Fodder beet revisited

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Abstract

The literature relating to crop husbandry for fodder beet and its feeding value is briefly reviewed, with an emphasis on New Zealand work. Information on current practice, and yields and costs for 3 fodder beet crops grown in 2010-11 near Waipukurau in Central Hawke's Bay is also provided. Good weed control to facilitate leaf area accumulation in the weeks after planting is a key to success when growing fodder beet. The bulbs have upwards of 60% sugars (mainly sucrose) and low crude protein (approximately 10%) and fibre content (neutral detergent fibre approximately 12%), making them potentially problematic as an animal feed. Even so, two farmers whose crops were sampled are achieving yields of 19-35 t DM ha^{-1} with crop expenses not including opportunity cost being 6-8 cents per kg DM. The sampled crops are fed to mature or growing deer and beef cattle in winter with little evidence of any animal health issues.

Additional keywords: *Beta vulgaris,* establishment, weed control, nutritive value

Introduction

Both in the dairy and sheep and beef farming sectors in New Zealand there has been an ongoing trend towards decreased numbers of farms, together with increased average farm size and intensification of farming activities. These changes have led to a renewed interest in cropping to manipulate seasonal feed supply patterns with a view to enhancing profitability of pasture based systems. One crop which is increasingly attracting attention in this context, especially in Southland at the present time, is fodder beet. Taxonomically, fodder beet is a member of the Chenopodiaceae. Together with the garden vegetables silver beet, and beetroot, and the related crops mangel and sugar beet, fodder beet is a subspecies of *Beta vulgaris* L. (Lange *et al.,* 1999). It is generally accepted that sugar beet was developed in Prussia in the eighteenth century as an alternative to obtaining sucrose from sugar cane, and that fodder beet is a cross between sugar beet and a form of beet used at that time for stock food, the mangel (Claridge, 1972; Langer and Hill, 1982). Claridge (1972) indicates that the sown area of mangels in New Zealand decreased from over 10,000 acres in the 1920s to around 1,000 acres in the 1960s, while fodder beet was not sown in New Zealand before the 1960s and about 1,000 ha per year was sown at that time. The authors believe the area currently sown annually to fodder beet in New Zealand to be around 10,000 ha. Reasons for farmer interest in this crop include the potential for high DM yields (>30 tonnes ha^{-1}) and the fact that fodder beet provides an alternative to brassicas in cropping rotations. This paper briefly reviews historical New Zealand research into the husbandry of fodder beet, mainly carried out in the 1970s; current practice, establishment costs, yield data and nutritional analyses for three crops sown in Central Hawke's Bay in the 2010-11 growing season are also reported.

Historical Research

Crop husbandry

Fodder beet has a seasonal cycle similar to kale, and is sown in the spring and harvested in autumn or winter. Fodder beet requires a pH of 5.5-6.0 or higher and is known to be sensitive to low soil sodium levels. Typical seeding densities are 70,000-100,000 plants ha^{-1} (7-10 plants m^{-2}) sown with a spacing of around 50cm between rows (Martin *et al.*, 1982). Cotyledons appear 2-3 weeks after planting (Percival and Bond, 1983) in early sowings and after 1-2 weeks in September-October sowings. Establishment out of a previous crop rather than from grass usually helps with weed control but may expose fodder beet seedlings to chemical residues from the previous crop. In the case of a crop such as winter oats a stale seed bed technique can be used and is a very effective tool for reducing weed problems and conserving soil moisture.

The first phase of crop growth is leaf area accumulation. It takes between 60-150 days from sowing for a LAI of 3 to be achieved and this LAI represents 80-90% light capture (Martin *et al.*, 1982; Martin, 1986). Because of the comparatively low density and long establishment time the crop must be sown with a precision seeder and good weed control is essential. This usually involves spraying for weed control both pre- and post-emergence. Weed problems are a frequently cited cause of reduced crop yield (e.g. McCormick and Thomsen, 1983). Assuming that leaf area accumulation is not compromised by presence of weeds, pests, or disease, or occurrence of drought, there follows a phase of rapid yield accumulation lasting from December or January depending on sowing date, until April or May, and characterised by rapid increase in bulb weights. For Canterbury, Martin and Drewitt (1984) found that sugar yield was about 80% of its ultimate value in March and changed little from May to August. Presumably low temperatures limit bulb growth in winter. By contrast, the same authors found that September sown crops yielded about 20% more, and December sown crops about 50% less than October sown crops. That sowing date should have a greater effect on yield than harvest date is logically deduced from data of Martin (1986) on light interception through the various growth stages. Later harvest extends the yield accumulation phase at a time when light levels are comparatively low. Early sowing extends the yield accumulation phase at a time when light levels are comparatively high (Figure 1). Additional establishment details are given by Martin *et al.* (1982).

Reported yields are typically around 15 t ha^{-1} bulb DM and around 5 t ha^{-1} leaf DM yield, but with a wide range and no consistency in how yield is reported by various authors (Table 1). Single plants can grow very large, therefore lower density crops can still attain a very high yield (e.g. Grower M, Pescini and McCrone, Table 1). Internet sources state that single plants exceeding 70 kg fresh weight have been recorded (Seed Force, 2011). Because some of the trial crops were grown to investigate potential for ethanol production, sugar yield has been reported here so that yield of total DM can be estimated from comparison of sugar yields for individual crops.

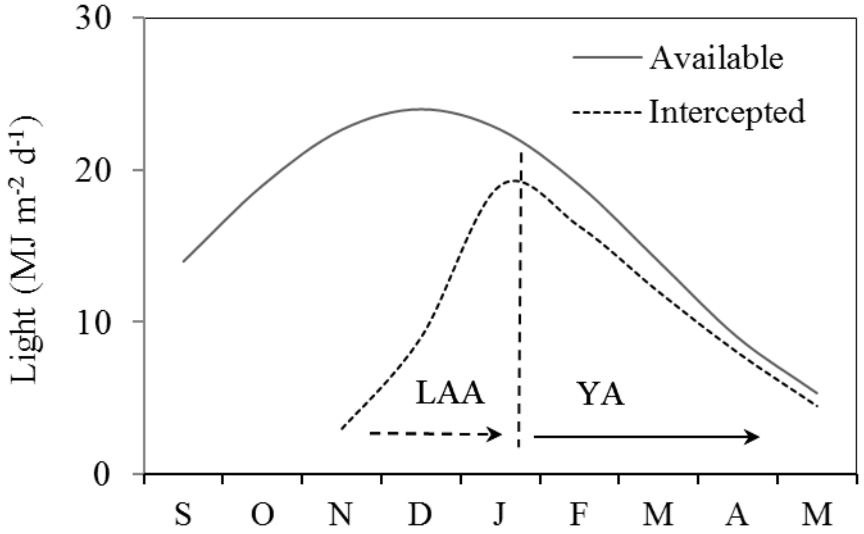

Figure 1: Available and intercepted light (MJ m^{-2} d^{-1}) for a November sown fodder beet crop based on Martin (1986). LAA denotes leaf area accumulation phase of crop growth. YA denotes yield accumulation phase. Providing other factors allow, earlier sowing results in approximately 20 MJ m^{-2} d^{-1} additional light interception with conversion efficiency stated by Martin (1986) to be 1-2 g DM MJ^{-1} (this equates to 1 t DM ha^{-1} in 3-5 d). Potential increase in light interception through delaying harvest is about 4 times smaller than additional light interception from earlier sowing.

Table 1: Selected yield data from historical New Zealand trials of fodder beet and sugar beet, and from three commercial crops measured as a part of the current study. LFW, leaf fresh weight; LDW, leaf dry weight; RFW, root fresh weight; RDW root dry weight; SB, sugar beet; FB, fodder beet; CHB Central Hawke's Bay.

Source	Cultivar or group	Density Plants m^{-2}	LFW ($t\ ha^{-1}$)	LDW ($t\ ha^{-1}$)	RFW ($t\ ha^{-1}$)	RDW ($t\ ha^{-1}$)	Sugar yield ($t\ ha^{-1}$)
Gray and McCormick, 1983. (Gisborne plains)	Amono SB	103,000			173		21.7
	Monoblanc FB	92,000			152		21.5
Martin, 1980. (Canterbury, Experiment 2)	Mean 4 SB cultivars	105,000	42.5		57.6	13.2	9.7
	Mean 8 FB cultivars	92,000	31.9		87.8	14.3	9.9
	Monoblanc	83,000	47.9		79.5	15.1	11.4
Pescini and McCrone (1980).	Mean of 13 growers	80,000	39.8		99.4		11.5
	Grower M	37,000	33.0		134		15.5
McCormick and Thomsen, 1983. (Waikato)	Monoblanc	174,000			108	20.3	11.9
Percival and Bond, 1983. (Central plateau)	Monoblanc	90,000		4.1		14.3	11.2
This study (CHB, Farm 1)[1]	Rivage	73,000	41.1	6.1	170	28.9	17.4
This study (CHB, Farm 2a)[1]	Rivage	67,000	20.0	2.5	95.7	18.1	11.4
This study (CHB, Farm 2b)[1]	Rivage	58,000	22.0	3.0	99.1	16.0	9.6

[1]Sown at 80,000 seeds m^{-2}; plant density estimated from plant numbers in transects at yield sampling.

Animal feeding issues

Clark *et al*. (1987) report the average nutritional composition of fodder beet bulb from 6 farms in Southern England as 6.2% (± 0.8%) crude protein (CP), 12.7 (± 2.2%) neutral detergent fibre (NDF) and 64.9% (± 6.1%) sugars (mainly sucrose). DairyNZ (2010) provide similar figures for fodder beet bulb and give values for leaves of 23% CP, 30% NDF and 10-12% sugars. Beet leaves and roots also contain approximately 10 times the level of the minor nutrients, Na, Cu and Zn, compared to kale (Dairy NZ, 2010). This data indicates three potential problems with fodder beet as a ruminant feed: low CP, low fibre and high soluble sugar levels.

Perhaps because of the possibility of acidosis from rapid volatile fatty acid production in ruminants on high carbohydrate diets or other digestive issues with low fibre feeds (Varga *et al.*, 1998; Chalupa and Sniffen, 2000) most reported trials of fodder beet feeding involve a diet of fodder beet mixed with other forages. Clark *et al*. (1987) fed sheep a 70:30 proportion of chopped fodder beet bulb and hay with 11 g d^{-1} urea to compensate for the low protein content of the diet and concluded that the *in vivo* ME value of fodder beet was 11.8 MJ kg DM^{-1}, about 10% less than would have been predicted from chemical analysis of the material fed. Similarly, Ferris *et al*. (2003) reported that inclusion of around 3kg DM d^{-1} of fodder beet bulb in the diet of lactating dairy cows significantly increased daily ME intake of cows but increased milk solids output proportionately less, so that feed conversion efficiency expressed as daily (milk energy output) (ME intake)$^{-1}$ decreased (P<0.001) from around 0.44 to less than 0.40.

A few trials have reported small positive effects from inclusion of fodder beet in the animal diet. For example, Fisher *et al*. (1994) reported that inclusion of 3.5 kg DM fodder beet in the diet of dairy cows in late lactation increased MS yield from 0.79 kg cow^{-1} d^{-1} to 0.87 kg cow^{-1} d^{-1} (P<0.01). Also, Keogh *et al*. (2008; 2009) reported that cows produced 1.22, 1.06 and 1.12 kg MS cow^{-1} d^{-1}, respectively, when fed diets containing approximately 60% fodder beet with grass silage, the same proportion of kale with grass silage, or grass silage alone.

Current practice and yield sampling

Materials and Methods

To augment published data and to provide information on current farmer experience with this crop, husbandry information, yield and feed quality samples were collected for three fodder beet crops on two farms near Waipukurau in Central Hawke's Bay.

Details provided by one of the two farmers for a typical fodder beet establishment scenario on his property appear in Table 2. Largely because of the multiple weed control operations required with fodder beet, costs total \$2,225 ha^{-1}, although this farmer reports that with experience it has proved possible to make some modest savings.

For three paddocks sown in late October 2010 following procedures similar to those outlined in Table 2, and sampled on 12 April 2011 at 10 randomly placed points across the paddock, all bulbs in a sample of either one or two row-meters were collected, and the fresh weight of leaves and bulb of each plant determined in the field using a battery operated digital balance to a precision of 10g. Subsamples of approximately 5 kg fresh weight leaf and 30 kg fresh weight bulb were kept for each paddock, taking care to select bulbs of various sizes representative of the size distribution in the crop, and taken to Massey University where bulbs were chopped to cubes of approximately 5 cm and %DM of samples of leaves and bulbs determined by drying for 48 hours at 85°C in a hot air draft oven.

After drying, samples of leaf and bulb were finely ground and sent for near infrared spectroscopy (NIRS) analysis at Hill laboratories. On 1 May 2011, the same farms were revisited and sampling undertaken as before at three randomly selected sites per paddock. Leaf and bulb samples were placed in a refrigerator at 5 ºC overnight and the next day couriered to Hill laboratories where they were dried at 65ºC, and analysed by NIRS with the samples previously collected and dried at 85ºC.

For all three paddocks sampled the fodder beet cultivar was Rivage supplied by Agricom. At Farm 1, the fodder beet was being grown as a winter feed for deer, and at Farm 2 as a winter feed for yearling and rising 2-year bulls.

Yield and Nutritional Analyses

Yields of the sampled crops in Central Hawke's Bay ranged from 19-35 t DM ha^{-1} (Table 1) and a previous year's crop on Farm 1 was measured at 43.2 t DM ha^{-1}. Kale yields in adjacent paddocks were also measured and averaged approximately 15 t DM ha^{-1}. Plant weight exhibited a skewed distribution (Figure. 2) with individual bulbs approaching 5 kg fresh weight, but a mean of 2.9 and 1.9 kg for Farms 1 and 2, respectively. Values obtained by NIRS at Hill laboratories for the three crops sampled in this study were similar to those in the literature, with bulb CP <10% DM and sugar content >60% DM (Table 3).

Table 2: Establishment details and approximate cost for a typical fodder beet crop in Central Hawke's Bay, following current practice.

Item		Details	Cost ($ ha^{-1})
Preparation		Spray (September): Roundup 4 l ha^{-1} (a.i. glyphosate 510g l^{-1})	47
Cultivation		Plough, roll, power harrow	285
Sowing		Precision drilled mid-October	210
Seed		80,000 monogerm beet seeds	356
Post-Sowing Sprays	1.	Roundup[1] 1 l ha^{-1} (a.i. glyphosate 510g l^{-1}) + 4 l ha^{-1} Nortron[2] (a.i. ethofumesate 500g l^{-1}) + 250 ml Lorsban[3] (a.i. chlorpyrifos 500g l^{-1}). (Applied post-sowing, pre-emergence).	256
	2.	1.5 kg ha^{-1} Goltix[2] (a.i. metamitron 700g kg^{-1}) + 1.1 l ha^{-1} Betanal Forte[2] (a.i. 160g l^{-1} phenmedipham and 160 g. l^{-1} desmedipham) + 250 ml ha^{-1} Lorsban[3]. (Applied post-emergence).	300
	3.	1.5 kg ha^{-1} Goltix[2]+ 1.2 l ha^{-1} Betanal Forte[2] + 250 ml ha^{-1} chlorpyrifos[3] + 1 l ha^{-1} Versatill[4] (a.i. 300 g l^{-1} clopyralid)	300
Fertiliser		Broadcast: 1600 kg ha^{-1} cropfine lime; 100 kg ha^{-1} muriate of potash; 100 kg ha^{-1} salt; 50 kg ha^{-1} calmag.	417
		Drilled with seed: 150 kg ha^{-1} DAP boron boost.	54
		Total cost	2,225

a.i. active ingredient; [1]A knock-down herbicide for any emerged broadleaf weeds; [2]a residual control chemical for certain broadleaf weeds; [3]an insecticide (to control springtails in particular); [4]for control of Californian thistle.

Table 3: Nutritional profile for leaf and bulb samples from a Central Hawke's Bay fodder beet crop, as determined by near infrared spectroscopy at Hill laboratories.

	Bulb			Leaf		
	Farm 1	Farm 2a	Farm 2b	Farm 1	Farm 2a	Farm 2b
CP (%)	6.2	9.9	10.7	25.3	22.4	22.2
NDF (%)	9.6	9.4	11.6	26.9	27.5	27.7
Sugars (%)[1]	60.3	62.8	59.6	8.8	10.5	11.6
Sugars (%)[2]	69.0	71.3	66.9	22.6	21.4	15.6
ME (MJ kg DM^{-1})	14.6[3]	14.7[3]	14.2[3]	10.4	10.4	11.2

[1]Sampled 1 May, dried at 65°C; [2]Sampled 12 April, dried at 85°C; [3]*In vivo* ME values for fodder beet are typically lower; see text.

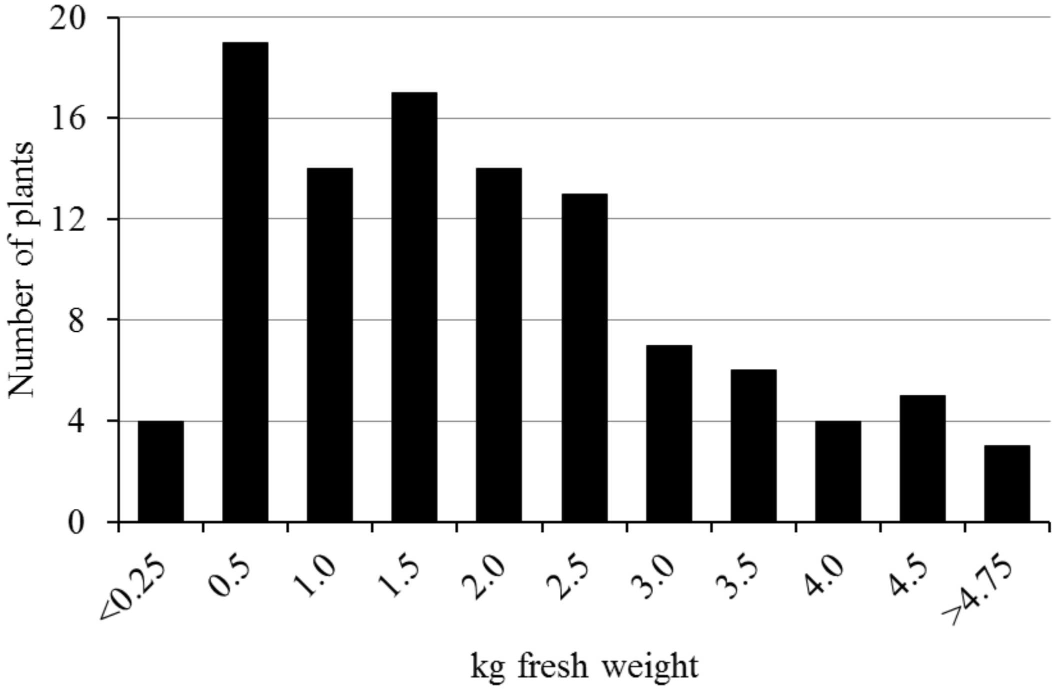

Figure 2: Plant fresh weight distribution (leaves plus bulb) for 116 plants from both Farms 1 and 2 planted late October 2010 and harvested on April 11, 2011. Leaf and root weight per plant were highly correlated (r >0.9) and proportion of root and shoot is indicated in Table1.

Discussion

Paddocks at Farm 2 (2a and 2b in Table 1) were sampled separately because two different fertiliser formulations had been used but the comparison can not be considered a formal trial because of confounding of fertiliser effects with other paddock effects such as soil variation.

As discussed above, the crop is potentially problematic as a ruminant feed in that the bulbs which formed about 85% of total yield for the three crops sampled in this study (Table 1) are high in sugars and low in CP and NDF (Table 3), compared to normal guidelines for ration balancing of ruminant feeds. Gibbs (2011) indicates that farmers feeding fodder beet to dairy cows need to introduce animals to the crop with care and watch for signs of acidosis and reports that where less than 35% of the diet is provided from other fibre-containing feed sources, clinical acidosis may be observed. Inter-planting of fodder beet and kale, since both crops have similar maturation times and compatible establishment requirements, is one strategy for reducing this risk though not a complete solution as anecdotal reports suggest some individual animals may feed preferentially on kale or fodder beet, when offered choice. More generally, leaves of other beet varieties are prone to oxalate accumulation, especially when leaves are younger. There do not appear to be reports of oxalate toxicity specifically relating to fodder beet feeding in New Zealand, but caution on this point would be advisable, even so.

The NIRS results appeared to be sensitive to drying temperature with a higher sugar content recorded after drying at 85°C than after drying at 65°C (Table 3) though because of the gap in sampling date, this point needs further investigation. The ME values for fodder beet bulb are also high. Gibbs (pers. comm., 2011) reports that ME values obtained from in-vivo testing of fodder beet are around 12.0-12.5 MJ kg^{-1}, compared with 10.5-11.5 MJ kg^{-1} for kale fed as a whole crop.

The perceived protein deficiency in fodder beet may not be as severe as is commonly assumed. Brookes and Nicol (2007) in their Table 14 reported that beef animals in July of live weight 300 kg and gaining 0.5 kg d^{-1}, require 325 g d^{-1} metabolisable protein and 79 MJME d^{-1}, or around 4 g protein MJME^{-1}. Assuming 15% leaf and 85% bulb (Table 1), and taking ME data in Table 3 at face value, crops tested in this study all provide at least 6 g CP per MJME, so can potentially meet this specification. If ME value *in vivo* is considered to be less than that indicated by the standard formula as suggested above and also noted by Clark *et al.* (1987) then the ratio approaches 7.5 g CP MJME^{-1}.

To manage the feed quality issues, the farmers whose crops sampled here are planting kale with fodder beet; either as a strip around the edge of each paddock of fodder beet comprising about 25% of paddock area (Farm 1), or in adjacent lanes in a technosystem (50:50 beet:kale area ratio, Farm 2). These two farmers are also feeding some baleage together with the beet. They have had largely positive experiences using fodder beet as a winter feed, although there was a problem in 2011 with deer refusing fodder beet bulbs offered *in situ*.

Farmer 1 reports that in winter 2009, 120 rising-2-year stags gained 9 kg body weight between 27 May and 27 July on 1 ha of fodder beet. From feed budgeting calculations of energy for body maintenance and weight gain, this represents about 14 t ha^{-1} DM consumed by the animals. Assuming 9 kg body weight gain equates to 5.2 kg carcase weight and a venison price of \$8.50 kg^{-1}, this winter weight gain on the fodder beet crop was worth about \$4,920 ha^{-1} in added value of animals. In short it has been possible to achieve animal performance outcomes that make growing a fodder beet crop in Central Hawke's Bay profitable. The authors hope to carry out a follow up study to evaluate more fully the contribution of fodder beet crops to winter feed supply in farm systems.

Conclusions

The data indicate that while yields in excess of 30 t ha^{-1} are feasible, they are not a foregone conclusion. It is clear from this brief review of published data and farmer experience that fodder beet is an exacting crop to grow, requiring attention to detail in the planning and establishment. Weed control is critical and herbicide costs are substantive (Table 2). However, given the yields and costs cited in Table 1 and Table 2, respectively, the cost of fodder beet on these two farms is between 6-8 cents kg^{-1} DM, not counting opportunity cost or benefits of regrassing after the crop. Even allowing for the risk and high per hectare cost, these two farmers are demonstrating that fodder beet is a viable and comparatively cheap winter feed supply option.

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