and, being a flint type hybrid, it has hard grain endosperm and is utilised for milling grits.

Of the three temperate cereals >Aranui= triticale was originally selected as a grain cultivar but failed to make a significant impact in that role and is now of interest as a silage cultivar. >Omaka= barley and >Hokonui= oats are both specialist forage cultivars utilised for both greenfeed and silage.

Trial design

A randomised complete block trial (3 replicates) was established on the Frewens Block of the Pasture and Crop Research Unit, Massey University on November 1, 1998 into a cultivated Manawatu fine sandy loam soil previously in pasture. Maize plots were initially drilled at approximately 150,000 seeds/ha and hand thinned twice (2 weeks and 4 weeks after emergence) to 100,000 pl/ha except TF94 (95,000 pl/ha) and Janna (110,000 pl/ha). No losses were observed after the final thinning. Target plant population for the temperate cereals was 350 pl/m^2. All plots were 5m in length with maize plots consisting of four rows at 70 cm spacings while plot width for the temperate cereals was 1.35m in 15cm rows. A minimum of 1.5m spacing was used between maize and temperate cereal plots to prevent shading. Fertiliser (37.5 kg N/ha, 25 kg P/ha, 25 kg K/ha) was applied to each plot by hand immediately after sowing to ensure adequate fertility. Insecticide pellets (200 g/kg turbufos) were applied at 5 kg/ha to all plots after sowing to control insect pests. Weeds were controlled with standard post emergence herbicides (terbuthylazine and MCPA/dicamba for maize and temperate cereal plots respectively).

Table 1. Description of the maize hybrids and small grain cereal cultivars.

Maize/Hybrid	CRM	Origin	Use
Janna	77	Europe	Grain/silage
P3905	87	U S	Grain/silage
P3730	99	U S	Grain/silage
TF94	94	U S	Silage
CF06	95	N Z	Experimental
CF08	95	N Z	Experimental
Clint	90	N Z	Grain
Temperate Cereals			
Hokonui Oats		N Z	Forage/silage
Omaka Barley		N Z	Grain/silage
Aranui Triticale		N Z	Grain/silage

CRM: Comparative relative maturity based on thermal time requirements between planting and maturity.

Measurements

Whole crop yield was measured at ear emergence (Feekes= growth stage(GS) 10.1) and the soft dough stage (GS 11.2) in the temperate cereal plots. At both harvest times four samples were taken from each plot consisting of a 1.0 m length of a drill row cut at ground level. At both harvest times subsamples (approximately 80 g) were taken for determination of dry matter (DM) % and *in vitro* digestibility. Analysis for digestibility was done at the Nutrition Laboratory, Institute of Food Nutrition and Human Health, Massey University. Ear numbers/m^2 were determined at the final harvest.

The outside rows were excluded from sampling in all plots.

The 50 % silking date was recorded in all maize plots and at 50 % kernel milk line (Wiersma *et al.*, 1993), plant height (the point of attachment of the tassel peduncle at anthesis), cob height (point of attachment) and leaf number above the cob were determined by measuring five plants per plot from the middle two rows. Yield sampling consisted of cutting eight plants selected randomly from the middle two rows in each plot. All plants in the middle two rows were assessed for root and stalk lodging. Two plants per plot were dried for determination of DM % and subsequently shredded, ground and analysed for *in vitro* digestibility.

Meteorological data were collected at AgResearch Grasslands, Palmerston North, less than 2km from the trial site. Temperature data were used to calculate thermal time requirements for the sowing to Feekes= growth stage 10.1 and sowing to 50 % silking in the temperate cereals and maize respectively. Determination of thermal time requirements for each hybrid/cultivar for each growth phase consisted of summing daily thermal times for that phase. Daily thermal time was calculated using the following equation:

Thermal Time $= \varepsilon\ \underline{(Tmax + Tmin)/}\ 2 - T_b\ 2$

Where: Tmax = daily maximum temperature

Tmin = daily minimum temperature

T_b = Base temperature: 8 °C for maize and 0 °C for temperate cereals

Results

All plots established well and no weed or pest problems arose. Initially the 1998/1999 season (November to March) was near normal but later became hot and dry (Table 2). No visible signs of drought stress were noticed in the trial plots but some crops in the area, particularly maize, did show symptoms of moisture stress (rolling of leaves). No pest or disease problems were encountered in the maize and triticale plots but netblotch (*Pyrenophora teres*) and crown rust (*Puccinia coronata*) infections appeared in the barley and oat plots respectively after ear emergence. By harvest most of the upper leaves in the barley and oat plots had suffered significant loss of green leaf area.

Triticale was the first of the temperate cereals to reach ear emergence (54 days after sowing) followed by barley and oats (Table 3). There were large differences in yield at that time and small, though still significant, differences in ME content. Triticale yielded 3,955 kg DM/ha considerably less than barley (6,356 kg DM/ha) and Oats (6,786 kg DM/ha). Metabolisable energy content of oats and triticale was identical (10.3 MJ ME/kg DM) with barley slightly less than this (10.0 MJ ME/kg DM).

Final yield and ME content was measured in the temperate cereals at the soft dough stage and in the maize plots at 50 % kernel milk line. Barley was first to reach soft dough (January 19) followed by oats (January 26) and triticale (January 29). The maize hybrids reached 50 % silking during the later half of January starting with Janna (January 15), the earliest hybrid while CF08 was the last to silk (January 31). Duration of the silking to harvest maturity stage in the maize hybrids varied from 48 days (Janna), 56 days (Clint) with the remaining hybrids falling into a narrow range of 60 to 62 days.

Thermal time to 50 % silking, cob height and leaf number above the cob for the maize hybrids are shown in Table 4. Janna required 630.4 degree days to reach silking while the latest hybrid (CF08) required 821.3 degree days (Table 4). Cob height, cob height ratio and leaf number all highlight the different architecture of TF94. Generally leaf number, plant height and cob height were positively associated with hybrid maturity whereas in TF94 leaf number above the cob was significantly greater, and the ratio of cob height to total height, significantly lower than all other hybrids. Cob height in TF94 was lower than in hybrids of similar maturity.

As expected the Maize hybrids yielded well above the temperate cereals, the only exception being the difference between Janna and triticale, which was not significant at the 5 % level of probability (Table 5). Among the maize hybrids yield reflected maturity (Figure 1). Triticale produced higher yields than oats and barley, which were similar. Barley ear populations (866 ears/m^2) were significantly higher than in oats (577 ears/m^2) and triticale (507 ears/m^2).

Differences in ME contents of maize hybrids and temperate cereals, were of lower magnitude but still significant (Table 5). Among the maize hybrids Clint produced the highest ME content forage (11.4 MJ ME/kg DM) with the only other differences being lower ME value in CF06 compared to P3905 and CF08. All maize hybrids achieved ME values better than the temperate cereals. Among the temperate cereals barley (9.7 MJ ME/kg DM) and triticale (9.5 MJ ME/kg DM) were better than oats (8.9 MJ ME/kg DM). The combined effect of high yield and high ME content resulted in ME yield in the maize hybrids being higher (185 to 238 MJ ME/ha) than that of the temperate cereals (102 to

139 MJ ME/ha) (Table 4). Ranking for ME yield mostly reflected yield ranking with an exception being Clint, which was among the best hybrids, a result of its high ME content.

Maize whole crop DM % at final harvest ranged from 40 % to 45 % but there were no significant differences among the hybrids. Similarly, there were no differences in DM % at final harvest among the temperate cereals (range 34 % to 41 %). The proportion of grain in maize whole crop DM ranged from 47 % to 53 % but again differences among the hybrids were not significant. Metabolisable energy content was not correlated with grain %, cob height or leaf number above the cob in the maize hybrids, but grain % was correlated 7 = +0.67) with whole crop yield.

Table 2. Long term and 1998/99 monthly mean temperature and rainfall.

	1998/99		Long Term Mean	
	Temp (°C)	**Rain (mm)**	**Temp (°C)**	**Rain (mm)**
November	14.4	93.9	14.2	78
December	16.5	36.4	16.1	94
January	20.0	39.4	17.3	79
February	19.0	20.1	17.6	67
March	19.1	34.3	16.4	69

Table 3. Thermal time > 0°C (TT_0) to GS 10.1, yield (kg DM/ha) and metabolisable energy content (MJ ME/kg DM).

	TT_0 (°C Days)	Yield	ME content
Barley	894	6356	10.0
Oats	964	6786	10.3
Triticale	808	3955	10.3
LSD (P<0.05)	-	1076	0.16

Discussion

The yield advantage of maize over temperate cereals, and of late hybrids over early hybrids in this trial was much as expected and was largely the result of longer growth duration. Maize plots were harvested from 34 to 72 days later than the temperate cereals, whereas there were no significant differences among treatments in average crop growth rates between sowing and harvesting. Average daily growth rates ranged from134 (oats) to 164 (barley) kg DM/ha /day. The temperate cereal yields achieved in this trial are at the upper end of yield potentials for spring sown crops in the Southern North Island (Bailey, 1998) but higher yields and earlier harvest could reasonably be expected from autumn sowing (Kerr and Menalda, 1976). However, in most dairy systems autumn sowing is not feasible because of seasonal feed deficits over the autumn - winter period and it is not until the occurrence of surplus feed conditions in the spring that paddocks can be spared for growing supplementary forage crops.

The presence of foliar fungal diseases in the barley and oat plots probably reduced forage yields. Yield depressions ranging from 19 % to 23 % due to the effect of crown rust have been reported in forage oats in the Manawatu (Eagles and Taylor, 1976). Losses of this magnitude signal that applications of foliar fungicides to control crown rust would be profitable. The cultivar description for Omaka barley indicates that it is resistant to net blotch, negating the need for fungicide application (Anon, 1997). However, the severity of infection in this trial calls into question this advice, particularly in the Southern North Island. It may be necessary to anticipate the occurrence of these fungal diseases, however, if fungicides are to be applied sufficiently early to avoid problems with harvest withholding periods, generally 7 weeks, after application.

Higher ME contents among the maize hybrids compared with the temperate cereals at final harvest are potentially significant for animal production. Low ME content results in reduced animal production because of both low energy density of the forage and reduced forage intakes (Ulyatt *et al.*, 1980). While ME contents in the temperate cereals harvested at ear emergence were similar to maize, yields were less than half those at the soft dough stage. Declining nutritive value with advancing maturity is typical of temperate cereals and is caused by the formation of fibrous stem material and increased lignin content (Hughes and Haslemore, 1981). The ME contents achieved by the temperate cereals in this trial are similar to that of wilted pasture silage, being at about the minimum necessary to support lactation (Ulyatt *et al.*, 1980).

Using thermal time to 50 % silking as a measure of maturity, Janna appears to have achieved poor yield for maturity in this comparison. With the exception of Clint, Janna has much earlier maturity than the other hybrids, making valid comparison difficult. Hybrid ranking for ME yield was similar to maturity ranking with the only exception being Clint which achieved greater ME yield for its maturity. This was entirely due to its high ME content. Possible explanations of the higher nutritive value of Clint in this trial include high stover nutritive value and high grain nutritive value. In New Zealand evaluation trials Clint has been shown to be vulnerable to lodging (Brenton-Rule *et al.*, 1996). Overseas research has shown that hybrids with increased resistance to lodging have lower nutritive value, a result of reduced stalk digestibility caused by increased fibre content and reduced fibre digestibility (Barrière *et al.*, 1997; Sibale *et al.*, 1992). Clint also produces grain with a large embryo (A. Hardacre pers. comm.). Maize grain embryos have high oil content, typically 17 to 20 % on a % dry basis (Earle *et al.*, 1946), compared to other grain components. Consequently, grain with proportionately large embryos may have high oil content and accordingly high energy density (Weiss, 1999).

The canopy architecture of the leafy hybrid, TF94, was clearly different to the other hybrids in this comparison however its performance was only average. While some comparisons have found that leafy hybrids achieve higher forage quality than conventional hybrids the differences may be small and not result in increased animal intake and performance (Kuehn *et al.*, 1999; Ballard *et al.*, 2001).

Whole crop DM % among the maize hybrids was generally above the targeted range (30 to 35 % DM). While the use of kernel milk line to identify optimum harvest time is generally a reliable technique, the underestimation of DM % using kernel milk line has been noted by other researchers in dry conditions (Havilah *et al.*, 1995). However there is some flexibility in maize harvest times before forage quality and animal performance are influenced (Bal *et al.*, 1997).

Table 4. Thermal time > 80C (TT8) to 50 % silking, cob height, cob height : total height ratio and leaf number above the cob for maize hybrids.

Hybrid	Silk TT_8 (°C Days)	Cob Ht (cm)	Cob Ht Ratio	Leaf No.
CF08	821.3	97.3	0.54	5.2
P3730	795.4	84.7	0.50	5.2
TF94	779.0	65.3	0.38	7.0
CF06	772.8	81.7	0.52	5.3
P3905	714.9	92.0	0.53	4.3
Clint	671.9	76.3	0.49	4.1
Janna	630.4	71.7	0.44	3.9
LSD (P<0.05)	14.6	13.0	0.048	0.31

Table 5. Final yield (kg DM/ha), metabolisable energy (ME) content (MJ ME/kg DM) and metabolisable energy yield (MJ ME/ha).

Hybrid/Cultivar	Yield	ME Content	ME Yield
Maize CF08	23,332	10.7	250,461
P3730	22,972	10.6	243,375
TF94	21,897	10.6	228,787
CF06	21,670	10.2	224,234
P3905	20,323	10.6	216,241
Clint	20,071	11.4	230,096
Janna	17,151	10.8	185,442
Triticale Aranui	14,651	9.5	138,512
Oats Hokonui	12,030	8.9	102,292
Barley Omaka	11,527	9.7	116,340
LSD (P#0.05)	2,508	0.41	28,182

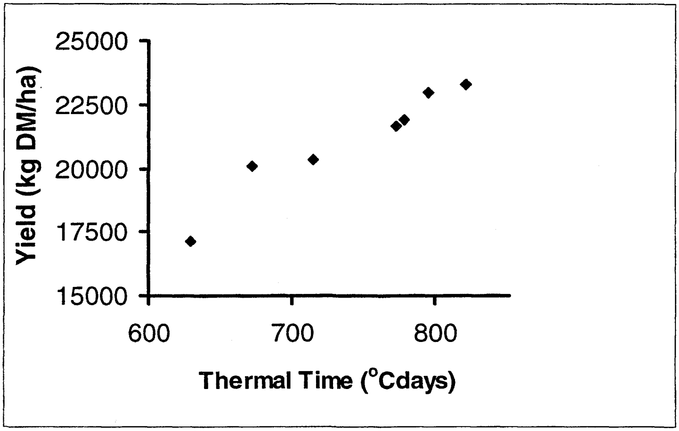

Figure 1. Association between thermal time (base 8°C) to 50 % silking and whole crop forage yield at 50 % kernel milk line in the maize hybrids.

Conclusion

Yield and ME content of the maize hybrids used in this study were significantly higher than for the temperate cereals harvested at the soft dough growth stage. Nutritive values in the temperate cereals harvested at the ear emergence growth stage were comparable with maize, but yields were greatly reduced. There were few differences among the maize hybrids for nutritive value with the exception of Clint which had significantly higher ME content than all other maize hybrids. There were large differences in yield among the maize hybrids, generally reflecting maturity. The disadvantages of the temperate cereals compared to maize suggest that they are not viable alternatives to maize in most dairying regions of the North Island. However, where maize production is risky or where early harvest is required they may be of use.

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