Measurement techniques and yield estimates of fodder beet in Canterbury and Southland

H.G. JUDSON[1], S. McKENZIE[1], S. ROBINSON[1], A. NICHOLLS[2] and A.J.E. MOORHEAD[1]
[1] *Agricom, P.O Box 3761, Christchurch, New Zealand*
[2] *Macfarlane Rural Business Ltd, Ashburton, New Zealand*
gjudson@agricom.co.nz

Abstract
A survey of commercial fodder beet crops across Canterbury and Southland was undertaken to determine average yields and to provide some basic information on commercial crops. Commercial yields were approximately 19 t DM/ha but higher yields (34 t DM/ha) were achievable. Dry matter content (DM%) of bulbs was higher for lighter than for heavier bulbs. Variation in DM% between bulbs was greater than the variation between parts (inner and outer fractions) of the bulb suggesting a rapid method of sampling multiple bulbs may lead to increases in accuracy of DM% assessment. A rapid coring method was tested.

Keywords: fodder beet, yield, survey, dry matter yield

Introduction
Fodder beet (*Beta vulgaris*) has become a popular forage for feeding sheep, cattle and deer typically through the autumn and winter months in southern New Zealand. This increased interest in fodder beet is a recognition of the crops high yield and utilisation potential and feed quality relative to other options (Westwood & Mulcock 2012; Chakwizira *et al*. 2013). The practical use of fodder beet grazed *in situ* for both beef and dairy cows is unique to New Zealand in its scale and has benefited from recent research (Gibbs 2011; Gibbs & Saldias 2014).

The estimation of crop yield is an important aspect of fodder beet usage. Accurate yield estimation is important for feed budgeting purposes, to allow appropriate allocations to livestock through full transition, to allow comparison of feed costs, selling crops *in situ* and benchmarking agronomic outcomes. Anecdotal evidence suggests large variations in crop yields across the industry but industry statistics are not yet available.

Estimates of fodder beet yield relies on the determination of fresh weight per unit area and DM% of both bulb and leaf. This paper describes the development of techniques to determine dry matter percentage and to provide some broad industry statistics on the commercial yields (both dryland and irrigated) being achieved in Canterbury and Southland.

Methods
Survey
Yields of commercial fodder beet crops in Canterbury and Southland were collected between 2011 and 2016. This included yields from the "Fodder Beet Profit Partnership" group (A. Nicholls unpubl. data) over 3 years (2014-2016) and on-farm survey data by Agricom. Fodder beet yield (t DM/ha) in each paddock (n=132) was assessed using a procedure similar to those described by Dairy NZ, Chakwizira *et al*. (2014) and A. Nicholls (pers. comm., for the Fodder Beet Partnership Group), as outlined briefly below.

Row spacing was determined for each paddock by random selection of a start row (row 1) and measuring the distance between the middle of the plants in this row across 10 inter-row spaces to row 11. The distance (in metres) was divided by 10 to determine row spacing.

At least five randomly selected sites within representative parts of each paddock were sampled. At each site, all beets were removed from a section of a single row, the length of which provided a 2 m^2 sample based on the row spacing (e.g., 4 m in length for a 50 cm row spacing or 4.44 m when row spacing was 45 cm). Any soil aggregating around the bulb was removed by scraping with a blade and then the tops were removed by cutting as close to the crown of the bulb as possible. The fresh weight of bulb and leaf was determined using portable scales with a resolution of 0.01 kg.

A sample of bulbs (n=3-5) and a subsample of leaf (approximately 300 g) were selected from each site for DM% determination. Leaf samples were oven-dried at 65°C for 48 hrs to determine DM%. Bulbs were cut into quarters lengthways and then one quarter was diced and shredded in a kitchen blender. Shredded samples were then weighed into pre-weighed trays and oven-dried at 65°C in a thin layer until constant weight was achieved at around 48 hrs.

Paddock yield (t DM/ha) was calculated as the average of site measurements:

$$\text{Site Yield (t DM/ha)} = \left[\frac{(\text{total fresh wt leaf (kg) x leaf DM\%}) + (\text{total fresh wt bulb (kg) x bulb DM\%})}{2} \right] \text{x10}$$

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Dry matter sampling method
DM% of both bulb and leaf was determined (using the method above) for a range of cultivars in field experiments.

The variation in DM% throughout the bulb was determined by separating bulbs (n=18) (from a range of low and medium DM% cultivars) into top, middle and bottom fractions and further into inner and outer fractions (see Figure 6). Each fraction was shredded and dried at 65°C for 48 hrs to determine DM%.

The use of a coring device was also evaluated for sampling bulbs. A corer (1 cm in diameter) was used to sample bulbs (n=56), from a range of cultivars, at the top of the bulb and on one side, extracting a 12-15 cm long sample. The other side was quartered longitudinally and its DM% determined.

Linear regression was used to describe the relationship between bulb weight, bulb DM% and DM yield. A Duncan test was performed on bulb fractions to determine significant differences ($P>0.05$) in DM%.

Results
The average commercial fodder beet crop yield in early winter for a range of cultivars, sowing dates, soil types, moisture profiles and soil fertility was 19 ± 0.5 t DM/ha (mean ± SEM) and varied from 8-34 t DM/ha (Figure 1).

On average, leaf made up 17% of this yield representing around 3.5 t DM/ha, but varied from 5-40%.

The DM% of fodder beet bulbs for different crop cultivars ranged from 8-28% and were negatively correlated with bulb size, in that heavier bulbs had a lower DM% (Figure 2). This represents approximately a 1 unit decrease in DM% for every 1 kilogram of additional fresh weight. Cultivars broadly conformed to groups based on DM %.

Figure 3 provides individual bulb dry matter content measurements for cultivars classified as having medium (cv. Rivage) or low (cv. Brigadier) dry matter contents. While these two cultivars represent two distinct populations, there was considerable variation between bulbs of the same fresh weight and cultivar, and individual cases can overlap these broad grouping.

Survey data were analysed to determine if the average DM% of the bulb was correlated with final yield of the crop. For a range of cultivars and crops yields (n=76), there was no relationship between the DM% of bulb and final crop yield (Figure 4).

The DM content of leaf averaged 11.4% (range 7-18%) for 68 leaf samples across cultivars (Figure 5).

There was significant ($P<0.05$) variation in the DM% of different fractions of the fodder beet bulb (Figure 6). The outer fraction (19.8%, average of top, mid and bottom outer portions) was higher in DM% than the

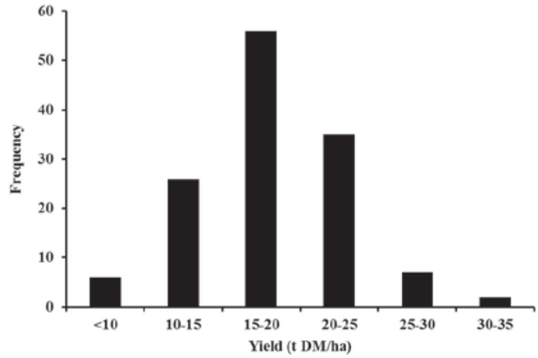

Figure 1 Frequency distribution of fodder beet dry matter yield from 132 commercial crops surveyed in Canterbury and Southland, New Zealand.

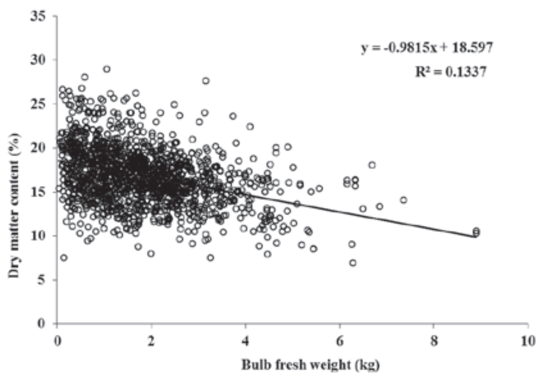

Figure 2 Dry matter content of fodder beet bulbs (n=1592) (variable fresh weights) from a range of crop cultivars surveyed in Canterbury and Southland, New Zealand.

equivalent inner fraction (18.3%) but the top (19.0%) no different to the bottom (19.2%) or mid-section (19.0%).

The coring method returned similar bulb dry matter contents to the more conventional longitudinal quartering method, regardless of DM% (Figure 7).

Discussion

The survey described here estimated average fodder beet yields across Canterbury and Southland to be approximately 19 t DM/ha. This is similar to estimates of 15-18 t DM/ha recorded in cultivar trials in southern New Zealand (Milne *et al.* 2014) but lower than the potential of this crop in some areas which are reported to have reached 40 t DM/ha (Milne *et al.* 2014). The highest yielding fodder beet crops in this survey reached 34 t DM/ha confirming that these yields are possible (Figure 1). Agronomic factors such as sowing date, field emergence, plant population, weed, insect and disease control, fertiliser applications and optimal irrigation are likely to affect yield alongside environmental conditions such as thermal time accumulation (◦C day)

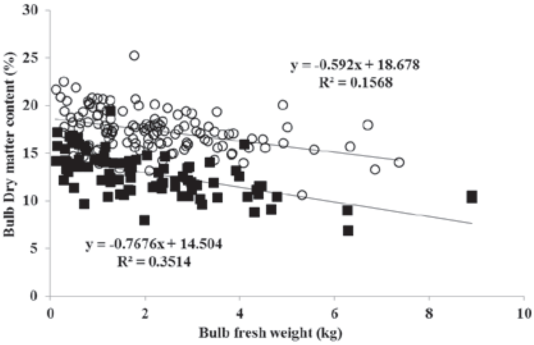

Figure 3 Bulb dry matter percentage of a low (n= 92) (■) and a medium (n=132) (○) dry matter content cultivar of various fresh weight.

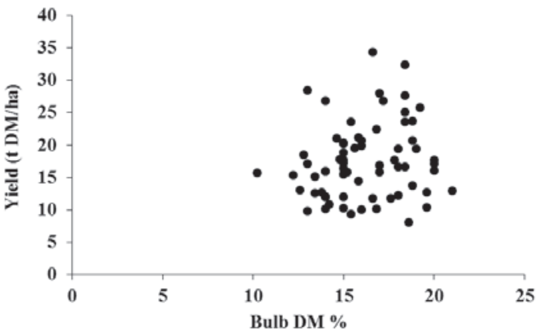

Figure 4 The relationship between fodder beet bulb DM% and total fodder beet crop yield (t DM/ha) for 76 crops.

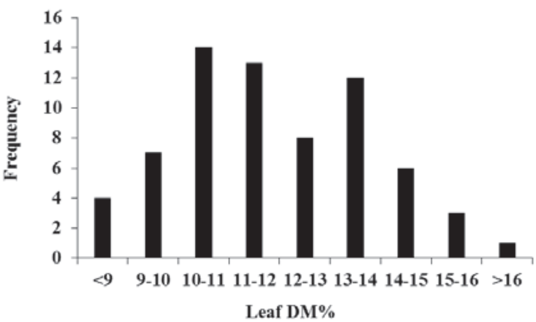

Figure 5 Frequency distribution of DM% for fodder beet leaf.

and soil type. Improvements in agronomy on-farm are likely to increase average yields, however, in many cases yields were constrained by growing crops on free-draining soils of low organic matter in dry and or drought affected sites. This suggests paddock selection may be a key factor in determining yield potential and maybe responsible for the wide range of yields reported here. Other crops such as kale yielded only 11 t DM/ha across similar areas (Judson & Edwards 2008).

Although this survey returned an estimated mean of 19 t DM/ha for fodder beet crops, it is important to give context around confidence in this estimate. Fodder beet crops are inherently variable due to the inevitable gaps in rows left by plants that failed to establish. In many cases, where only 3-5 sites in paddocks have been sampled to generate the paddocks mean, 95% confidence intervals are typically greater than ± 2 t DM/ha and more likely ± 4 t DM/ha.

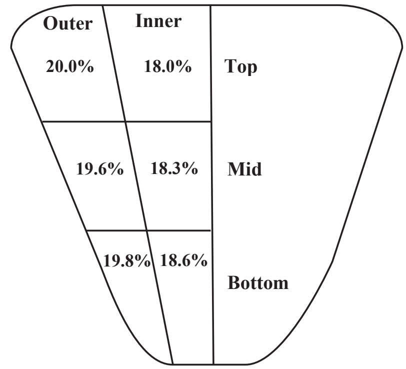

Figure 6 Dry matter percentages as measured for different parts of the fodder beet bulb (mean of 18 bulbs).

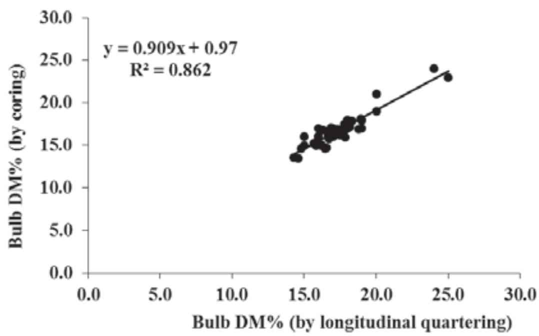

Figure 7 Relationship between dry matter content estimates of fodder beet bulbs using longitudinal quartering or a coring technique.

Leaf measured in early winter contributed 17% of the total DM yield which on average equated to around 3.5 t DM/ha. This probably represents a mid-way point between greater autumn leaf yields and potentially lower yields towards the end of winter as leaf drop occurs. However, the survey did highlight that leaf made up much less of the total DM in some crops which may be an issue if leaf is being relied on as an important protein source. There was considerable variation in the dry matter percentage of leaf (7-18%), averaging 11.4% DM. Using the same fresh weight this range in DM% would have seen leaf yields vary from 2.1 to 5.5, which is not large in the context of the total yield, but again may be important if leaf is being considered an important source of protein.

Bulb dry matter percent varied widely (8-28%) and was negatively correlated with bulb size. Regardless of variety, increasing bulb size was found to reduce DM% by 1 percentage unit for every extra kilogram in bulb fresh weight. This has important implications for measuring DM% to calculate DM yields. Selecting a sample of bulbs that do not represent the average bulb size of the paddock will lead to over or underestimating of the DM% and therefore the yield. There was also a considerable range (8-10 percentage units) in the DM% of bulbs within a cultivar for similar sized bulbs. This possibly reflects environmental effects such as soil moisture, fertility and crop age, and highlights the danger of using "average values" to determine the DM% of a crop.

There was no relationship between average bulb DM% and total yield. This contrasts with the finding of Milne *et al.* (2014) who reported a strong correlation between these variables for seven cultivars in field experiments across Canterbury and Southland. A lack of an effect of DM% on yield in this survey suggests that in commercial crops total DM yield may be more sensitive to factors other than DM%, such as soil moisture profiles and fertility.

The different parts of the fodder beet bulb returned different DM contents, with outer segments being higher than inner segments. This supports the advice to submit longitudinal sections of both inner and outer bulb for DM% assessment to capture this variation. However, given the variation in DM% between bulbs (Figure 3), even within a paddock of the same cultivar, was much larger (8-10%) than within a bulb (1-2%), increasing the number of bulbs sampled will lead to a better estimate of bulb DM%. The coring device provided a rapid, in-paddock method of sampling numerous bulbs.

Summary

This survey has provided some understanding of both yield and DM% of fodder beet crops across parts of Canterbury and Southland. This information provides growers and researchers with commercial benchmarks for other comparisons. It has highlighted the danger of using a single bulb for DM% measurement and the need to test leaf material for DM%. It also provides some validation of a coring technique for sampling bulbs for DM%.

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