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Cereal forage breeding for New Zealand agriculture

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Abstract. Cereal forages provide both arable and livestock farmers with high yields of high quality dry matter to use as either standing or conserved strategic forage supplements where deficits occur when animal feed requirements exceed pasture growth. Crop & Food Research has breeding programmes for both single and multi-grazing forage oats and triticales, and both green-chop and whole-crop silage forage oats, triticales and barleys. It also has an associated cereal forage management research and tech-transfer programme to ensure cereal forages achieve their potential under New Zealand's variable soil and climatic conditions. This has led to the development of new cereal forage cultivars, an increased understanding of their dry matter and quality development, and management support packages including a cereal silage booklet and maturity predictor for whole-crop cereal silage.

Introduction

Fodder production in New Zealand farming systems must satisfy both the seasonal livestock feed requirements and fit into the production pattern driven by climatic influences. Livestock feed requirements vary seasonally with their reproductive cycle, lactation, and number of stock on each farm. In contrast, perennial pasture and annual crop productivity follows seasonal trends that closely parallel climate patterns. Pasture growth varies much more from season to season than does animal feed requirement, creating a demand for supplementary feeds that have traditionally been supplied as hay and silage.

Access to new purpose-bred small grain cereal forage cultivars, especially oat and triticale developed for single, and multi-graze uses and/or silage and hay feed supplementations, has given farmers greater flexibility to manage their livestock feed requirements. Early autumn sowing of facultative, short season cereal cultivars for grazing by lactating or pregnant cows, for example, is often required, particularly where high winter growth rates of animals are required. Oat and triticale forage crops are increasingly used for this purpose. If sown in late February (South Island) or early April (North Island) when soil temperatures are still high, early herbage growth in these cereal forages will capitalise on good autumn nitrogen mineralisation rates at a time when pasture growth rates are slowing.

According to de Ruiter *et al.* (2002), small grain cereals provide a high energy supplement in autumn and winter and can provide a high fibre feed source from spring sown crops. Small grain cereals can contribute to lactating cattle nutrition as a grazed forage, silage or grain.

The flexibility of cereal forage allows different sowing and harvesting options, depending on current feed supply and demand. Triticale has a greater potential for multiple grazing in the cooler (winter environments) whereas oat is more suited to single-graze situations. However, in cut and carry situations where cutting height can be controlled and/or in warmer winter regions where light grazing is possible allowing good vegetative regrowth, oats are also a multi-graze option. Oat and triticale can generate a large amount of herbage in late autumn and winter for single grazing in late winter early spring, and can also be used to complement maize in the North Island for double cropping silage systems.

Cultivar development

The Crop & Food Research (CFR) forage breeding and cultivar development activities are centred around facultative daylength sensitive forage plant populations, with vigorous screening for plants with good resistance to barley yellow dwarf virus (BYDV), crown rust *(Puccinia* coronata *f. sp.* Avena *Eriks. & Henn.),* and stem rust *(Puccinia graminis* pers. F. *avenae Eriks*. & *Henn*.) in oats and stripe rust (*Puccinia striiformis*) in triticales.

Grazing cultivars Enterprise and Lordship oats, Dictator barley and Crackerjack triticale have been released in Australia. Releases have been made in the USA under the Everleaf™ brand, for winter green-feed production in California and spring production under irrigation for silage production in northern USA. A range of oat cultivars have been introduced to farmers in the Himalayan region of Nepal for winter forage production and small bag silage making between rice and maize crops. Other cereal forage lines are currently being evaluated in Europe, South America and South Africa.

Cereal forage characteristics

The single-graze programme focuses on developing cultivars with rapid biomass production, longer winter vegetative growth phases and greater winter hardiness. These maintain optimum green-feed quality for as long as possible over winter and early spring providing greater flexibility for managing animal feed supply. In the breeding process we are screening and selecting plants for genetic variation for day-length sensitivity and temperature interactions from autumn-sown populations. Milton, a single-graze oat, was released by Agricom (New Zealand) in 2004. This is a rust-resistant cultivar with a similar length winter vegetative plant growth phase to earlier releases Stampede in 2000, and Hokonui and Otama in the mid 1990s. Farm scale trials in the lower North Island of New Zealand in 1999 and 2000 showed that the yield of Stampede was invariably superior to earlier oat releases. Future releases are likely to include alternative species with faster and early biomass production capability, from early autumn and spring sowings. These will provide greater potential for double cropping as a complement to maize in the North Island and for use as short season, spring sown, green-feed crops in the South Island.

The multi-graze programme focuses on a plant type with a long vegetative phase and good regrowth recovery. The growing tip is close to ground level during the short daylength phase to prevent being grazed off, allowing the grazed tiller to regrow and any tillers damaged during grazing to be replaced by new tillers.

Doubletake triticale was a successful multi-graze release by Agricom in 2000. This cultivar can sustain two grazings when sown in early autumn and then be managed for either green-chop (boot) or whole-crop (cheesy dough) silage. Its advantages over ryecorn are higher winter dry matter production and greatly increased whole-crop silage potential. Future releases are likely to have more focus on a slower developing, more flexible single mid-late winter graze type, but still with the green-chop or whole-crop silage option.

Biomass production and quality

Small grain cereals can produce significant quantities of quality biomass before floral initiation when sown between late February (late summer) and early April (early autumn). Forage crops required for green-feed should be utilised before stem elongation at about Zadok's growth stage 32 if maximum feed quality is required for fast growing or lactating animals. Beyond this growth stage there is a decline in feeding value that is related to the change in leaf to stem ratio with maturation. From a plant breeding perspective, the most practical way to address this problem is to extend the winter vegetative period. Herbage from the maturing plant is likely to improve the condition score of dry dairy stock, or can be used to supplement pasture-fed cows in early lactation (Clark 2000).

Trials conducted at Crop & Food Research, Lincoln (de Ruiter 2000) and reported here for Culverden, North Canterbury, have provided information on the development of yield and changes in nutritive value of herbage during plant maturation. Autumn-sown trials were established in Culverden, North Canterbury in two seasons (2004 and 2005) to compare performance of a limited number of established and new cultivars. In the first year, trials were sown in randomised complete block designs, with three replications, at the McIntosh, Jones and Backhouse properties on 5 March, 11 March, and 31 March, respectively. Entries comprised cereal cultivars suitable for a one-off late-winter grazing (Hokonui and Stampede oats, CRTR22 triticale) or use as winter grazed feed followed by silage production in late December/early January (e.g. Doubletake and CRTR20 triticale). The objective was to determine the suitability of oat and triticale selections for dairy winter grazing and to make comparisons with tetraploid Italian ryegrass as options for spring grazing. The main focus for these trials was cultivar evaluation for yield and quality to assist farmers in selecting for best feed options.

In the following year (2005), trials were established on two properties (Kinney and Francis) on 10 March and 18 March 2005, respectively. Cultivars were similar to the 2004 trials except for the omission of Hokonui oats. The trials were sown as un-replicated 50m x 10m blocks in uniform paddocks. Multiple sub-samples were taken for assessment of yield and quality variability.

Results

<u>Yield</u>

The single-graze triticale (CRTR22) showed good early growth at the McIntosh site (Year 1) and was marginally better than the oat cultivars (Stampede and Hokonui). Early growth of Doubletake was superior to Italian ryegrass (Figure 1). However, there was little difference in productivity between CRTR20 and the Italian ryegrass. Early growth of Doubletake was slower than for the single-graze types. Recovery after manual clipping was slow in year 1 because of cool temperatures and excessively close clipping. Regrowth was also slow in areas grazed by cattle on 18 May. In the period from 18 May to 24 August dry matter growth was 2.1 and 2.2 t/ha for Doubletake and ryegrass. Slow recovery was possibly also due to the low post grazing residuals of 173 kg/ha and 87 kg/ha for Doubletake and Italian ryegrass, respectively. In year 2, total biomass production at 7 September comprising initial growth and regrowth from successive cuts made on 13 June and 22 July was 7.0 t/ha. Under the same cutting protocols, Italian ryegrass produced 6.2 t/ha. The importance of early sowing and good early growth and establishment was demonstrated in the comparative yields attained at the respective sites (Table 1). There was a significant yield difference in triticales when comparing the McIntosh and Jones sites (year 1) and this difference was not likely to be caused by differences in soil fertility or temperature between these sites. Successful establishment and early growth during the month of March was critical for achieving acceptable yield. The yield loss from delayed sowing was most apparent at the Backhouse site sown 20 days later than at the Jones site and 26 days later than at McIntosh's.

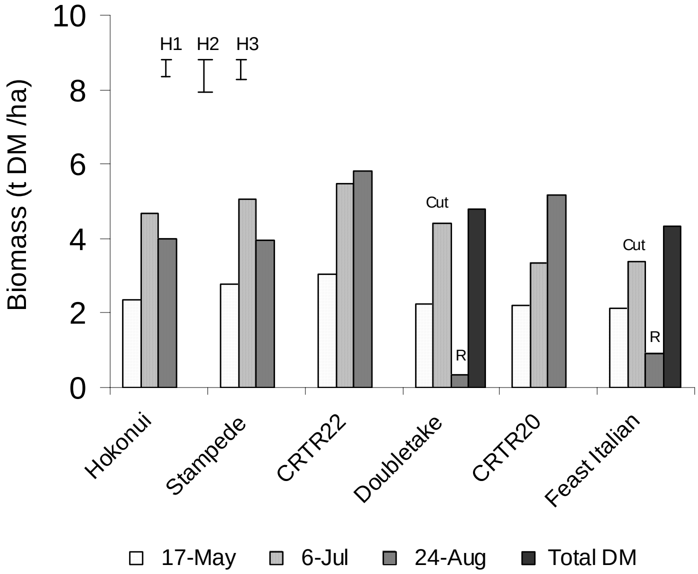

Figure 1: Biomass production (t/ha) for cereals and Feast II Italian ryegrass sampled on three dates at McIntosh site (2004). The data are accumulated yields for all entries except Doubletake and Feast Italian ryegrass. Re-growth is indicated by R. Vertical bars are LSDs (5%).

Table 1: Biomass yields for late winter harvests of cereals and Italian ryegrass in 2004. Sites were sampled on 10 August (Jones and Backhouse) and 24 August (McIntosh).

Cultivar	McIntosh (Sown 5 March)	Jones (Sown 11 March)	Backhouse (Sown 31 March)
	---------------------- (t DM /ha) --------------------------		
Hokonui	4.0	3.9	2.8
Stampede	4.0	3.9	3.0
CRTR22	5.8	5.0	3.4
Doubletake	4.8 [a]	4.0	2.8
CRTR20	5.2	4.3	2.5
Italian ryegrass cv.Feast II	4.3 [a]	3.8	2.1
LSD (5%)	0.49	1.02	0.79

[a] accumulated yield from cut made on 6 July and re-growth to 24 August.

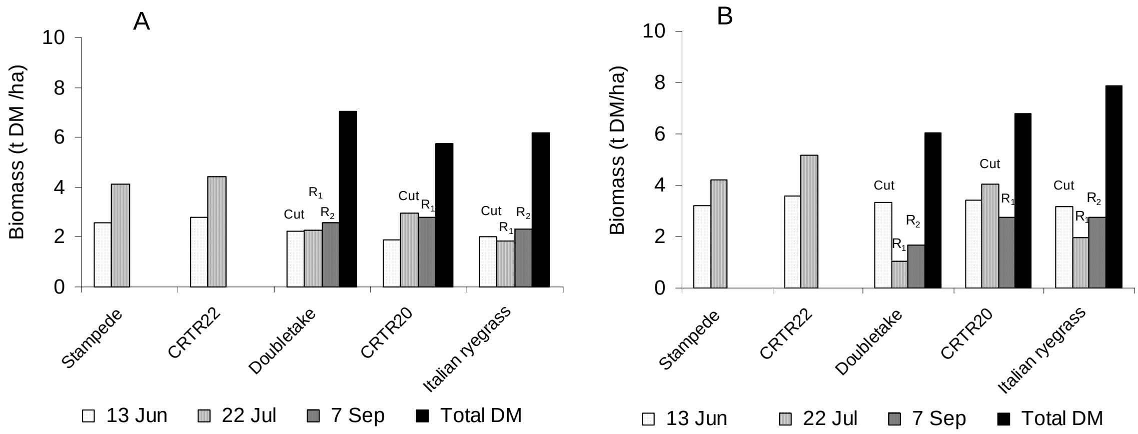

Figure 2: Comparative biomass production (t/ha) for cereals and Feast Italian ryegrass sampled on three dates at Kinney (A) and Francis (B) sites in 2005. Successive biomass re-growth from earlier cuts are indicated by 'R_X', otherwise the data are accumulated yields uncorrected for residual herbage.

Table 2: Comparative accumulated yields for cereals and Italian ryegrass at two sites. Harvests for single-graze cultivars (Stampede and CRTR22) were completed on 22 July, and the remaining cultivars were carried though to the spring 'green-chop' (final sampling was on 4 November). Yield data are for total accumulated biomass adjusted for an assumed 0.5 t/ha residual at respective harvests.

	Stampede [a]	CRTR22 [a]	Doubletake [b]	CRTR20 [c]	Feast Italian ryegrass [d]
	---------------------	----------	t/ha	----------	---------------------
Site 1: Kinney					
Direct drilled (10/3/05)	4.0	4.2	12.0	11.4	5.3
Cultivated and drilled (18/3/05)	3.3	3.7	14.5	14.2	5.6
Site 2: Francis					
Sowing 1 (18/3/05)	3.7	4.7	11.0	14.1	8.7
Sowing 2 (13/4/05)	-	-	13.2	12.8	5.1

[a] accumulated yield data only, final harvest on 22 July.
[b] cuts made on 13 June, 22 July, and 4 November.
[c] cut made on 22 July and 4 November.
[d] successive cuts made on 13 June, 22 July, 7 September and 4 November.

In year 2, early harvest of single-graze types had better yield than multi-graze triticales or the Italian ryegrass (Figure 2). The total accumulated productivity from the ryegrass up to 7 September at the Kinney site was equivalent to CRTR20, but approximately 1 t/ha less than Doubletake. These results mirror those for the previous year at the McIntosh site.

At another more fertile site (Francis), the total harvested biomass from Italian ryegrass was superior to the multi-graze triticales. Whilst the mean biomass yields for Italians and multi-graze cereals were comparable, the Italians do give farmers a level of versatility for spring feeding that the cereals do not possess. However, later biomass production from cereals (for use as green chop or silage from mature crops) is well in excess of the yields attainable from the Italian ryegrass (Table 2).

Quality

Typical patterns for changes in herbage quality in year 1 (protein, total soluble sugar and starch, and metabolisable energy) are given in Figure 3. There was a strong site effect for protein content that reflected the differing fertility status of the sites. Protein content declined sharply with successive harvests, particularly in the triticales at the McIntosh site.

Soluble sugar levels of first growth were higher in oats than in triticales. The levels increased with maturation whether the crops were cut or not. At the time of final cut at the McIntosh site on 24 August, the soluble sugar levels in single-graze triticale (CRTR22) was exceptionally high and comparable to regrowth herbage from multi-graze triticales or annual ryegrass. First cut oats had high ME (12 MJ/kg) but tended to lose ME quality as the digestibility declined during stem elongation (especially Stampede). ME of oats was higher than triticales through to early spring but was inferior to annual ryegrass throughout the winter grazing period.

In year 2, soluble sugar and starch were slightly higher in Stampede oats than in the triticales at a similar early growth stage (early stem elongation). Soluble sugars in regrowth tended to be lower (16-18 %) although there was significant variability within the triticales. Soluble sugars content in annual ryegrass was equivalent to triticales at comparable harvest dates.

Protein content was highest in the earlier cuts and exceeded 17% in year 1, except for Stampede oat (Figure 3), but in all cases declined sharply with the onset of stem growth. Protein content was generally lower in oats than in other cultivars. Protein content in regrowth herbage varied considerably from trial to trial and also differed between years. For example, the protein contents in regrowth material were lower than in the initial growth in year 1, but were equivalent or higher in year 2 (data not shown). In all trials, the protein content in regrowth was closely related to soil nitrogen fertility. Therefore, it was important to fertilise crops soon after cutting to stimulate regrowth and maintain adequate herbage protein levels.

In year 2, metabolisable energy was significantly higher (>12 MJ/kg) in the oats at the early harvests. Metabolisable energy was lower (11-11.5 MJ/kg) in successive regrowths in triticales and slightly higher in annual ryegrass (11.8-12.2 MJ/kg).

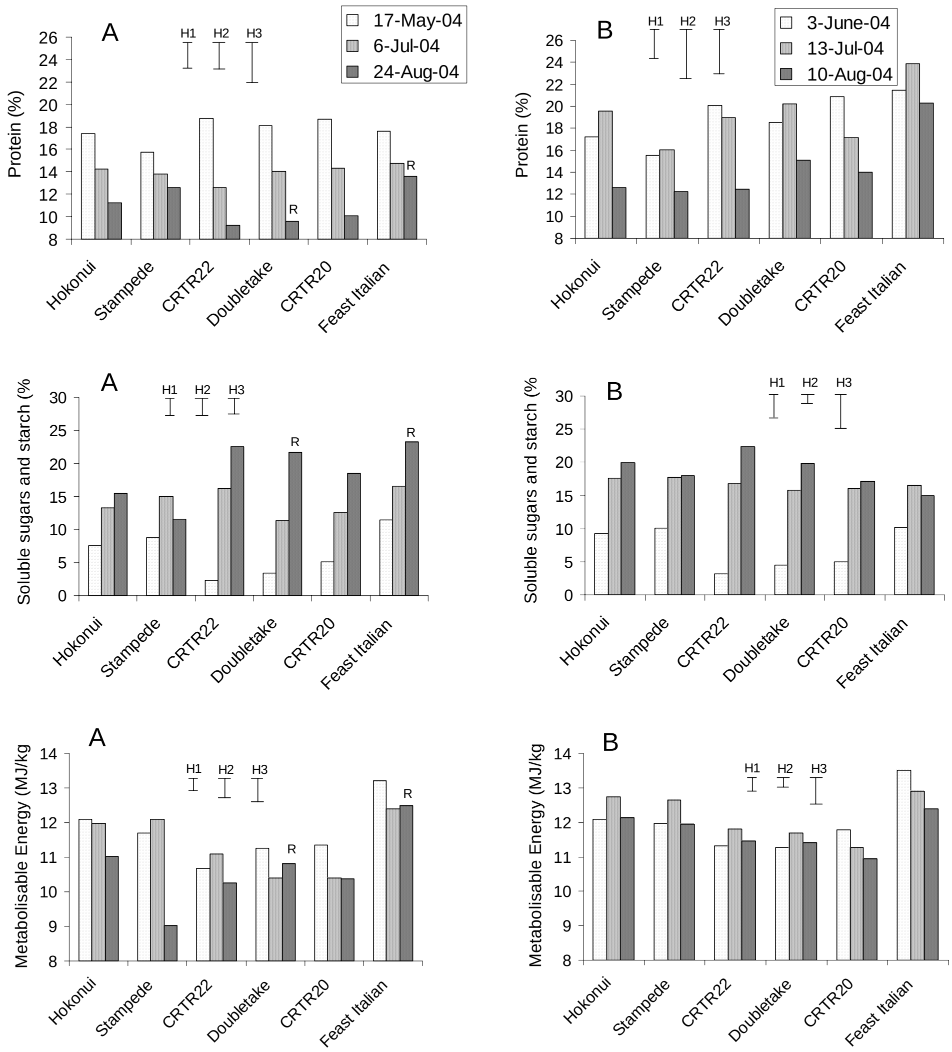

Figure 3: Near-infrared predicted protein, soluble sugars and starch, and metabolisable energy of cereals and Feast Italian ryegrass in successive harvests at McIntosh (A) and Jones (B) sites (year 1). Vertical bars are LSDs (5%).

Cereal forage cultivar commercialisation

Cultivar development

Breeding and development of cereal forages has been a cooperative effort between CFR and its commercial partner, Agricom (New Zealand) Ltd. New cultivars developed by CFR are licensed to Agricom for seed production and marketing.

Cereal forage management research and technology transfer has enabled cereal forages to achieve their potential under New Zealand's variable soil and climatic conditions. This has involved:

1. Intensive research into management of yield and quality such as sowing date effects, and the impact of grazing height and plant recovery in multi-graze situations.

2. Regional cultivar testing to document the performance of potential new cultivars over a range of soil and climatic conditions.
3. Intensive grazing management trials to monitor animal performance on differing forage species and cultivars.
4. On-farm research (MAF Sustainable Farming Fund) to identify how cereal forages fit into farming systems.

Cereal forage technology transfer

Technical information to support cultivar commercialisation and cereal forage utilisation is delivered by field days, seminars, training sessions, and media articles, and is available on the Agricom website (www.agricom.co.nz).

Cereal management guides have been routinely produced to assist uptake of agronomic information among forage growers, many of whom have little experience growing arable crops despite the increasing use of cereals for animal feeding. In addition, a comprehensive booklet (de Ruiter and Hanson, 2004) contains prescriptions for growth and use of spring cereals for silage production and is available on request from the authors.

Cereal forage harvest prediction software

Harvest timing of spring crops for cereal silage is always a vital decision to ensure the best quality of herbage for conservation and yet achieve the best yield. Harvest prediction software that assists growers to optimise the timing of harvest has been released by Crop & Food Research in collaboration with Agricom (de Ruiter and Milne 2004).

Harvest date predictions are made on the basis of known whole crop dry matter content at Zadok's growth stage 49 (awn tip appearance) and standardised cultivar specific dry down rates in response to thermal time during grain growth (de Ruiter et al. 2004). This has enabled predictions of ideal silage maturity (crop reaching 38% dry matter content) to be made up to 30 days before harvest using either current weather or long term historical weather information. This allows growers and contractors more lead time to organise and prioritise harvesting and ensiling operations and therefore ensure optimum yield and quality at silage harvest.

Acknowledgement

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