Twenty-five tonnes of high quality forages annually in Canterbury

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Abstract

Recent developments in cereal breeding for forage production have given the potential to greatly increase annual forage dry matter (DM) production. This paper reports on the findings from two cereal forage production trials on irrigated Canterbury land. Trial 1 studied the potential of a range of single and multi-grazed cereal forages over a 9 month period to produce high yields and quality from both grazing and whole-crop silage forage. Trial 2 studied the suitability of different cereal/legume combinations for green-chop silage grown over a three month summer period. These two cereal forage systems, when combined in a 12 month period, produced in excess of 25 tonnes of high quality forage per hectare, almost double the DM production achieved using current perennial pasture based systems. Trial 1 showed no significant difference in the total DM produced by either single or multi-graze treatments. In Trial 2 pea/cereal combinations produced over 6 t DM/ha. Due to an earlier final harvest the multi-graze system is more easily combined with the summer crop and more likely to produce a lower cost and more sustainable forage system. Animal performance on forage produced in Trial 1 showed that dairy calves can grow well on cereal forages during winter.

Keywords: cereal, feed supplements, forage, forage yield, legume, silage

Introduction

Intensification of pastoral farming in Canterbury has occurred rapidly in recent years. There have been two major changes in land use. Firstly, during the 1990's, large areas changed from dryland sheep to irrigated dairying. Secondly, recent improved sheep meat returns have driven increased production targets on dryland and irrigated sheep properties. These changes have led to a requirement for increased quantity and quality of herbage grown on-farm.

Historically, the majority of the intensive pastoral area of New Zealand is based on ryegrass/white clover pastures. In Canterbury under irrigation these peak at around 15 t dry matter (DM)/ha on the light stony soils (Moss 1987) and 17 t DM/ha on the more productive heavy soils (Fraser & Vartha 1979). Previous cereal forage research (Martin & Knight 1987) had primarily been concerned with grazing cereal cultivars bred for grain production.

The introduction of cereal cultivars bred for forage production and suitability for whole-crop silage (de Ruiter 2001; de Ruiter *et al.* 2002), and improved knowledge of double cropping systems, has revealed the potential to substantially exceed the annual herbage production of current perennial pasture based forage systems for grazing both *in situ* and conserved forage. Jermyn *et al.* (1993) reported that peas were compatible with cereal crops while Neizen *et al.* (1998) produced high quality silage with high proportions of the legume sulla in the mixture and also found that ensiling herbage using a mini silo method produced excellent silage.

This paper will report on two forage trials, conducted on separate sites but which have the potential for succession in a 12 month period, and the ability to produce in excess of 25 t DM/ha of high quality forage. These trials were carried out independently, the first was a two year study conducted at Winchmore Research Station in mid-Canterbury on irrigated light soils. The aim of this trial was to demonstrate the production potential of forage cereals. Scenarios in this study included either single or multi-graze systems for wintering of stock, and included conservation for whole-crop silage. Animal performance measurements were recorded over the winter grazing periods.

The second trial investigated the potential to increase forage production where a window of opportunity exists between the removal of summer harvested crops and autumn sowing of subsequent crops. This plot trial was conducted at the AgResearch Lincoln farm and investigated a range of cereal/legume mixtures grown under irrigation over the January to March period. Measurements included herbage dry matter accumulation and testing the mixtures for conservation as silage.

In addition to these two trials, cereal whole-crop silage from the Winchmore trial and forage pea/triticale silage grown at Lincoln in association with the plot trial was fed to milking cows in autumn. The results from this feeding trial are reported by Stevens *et al.* (2004).

Methods

Trial 1 – Winchmore

Site

Trial 1 was sited at Winchmore Research Station on a Lismore stony silt loam under border strip irrigation.

Table 1 Botanical and common names of cultivars used in Trial 1.

Treatment	Botanical name	Common Name	Cultivar
Perennial pasture	*Lolium perenne* L.	Perennial ryegrass	Nui
Perennial pasture	*Trifolium repens* L.	White clover	Huia
Multi-graze 2002	*Lolium multiflorum* L.	Italian ryegrass	Tama
Multi-graze 2003	*Lolium multiflorum* L.	Italian ryegrass	Warrior
Single-graze	*Avena sativa* L.	Oat	Hokonui
Single-graze & spring silage	*Avena sativa* L.	Oat	Stampede
Single-graze	*Avena sativa* L.	Oat	Makuru
Multi- graze & spring silage	*Triticosecale*	Triticale	DoubleTake
Spring silage	*Triticosecale*	Triticale	Rocket
Single-graze	*Triticosecale*	Triticale	4992.9.2
Spring silage	*Hordeum vulgare* L.	Barley	Boss
Multi-graze (not used for silage)	*Secale cereale* L.	Ryecorn	Rahu

Table 2 Treatments used in Trial 1 in 2002/03, between brackets variations for 2003/04.

	Autumn treatment	Spring treatment
Single-graze	4992.9.2 triticale	DoubleTake triticale (Rocket)
	Stampede oats	Stampede oats (Rocket)
	Hokonui oats	Rocket triticale
Multi-graze	Tama Italian ryegrass (Warrior)	Whole-crop silage
	Perennial ryegrass/ white clover	Whole-crop silage
	Tama plus DoubleTake triticale	Whole-crop silage
	DoubleTake triticale	Whole-crop silage
	Rahu ryecorn	Boss barley whole-crop silage (Rocket)

The trial was conducted over a two year period from March 2002 to January 2004. Over the period of the trial soil fertility showed little change; pH stayed at 6.0, Olsen phosphorus (P) dropped from 23 to 21 µg/ml, quick test (QT) potassium (K) from 5 to 4 and sulphate-sulphur (S) from 6 to 5 µg/g.

The trial area was laser-levelled and re-bordered during summer 2002 just prior to sowing. Eight treatments replicated three times were allocated in a complete randomised block design. Plots were large in size (0.33 ha) to achieve a minimum grazing period of 21 days and for demonstration purposes. The species and cultivars used are listed in Table 1.

Autumn sowings occurred in mid-March with fungicide treated seed. Cereal sowing rates were adjusted by seed weight and germination % to achieve 300 plants/m^2. The grass treatments were Italian ryegrass (sown at 30 kg/ha) and Nui perennial ryegrass (sown at 20 kg/ha with 3 kg/ha Huia white clover). The perennial ryegrass/ white clover pasture was considered to be a control.

After grazing in mid-winter, the single-graze plots were sprayed with 2 l/ha of Roundup herbicide and Pulse, then conventionally cultivated before sowing the cereals in early October. Insecticide treated cereal seed was sown at a rate to achieve 300 plants/m^2.

In autumn of both years 175 kg/ha of Cropmaster 15 (N:P:K:S,15:10:10:8) was applied at sowing with a further 100 kg/ha of urea (46% N) applied 4 weeks after sowing. Spring sown plots received an application of 150 kg/ha of Cropmaster 15 at sowing and subsequently two applications of 190 kg/ha of urea. All spring sown cereals had Axall herbicide (3 l/ha) and Opus fungicide (300 ml/ha) applied in mid-November in both years and in mid-December 2002 an application of Amistar fungicide (700 ml/ha), Opus (300 ml/ha) and Piromor 50 insecticide (200 ml/ha). The autumn sown cereals had an application of Opus fungicide (300 ml/ha) in mid-December in both years. All cereal silage crops had straw shortener (1.25 l/ha Cycocel 750) applied in spring.

Plots were irrigated once in autumn and four times during spring/early summer. Border strip irrigation applied approximately 100 mm water/irrigation with 50 mm retained in the topsoil for plant use.

Multi-grazed treatments were grazed in May and early-September and single-grazed treatments were grazed in August then cultivated and resown. The same group of animals to be used on all grazings, therefore enabling animals to become accustomed to a cereal forage based diet.

Treatments

Cultivar treatments used in 2002/2003 and 2003/2004 are presented in Table 2. In 2003/2004 Makuru oats was added to the single-graze treatments sown in autumn and all single-graze treatments were spring sown in Rocket triticale for whole-crop silage. Also Warrior Italian ryegrass replaced Tama in 2003/2004 and the Tama plus DoubleTake treatment in 2002/2003 was removed in the following year. There was also a change in the Rahu ryecorn treatment, Rocket triticale was used as the spring crop in 2003/2004 in place of Boss barley.

Forage yield

Pre and post grazing forage yield was determined by cutting two 0.375 m^2 representative quadrats to 1 cm above ground level. Total forage yield at time of silage harvest was determined by cutting ten 1 m rows of representative areas to 1 cm height. The residual after silage removal was determined by cutting (to 1 cm) five 1 m rows of representative stubble. Silage harvest was conducted at the milky dough stage of grain maturity.

Grazing management

The pre grazing forage mass was used to calculate the number of calves (nine month old dairy heifers) allocated to each treatment so that each animal received a similar forage allowance. The calves were weighed at the start and end of each grazing period. Animals were removed when forage biomass reached 500 kg DM/ha from the multi-grazed cereal and annual grass and 1000 kg DM/ha in the perennial ryegrass plots. The single-grazed treatments were grazed to very low residuals (<500 kg DM/ha). The higher residual on the perennial ryegrass was due to higher tiller density and DM %.

Trial 2 – Lincoln

Site

The plot trial at Lincoln investigated a range of cereal/legume mixtures grown over the January to March period. The trial was sited at the AgResearch Lincoln farm on Wakanui silt loam soil and was drilled on 15 January 2003 into a cultivated seedbed using a cone seeder. Soil test results prior to sowing were; pH 5.6, P 19 µg/ml, QT K 18 and sulphate-S 11 µg/g.

The trial was a split plot design with four replicates. There were four legume main treatments and six cereal and no cereal sub-treatments. Plot size was 15 m x 3 m. Species and sowing rates (Table 8) were chosen to give a range of legume/cereal mixes to achieve equal portions of cereal and legume at harvest. Sowing rates were adjusted to achieve 60, 20, 60 and 60 plants/m^2 for peas, beans, cereals and grass, respectively, allowing for seed weight and germination %. Prior to drilling, 150 kg/ha superphosphate (N:P:K:S, 0:9:0:11) was broadcast and three irrigations were applied with a travelling sprinkler irrigator from mid-January to early-February. Twenty-five mm of water was applied at the first irrigation and 50 mm at the second and third. The pea crop developed powdery mildew (*Erysiphe polygoni* DC) in early-March and all pea and pea mixture plots were sprayed with 160 ml/ha of Folicur fungicide in 120 l/ha water. No further disease control was required on any treatments.

Herbage determinations

On 25 March 2003 herbage from three 1 m row lengths was cut from each plot and dissected into legume and cereal. These components were weighed green, sub sampled and dried at 80^o C in a forced-air oven, for 48 hours, for dry matter determination.

Silage

At the end of March forages were cut with a rotary mower and wilted overnight. Herbage from each sub plot was chopped to approximately 25 mm lengths. Herbage was compressed to a common density by a hand operated lever system into a 20 l plastic bucket lined with a heavy plastic bag, following the method of Niezen *et al.* (1998). This plastic bag was tied off as tightly as possible and the bucket lid taped on. These buckets were stored under cover and out of direct sunlight.

In May 2003, the buckets from replicate one were opened and assessed for colour, mould and odour. Buckets were emptied in a row, with 2 m between heaps, onto a bare runoff paddock and 200 ewes allowed access. After 10 hours (overnight) their preferences were recorded.

Table 8 Crop species, cultivars and sowing rates used in Trial 2.

Crop	Botanical name	Cultivar	Sowing rate (kg/ha)
Peas	*Pisum sativum* L.	Magnus	220
Dwarf beans	*Phaseolus vulgaris* L.	Labrador	150
Runner beans	*Phaseolus coccineus* L.	Scarlet	190
Haricot beans	*Phaseolus vulgaris* L.	Navy bean	170
Barley	*Hordeum vulgare* L.	Boss	28
Wheat	*Triticum aestivum* L.	Sapphire	24
Oats	*Avena sativa* L.	Stampede	27
Triticale	*Triticum (x Triticosecale)*	DoubleTake	28
Italian ryegrass	*Lolium multiflorum* L.	Tabu	7
Ryecorn	*Secale cereale* L.	Rahu	13

Table 3 Trial 1 – herbage yields (DM kg/ha) for the single-graze treatment.

Autumn cultivar	Grazed yield	Spring cultivar	Silage yield	Total yield
2002/2003				
4992.9.2	7130 b[1]	DoubleTake	16875 a[1]	24005 ab[2]
Stampede	7400 b	Stampede	21280 a	28680 b
Hokonui	5960 a	Rocket	15579 a	21539 a
2003/2004				
4992.9.2	2939 a[1]			
Stampede	3954 a			
Hokonui	3536 a			
Makuru	2945 a			

Means with the same letter are not significantly different [1] P<0.05, [2] P<0.1.

Table 4 Trial 1-herbage yield (DM kg/ha) for the multi-graze treatment. Grazing 1 – herbage accumulated from sowing till first grazing. Grazing 2 – herbage accumulated between grazings 1 and 2, excluding grazing 1 residual.

Cultivar	Grazing 1	Grazing 2	Graze total	Silage	Total yield
2002/2003					
Italian	2460	1320	3780 b	not sampled	
Nui	1600	500	2100 a	not sampled	
Italian/DoubleTake	3430	1140	4570 c	not sampled	
DoubleTake	3800	1240	5040 cd	18052	
Rahu	4600	1200	5820 d	15736[a]	
2003/2004					
Italian	1670	1640	2803 a	12370 a	15675
Nui	1720	1560	2788 a	12757 a	15545
DoubleTake	2710	900	3116 a	17784 a	21394
Rahu	2170	1730	2909 a	11739[b]a	15639

Means with the same letter are not significantly different P<0.001.
[a] Boss barley spring sown silage crop.
[b] Rocket triticale spring sown silage crop.

Data analysis

All data sets were analysed by analysis of variance using Genstat for Windows 7th edition (VSN International Ltd).

Results

Trial 1

The data sets are presented for each year individually because of changes in the cultivars used.

Single-graze

In Year one, there were significant differences between the total amounts of DM produced from cultivars in the single-grazing/ spring silage cropping system (Table 3). The autumn sown Stampede oats and the 4992.9.2 triticale produced more than Hokonui oats at the single-graze but the spring sown silage crops were similar. The Stampede treatment produced more, at over 28.6 t/ha, than the Hokonui oats/Rocket triticale (21.5 t/ha).

There were no significant differences in grazing forage biomass for single-graze cultivars in year two (Table 3). Similarly there were no differences in spring yields of crops sown for silage.

Multi-graze

Measurements were not taken for DM produced from spring silage from all treatments, therefore silage yield and total DM produced for the year could not be determined. However, as an indication of potential accumulated yield, DoubleTake triticale produced 18000 kg DM/ha for a total in excess of 23000 kg DM/ha/yr. The total forage masses produced by Rahu ryecorn and DoubleTake triticale were in excess of 5000 kg DM/ha whereas the perennial ryegrass produced significantly less at 2000 kg DM/ha ($P<0.001$).

There were no significant differences in forage production in the second year (Table 4) between cultivars used in the multi-grazing systems although the DoubleTake treatment produced over 21 t/ha DM.

Animal performance

Trial 1

Animals grazing Hokonui grew significantly less (Table 5) than the other cultivars.

Table 5 Trial 1 – single-graze treatment liveweight gain (g/head/day) in 2003/2004.

Cultivar	Liveweight gain
4992.9.2 triticale	272 b
Hokonui oats	141 a
Makuru oats	240 b
Stampede oats	288 b

Means with the same letter are not significantly different P<0.01.

Table 6 Trial 1 – multi-graze treatment liveweight gain (g/head/day).

Cultivar	Grazing 1	Grazing 2
2002/2003		
Italian ryegrass	741 b	695 b
Nui ryegrass	278 a	264 a
Italian/DoubleTake	669 b	797 b
DoubleTake triticale	691 b	691 b
Rahu ryecorn	693 b	253 a
2003/04		
Italian ryegrass	628 c	598 c
Nui ryegrass	341 a	218 a
DoubleTake triticale	485 b	561 c
Rahu ryecorn	434 b	271 b

Means with the same letter are not significantly different P<0.001.

Table 7 Trial 1 – animal performance (kg liveweight gain/ha/day) for the multi-graze treatment.

Cultivar	Grazing 1	Grazing 2
2002/2003		
Italian ryegrass	7.6 b[1]	9.6 b[1]
Nui ryegrass	3.3 a	2.7 a
Italian/DoubleTake	8.8 b	9.2 b
DoubleTake triticale	10.3 b	8.4 b
Rahu ryecorn	11.3 b	3.1 a
2003/2004		
Italian ryegrass	8.9 a[2]	9.0 b[2]
Nui ryegrass	6.7 a	3.9 a
DoubleTake triticale	9.3 b	10.6 b
Rahu ryecorn	6.7 a	4.4 a

Means with the same letter are not significantly different [1] P<0.01, [2] P<0.05.

Because of a snowfall during grazing there was no single-graze animal data from Year one.

There was a significant difference between cultivars (Table 6) in the amount of per head liveweight (LW) gain over the grazing periods. DoubleTake, DoubleTake/Italian ryegrass and Italian ryegrass all produced around 700 g/head/day whereas animals grazing perennial pasture produced significantly less at both grazings and Rahu ryecorn less at the second grazing. Liveweight gain on a per hectare basis (Table 7) followed a similar pattern.

The pattern of animal growth rates in Year 2 (Table 6) were very similar to the first year with DoubleTake and Italian ryegrass producing significantly better results. On a total animal liveweight gain per hectare basis, perennial pasture, Rahu ryecorn and Italian ryegrass (Table 7) all produced between 170-260 kg LW gain/ha, whereas DoubleTake triticale was significantly higher than all other forages at the first grazing and higher than Nui ryegrass and Rahu ryecorn at the second.

Trial 2

Legume and total yield from the pea treatments was significantly higher than any of the bean treatments (Table 9). Only the pea mixtures produced equal portions of legume and cereal whereas the bean mixtures were dominated by the cereals. Triticale, barley and oats yields were similar and significantly higher (P<0.05) (Table 9) than that of wheat and ryecorn. Italian ryegrass had a significantly lower yield than the cereals but there was potential for further growth after the silage was cut.

Table 9 Trial 2 – forage yields of the main effects (kg DM/ha).

	Legume yield	Cereal yield	Total yield
Legumes			
Peas	3735	2744	6112
Dwarf beans	1210	4435	5006
Runner beans	951	5083	5308
Haricot beans	1225	4900	5425
LSD (P<0.05)	378	492	560
Cereals			
Nil	3378	0	3378
Barley	1068	5371	6439
Wheat	1665	4108	5772
Oats	1289	5695	6984
Triticale	1291	5488	6779
Italian ryegrass	2271	1660	3931
Ryecorn	1499	3466	4965
LSD (P<0.05)	363	534	541

When the silage buckets were opened all treatments had ensiled with no visual mould present. The pure legume or mixes with high percentages of legume had a slightly stronger odour and darker colour compared to the mixes with larger cereal components. When fed to sheep all treatments were consumed with no residue.

Discussion

Trial 1

In this study the best treatments, in both single or multi-graze options, produced total yields over 23 t/ha DM in the first year and the grazed yields in the second year have a similar trend. Later sowing dates and some pugging during grazing may explain the lower yields produced in the second year.

The results from the grazing of dairy heifer calves showed that it is possible to grow young animals on cereal forages during winter under both multi- and single-graze systems. The growth rates on the cereal forage treatments were comparable to that on Italian ryegrass and much higher than that achieved using traditional perennial ryegrass pastures. High per head animal growth indicate the cereal forages were of high quality. When conserved as whole-crop silage and fed as supplements to dairy cows, high milk production was achieved (Stevens *et al*. 2004).

The multi-graze system provided several advantages over the single-graze/resown option. Multi-graze crops matured and were harvested earlier (mid-December compared to mid-January) than single-silage crops and had lower production costs due to reduced cultivation requirement and lower sowing costs. The earlier harvest creates an opportunity for a legume/cereal silage to be sown in mid-January and harvested in March. A system comprising multi-graze cereals with a summer crop giving close to 12 months of continuous forage would produce the highest DM yield. The use of direct drilling or single pass cultivation technologies could also extend the growing times of these crops. Because of limited time between critical crop management events, this system would require very strict adherence to the calendar of operations. This produces a compromise between potential yield, quality and also the effect on subsequent crop production (de Ruiter *et al.* 2002).

Trial 2

The peas were the only legume to compete with the cereals and produce a forage mix with a significant legume fraction. Bean species used in this trial did not yield well and therefore do not have a place in forage systems where high yield and high legume content are primary objectives. Silage made from pea mixtures were of high quality and therefore legume crops sown for conserved feed was a good land use option. Pea/cereal yields in excess of 6 t/ha were produced over a 69 day period. Although the cereals were sown at low seed rates, tillering was very strong and comparatively high yields resulted. Early sowing is important to ensure good biomass growth over the January to March period.

Conclusions

Cereal forages have the ability to greatly exceed current perennial pasture forage production levels. Multi- and single-grazed systems showed no difference in the total DM produced over a 12 month period. This trial demonstrated that there was a window of opportunity for short term crops between harvest of the multi-graze silage in late-December and sowing of the subsequent crop in mid-March. This window of opportunity could be filled with a summer crop. Multi-graze crops sown in autumn have the potential to produce over 20 t of high quality DM in 9 months. The remaining 3-months offer the potential for a summer legume/ cereal crop of around 6 tonnes of high quality forage. This forage system will produce in excess of 25 t of high quality forage per annum. Peas intercropped with triticale, barley or oats produced high yields with a legume proportion exceeding 50% when grown from January to March. The bean components of cereal legume mixes did not compete well with the cereals and were considered unsuitable for silage production at this time of the year.

High per head production was achieved using calves grazing the winter cereal crop. Production per head on cereals was comparable to that from Italian ryegrasses, however the per hectare production was superior on cereals. Legume/cereal silage was successfully ensiled and the resulting silage was consumed by sheep and also supported high milk production when fed as a supplement to dairy cows as did whole-crop silage produced from multi-graze DoubleTake.

ACKNOWLEDGEMENTS

The authors would like to thank Agricom (New Zealand) Ltd for their funding and support of the trial at the AgResearch Winchmore Research Station, and Winchmore farm staff for their assistance in the trial management. Thanks also to Global (Ltd) for their funding and support for the research at the AgResearch Lincoln Research farm and Todd White and David Baird for statistical analysis.

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