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Use of fodder beet to increase post weaning growth rate, MSA compliance and winter throughput of pasture finished cattle in southern Australia

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Abstract

Pasture based beef production in Southern Australia is constrained by seasonal variation in feed quality and availability. As a result, it is difficult for meat processors to maintain a continual supply of pasture fed beef of consistent eating quality throughout the year. This project sought to investigate the use of irrigated fodder beet (*Beta vulgaris*) to increase growth rates and reduce time to slaughter of young beef cattle in the Limestone Coast region of South Australia. Fodder beet was grown on 6 commercial farms across two years (2016-2017), with yearling steers grazed from March onwards each year. Average daily growth rates of 0.92 kg/day were achieved throughout late autumn and winter, with per hectare liveweight gains of up to 1875 kg, although performance between sites was variable and a number of challenges were highlighted. The accelerated growth rate allowed a proportion of the herd to be slaughtered directly off fodder beet, with desirable carcass characteristics. Although further work needs to be undertaken initial findings show fodder beet is able to provide such high yields of a high quality (11 MJ ME/kg DM, 12-13% CP) standing feed source from late summer through winter make it an incredibly attractive option for filling the autumn-winter feed gap in south eastern Australia.

Executive summary

Pasture-based beef production in Southern Australia is constrained by seasonal variation in pasture growth and availability, with abundant growth in spring but significant feed deficits during autumn and early winter. The minimal pasture growth of conventional dryland pasture systems during this time have proved unsuitable for finishing of cattle in autumn and winter, leading to low growth rates and poor Meat Standards Australia (MSA) compliance due to high pH and dark meat colour. As a result, producers are unable to consign cattle for slaughter consistently during this time. The seasonal nature of supply is a major constraint for the development of specific ‘pasture-finished’ branded product lines. Therefore, there is significant need for alternative grazing systems which can aid in addressing the supply and MSA compliance challenges during these seasons.

The use of irrigated forages to fill seasonal pasture supply shortages is commonplace throughout the Limestone coast region of South Australia. There is a myriad of options available, from perennial pastures through to annual pastures, forages and crops. Fodder beet (*Beta vulgaris*) is a new option to Australian producers and is a very strong candidate to complement existing grazing systems by effectively filling autumn/winter feed gaps. Fodder beet is characterised by very high dry matter production, high energy content and relatively low cost of production per unit of metabolizable energy. Grazing of fodder beet *in situ* has revolutionised the New Zealand beef industry by allowing cost effective accelerated weight gain during winter. The soil types and summer climate within the Limestone Coast are suitable for fodder beet production. This is predicted to be associated with higher cattle weight gain during autumn and winter, increased supply of (pasture certified) finished stock in autumn and winter with higher carcass merit (MSA Index, MSA marbling) and increased MSA compliance.

This project sought to implement and evaluate the role of fodder beet in commercial beef production systems throughout the Limestone Coast region of South Australia. Six commercial sites were established across two seasons (2016-17) to characterise the agronomic needs of fodder beet, potential animal performance and economics in the farm system. Fodder beet crops were sown in

Spring (October-November) of 2015 and 2016 for grazing in the autumn of 2016 and 2017 respectively using agronomic programs adapted from New Zealand. Yearling British breed steers averaging 340kg were stocked at 10 head/ha (approximately 120 dry sheep equivalents) onto the crops and transitioned onto an *ad libitum* diet of fodder beet over a 21 day period. Once at *ad libitum* intake, steers were strip grazed into the crop and provided *ad libitum* access to low quality cereal straw or pasture hay. An equal number of steers of the same genetic background were managed under each participating properties normal business practice for comparison as a control. Steers were weighed at 4-6 week intervals throughout the grazing period and slaughtered once they had reached 600-640 kg live weight. Carcasses were graded to Meat Standards Australia specifications at Teys Australia abattoir, Naracoorte, South Australia. Both fodder beet crops and control pastures and forages were sampled regularly for quality, yield and utilisation during the grazing period.

Fodder beet crops used an average of 6.02 ML/ha of water to grow 25,583 kg of dry matter per hectare (4250 kg/ML water). Feed quality was exemplary, with 11% dry matter, 11.2 MJ ME/kg DM and 12.6% CP for the whole crop. Total establishment cost averaged $3049/ha, which equates to 12c/kg DM. An average utilisation of 89% was able to be achieved by strip grazing animals, which means the actual cost of feed consumed was 13.3c/kg DM.

Across the 6 sites the average daily gain of cattle whilst grazing fodder beet was 0.92kg/d, which was significantly higher than the average of 0.76kg/d across control sites during this same period. However, control animals accelerated their weight gain in spring and increased their overall average daily gain to 0.96kg/day. A number of issues were encountered across the sites, mainly around managing consumption of the leaf component of the beets and managing the consistency of intake. As a result the per hectare liveweight gain of fodder beet systems ranged from 856-1875kg/ha, which resulted in a range in cost of production from $1.87-4.24/kg liveweight gain. Consequently, gross margin figures ranged from -$1233 to +$2681/ha. These results show the production potential of fodder beet grazing systems, but highlight the importance of crop yield and the efficiency of utilisation by the animals grazing it to maximise liveweight gain and thus gross margin.

The carcase quality of steers slaughtered directly off fodder beet was acceptable, with a proportion of animals able to be slaughtered earlier in the year due to the maintenance of higher growth rates during autumn and winter. Once adjusted for carcase weight, fodder beet steers had significantly lower rib fat depth than control grazed animals (5.7 vs. 7.9 mm) and lower ossification score (134 vs. 144), yet higher eye muscle area (72.5 vs. 72.3 cm^2) and MSA marble score (395 vs 387). One consignment of fodder beet grazed steers had encountered some nutritional perturbation and as a result had variable and lower growth rate. As a result there were some animals that had high ultimate carcase pH, and were non-compliant to MSA specifications. All other animals slaughtered off fodder beet were compliant to MSA specification. 92.5% of the control animals were compliant to MSA specifications.

The ability for fodder beet to provide such high yields of a high quality (11 MJ ME/kg DM, 12-13% CP) standing feed source from late summer through winter make it an incredibly attractive option for filling the autumn-winter feed gap in south eastern Australia. There is considerable scope to increase weight-for-age in pasture-based finishing systems and shorten time to slaughter, enabling producers the opportunity to access seasonal price premiums. For fodder beet systems to be economical, crop yields need to be maximised through site preparation and weed control, and animal performance must be optimised. There are however, a number of factors pertaining to the composition of fodder beet intake and mineral nutrition that need further investigation to optimise animal performance and enable producers to implement this grazing system with confidence.

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1 Background

1.1 Define the suitability and quantify specific agronomic needs of fodder beet establishment in the Limestone Coast, SA

1.1.1 Suitability of fodder beet in pastured beef production

Pasture-based beef production in southern Australia is constrained by seasonal variation in pasture growth and availability, with abundant growth in spring but significant feed deficits during autumn and early winter. The minimal pasture growth during this time have proved unsuitable for finishing of cattle in autumn and winter, leading to low growth rates and poor MSA compliance due to high pH and dark meat colour. As a result, producers are unable to consign cattle for slaughter consistently during this time. This seasonal nature of supply is a major constraint for the development of specific 'pasture-finished' branded product lines. Thus, there is significant need for alternative grazing systems which can aid in addressing the supply and MSA compliance challenges during these seasons. The project will facilitate enhanced relationships between commercial beef producers and processors.

Fodder beet (*Beta vulgaris*) is a very strong candidate to complement existing grazing systems and effectively fill autumn/winter feed gaps. Fodder beet is characterised by very high dry matter production (20-30 tonnes/ha), high energy content (>11 MJ ME/kg DM) and relatively low cost of production (<$140/tonne DM), despite high establishment costs of $2500-$3000/ha. The soil types and summer climate within the Limestone Coast are suitable for fodder beet production. This is predicted to be associated with higher cattle weight gain during autumn and winter, increased supply of (pasture certified) finished stock in autumn and winter with higher carcass merit (MSA Index, MSA marbling) and increased MSA compliance.

Other irrigated forage crops are available to fill the 'feed gap' period, such as forage brassicas (rape, kale), turnips, swedes, maize and sorghum. Typically the dry-matter (DM) yields are much lower than fodder beet (12-14 vs. 25-30 t DM/ha), and thus a greater land area is required to finish stock. Increasing the area that is occupied by annual forage crops reduces the area available for perennial pastures and thus limits overall carrying capacity.

1.1.2 Agronomic need for fodder beet in the Limestone Coast, South Australia

The basic agronomic requirements for fodder beet are readily available from New Zealand, with further information able to be obtained from the commercial beetroot and sugar beet industries throughout the world. Fodder beet is reported to be extremely resilient under alkaline soil conditions and has a high requirement for sodium. Both of these conditions are frequently encountered in soils and water throughout the Limestone Coast, which makes fodder beet an even more attractive option to fill feed gaps. This project aimed to characterise any specific requirements of fodder beet agronomy over and above the existing literature, particularly in highly saline and alkaline environments.

1.2 Determine animal performance and cost of gain on fodder beet relative to conventional dryland pasture based finishing systems

Very little performance data and economic figures have been published on fodder beet grazing systems, despite its extensive use in New Zealand beef and dairy industries. No published data from Australian production systems exists at this time.

The majority of literature exists around the inclusion of beet in dairy cattle diets, where reported performance is mixed. Ferris *et al.* (2003) and Keogh *et al.* (2009) reported increases in energy corrected milk yield, yet a decrease was reported by Eriksson *et al.* (2003) and Mogensen and Kristensen (2010). Waghorn *et al.* (2018) fed dry, wintering dairy cows an 85% fodder beet, 15% barley straw diet, reporting poor intakes and growth rates compared with pasture silage.

For beef cattle, liveweight gains of 0.81-0.98 kg/d for weaner Charolais steers and heifers grazing fodder beet *ad libitum* were reported by Gibbs *et al.* (2015). No quantification of per hectare gains or economics were made. Subsequent work by Saldias and Gibbs (2016) reported average daily gains of 1.01 kg/d and a total of 3295 kg/ha liveweight gain over 130 d for steers grazing beet *ad libitum*. The Beef and Lamb New Zealand "Fodder Beet Profit Partnerships" program was implemented to follow performance of 12 dryland Canterbury foothill farms implementing fodder beet systems over three growing seasons (2013-2016). Yearling Angus steers and heifers averaged 0.49-0.58 kg/d, with highly variable gains from 0.2-1.2 kg/day.

Little data exists on the cost of live weight gain associated with fodder beet grazing, with the only reference available at the time of this report being from Cvitanovich (2016), who quoted $NZD 2.27/kg liveweight gain for replacement dairy heifers. The Beef and Lamb New Zealand "Fodder Beet Profit Partnerships" program reported the cost of dry matter production to be $NZD 0.13 per kilogram, with an average gross margin of $NZD 2,231/ha.

Fodder beet is rapidly digestible, with 85% of organic matter digested within 3 hours of consumption (Sabri *et al.* 1988). It has been reported to reduce nitrogen digestibility (Eriksson *et al.* 2003) and the efficiency of microbial production (Znidarsic *et ali.* 2010) relative to grass forages, although more recent work by Predergast and Gibbs (2015) reported significant increases in total amount and efficiency microbial N production from fodder beet diets. The high sugar content of fodder beet alters the volatile fatty acid ration, with higher proportions of propionate and butyrate (Eriksson *et al.* 2003). The high sugar content of fodder and sugar beets is thought to pose a significant risk to ruminal acidosis, however a comprehensive review by Evans and Messerschmidt (2017) of the substitution of starch with sugars in dairy cattle diets reported no significant impacts when animals are transitioned slowly and fed at multiple points throughout the day. However, the review recommended that further work is required to explore the full metabolic effects of feeding beets in ruminant rations and the resultant potential for modern production systems (Evans and Messerschmidt. 2017).

Little has been reported on the trace mineral composition of fodder beet, and the required supplementation strategies to ameliorate imbalances or deficiencies. Anecdotal evidence from certain members of the NZ industry reported the need for phosphorus supplementation to increase total intake and rectify the balance with calcium. El-Khodery *et al.* (2008) reported hypocalcaemia in sheep consuming beet tops, and Dittmer *et al.* (2017) fed yearling ewes on fodder beet and observed hypocalcaemia, hypophosphatemia and rickets, indicating the potential for Ca and P issues.

The varied performance and recommendations around fodder beet grazing systems from other countries necessitated the development of this project, to evaluate the potential role this feed source may have for southern Australian beef production.

1.3 Determine the effect of fodder beet finishing on carcass merit defined by both MSA compliance and MSA Index

There is little information published in the literature on the carcase quality and performance of cattle that have grazed fodder beet. Hardy and Fisher (1996) reported satisfactory conformation and fat cover in Belgian Blue and Charolais x Holstein-Friesian bull calves that had grazed fodder beet, although the genotype and sex do not relate to Southern Australian systems. The only other literature published is from Johnston *et al.* (2016), who reported slightly lower carcase weights, but higher total lean meat and sub primal yield for fodder beet finished steers compared with their grass finished counterparts.

It is the authors understanding that work is being conducted in New Zealand at this stage on carcase grading characteristics and sensory attributes of fodder beet finished beef, although no results are available at the time of this report.

2 Project objectives

2.1 Define the suitability and quantify specific agronomic needs of fodder beet establishment in the Limestone Coast, SA

2.2 Determine animal performance and cost of gain on fodder beet relative to conventional dryland pasture based finishing systems

2.3 Determine the effect of fodder beet finishing on carcass merit defined by both MSA compliance and MSA Index

3 Methodology

3.1 Experimental sites

This project was conducted on four commercial farms in the Limestone Coast region of South Australia across two years (2016 and 2017). Details for each site are presented in Table 1.

At each site an area was designated under centre pivot irrigation to plant fodder beets. Preparation of beet sites commenced 4-6 weeks prior to sowing. Beets were planted using vacuum operated precision planters calibrated to sow at 100,000 seeds per hectare.

8-10 month old *Bos taurus* steers (340±40 kg live weight) were allocated to were allocated to the beet crops at a stocking rate of 10 head/ha (120 Dry sheep equivalents/DSE/ha) in March of each year. A matching number of control (CON) animals were then allocated to the individual businesses conventional grazing practices for that time of year. Experimental animals were randomly allocated to either treatment group from the same cohort of animals one week before commencing BEET grazing.

Table 1: Details of trial sites for the year one (2015-16) and two (2016-17) Fodder Beet grazing trials

	YEAR ONE			YEAR TWO		
SITE	**A**	**B**	**C**	**D**	**E**	**F**
Owner	Hilton Rural Trading- B. & A. Nunan	Ceres Pty Ltd- J. & M. Andre	Mackareth Farms- T. Mackareth	Hilton Rural Trading- B. & A. Nunan	Ceres Pty Ltd- J. & M. Andre	Ceres Pty Ltd- J. & M. Andre
Soil type	Acidic sand over limestone	Dark Clay-loam over limestone	Dark Clay over limestone	Acidic sand over limestone	Dark Clay-loam over limestone	Dark Clay-loam over limestone
Previous crop	Perennial Pasture (grass/legume)	Forage Brassica	Perennial pasture (grass/legume)	Forage Brassica	Forage Brassica	Leafy Turnip
Property Location	Bray	Kangaroo Inn	Lochaber	Bray	Kangaroo Inn	Kangaroo Inn
CON feed source	Ryegrass Hay, Ryegrass and clover silage	Forage turnip and forage oats	Mature Sorghum and Pasture Hay	Fescue, Clover, Chicory pasture + Ryegrass Hay/Ryegrass and Clover Silage	Perennial Ryegrass, Fescue, Clover pasture	Perennial Ryegrass, Fescue, Clover pasture
Area sown to BEET	10	6.5	6.5	10	6	6.5
BEET Stocking Rate (DSE)	120	120	120	120	120	120
Control Stocking Rate	14	18	12	16	11	11
BEET Sowing Date	31/10/15	29/10/15	20/10/15	21/11/16	22/12/16	22/12/16
Days to grazing*	137	126	125	126	127	127
BEET start date	16/03/16	3/03/16	22/02/16	27/03/17	28/04/17	28/04/17

*Number of days between crop being sown and commencement of induction feeding

3.2 Crop and Pasture measurements

3.2.1 Fodder Beet Crop measurements

A measurement of dry matter content and yield assessment was conducted prior to grazing, once beet crops had matured at 150 days post-sowing and then at four other points during the grazing period.

Yield assessments were conducted by randomly selecting eight, 5 m sections of row throughout the crop. All beets within the chosen 5m sections were harvested, leaf material and bulbs separated, cleaned of dirt and then weighed separately. Sub-samples (400 g) of leaf and bulb were taken from each section, pooled and frozen for chemical analysis by Cumberland Valley Analytical Services (Waynesboro, Pennsylvania, USA) via Forage Lab Australia (Bendigo, Victoria, Australia). An additional 200 g sample was taken from each section, pooled and measured for dry matter content using the microwave method (Lacerda *et al.* 2009). Yield estimates were conducted three times throughout the grazing period, with the sections of crop chosen at each time taken within 40 m of the grazing face at that time so as to represent the qualities of the crop that will be encountered at that time of grazing. Once the total fresh weight of plant matter and dry matter content was determined, the dry matter yield was calculated:

$$Dry\ matter\ yield\ (kg\ per\ ha) = \frac{(total\ fresh\ weight\ of\ bulb\ x\ bulb\ DM) + (total\ fresh\ weight\ of\ leaf\ x\ leaf\ DM}{total\ \#\ metres\ of\ crop\ harvested\ x\ row\ spacing\ in\ metres\ x\ 10{,}000}$$

Beet crop utilisation was estimated at four points throughout the grazing period by measuring four $5m^2$ areas, collecting and weighing the residual plant matter at each.

3.2.2 Control feedbase measurements

Control pastures were sampled four times throughout each experimental period (March-December). At each sample time point, pasture from 8-10 quadrats (50x50cm) was harvested at equally spaced distances along each paddocks diagonal transect. All pasture within each quadrat was harvested with 12V electric shears to a height of 3cm above ground level. Pasture was placed in brown paper bags and each sampled weighed as soon as possible. For each paddock at each sample time point, quadrats were pooled and two separate subsamples of 400 g were taken. One subsample was oven dried at 60^{o} C for 48-72 h for calculation of dry matter content. The second subsample was frozen and sent to Cumberland Valley Analytical Services (Waynesboro, Pennsylvania, USA) via Forage Lab Australia (Bendigo, Victoria, Australia).

Once dry matter was determined for each pasture and sample time point, the total DM mass was calculated for the quadrats sampled, and then a per hectare mass calculated based on the total area harvested by quadrats. In addition, visual estimates of Feed on Offer (FOO) were taken at each sample time point with the use of an MLA Pasture Ruler to compare with the harvested estimates. Any notable features of pasture composition or distribution were noted at each sample time point.

3.3 Induction feeding protocol

3.3.1 Fodder Beet induction feeding

Due to the high soluble carbohydrate content of fodder beet, a strict induction feeding protocol was implemented to ensure appropriate rumen adaptation and to minimise the risk of ruminal acidosis. Having determined the yield of each crop, the intake of beet was controlled during the induction period by harvesting beets with a front end loader or beet bucket and then trail feeding cattle in an adjacent paddock. Allocation was made based on area harvested and weight of the harvested plants.

All sites followed a basic induction feeding protocol adapted from New Zealand recommendations. For sites A-F, animals were all >12 months of age, feed allocation commenced at 1 kg DM/head per day, increasing by 1 kg of DM every two days. Residuals were monitored and all three sites maintained 1 kg/head/day allocation for the first 4 days until animals were familiar with being able to consume beets. Animals at site G were introduced to beet at 0.5 kg of DM/head/day, and after 4 days of feeding at this level were increased by 0.5 kg of DM every two days. Allocation of beets increased until approximately 40% residual was remaining from the previous day, 20% from the day before that and 0-5% from two days before. A source of low quality roughage was provided *ad libitum* throughout the grazing period.

3.3.2 Control feedbase induction

Control fed animals were managed according to the normal enterprise practice for the particular feed type and season. The feed bases utilised were forages with low soluble carbohydrate content and similar in composition to feed being consumed prior to the experimental period. As a result, induction feeding protocols were minimal and involved feeding rapid introduction to the forage.

3.4 Measurement of growth performance

Animals were weighed at the start of the trial and then at 4-8 week intervals throughout the duration until beet crops were consumed and control animals were slaughtered (Sites A-F) or reach market weight (Site G). Individual average daily weight gain was calculated by linear regression.

3.5 Post-grazing animal fate

Once beet crops were fully grazed for sites A-F, animals were weighed and visually assessed for fat cover, with those weighing >550 kg and deemed to have even cover of at least 5mm over the rump were slaughtered. Animals grazing beets that did not reach marketable weight or condition were returned to dryland pastures or sold as store animals. CON animals were grazed until they reached a desirable weight (>550 kg) and condition (estimated >5 mm rump fat cover). All animals were slaughtered at Teys abattoir, Naracoorte South Australia as per industry practice. All carcasses were graded under Meat Standards Australia (MSA) grading protocols.

Animals from site G grazed beet until the crop was utilised, with those weighing from 450-500kg consigned to a feedlot, whilst the lighter individuals were returned to dryland pastures as per the CON treatment. Feed base and animal measures continued until all beet and CON animals were consigned for sale to the feedlot.

3.6 Statistical analysis

Due to the differing feed sources in each system analysis of animal performance is within each system with the unit of replication being individual animal.

Statistical analyses were conducted using Genstat 15th Edition and significance defined as P<0.05.

Live weight data was analysed using a linear mixed model with fixed effects of date, treatment and the date-by-treatment interaction. Animal ID was fitted as a random effect to account for the repeated measures on each individual.

Primary analysis of carcass traits was conducted using a linear mixed model with fixed effect of treatment and random effect of trial site. All carcass traits were then analysed in a second linear mixed model with fixed effects of hot standard carcase weight and treatment, with random effect of trial site.

4 Results

4.1 Feedbase results

4.1.1 Dry matter yield and feed Quality

Total water usage for beet sites averaged a total of 6.02 ML/ha, comprising 162mm rainfall and 4.4ML/ha of irrigation (Table 2). Total annual rainfall for each control site ranged from 593-829mm, which is typical for the region (Table 3).

The yield of spring sown beet crops (Sites A-F) averaged 25,583 kg DM/ha, average utilisation was 89%, and thus the utilised yield was 22,768 kg DM/ha. The autumn sown crop at site G yielded 15750 kg DM/ha, with utilisation of 92% and thus 12880 kg DM/ha utilised yield. Bulb:leaf ratio varied between sites, ranging from 63:38% to 74:26% (Table 4).

The total utilised yield of control feed sources was not able to be measured, nor the utilisation. Feed on offer was recorded at multiple points throughout the experimental period (Table 5).

Dry matter content of beet averaged 11%, which is typical for the Brigadier variety (Table 6). Feed quality of beet was high, with metabolisable energy content and crude protein averaging 11.2% and 12.6%, respectively. The low starch content (1.1%) and high ethanol soluble carbohydrate (ESC) content (24.6%) was as expected. The high sugar (ESC) content with low neutral detergent fibre (NDF) content highlights the potential challenges with feeding beet haphazardly and the risk of ruminal acidosis (Table 6).

The trace mineral content of fodder beet was consistently lower than NRC requirements (Table 6). This was known at the commencement of the work, hence the administration of dicalcium phosphate in a loose lick supplement. Magnesium content of whole beet plants was generally acceptable, with two crops exhibiting high levels. However, the high potassium levels observed will have reduced any potential toxic effects of the high magnesium, and rendered the available levels in the remainder below requirements for optimum growth (Table 6). Calculation of the grass tetany index for beet sites reveals that sites B and C were below the risk threshold, with ratios of 1.67:1 and 2.12:1 respectively, whilst the remaining sites exhibited extremely high ratios, ranging from 3.06-5.05:1.

Copper concentration of whole beet plants was below NRC requirements for optimal growth across all sites (Table 6).

Control feed sources were of variable trace mineral content, presumably due to the diversity of species and stage of growth. Overall, control forages were high in potassium, with all except site B exhibiting grass tetany indices in excess of 2.2:1, ranging from 2.72-3.06:1.

Table 2: Growing season rainfall and irrigation applied to fodder beet crops (Bureau of Meteorology 2018)

						SITE		
			A	B	C	**D**	**E**	**F**
RAINFALL	2015	Oct	0	6.2	3.4			
		Nov	29.9	35.4	2.9			
		Dec	11.2	13.6	9.2			
	2016	Jan	17	13.2	10			
		Feb	47.5	36	20.4			
		Mar	20.5	23.8	26			
	2016	**Oct**				4.8	3	3
		Nov				23.6	31	31
		Dec				57	42	42
	2017	**Jan**				46.6	51.2	51.2
		Feb				17	26.4	26.4
		Mar				36.2	61.4	61.4
		Rainfall total (mm)	126.1	128.2	71.9	185.2	215	215
		Irrigation applied ML/ha	5.5	2.5	4	5.5	5	5.2
		Total water application ML/ha	6.7	3.7	4.7	7.3	7.1	7.3

Table 3: Growing season rainfall for control pastures at each experimental site (Bureau of Meterology 2018)

YEAR	MONTH	A	B	C	D	E/F
2016	JAN	19.6	13.2	16.8		
	FEB	29.6	36	29.8		
	MAR	19	23.8	22		
	APR	23.2	26.8	14		
	MAY	119.2	117.6	43.6		
	JUN	118.4	128.2	44.8		
	JUL	110.2	122.6	94.4		
	AUG		94.6	58.6		
	SEP	127.8	126.8	91.4		
	OCT	72.6	66.8	94.2		
	NOV	24.6	31	23.4		
	DEC	10.8	42	60.2		
2017	JAN				56.6	51.2
	FEB				20	26.4
	MAR				38	61.4
	APR				66.4	50.8
	MAY				60	99.2
	JUN				35	35
	JUL				139	120
	AUG				99.8	107.4
	SEP				70.4	91.2
	OCT				29.8	46
	NOV				38.6	46.6
	DEC				18.6	30
2018	JAN					
	FEB					
	MAR					
	APR					
	MAY					
	JUNE					
	JUL Y					
	AUG					
	SEP					
	OCT					
	NOV					
	Rainfall total (mm)	**675**	**829.4**	**593.2**	**672.2**	**765.2**

Table 4: Average dry matter yield, bulb:leaf proportion and utilisation rate of fodder beet crops across six trial sites

	SPRING SOWN-AUTUMN GRAZED CROPS					
	A	B	C	**D**	**E**	**F**
Average yield (kg DM/ha)	27000	20000	32000	24500	25500	23300
Bulb:Leaf proportion	71:29	74:26	70:30	64:36	62:38	64:36
Area (ha)	10	6.5	6.5	10	6	6
Utilisation (%)	85	95	95	88	89	86
Predicted harvested yield (kg)	23000	17000	19800	21560	22695	20038

Table 5: Feed on offer (FOO) of control pastures during the experimental period across six trial sites

A		B		C		D		E/F	
Date	FOO	Date	FOO	Date	FOO	Date	FOO	Date	FOO
27/04/2016	130	27/04/2016	6000	27/04/2016	5000	26/04/2017	327	26/04/2017	980
25/05/2016	1076	25/05/2016	7000	25/05/2016	45900	31/05/2017	1314	31/05/2017	1276
29/06/2016	1181	29/06/2016	6850	29/06/2016	4540	26/07/2017	1455	26/07/2017	1245
27/07/2016	1068	27/07/2016	4200	27/07/2016	4320	30/08/2017	1427	30/08/2017	1050
31/08/2016	1137	31/08/2016	2000	31/08/2016	4100	27/09/2017	1831	27/09/2017	1347
28/09/2016	1182	28/09/2016	1590	28/09/2016	2900	18/10/2017	2218	18/10/2017	2089
26/10/2016	2185	26/10/2016	1890			22/11/2017	1464	22/11/2017	1014
30/11/2016	1829	30/11/2016	2580			13/12/2017	792	13/12/2017	458
28/12/2016	258								

Table 6: Nutritional composition of whole BEET crops (Values presented are adjusted for bulb:leaf ratio of each crop). *Colour shading of mineral concentration denotes level as deficient (orange), adequate (green) or excessive (red) based on the National Research Council (2000) requirements for yearling British breed steers.*

	A	B	C	D	E	F
Dry Matter (%)	11.00	10.50	10.30	10.97	11.15	12.33
ME (MJ ME/kg DM)	10.91	11.62	9.81	11.58	11.72	11.75
CP (% DM)	10.34	13.42	15.45	12.25	14.09	12.43
SP (% DM)	5.15	7.15	7.26	6.55	7.94	7.61
SP_CP (%)	48.61	55.54	44.25	53.84	61.19	63.42
ADF (% DM)	13.52	9.18	14.06	11.72	11.19	12.08
ADF_NDF (%)	70.71	58.42	60.70	54.00	56.81	51.97
NDF (% DM)	19.56	15.61	23.16	21.34	19.28	22.24
Lignin (% DM)	3.22	1.70	2.39	1.52	1.50	1.71
ESC (% DM)	40.81	37.44	19.02	17.22	17.44	17.47
Starch (% DM)	0.87	1.20	0.67	1.19	1.25	1.44
Crude Fat (% DM)	1.06	1.54	1.66	2.01	2.47	1.83
DCAD (Meq/100g DM)	77.26	88.73	122.97	59.26	81.55	77.74
Ash (% DM)	13.53	13.08	20.21	11.85	12.32	10.66
Ca (% DM)	0.31	0.65	0.66	0.41	0.58	0.35
P (% DM)	0.19	0.25	0.23	0.26	0.23	0.27
Mg (% DM)	0.24	0.45	0.66	0.35	0.37	0.31
K (% DM)	2.08	1.84	2.79	2.84	2.91	3.33
S (% DM)	0.12	0.16	0.19	0.13	0.15	0.13
Na (% DM)	3.10	3.76	4.73	1.92	2.07	1.21
Cl (% DM)	3.67	3.96	5.04	3.03	2.60	1.86
Fe (% DM)	94.08	96.36	623.20	187.42	113.72	188.90
Mn (% DM)	19.21	10.97	40.54	34.92	11.16	12.55
Zn (% DM)	19.64	33.26	38.09	48.27	33.92	33.16
Cu (% DM)	4.66	5.33	5.33	10.24	7.43	8.73

Table 7: Nutritional composition of control feedbases. *Colour shading of mineral concentration denotes level as deficient (orange), adequate (green) or excessive (red) based on the National Research Council (2000) requirements for yearling British breed steers.*

	A	B	C	D	E/F
Dry Matter (%)	21	21	85	17.5	17.43
ME (MJ ME/kg DM)	10.98	11.5	10	10.06	9.55
CP (% DM)	15.92	9.25	9.5	18.85	20.33
SP (% DM)	7.91	3.5	3	8.63	7.25
SP_CP (%)	0.5	38.65	31.5	46.16	35.33
ADF (% DM)	32.62	16.45	35.9	31.23	31.45
ADF_NDF (%)	0.68	90.95	57.6	67.16	72.28
NDF (% DM)	48.32	18.05	62.4	46.76	43.65
Lignin (% DM)	0.22	1.41	2.71	4.52	5.19
ESC (% DM)	5.12	32.1	12.7	3.13	2.18
Starch (% DM)	0.91	7.7	1.2	0.79	0.6
Crude Fat (% DM)	4.12	2.73	1.11	4.47	4.21
DCAD (Meq/100g DM)	42.29	4.47	30.56	29.83	34.43
Ash (% DM)	11.02	12.36	8.91	10.28	12.63
Ca (% DM)	0.82	1.43	0.33	0.78	0.85
P (% DM)	0.37	0.43	0.16	0.41	0.31
Mg (% DM)	0.21	0.33	0.46	0.25	0.23
K (% DM)	2.98	2.99	2.36	2.81	3.31
S (% DM)	0.25	0.47	0.13	0.25	0.31
Na (% DM)	0.54	0.69	0.12	0.54	0.35
Cl (% DM)	1.49	2.58	0.95	1.76	1.65
Fe (% DM)	246.89	71.5	141	243.38	517
Mn (% DM)	88.75	10	26	92.13	50.75
Zn (% DM)	31.02	28.5	46	32.75	27.25
Cu (% DM)	6	5	8	7	8.25

4.1.2 Cost of production

The base prescription for the growing of beet and typical cost are outlined in Appendix 1. This was the base protocol adhered to for the establishment of experimental sites, with slight variation based on soil type and market price of the consumables.

Total establishment cost and total serviced cost for each site are listed in Table 8, with a detailed breakdown presented in Appendix 2. Total establishment cost averaged $3049/ha, ranging from $2898-$3190/ha. Addition of supplements and labour to calculate total serviced crop cost ranged from $3106-$4263, averaging $3810/ha (Table 8). Per hectare costs of CON feedbases were considerably lower, ranging from $83-$196/ha (Table 9).

Based on the utilised yield measurements, the cost of utilised fodder beet "as established" ranged from 12.8-22.5 cents/kg DM, averaging 15 cents/kg DM for the autumn grazed sites (Table 8). Accounting for the costs of servicing the crop increased the cost to range from 15.2-24.1 cents/kg DM, averaging 19.3 cents/kg DM (Table 8). As the total yield, and harvested yield of DM for CON pastures could not be quantified the cost/kg DM can not be determined.

Table 8: Total cost to establish and service fodder beet experimental sites

	A	B	C	D	E	F
Site Preparation	150	166	140	150	166	166
Seeding	610	643	630	635	668	668
Herbicide	1576	1590	1586	1676	1590	1640
Insecticide/Pesticide	43	45	43	43	45	45
Fertiliser	328	444	427	355	440	438
Irrigation	238	153	206	251	219	233
TOTAL ESTABLISHMENT	**2944**	**3041**	**3031**	**3110**	**3129**	**3190**
Supplements	375	769	618	300	492	692
Labour	188	392	447	219	250	381
TOTAL SERVICES	**563**	**1162**	**1066**	**519**	**742**	**1073**
TOTAL SERVICED COST	**3507**	**4203**	**4097**	**3629**	**3871**	**4263**
Cents/kg DM Established	12.8	17.9	15.3	14.4	13.8	15.9
Cents/kg DM Serviced	15.2	24.7	20.7	16.8	17.1	21.3

Table 9: Total costs associated with growing and servicing control feed base sources

<table>
<tr><th></th><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th></tr>
<tr><td>Pasture</td><td>10</td><td>93</td><td>20</td><td>12</td><td colspan="2">10</td></tr>
<tr><td>Fertiliser</td><td>50</td><td>50</td><td>20</td><td>52</td><td colspan="2">45</td></tr>
<tr><td>Labour</td><td>25</td><td>30</td><td>20</td><td>25</td><td colspan="2">25</td></tr>
<tr><td>Machinery</td><td>2</td><td>3</td><td>3</td><td>2</td><td colspan="2">3</td></tr>
<tr><td>Hay</td><td>20</td><td>15</td><td>50</td><td>0</td><td colspan="2">0</td></tr>
<tr><td>Mineral</td><td>5</td><td>5</td><td>4</td><td>0</td><td colspan="2">0</td></tr>
<tr><td>TOTAL COST ($/ha)</td><td>112</td><td>196</td><td>117</td><td>91</td><td>83</td><td>0</td></tr>
</table>

4.2 Animal performance results

4.2.1 Live weight gain

Summary statistics for liveweight gain of beet and CON steers during the beet grazing period is presented in Table 11. Gains were significantly higher (Means of 0.92 vs. 0.76 kg/day) for beet vs CON steers during this period (Table 10). Overall liveweight gain to slaughter saw compensatory gain of CON animals increase the overall means, reducing the significance of any difference in all sites except D (Table 10). Performance of steers at site D was compromised due to preferential grazing of leaf material and an imbalance in the composition and consistency of intake. As a result, overall gain of CON steers exceeded that of beet steers because of the weight loss and slow recovery post change in diet.

Table 10: Summary statistics for steer average daily gain (kg/d) during the beet grazing period

	A		B		C		D		E		F
	BEET	CON	BEET	CON	BEET	CON	BEET	CON	BEET	CON	BEET
Min	0.18	-0.55	0.40	-0.10	-1.00	0.34	-0.21	-0.12	0.66	0.59	-0.57
Max	1.36	1.23	1.50	1.17	2.83	1.08	0.94	1.76	1.39	1.68	0.50
Mean	1.06	0.66	0.94	0.52	1.27	0.70	0.51	0.94	1.10	1.01	0.22
SD	0.15	0.39	0.21	0.24	0.79	0.17	0.25	0.22	0.15	0.20	0.16
CV	0.14	0.60	0.23	0.46	0.62	0.24	0.49	0.23	0.13	0.20	0.72

Table 11: Mean average daily gain (kg/d) for beet and CON grazed steers (Values are means ± SEM) (Values with differing subscripts are significantly different P<0.05)

	A	B	C	D	E	F
BEET	0.96±0.01	0.83±0.06	1.17±0.06	$0.57±0.04^a$	0.98±0.04	1.06±0.06
CON	0.94±0.03	0.74±0.06	1.07±0.07	$0.95±0.03^b$	1.12±0.03	0.96±0.01

4.2.2 Carcase traits

The carcase traits for steers slaughtered directly off beet, and their relative CON counterparts are presented in Table 12. Given that steers were slaughtered at different time and ages, the carcase trait data was analysed with hot standard carcase weight (HSCW) as a fixed effect to compare traits at a standardised carcase weight. beet steers had significantly less rib fat cover, lower ossification, larger eye muscle area and higher MSA marbling scores than CON counterparts at a standardised carcase weight (Table 12). All MSA non-compliance was due to carcass ultimate pH, with beet and CON compliance of 89.8% and 92.5% respectively. However, all non-compliant beet animals were from site D where animal intake and growth was compromised. Removal of these animals from the dataset results in 100% compliance to MSA specifications.

Table 12: Mean values for carcase traits of beet and CON grazed steers (Values with differing subscripts are significantly different P<0.05)

			With HSCW as fixed effect	
	BEET	CON	BEET	CON
HSCW(kg)	307±1.7[a]	333±1.6[b]	N/A	N/A
RFAT(mm)	5.68±0.26[a]	7.86±0.24[b]	6.20±0.27[a]	7.39±0.25[b]
OSS	134±1.1[a]	144±1.0[b]	135±1.2[a]	143±1.1[b]
EMA(cm^2)	72.47±0.49[a]	72.29±0.47[a]	73.82±0.49[a]	71.07±0.47[b]
LTEMP°C	6.01±0.07[a]	5.87±0.07[a]	5.99±0.08[a]	5.89±0.07[a]
pH	5.59±0.001[a]	5.63±0.001[b]	5.594±0.01[a]	5.629±0.01[b]
MSA MB	395±5.3[a]	387±5.1[a]	408.7±5.2[a]	375±5.2[b]
MSA INDEX	61.67±1.23[a]	61.37±1.17[a]	61.67±1.23[a]	61.37±1.17[a]
% MSA compliance	89.8[a]	92.5[b]		

4.2.3 Per hectare production and gross margin

Liveweight gain of beet systems ranged from 888kg-1875 kg/ha, averaging 1329 kg/ha over 150 days of grazing (Table 13). This production is over a 12 month period given the time required for site preparation and crop growth. Highly variable per hectare gains resulted in a large range in gross margins. Taking the serviced crop cost and market price at time of slaughter into consideration, the gross margin for beet systems ranged from -$1233 to $2681/ha (Table 13).

CON grazing systems had lower GM values as expected, due to the lower liveweight gains per hectare. Calculated values varied between $120 and $654 gross margin, varying with production system and season (Table 14).

Table 13: Per hectare liveweight gain, cost of production and gross margin figures for beet grazed steers

	A	B	C	D	E	F
kg LWG TOTAL	18751	6637	8540	8557	10560	11247
kg LWG/ha	1875	1021	1314	856	1625	1730
Serviced crop cost ($/ha)	3507	4203	4097	3629	3871	4263
COP ($/kg LWG)	1.87	4.12	3.12	4.24	2.38	2.46
Market price ($/kg LW)	3.30	3.30	3.30	2.80	2.80	2.80
Gross income ($/ha)	6188	3370	4336	2396	4549	4845
Gross Margin ($/ha)	2681	-833	239	-1233	678	582

Table 14: Per hectare liveweight gain, cost of production and gross margin figures for CON grazed steers

	A	B	C	D	E	F
kg LWG TOTAL	18979	18529	7187	9805	14481	
Kg LWG/ha	95	132	72	218	263	
Serviced crop cost ($/ha)	112	196	117	91	83	
COP ($/kg LWG)	1.18	1.48	1.63	0.42	0.32	
Market price ($/kg LW)	3.30	3.30	3.30	2.80	2.80	2.80
Gross income ($/ha)	313	437	237	610	737	
Gross Margin ($/ha)	201	241	120	519	654	

5 Discussion

5.1 Define the suitability and quantify specific agronomic needs of fodder beet establishment in the Limestone Coast, SA

This project has shown that fodder beet can be successfully grown across a range of soil types throughout the Limestone Coast region of South Australia. The dry matter yields of 23-32 t/ha for spring sown, autumn grazed crops are comparable with those reported from NZ (Beef + Lamb New Zealand 2017). The primary success of fodder beet crops is underpinned by the success in plant establishment and the extent of weed competition. High burden of competitive summer weeds such as Fat hen (*Chenopodium album*) and Wireweed (*Polygonum aviculare*) pose a risk for achieving optimum yields of beet crops in this region. Implementation of pre-sowing “knock-downs” help to reduce weed burden significantly. Ensuring a fine seedbed and consistent seed placement ensures that plant establishment is optimal and beet plants are able to be competitive until canopy closure. Keys to optimum seeding are the use of sound vacuum operated planters, slow seeding speed (3-5 km/h) and seeding depth of 20 mm. This work has highlighted that plant losses at the 4-6 leaf stage through fungal infections and “damping off”. This significantly threatens yield potential and provide opportunities for competitive plants to secure a position in the crop. Foliar applications of Phosphonic acid were administered once this was recognised as an issue to reduce the extent of the damage. Reducing the impact of damping off in these young plants will increase plant numbers (and resultant yield) by 5-10%. Seeds are now able to be treated with commercially available fungicides to attempt to reduce the plant losses in seedlings.

Once plant establishment is secured, provision of sufficient fertiliser inputs and water also play pivotal roles for the crop growing out successfully. Fertiliser inputs will vary with soil type and existing fertiliser history, although a prescription of 299 units N, 140 P, 350 K and 50 S is a good base prescription to be administered across the growing period. Unlike recommendations from NZ, there is no need to administer agricultural salt in the Limestone Coast region due to existing soil and water salinity. Zinc, manganese and boron are also required and need to be applied at multiple points throughout the growing period to ensure plants do not become deficient.

Time of seeding also plays a role in achieving maximum yield, with earlier spring sown crops maximising light and heat capture during summer and reaching maturity well before day length shortens and temperatures decline. However, it is not always practical to sow crops at the optimum time during spring due to wet conditions on heavier soil types and/or the presence of a preceding crop or forage.

Total costs of establishment were slightly higher than expected. The cost of establishment is driven by the high cost of in-crop chemicals (approximately 40% of growing cost), which are commonly used for horticultural crops. These chemicals are crucial to ensure good weed control pre-and-post-emergence of beet plants, which underpins the success of plant establishment and thus crop yield. Currently there are efforts being made by SeedForce Australia and Bayer crop chemicals to evaluate alternative chemicals and have them certified for use with beet crops. This will dramatically lower the cost of the crop and make it even more viable for use in southern Australian livestock systems.

At the current cost of chemical, seed and site preparation, the profitability of fodder beet systems is maximised by optimising crop yield through water and fertiliser inputs. Even at higher water inputs the crops were very water efficient, returning 39-67 kg DM/mm/ha. This is similar to efficiencies achieved with Maize in Australia (Greenwood *et al.* 2005) and considerably higher than values achieved for Perennial Ryegrass (21 kg), Phalaris (19 kg), clover (15-18 kg) (Neal *et al.* 2011) or Lucerne (16 kg) (Rogers *et al.* 2016).

The ability for beet to provide such high yields of a high quality (11 MJ ME/kg DM, 12-13% CP) standing feed source from late summer through winter make it an incredibly attractive option for filling the autumn-winter feed gap in south eastern Australia.

5.2 Determine animal performance and cost of gain on fodder beet relative to conventional dryland pasture based finishing systems

The overall energy and protein level of fodder beet crops grown in this project was favourable for growth of young cattle, although overall CP level could be increased by 2-3% safely. The values reported herein are higher than expected, and higher than that published in the literature elsewhere. Optimising plant density and maintaining leaf health in fodder beet crops enabled a higher proportion of leaf material overall, which resulted in a higher protein content of the whole diet. Although beet is energy dense, low in NDF and contains adequate protein for growth, it is likely intake is limited due to physical fill due to the high moisture content of the feed and/or feedback from hepatic oxidation pathways (Allen 2014). Both factors are affected by meal frequency and size, which were not measured in this study. Controlled measurement of grazing behaviour and digestion kinetics would provide greater understanding of animal performance on beet and allow such effects to be properly understood.

Fodder beet cost an average of 15 cents/kg DM utilised, or 19.3 cents/kg utilised when crop servicing (supplement and labour) were included. No published data on the cost of production for other summer/autumn forages is readily available at the time of this report. Barley is a common supplement used in southern Australian beef and sheep systems, with a typical market value of $250/tonne, although at the time of this report the market value is $390/tonne. Based on a 90% DM content of mature barley grain, these values equate to 27.7 and 43.3 cents/kg DM respectively. Feeding grain to cattle requires further processing (rolling/cracking) and feeders to maximise its utilisation, all at an extra cost. In addition, the feeding of cereal grains renders cattle ineligible for pasture/grass-fed certification.

Cattle growth rates in excess of 1 kg/day were achieved from March- September by grazing fodder beet *in situ*. Whilst CON cattle growth rates were considerably lower throughout March-September, accelerated gains during spring raised their overall growth rate for the March-December period. These results further highlight the production bottleneck and difficulties faced meeting market specifications during the autumn-winter period in pasture based beef production systems. This higher growth rate enabled some animals to be slaughtered in late winter/early spring as intended. Higher autumn-winter growth will always be beneficial to reaching slaughter weights earlier in the spring, but the ability to finish animals directly from fodder beet will capture the greatest value from the crop as animals will not be consuming dryland pastures in the spring and are able to be slaughtered when market prices are typically highest.

Between animal variation in weight gain was not significantly different for beet vs. CON animals. Whether the variability in growth performance was due to subclinical deficiencies or illness, or simply shy feeding and social dynamics of the herd is unknown. Trace mineral analysis of BEET diets showed that calcium and particularly phosphorus levels need to be increased to meet daily requirements. Granular di-calcium phosphate (DCP) was supplemented to animals on all sites whilst grazing beet to increase dietary levels. As individual intake was not measured the level and consistency of supplement intake within a mob is unknown. The high potassium levels of beet measured are of concern, particularly as they may lead to impairment of calcium and magnesium absorption, thereby limiting availability of what are already low to moderate levels respectively. Calculation of the "grass tetany index" (K/Ca + Mg) (Kemp and Hart 1956) for each site revealed ratios of 3.73, 3.03 and 5.71 for sites D, E and F respectively. Index values greater than 2.2 are associated with increased risk of grass tetany (Jefferson *et al.* 2001) and thus beet rations are at considerable risk of impairing metabolic pathways reliant on calcium and magnesium to function. High grass tetany indexes can be lowered through reduction in K level or additional supplementation of Ca and Mg. The DCP supplemented to cattle grazing these crops would have lowered the index somewhat although further work on additional Ca and Mg supplementation is required. Copper, zinc and molybdenum levels were all below requirements for growth. All animals involved in the study were treated twice with an injectable trace mineral supplement throughout the trial which would have assisted in meeting requirements. As animal status was not measured the extent to which further supplementation needs to occur cannot be determined.

The growth performance of animals of site D was lower than expected, with the continued lower growth performance and slower rate of grazing indicating that voluntary intake of beet was lower. The excessive crop allocation and preferential grazing of the leaf material post-induction feeding has likely caused digestive perturbation, either directly as a result of excessive protein intake and accumulation of ammonia in the rumen, or through subacute ruminal acidosis as a result of returning to consumption of the high sugar bulbs when crop allocation was rectified (Humer *et al.* 2018). Hypomagnesemia and a heightened stress response leading to reduced growth rates and energy accumulation may have occurred as a result of the high protein intake or hyperkalemia (Berg *et al.* 2016). The high rate of carcass non-compliance observed for site D animals grazing beet indicates these animals had a low muscle glycogen content at slaughter, either as a result of sub-optimal energy intake (due to low or variable beet consumption) or increased energy utilisation pre-slaughter due to a heightened stress response. The exact sub-clinical cause of reduced intake cannot be determined but has obviously led to a negative association with consumption of the crop. This highlights the delicate nature of beet crop allocation and the potential for long term effects on grazing behaviour and growth performance.

Per hectare productivity of beet systems was extremely high (1106-1875 kg live weight gain) due to the intense stocking rate (120 DSE). For comparison, the average for Southern Australian beef production systems reported in the Southern beef situation analysis (MLA, 2014) was 45.2 kg, with the top 20% of >650 mm annual rainfall systems achieving 384 kg/ha. Whilst the productivity of the beet sites has not been distributed across the rest of the enterprises' productivity, the high carrying capacity and productivity of such small areas has potential benefits in the conservation of pasture elsewhere on the farm. These benefits can be harnessed through lower supplementary feed costs for the rest of the herd, or increased carrying capacity of other stock classes, all of which will aid the overall system productivity. Increasing the consistency of growth across the mob grazing beet will only further increase per ha productivity and profitability.

A suggested option to optimise the productivity of beet systems would be to draft the heaviest animals to graze the crop, thereby ensuring that the majority are able to reach slaughter weight and condition by the time the crop is consumed. This capitalises on the higher cost of production with beet by ensuring they are marketable when prices are highest. Another alternative to ensuring even performance on beet would be to transition 20% more animals onto the crop than targeted, removing the lower performing individuals 4-6 weeks after introduction to the crop. The implementation of either strategy is dependent on the individual production system, the number of animals available and the reason they are using beet in their system.

5.3 Determine the effect of fodder beet finishing on carcass merit defined by both MSA compliance and MSA Index

Steers slaughtered directly off beet had high carcass quality due to the increased weight-for-age, eye muscle area and decreased ossification. They were also able to be slaughtered from July-September, when market prices are at their highest (Figure 2). All animals slaughtered off beet from sites other than D had suitable carcase pH to meet MSA grades, which is testament to the high energy nature of the diet and the continual growth rate of cattle during the colder months. Typically consignments of cattle from the Limestone Coast region slaughtered during winter have issues with high carcass pH or

“Dark Cutting”, with up to 45% of some consignments failing to make MSA specifications (McGilchrist *et al.* 2014). CON steers also exhibited a low incidence of carcase pH related issues, due to the favourable seasons and abundance of feed.

Despite CON animals being slaughtered at a heavier weight, beet steers had significantly higher marbling scores. Interestingly, subcutaneous fat (Rib Fat) levels were lower for beet animals. This effect eludes to differences in the composition of weight gain as a result of the highly digestible nature of the beet diet. Typically, it is expected that fat deposition in ruminants occurs in the order of visceral, intermuscular, subcutaneous then intramuscular (Pethick *et al.* 2005). However, evidence exists for nutritional effects on increased intramuscular fat relative to other depots. Lowering the protein:energy ratio in feedlot diets has a tendency to increase marbling (Oddy *et al.* 2000; Pethick *et al.* 2000), as does Vitamin A deficiency (Harper and Pethick 2004; Kruk *et al*. 2018). Both of these effects may result under a beet feeding regime. However, the highly fermentable nature of beet and high availability of glucose is most likely driving the increased deposition of intramuscular fat (Rowe *et al.* 1999; Pethick *et al.* 2005). As intake and rumen fermentation parameters were not measured, the effect cannot be fully quantified.

As with any beef finishing system, animals need to be drafted prior to slaughter based on liveweight and body condition. Consideration of previous growth rate may also highlight if intake or growth path have been compromised.

6 Conclusions/recommendations

This work has shown the high yielding potential of fodder beet, and the accelerated weight gains that are able to be achieved when grazing cattle from late summer through winter in the Limestone coast. There is considerable scope to increase weight-for-age in pasture based finishing systems and shorten time to slaughter, enabling producers the opportunity to access seasonal price premiums. For fodder beet systems to be economical, crop yields need to be maximised through site preparation and weed control, and animal performance must be optimised. There are however, multiple factors pertaining to the composition or fodder beet intake and mineral nutrition that need further investigation to optimise animal performance and enable producers to employ this grazing system with confidence.

6.1 Crop establishment

Maximising the yield of fodder beet begins with optimising plant distribution and development. This is a combination of seed establishment and plant survival. Seed bed preparation is paramount to good plant establishment and subsequent growth. The seed bed must be fine and as free from as much debris and dry plant residuals as possible. 1-2 spray “knockdowns” should be conducted to reduce weed burden. Preparation for beets should be conducted in previous growing seasons by growing other species that permit the use of broadleaf sprays to reduce the weed burden in the paddock.

Seeding should be conducted using a vacuum operated planter appropriately calibrated for beet seeds. Seeding should be conducted at 4-5 km/h to enable optimum seed placement. Once sown, pre-emergent herbicides should be applied as soon as possible. Crops should be inspected weekly for the first 8 weeks to inspect for disease and ensure the correct stage of growth for the application of post-emergent herbicides.

Control of fungal pathogens in early life is also necessary to maximise plant populations. Seed is now treated although paddocks with a high pathogen load may still be troublesome. The application of phosphonic acid post germination can help boost plant immune status and reduce the effects of "damping off".

6.2 Animal management

Accurate measurement of crop yield is the most important step when introducing animals to fodder beet. Guessing will lead to inaccurate allocation of crop and the risk of overfeeding. Errors during transition feeding will be very hard to recover from. Once animals are fully transitioned any changes in yield are not an issue as animals are at an *ad libitum* intake and daily crop allocations are based on the residuals from the prior 2-3 days.

If possible it is recommended that feeding of fodder beet crops be managed by one or two people, so that day-to-day changes can be noted and consistency maximised. Extra care should be taken in the initial stages of feeding on the crop face to ensure there are no shy feeders and all animals are keen to access the crop. Treat the crop face like a trough, ensuring there is enough space (>1 m/head) for each individual to eat easily without competition. Be diligent managing crop residuals when grazing to optimise utilisation without restricting intake. New Zealand recommendations state that 50% residual should be present from the day prior, 20% from the day prior to that, and no residual from the day before that. There is no evidence to suggest this is an incorrect tactic to maximise utilisation.

As with any finishing system, ensuring the trace mineral supplementation of animals will allow them to grow optimally. A broad-spectrum trace mineral supplement should be employed by whatever method desired (injectible, loose lick, liquid). Additional phosphorus should be supplemented in the correct ratio with calcium. This is easily achieved through provision of DCP *ad libitum*.

Animals must be provided with a roughage supplement to promote salivation and rumen buffering. The choice is dependent on price and availability, with cereal straw or low-quality pasture hay offered *ad libitum* being obvious choices for producers in the Limestone Coast. If higher quality hay or silage is used it must be rationed so as not to allow overconsumption at the expense of fodder beet intake. All supplements and fodder beet crops should be feed tested prior to feeding to determine the appropriate ratios to be fed and any nutritional imbalances.

7 Key messages

7.1 Define the suitability and quantify specific agronomic needs of fodder beet establishment in the Limestone Coast, SA

- Fodder beet can provide 20-30 t DM/ha of high quality (11 MJ ME/kg DM, 13% CP) forage at a low cost (15 cents/kg DM).
- Fodder beet is available for grazing from late summer through winter when other feed sources are not available, or deteriorating in quality.

7.2 Determine animal performance and cost of gain on fodder beet relative to conventional dryland pasture based finishing systems

- Average daily gains of >0.9 kg/day can be sustained through autumn and winter by grazing fodder beet.
- Increased weight gain and high stocking rates (120 DSE) facilitate excellent per hectare liveweight gains (>1500 kg/ha) although performance between sites was variable.
- Consistency and accuracy of crop allocation when feeding fodder beet is crucial to live weight gain success.
- Supplementation with phosphorus is required to balance the Ca: P ratio in the diet.
- Further work is required to optimise individual animal performance and reduce variability in performance within fodder beet grazing systems.

7.3 Determine the effect of fodder beet finishing on carcass merit defined by both MSA compliance and MSA Index

- Accelerated weight gains of cattle grazing fodder beet can facilitate earlier finishing of animals.
- At a given weight, fodder beet fed steers were physiologically younger (lower ossification), had less rib fat, yet had larger eye muscle area and higher MSA marble scores.
- MSA compliance of fodder beet steers did not differ to control animals.
- Optimisation of beet feeding systems will further inform carcass quality and consistency results.

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9 Appendix

Appendix 1: Standard pricing and protocol of inputs required to grow a fodder beet crop

	Cost ($/unit)	Application rate (ha)	# applications	Total Cost
Site Preparation				
Soil test	130	1	1	130
Pre sowing fertiliser				
DAP (kg)	0.5	200	1	100
Pre emergent herbicide				
Pyramin (Chloridazon) (kg)	90	5	1	450
Betanal Flow (Phenmedipham) (L)	91.4	5.5	1	502.7
Matrix (Ethofumesate) (L)	85.6	5	1	428
Seeding				
Seed (box)	435	1	1	435
Snail Bait (kg)	1.24	8	1	9.92
Post emergent herbicide				
Matrix (Ethofumesate) (L)	85.6	2	1	171.2
Firepower 520 (haloxyfop)(L)	45	0.15	1	6.75
Platinum 240(clethodim) (L)	12.5	0.5	1	6.25
Ken-Trel 300 (lontrel, Clopyralid) (L)	18	0.5	1	9
Post emergent Insecticide				
Pyrinex Super 420EC (Chlorpyrifos + bifenthrin) (L)	9.55	0.5	1	4.775
Kensban 500 (Chlorpyrifos) (L)	8.5	2	1	17
Alpha Scud (alpha-cypermethrin) (L)	6.75	0.4	1	2.7
Post emergent Fertiliser				
SprayPhos 400 (L)	4.5	0.75	1	3.375
Signature MC (L)	3.2	2	2	12.8
Signature ZMC 341 (L)	3.2	2	2	12.8
Signature Boron (L)	9	2	2	36
Plasma Power (P,S,Mg,Zn,Cu, Mn trace) (L)	10.95	4	2	87.6
MOP/Urea (kg)	0.568	100	2	113.6
SOA (kg)	0.45	90	1	40.5
DAP (kg)	0.5	100	1	50
		TOTAL	**Seed ($/ha)**	**435**
			Fertiliser ($/ha)	**456.675**
			Herbicide ($/ha)	**1573.9**
			Insecticide/Pesticide ($/ha)	**31.695**

	GRAND TOTAL ($/ha)	**2629.97**

Appendix 2: Detailed cost breakdown of costs associated with the establishment of fodder beet crops

SITE	A			B			C			D			E			F			G		
Variable Costs	# units	$/unit	$ Total	# units	$/unit	$ Total	# units	$/unit	$ Total	# units	$/unit	$ Total	# units	$/unit	$ Total	# units	$/unit	$ Total	# units	$/unit	$ Total
Cultivation	20	75	1500	12	90	1080	13	70	910	20	75	1500	12	90	1080	12	90	1080	20	90	1800
Seeding	10	175	1750	7	175	1138	7	175	1050	10	200	2000	7	200	1300	7	200	1300	10	200	2000
Seed	10	435	4350	7	435	3045	7	435	3045	10	435	4350	7	435	3045	7	435	3045	10	435	4350
Snail bait	80	1	99	50	1	62	50	1	62	80	1	99	50	1	62	50	1	62	80	1	99
Fertiliser																					
DAP	3400	1	1700	3000	1	1500	2800	1	1400	3400	1	1700	2800	1	1400	2800	1	1400	2500	1	1250
MOP/Urea	1000	1	568	1000	1	568	900	1	511	1000	1	568	1000	1	568	900	1	511	1000	1	568
SOA	1000	0	450	1000	0	450	1000	0	450	900	0	405	900	0	405	1000	0	450	1000	0	450
Spreading	40	8	320	20	10	200	20	8	160	40	8	320	20	10	200	20	10	200	30	10	300
Trace element																					
Spray	20	4	80	12	4	48	18	6	108	40	6	240	18	6	108	18	6	108	20	6	120
spraying	20	8	160	12	10	120	18	8	144	40	8	320	18	10	180	18	10	180	20	10	200
Herbicide																					
Pre emergent chemical	10	1380	13800	7	1400	9100	7	1390	9035	10	1450	14500	7	1350	8775	7	1400	9100	10	1400	14000
Post emergent chemical	10	180	1800	7	170	1105	7	180	1170	10	210	2100	7	220	1430	7	220	1430	10	200	2000
Application	20	8	160	13	10	130	13	8	104	20	8	160	13	10	130	13	10	130	20	10	200
Insecticide																					
Chemical	10	25	250	7	25	163	7	25	163	10	25	250	7	25	163	7	25	163	10	25	250
Application	10	8	80	7	10	65	7	8	52	10	8	80	7	10	65	7	10	65	10	10	100
Irrigation																					
Water (ML)	55			23			31			58			33			35			30		
Diesel (36L/ML)	1980	1	2376	828	1	994	1116	1	1339	2088	1	2506	1188	1	1426	1260	1	1512	1080	1	1296
TOTAL ESTABLISHMENT COST			29443			19767			19703			31098			20336			20736			28983

SITE	A			B			C			D			E			F			G		
Variable Costs	# units	$/unit	$ Total	# units	$/unit	$ Total	# units	$/unit	$ Total	# units	$/unit	$ Total	# units	$/unit	$ Total	# units	$/unit	$ Total	# units	$/unit	$ Total
TOTAL ESTABLISHMENT COST			29443			19767			19703			31098			20336			20736			28983
per hectare establishment cost			2944			3041			3031			3110			3129			3190			2898
Crop Service Costs																					
Labour (hours)	75	25	1875	102	25	2550	116	25	2906	88	25	2188	65	25	1625	99	25	2475	25	25	625
Roughage (bales)	30	50	1500	35	100	3500	36	70	2520	40	50	2000	22	100	2200	30	100	3000	40	25	1000
Mineral Supplement	750	3	2250	500	3	1500	500	3	1500	1000	1	1000	500	2	1000	750	2	1500	500	1	450
TOTAL CROP SERVICE COST			5625			7550			6926			5188			4825			6975			2075
per hectare service cost			563			1162			1066			519			742			1073			208
TOTAL CROP COST			35068			27317			26629			36285			25161			27711			31058
per hectare serviced crop cost			3507			4203			4097			3629			3871			4263			3106