Tools to aid with the Nitrogen nutrition of Blackcurrants and Boysenberries

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December 2007

A Report for Blackcurrants NZ Ltd
New Zealand Boysenberry Council
R J Hill Laboratories Ltd

MAF Sustainable Farming Fund Grant 05/008

ACKNOWLEDGEMENTS

The authors wish to acknowledge the contribution of the blackcurrant and boysenberry growers who provided sites for this work, in particular David Eder and Glen Holland for the extra time involved with the monitor sites. Many staff at HortResearch Lincoln have been involved, in particular Cath Snelling for work in the fruit quality area and technicians who have maintained the pot trials and the crop removal study. John Turner formally of Hill Laboratories has helped organise and interprete the soil N data.

This work was financed by a two year Sustainable Farming Fund grant, 05/008 with further contributions from Blackcurrants NZ, NZ Boysenberry Council, Hill Laboratories and Nutrient Solutions Ltd.

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EXECUTIVE SUMMARY

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December 2007

This project ran for two years, 2005/06 and 2006/07. The objectives were to develop an understanding of nutrient requirements, especially nitrogen in blackcurrants and to develop a system for monitoring nitrogen in blackcurrants and boysenberries.

- **In pot trials on blackcurrants** nitrogen (N) was the main nutrient to which blackcurrants responded. A lack of nitrogen reduced yield, caused leaf symptoms and stunted plants. In the field an additional nitrogen treatment on a low soil N site also gave yield responses to nitrogen.
- Low boron levels caused premature fruit fall although this had little influence on yield.
- Reducing levels of potassium, calcium or sulphur caused no yield depression or leaf symptoms.

- **In crop removal studies on blackcurrants**, in one year old plants, roots contributed as much to plant weight as shoots. By year 2, shoots (without leaf) contributed 65% to plant weight.
- Nitrogen is the major nutrient that accumulates with age. Potassium removal does not become significant until fruit is produced.
- A 10-12 t/ha blackcurrant crop is likely to remove 55-65 kgN/ha, 10-12 kgP/ha, 43-50 kgK/ha and 5-7 kgS/ha.

- **In field studies soil nitrogen tests** showed no relationship to **blackcurrant** yield. However several were useful to identify whether fertiliser nitrogen was required.
- The **soil AMN** test was the most useful test as it picked up the seasonal variation associated with the winter leaching of nitrogen.
- **Soil organic matter** (or Total soil nitrogen or carbon) was also useful to help characterise a soil. This would be useful for new blocks, otherwise every 3-4 years on monitor blocks to track changes associated with mulching of prunings and inter row ground cover.
- There was no advantage in using the ratios of soil C:N or AMN:TN.
- On the sites where nitrogen was likely to be the most limiting factor to yield, there was some relationship between yield and soil AMN plus fertiliser N applied (R^2=0.43).
- Using this relationship it required 95-100 kgN/ha to produce a 10-12 t/ha crop.
- Typical soil AMN values (of 80 kgN/ha) indicate that many growers therefore would require no more than 25-30 kgN/ha, with a likely range of 0-60 kgN/ha. Fertiliser requirements are likely to be less where soil OM levels >4%.

- In the field, **leaf nitrogen** values for blackcurrants were all in the optimum range, irrespective of crop vigour, cultivar or yield. This was because nitrogen was diluted in those crops with more foliage. The timing of leaf sampling may need to be brought forward to show more crop variation. Alternatively consideration needs to be given to relating leaf N to bush volume when interpreting the results.
- Leaf analysis from both the pot trial and field samples would suggest that **leaf potassium standards** for normal growth could be reduced slightly to 1.3-1.8%K.
- Soil samples would suggest that **soil standards** for potassium could be reduced to QTK 8-15 and sulphate sulphur levels to 10-20.

- **In field studies on boysenberries** the same soil nitrogen tests showed little relationship with yield. This was likely due to the high annual return of prunings which have lifted soil OM and hence soil AMN levels.
- When additional nitrogen was applied on one site (where soil AMN + fertiliser N was >160 kgN/ha) while vegetative responses occurred, it was difficult to identify fruit yield responses.
- The best yields were likely to come from crops with soil AMN values 130-160 kgN/ha and soil organic matter >6%, depending on the season.
- Leaf nitrogen values in post harvest primocane showed a slight but consistent relationship to yield in both years. This indicates that those crops with good nitrogen fertility had sufficient nitrogen to also produce good cane growth for the following season.

- **Sap nitrate testing of blackcurrant and boysenberry** leaf petioles gave variable results and declined with crop maturity. While it was able to reflect differences when additional N was applied to both crops, it was considered impractical for growers to use.

INTRODUCTION

This project had two objectives;

1. **to develop an understanding of the nutrient requirements, especially nitrogen in blackcurrants (the boysenberry industry was not involved in this part of the work).**
2. **to develop a system for monitoring nitrogen in blackcurrants and boysenberries.**

The project ran for two seasons, 2005/06 and 2006/07.

To meet the **first** objective pot trials were initially undertaken by HortResearch staff at Lincoln (Part 1 of this report). These looked at the importance of nitrogen, potassium, calcium, sulphur and boron on yield, fruit anthocyanin and ascorbic acid content and the ease of fruit removal from the plant. The fruit quality work was paid for by a HortResearch grant from FORST under the Healthful Berries programme and is reported elsewhere.

To support the first objective, crop nutrient removal was measured on bushes grown in the field at Irwell, Canterbury. These represented the three main cultivars of blackcurrants (Part 2 of this report). One year old (2005/06) and two year old plants (2006/07) were destructively sampled and partitioned into leaf, stem, roots and fruit. Blackcurrants NZ are to finance the continuation of this work for a third year (2007/08).

The **second** objective was met by monitoring in the field the nitrogen status of commercial crops of blackcurrants (in Nelson and Canterbury) and boysenberries (Nelson), (Parts 3 and 4 of this report). This was done by using existing and new soil N tests. Soil data was complemented by leaf nitrogen sampling and leaf petiole sap nitrate nitrogen analysis as well as yield and crop growth data. In year 1, 2005/06, a limited number of properties (10 blackcurrant and 4 boysenberry) were used to standardise measurements. On each property two crops were monitored. In year 2, 2006/07, the number of properties was expanded to involve 19 blackcurrant and 7 boysenberry growers.

To support the second objective, one blackcurrant crop and one boysenberry crop were given extra nitrogen in both years. This was to identify whether any of the tests were sensitive enough to pick up differences in nitrogen status which could be related to crop yield.

PART ONE: POT TRIALS ON BLACKCURRANTS

1.1 MATERIALS AND METHODS

'Ben Ard' blackcurrants were propagated from hardwood cuttings in the winter of 2004. These were grown in sand culture in 33 L polystyrene bins in a shadehouse at HortResearch, Lincoln. Bins were filled with river sand of fine particle size (46% was < 1 mm, 21% was 1-2 mm, and 33% was > 2 mm) from the Fulton Hogan quarry, Templeton, Canterbury.

Each treatment had four replicates, each consisting of a single container of three plants (a total of 12 plants per treatment), except for the control treatment, which had double this number of replicates (24 plants). Plots were laid out in a modified randomized complete block design. There were 60 plots and 180 plants in total.

Figure 1a. "Ben Ard' blackcurrants in nutrition trials in shadehouse, 6 December 2006.

Liquid feed was manually applied 2-3 times a week from September to the end of March, then every 1-4 weeks through the autumn and winter. Feed treatments were designed to provide variable and lower concentrations of nitrogen (N), potassium (K), calcium (Ca), sulphur (S) and boron (B) compared to the control, as outlined in Appendix 1, Table 1a. A higher N treatment was also included together with various Ca sources. Nitric acid was used to adjust the pH of all feed treatments to approximately 6.0. Supplemental water was applied as required as calculated by a water budget.

Light intensity and chill accumulation (hours under 7^{o}C between 1 May and 31 August) were also measured.

Bumble bees (one standard hive from Biobees Ltd) were introduced for pollination from early October in both years. Earlier in the spring pollination was carried out manually using a paintbrush. Fully expanded leaves (third to fourth leaf from the shoot tip) were collected from each treatment in mid December and sent for nutrient analysis (Hill Laboratories Ltd.). Leaf area and dry weight were also measured.

Fruit was harvested on 19th January 2006 and 16th January 2007 and yields and berry weights recorded. In 2006, fruit were frozen for later biochemical analyses of the extracted juice for the Healthful Berries project (for full details refer to HortResearch Client Report 21476, June 2007).

1.2 RESULTS AND DISCUSSION

Chill accumulation was lower in 2005, a milder year, with 1285 hours compared to 1560 hours in 2006 which had several cold spells. This, coupled with a warmer spring in 2006 meant that bud break and flowering was approximately 10 days earlier in 2006 compared to 2005 (50% flowering occurred on 10 October in 2006 compared to 20 October in 2005). Bud break occurred later on basal wood, perhaps because of reduced light penetration.

Although treatment differences had little effect on the mean flowering date, in 2006 the high N treatment had the highest fruit set, 82.3% compared to 66.7% in the control, while low Ca had the lowest fruit set, 62.3%, (Std error 3.8%). In 2005 there was a period of moisture stress. The low B treatment flowered a week earlier than other treatments. This led to a better fruit set (95%), compared to shell Ca and medium N treatments (54-66%), which still had not finished flowering when the moisture stress occurred.

1.2.1 Leaf Analysis

Leaf analysis results are presented in Tables 1b and 1c of the Appendix for 2005 and 2006 respectively. Nitrogen, phosphorus and potassium levels were higher in 2005 when plants were fed more nutrient solution relative to their plant size. As plants growth was greater in 2006 these nutrient levels were diluted while calcium and magnesium levels in particular lifted. Zinc and perhaps copper levels would be considered marginal in 2006 although leaf N and Ca were also low (Kay and Hill 1998). In general where nutrient levels were altered the herbage levels also changed, although there was some variability. This effect was most pronounced where boron was reduced or eliminated from the nutrient solution. The variability in nutrient content is likely a consequence of climatic differences between seasons affecting growth, the leaching of nutrients, nutrient effects on growth, and nutrient interactions. An interaction between the major cations calcium and potassium is evident and is more clearly seen in the field work (Part 3).

1.2.2 Yield and Growth

In 2005 there were some nutrient treatment effects on berry yield, Table 1d. However yields were low as plants were young. Yields increased dramatically in 2006 with the control yield equivalent to 11 t/ha in the field. In both years but particularly 2006, berry yield increased as N was increased. Although berry weight did not significantly alter with treatment, the lightest fruit was in plants in the low N treatment.

A low level of potassium tended to decrease yield in 2005. This did not occur in 2006 despite lower herbage K values. Reducing sulphur tended to increase yield in both years. However S levels in the nutrient solution were still high and in this instance lower sulphate sulphur may have enhanced nitrate nitrogen uptake thereby increasing yield.

Table 1d. Mean yield of each treatment, pot trials on 'Ben Ard' blackcurrants, HortResearch, Lincoln

Treatment	**Yield (g/plant)**		**Berry wt (g)**		**Light Interception (% Incident PAR)**
	2005/06	**2006/07**	**2005/06**	**2006/07**	**2006/07**
1. Control	209	1336	1.14	0.82	85.1
2. Low N	87	196	0.83	0.64	77.3
3. Med N	125	737	1.06	0.80	80.3
4. High N	284	2057	1.24	0.85	89.1
5. Low K	139	1432	1.10	0.78	85.4
6. Med K	195	1450	1.17	0.79	81.0
7. Low Ca	136	1434	1.21	0.82	85.4
8. Med Ca	137	1395	1.18	0.85	80.1
9. Shell Ca	158	1594	1.38	0.86	80.8
10. Low S	235	1725	1.21	0.81	81.3
11. Med S	260	1571	1.23	0.80	83.8
12. NH_4-N	204	1802	1.22	0.82	76.1
13. No B	184	1306	1.24	0.81	90.3
14. Low B	247	1629	1.31	0.87	80.8
SE*	22	148			

* SE represents standard error of the difference between treatment means

The only treatment that visually affected growth was N as evidenced in Figure 1b. Mean shoot length in 2005 significantly increased with increasing rate of N.

Figure 1b. Low N (container on left) vs high N, 2006.

In 2006/07, the nil boron treatment caused premature fruit drop a month before harvest. Plant variability and the limited number of plants in each treatment meant overall it was difficult to see any boron affect on fruit yield. Shedding of buds, flowers and fruit are typical symptoms of boron deficiency and are exacerbated by moisture stress (Mengel and Kirkby 2001). Many Nelson and Canterbury soils are low in boron, so this is likely to be an issue in the field. Even so the leaf B standards still appear high and there is evidence to suggest other standards such as potassium may also be too high. A previous lack of information on blackcurrant nutrient status, has meant the current standards are based on the levels in healthy plants rather than when deficiency symptoms are observed, or yield is affected.

Light interception was also measured in 2006/07, Table 1d. Although there was a trend towards decreasing light interception with increasing nitrogen level and hence bush size, the differences were not significant. This is likely to be a greater problem in the field with older bushes where old wood and shading within and between rows can be high. This is discussed further in Part 3.

PART TWO: CROP REMOVAL STUDIES ON BLACKCURRANTS

2.1 MATERIALS AND METHODS

Plants of the three most common cultivars 'Ben Ard', 'Ben Rua' and 'Magnus' were established from cuttings in the summer of 2004/05. These were planted out in the field in winter 2005 at Irwell, Canterbury at commercial spacings (3 m x 0.3-0.35 m).

In May 2006 and 2007, three plants of each variety were harvested once leaves had fallen, and sent for whole plant nutrient analysis of roots, stems and leaves. Leaves were collected by enclosing the bushes in nets. Fruit were also harvested from the first year plants (19 January 2006) and second year plants (28 December 2006) and the fruit nutrient contribution added to that of the bush. Fruit and bush harvests will be repeated in 2008 following a third year of growth. This work is to be financed by the Blackcurrants NZ.

Figures 2a and b. 'Ben Ard' blackcurrant lifted from the field and prepared for plant analysis for nutrient content.

2.2 RESULTS AND DISCUSSION

Total nutrient removal is presented in Table 2a on a per hectare basis for the 2005/06 and 2006/07 seasons for the three cultivars. Year 2 net removal is the total accumulated by the bush at the end of Year 2, minus that removed in Year 1.

In year 1, 14-20 kgN was removed, 2-3 kgP and 5-7 kgK/ha. By year 2, these values had approximately trebled. The net removal in the second year ranged from 26-36 kgN, 6 kgK and 13-15 kgK/ha showing nitrogen still to be the major driver of growth.

Table 2a. Total nutrient removal calculated per hectare (8333 plants per hectare) over two growing seasons from three blackcurrant cultivars, Irwell, Canterbury.

	Major Nutrients (kg/ha)						**Minor Nutrients (g/ha)**				
	N	**P**	**K**	**S**	**Ca**	**Mg**	**Fe**	**Mn**	**Zn**	**Cu**	**B**
'Magnus' Year 1	17.9	3.2	6.6	2.0	14.9	2.7	439	27	67	14	26
'Magnus' Year 2	55.2	9.4	21.3	4.0	37.4	6.3	777	92	194	42	116
'Magnus' Year 2 net removal	**37.3**	**6.2**	**14.7**	**2.0**	**22.5**	**3.6**	**338**	**65**	**127**	**28**	**90**
'Ben Ard' Year 1	14.2	2.2	4.6	1.6	12.6	2.3	335	28	50	9	15
'Ben Ard' Year 2	39.8	8.0	17.8	4.3	35.6	5.6	822	118	163	29	98
'Ben Ard' Year 2 net removal	**25.6**	**5.8**	**13.2**	**2.7**	**23.0**	**3.3**	**487**	**90**	**113**	**20**	**83**
'Ben Rua' Year 1	20.2	3.1	6.9	2.3	16.7	3.2	555	34	68	12	26
'Ben Rua' Year 2	49.3	9.2	21.1	5.6	33.5	5.8	1161	120	195	29	113
'Ben Rua' Year 2 net removal	**29.1**	**6.1**	**14.2**	**3.3**	**16.8**	**2.6**	**606**	**86**	**127**	**17**	**87**

In year 1 there was a significant amount of root growth followed by shoot then leaf growth, Table 2b. By year 2 shoot growth was by far the largest contributor to plant weight and overall nutrient removal. Herbage analysis showed roots and leaves contained similar amounts of N, roots more P and K, and leaves more S, Ca, Mg and micronutrients such as boron.

Table 2b. Dry weight of vegetative plant parts (mean of 3 plants) of one and two year old plants of three blackcurrant cultivars, Irwell, Canterbury.

Cultivar	Plant part	Dry Weight (g) 2006	Dry Weight (g) 2007
'Magnus'	**root**	63.05	80.90
'Magnus'	**shoot**	58.21	323.33
'Magnus'	**leaf**	34.36	81.37
'Ben Ard'	**root**	51.44	93.23
'Ben Ard'	**shoot**	36.86	215.00
'Ben Ard'	**leaf**	28.41	61.73
'Ben Rua'	**root**	71.89	77.10
'Ben Rua'	**shoot**	52.28	271.33
'Ben Rua'	**leaf**	36.62	65.00

Using the above data and individual plant nutrient removals it is possible to estimate nutrient usage for a 10 or 12 tonne crop of blackcurrants. This indicates that moderately yielding blackcurrant bushes remove approximately 55-65 kgN/ha, Table 2c. While fruit can remove at least as much nitrogen as shoots, it is not until significant fruit is produced that total potassium removal approaches that of nitrogen. Sulphur removal is low which may help explain why pot trials showed no benefit from extra sulphur. Fruit removal was similar to that estimated from overseas data (Officer *et al*., 2004).

It is likely that mature commercial crops which contain more wood will contain more nutrients than those outlined below in Table 2c. A third years data should help demonstrate this.

Table 2c. Nutrient Usage, kg/ha (8333 plants/ha) for the three main blackcurrant cultivars based on fruit yield, the amount of extension growth and the mean nutrient concentration of year 1 and year 2 plant parts.

Cultivar	**Plant part**	**Fruit yield kg/ha**	**Bush Dry Wt gm**	**N**	**P**	**K**	**S**
					kg/ha		
Magnus	Root		17.85	2.2	0.5	0.8	0.2
	Shoot		265.12	23.6	4.5	9.9	3.0
	Leaf		81.37	13.8	1.2	2.9	1.3
	Fruit	10000		23.0	6.0	29.0	2.0
	Total			**62.6**	**12.2**	**42.7**	**6.6**
Ben Ard	Root		41.79	5.2	1.2	2.0	0.5
	Shoot		215.00	20.0	3.3	7.5	1.8
	Leaf		61.37	8.2	0.9	1.5	1.3
	Fruit	12000		28.8	6.1	38.1	2.5
	Total			**62.2**	**11.6**	**49.1**	**6.1**
Ben Rua	Root		5.21	0.8	0.2	0.3	0.1
	Shoot		219.05	21.9	3.3	8.5	1.9
	Leaf		65.00	8.6	1.1	2.0	1.3
	Fruit	12000		23.4	5.1	32.8	1.8
	Total			**54.7**	**9.6**	**43.5**	**5.1**

Although 'Magnus' bushes may be larger and contain more nutrients their yields are lower. Therefore there appears little difference in nutrient usage between the three cultivars suggesting that nutrient recommendations for at least the main cultivars of blackcurrants should not have to be cultivar specific.

PART THREE: FIELD STUDIES ON BLACKCURRANTS

3.1 MATERIALS AND METHODS

3.1.1 Field Monitoring

Sites were chosen in winter 2005. Two blocks were set up on 6 properties in Canterbury, from Woodend in North Canterbury to St. Andrews in South Canterbury, and 4 properties in Nelson, in the Upper Moutere and Motueka Valleys. In total there were 22 blocks (there were two extra at Woodend).

In 2006 a further 6 Canterbury (12 blocks) and 4 Nelson properties (7 blocks) were added to the project to give more diversity.

Crops were chosen from the three major varieties grown. 'Ben Ard', the major cultivar was common to all, with the second either 'Ben Rua' or 'Magnus'. Within each block, two adjacent rows representative of the block were used for sampling.

Figure 3a. Typical 'Ben Ard' crop, South Canterbury.

In both years, the crops were soil tested (0-15 cm sampling) in the late winter/early spring. Analysis included a basic soil test and the new soil N profile being marketed by Hill Laboratories, Hamilton.

- Basic soil test - pH, Olsen P (phosphorus), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na) and sulphate sulphur (SO_4-S).
- Soil N profile - total nitrogen (TN), organic matter (OM) and total carbon (TC), soil available N also known as anaerobic mineralisable N (AMN), the C:N ratio and the AMN:TN ratio.

In 2005 leaf samples were taken in mid December the recommended time for sampling, in accordance with standard sampling procedures (Clarke *et al*; 1986). This was several weeks before harvest. All herbage samples were detergent washed and dried before analysis by Hill Laboratories. Full nutrient analysis was carried out on all 'Ben Ard' samples and leaf N analysis on the other cultivars.

In 2006 leaf sampling was repeated, except that sampling was brought forward two weeks to early December.

In 2005 petiole sap nitrate nitrogen (NO_3-N) tests were measured on samples taken at the same time as leaf sampling. The technique is outlined in the Supplement on page 34 of this report. In 2006 further sap testing was carried out earlier in the season, in mid October.

Crops were also scored for vigour and growth and in 2006 also bush size and light interception. Growers provided data relating to seasonal inputs and block or row yield.

3.1.2 Additional Nitrogen Site

One site at Woodend (D.J. Eder and Son) was set aside for extra nitrogen work. Two rows received additional N and there were two 'control' rows as per the normal monitoring. Treatments were separated by a buffer row. Nitrogen was applied at the beginning of July, 50 kgN/ha, as urea (46%N) in 2005 and as CAN (27%N) in 2006.

Data collected included separate soil N tests and additional leaf N and petiole sap NO_3-N tests, to ascertain changes with leaf maturity. Fruit nutrient analysis and some stem analysis was also carried out in 2005/06. Crop vigour, shoot growth, crop light interception (a measure of bush density), fruit size and yield were also measured.

3.2 RESULTS AND DISCUSSION

The 2005/06 season followed a mild winter and there were initial concerns that some blackcurrant crops had not received sufficient winter chilling, particularly 'Magnus'. Although all crops were irrigated, the early summer was dry and some blackcurrant crops, particularly in Nelson suffered from moisture stress. Severe winds before harvest caused yield losses in South Canterbury.

The 2006/07 season followed a much wetter and colder winter, causing more winter leaching and poor spring growth. Several 'Ben Ard' crops in both regions were affected by late frosts, reducing yields. The earlier 'Magnus' escaped much of this. Despite 'Ben Rua' crops looking poor some yielded quite well.

Results of the various analyses are given in Appendix 3, the primary sites Table 3a (2005) and Table 3b (2006) and the secondary sites in Table 3c, (2006).

3.2.1 General Soil data – soil fertility on most sites was good, in particular soil pH. Olsen P values were low on several sites and potentially yield limiting to young plants. These are unlikely to be yield limiting to most mature crops as often low P fertility sites yielded as well or better than high P fertility sites. Excessive soil P (>60) on some sites could potentially lead to P leaching on the lighter soils. These crops were largely on ex tobacco or horticultural ground.

Soil potassium (K) levels were variable and were lower in the second year on the primary sites. This reflected low fertiliser K inputs in 2005 and higher winter leaching in 2006. As many (Canterbury) soils have good reserves of K, on some sites lower K levels may be adequate, eg. QTK 7-8. Higher K inputs would be expected for any peat soils, eg. SC15 and 16, the heavier Moutere sites, eg. PN3-6 where soil K reserves are lower, and where Mg values are excessive, eg. SN15. Other than on this site, soil Mg levels were generally optimal for plant growth.

Most soils had low sulphate sulphur (SO_4-S) levels in both years. This reflects their light to medium texture (sandy to stony silt loams) and low levels of carbon. Excessive SO_4-S leaching would have occurred in the winter of 2006. Provided S fertilisers are always used there is a case for reducing the soil standards to10-12. The timing and form of S may be important. Elemental S would help drip feed SO_4-S to the plants.

Soil Nitrogen data – most of the blackcurrant sites were on soils with medium levels of total nitrogen (0.2-0.5%) and low levels of organic matter (3-7%), Kay and Hill 1998. The lighter sandier sites near Motueka had lower levels. **Total nitrogen** on its own is of limited value as only part of this N is available to the plant. However it may help characterise the soil as it shows some relationship to yield (see later data). **Organic matter** (as calculated from the soil total carbon result) represents the potential pool of N that can be mineralised for plant growth. The low levels of organic matter and total carbon reflect not only soil type, but also paddock history, inter row cultivation, the presence or absence of ground cover between rows and the degree of mulching of prunings and ground cover. Organic matter levels were lower in 2006. The low levels of carbon found are considered below optimum for blackcurrant plant growth (Officer *et al*., 2004).

The **carbon to nitrogen ratio** for all sites fell between 8-12:1, typical of many arable and horticultural soils (optimum 10-12:1). Sites with low ratios are more at risk from nitrate nitrogen leaching. Sites where prunings and ground cover clippings are mulched and possibly spread under the rows may in the long term maintain better C:N ratios and higher levels of OM.

The **soil available N (AMN)** test is intended to predict how much N will release from the organic pool under ideal conditions. The levels range from <50 kgN/ha (very low) up to 200 kgN/ha (medium), with most 70-110 kgN/ha. On the primary sites values averaged 102 kgN/ha in 2005 and 91 kgN/ha in 2006. Results were generally similar in Nelson in both years, but lower in Canterbury in 2006 due to the cool and wetter winter conditions, (Tables 3a-3c). Canterbury sites averaged 97 kgN/ha over both years,18% higher than values measured in 2003 in a previous survey (Officer *et al*., 2004). As many crops have low soil AMN values and only receive low to moderate inputs of fertiliser N and yet still yield well, this suggests that blackcurrants do not have a high demand for nitrogen.

The purpose of the **AMN to Total N ratio** is to provide a more sensitive measure of the N that is available to the plant from the OM (ie. it has the potential to replace the C:N ratio). On the primary sites, the range was small, 1.5-3.6 in 2005, and 2-3.5 in 2006. The secondary sites, showed more variation, 1.8-3.7 in 2006. The Nelson sites tended to increase from 2005 to 2006 and the Canterbury sites to decrease between seasons. The lowest ratios were on sites with the lowest AMN, hence the test gave no benefits over using the soil AMN test alone.

3.2.2. Relationships between soil test data

In 2005, there was a strong linear relationship between soil OM and TN (R^2= 0.97). By contrast the relationship between OM and the AMN:TN ratio was weaker and more complicated (R^2 = 0.45). There was a stronger logarithmic relationship between the soil OM and the AMN test (R^2= 0.79) as compared to TN and AMN (R^2 = 0.65).

These results suggest that either OM or TN may be a useful test to help characterise the soil when planting a new block. As these should not change much between seasons there is no need to use the test every year. The AMN test is a useful test to use annually in late winter to pick up changes between seasons including leaching of N. This appears a more useful test than the AMN:TN ratio.

3.2.3. Relationships between soil N tests and yield

Relationships between any nitrogen test and yield were poor in both seasons (R^2 <0.1). This is not surprising as many factors other than N can affect yield.

Climate has a large effect. Lack of winter chilling affected 'Magnus' in 2005 while frost affected 'Ben Ard' crops in 2006 and to some extent 'Ben Rua' crops. Wind prior to harvest damaged South Canterbury crops in 2005/06. Individual crops also suffered from seasonal moisture stress, particularly in Nelson in 2005.

Pests such as clearwing, aphids, scale, and tarsonemid mite and **diseases** such as botrytis can all severely reduce the yield of individual crops and be more prevalent in certain seasons. Clearwing in particular damaged wood in Nelson.

As blackcurrants fruit on second year wood, nutrient and climatic conditions or disease and pest damage in one year may not be reflected in yield until the following year. From a nitrogen perspective, N has to be partitioned between wood for next year's production and the current fruit crop. Relationships between 2005 soil N factors and 2006/07 yield were only marginally better than using 2005/06 yields, in part due to many 'Ben Ard' crops (or half the data set) being affected by frosting in spring 2006.

The ability of soil N tests to reflect crop yield is confounded by growers using fertiliser N. Fertiliser N inputs ranged from 0- 55 kgN/ha in 2005 and 0- 60 kgN/ha in 2006. On most sites fixation of N by clover in the inter row ground cover and any recycling of this and prunings also add to the N pool. Although blackcurrants are shallow rooting they are also likely to pick up some extra N from below the soil sampling depth.

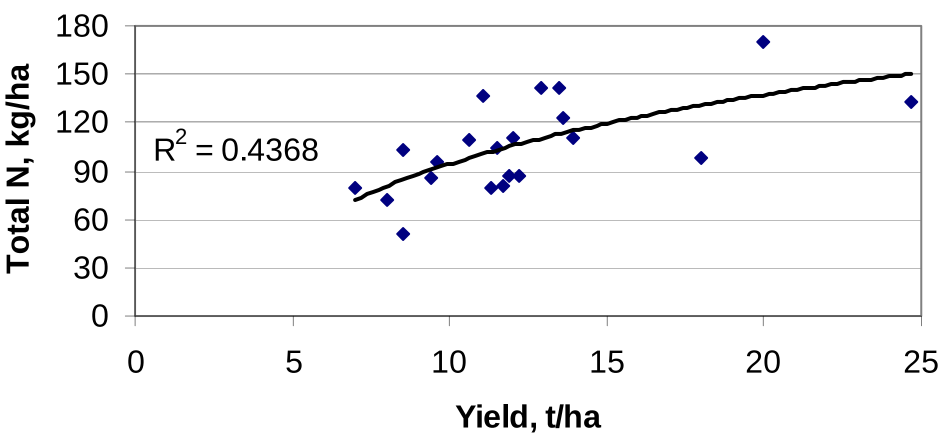
When fertiliser N inputs were added to the soil AMN value, relationships between yield and nitrogen slightly improved in both years. Little further improvement could be made by allowing for whether nitrogen was broadcast or banded near the row, or by allowing for different efficiencies of utilisation of soil compared to fertiliser N, or by allowing for soil N available below sampling depth. In most cases roots would be expected to cover much of the inter row area except where trickle irrigation along the rows encourages roots to stay within this zone. Relationships were sometimes better when only 'Ben Ard' data was used.

Estimates of bush size, the amount/volume of extension growth and how much light could be seen through the row were also measured during the 2006 season. Again these relationships to yield were poor when all data was used.

3.2.4 Best Sites

As most low yielding sites showed no evidence of nitrogen deficiency, the assumption can be made that some factor other than N has reduced yield on these sites. Relationships between yield and OM, TN and AMN plus fertiliser N can be improved by removing low yielding sites. Further improvements can be made by removing the less efficient nitrogen sites (ie. those that contained surplus N). These sites did not return at least 80 kg of fruit for every kilogram of N available. Using both years data, Figure 3b shows the correlation between soil AMN plus fertiliser N and yield can be improved to $R^2 = 0.43$.

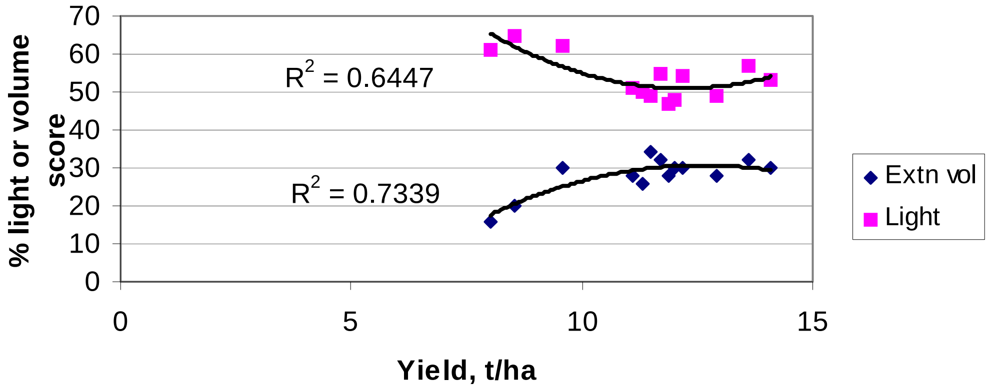
Figure 3b. Yield vs Total (soil + fert) N- best sites 2005 + 2006



This relationship was stronger, $R^2 = 0.56$, in 2005/06 the drier year. Better yield relationships were also shown for OM and TN, particularly in 2005/06. Although these relationships are not strong, they are nevertheless useful to demonstrate a trend towards nitrogen increasing yield, as demonstrated in the pot trials. From this we can make some tentative guidelines for fertiliser N use (see recommendations).

The same approach was taken for the 2006 estimates of bush size, extension growth volume and the amount of light seen through the rows. Here relationships to yield improved markedly, in particular those to extension growth and light, Figure 3c.

Figure 3c. Blackcurrant yield vs light through the crop or extension wood volume, best sites 2006



Yields tended to be better on bushes which had sufficient density of wood as reflected by the light readings and fairly good extension growth. However high density bushes whether through lack of pruning or excessive new cane growth had similar or even reduced yields.

Yield was less related to bush size as the lower portion of a taller bush does not contain much fruit. This relationship improved ($R^2 = 0.5$) when only 'Ben Ard' data was used, reflecting the different growth habits of the different cultivars. Various bush measurements are currently being evaluated in a new project.

3.2.5 Leaf nutrient status

Leaf N data is given for all sites in the Appendix, Tables 3a-3c. Full analysis of 'Ben Ard' samples is given in Tables 3d (2005) and 3e (2006). In 2005 leaf N values on the primary sites average 3% N and ranged from 2.7% (low) to 3.5%N (above average). In 2006 the same sites averaged 2.8% N and ranged from 2.5-3.4%N. Lower results in 2006 are more likely to be a consequence of winter leaching (the differences were more pronounced in Canterbury), rather than from moving sampling forward two weeks in 2006. Many of the extra sites used in 2006 had low leaf N values (2.2-3%N) and several could be classified as deficient.

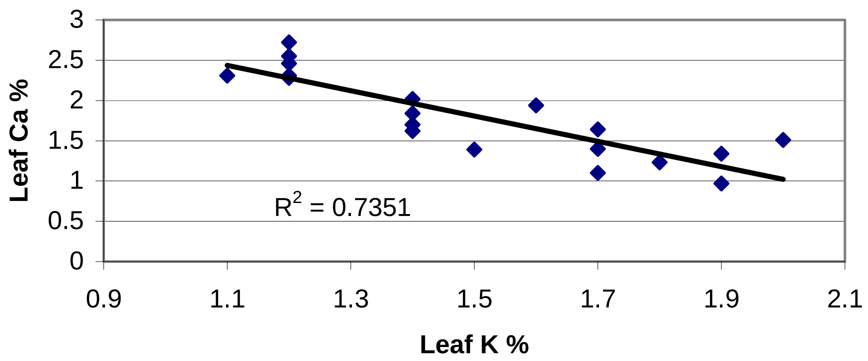
There was no relationship between leaf N and yield in either year or when only the best sites were used. Nor was there any relationship between leaf N and soil N status or observed plant vigour. This indicates that on its own leaf N analysis in December is of limited use (see 3.2.7 for more clarification). Blackcurrants can yield well on both moderate and large sized bushes. On large bushes, leaf N is likely to be lower than small bushes because of dilution of nitrogen through a larger bush volume.

Full nutrient analysis of 'Ben Ard' blackcurrants in both years complemented the soil results in that several sites were marginal in phosphate. Sulphur levels were good indicating that provided fertilisers containing S are used, then plants can access sufficient S. The use of fine sulphur fungicidal/gall mite sprays is also beneficial. Boron levels were low on many sites, particularly in 2006. The highest levels were on properties where B fertiliser was used.

In both years, many sites had low leaf K levels. The higher levels were found where potassium fertiliser was used. The pot trial work showed marginal levels still gave near optimum bush yield in two year plants. This suggests the leaf standards for potassium may be a bit high. Routine grower samples reinforce this view.

Leaf Ca levels varied between years and sites and with leaf K status. This relationship was stronger in 2006, Figure 3d, the wetter year when K was more likely to have leached. This may have implications to the storage quality of fruit (skin thickness) and the end use of the fruit.

Figure 3d. Leaf Ca vs Leaf K, Ben Ard 2006



3.2.6 Leaf sap nitrate levels

Sap nitrate levels measured in December 2005 were low as it was difficult to extract sufficient sap from petioles. This suggests that December was too late for measurement. Therefore relationships between petiole sap NO_3-N and yield were poor ($R^2 = 0.17$). Higher levels were found in a late flowering ‘Murchison’ crop so in 2006 sap testing was repeated but at an earlier date. Sap NO_3-N levels were much higher and were again highest in ‘Murchison’. Again there was no relationship with yield, irrespective whether all or just the best yielding sites were used. Further analysis of a ‘Ben Ard’ and ‘Murchison’ crop throughout the season showed a rapid decline in activity with increasing crop maturity.

While sap testing may be a useful tool for research, it would be difficult for farmers to use because of problems with when to sample each cultivar, the condition of the petiole used (later in the season petioles become hard) and the need to calibrate individual grower equipment to the standards. It also requires some practice to use, some financial outlay and time to complete and interprete the results.

3.2.7 Blackcurrant Additional N Plot

Data is presented in Table 3f for where an additional 50 kgN/ha was applied in late winter to ‘Ben Ard’ blackcurrants and compared to the grower control.

In general fertiliser N has had little effect on soil N values. However there is a slight improvement in leaf N and sap NO_3-N values throughout the season when additional N is used, Figures 3e and 3f. Both results decline with maturity.

Leaf N results rapidly drop in November implying a great demand through leaf expansion and fruiting at this time. If soil nitrogen levels were low and no fertiliser N had been applied by this time then it is unlikely yield will be maximised. This raises doubts as to whether December is the most suitable time for leaf sampling.

Petiole sap NO_3-N levels can fluctuate making it difficult to calibrate this test to aid with recommendations. Maintenance fertiliser was applied immediately after the early November sampling hence the slight increase later in the month.

Fig 3e Ben Ard leaf N with and without an extra 50kgN/ha, 2006/07

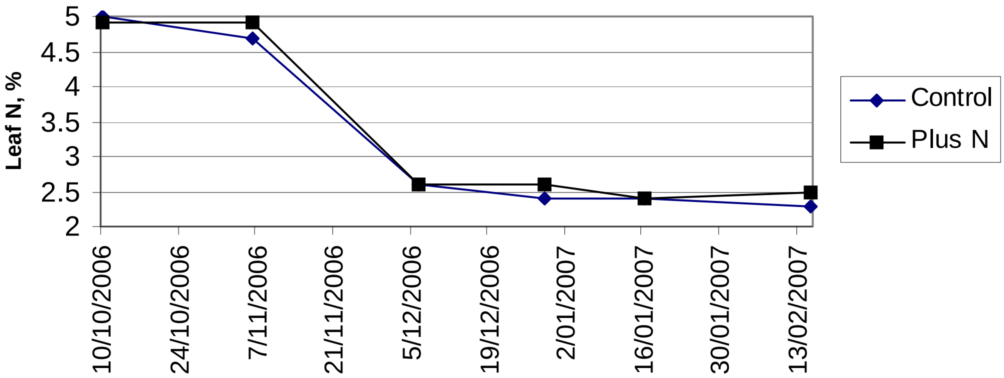
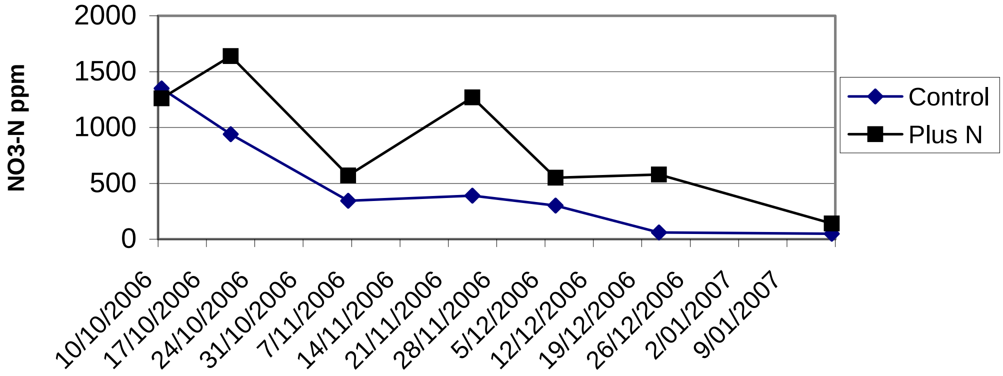


Fig 3f. Ben Ard petiole sap nitrate with and without an extra 50kgN/ha, 2006/07



PART FOUR: FIELD STUDIES ON BOYSENBERRIES

4.1 MATERIALS AND METHODS

4.1.1 Field Monitoring

Sites were chosen in winter 2005. Two blocks were set up on three properties and one on two other properties on the Waimea Plains, Nelson, (8 sites) in the same manner as for the blackcurrants. In 2006 a further two blocks were monitored on three other properties, in total 14 sites.

Figure 4a. 'Mapua' boysenberries, winter 2005.

Crops were soil tested in the early spring of 2005 and 2006 in the same manner as for the blackcurrant sites. In both seasons leaf samples were taken at the end of January on the new season's primocane, in accordance with standard sampling procedures (Clarke *et al*., 1986).

Leaf sap samples were only measured in the second year as initial results showed negligible NO_3-N activity. In the second season analysis were carried out in October 2006 on existing florocane.

Crops were also scored for vigour and growth. Growers also provided data relating to seasonal inputs and block or row yield.

4.1.2 Additional Nitrogen Site

One site near Richmond (A.E. Field and Sons) was set aside for extra work on nitrogen. This was also a monitor property. An additional two rows were set aside to monitor so that there were two rows with additional N and two 'control' rows. The treatments were separated by a buffer row. Nitrogen was applied at the beginning of July, 50 kgN/ha, as urea (46%N) in 2005 and as CAN (27%N) in 2006. In addition to the normal analyses carried out, extra data was collected. This included separate soil N tests and additional leaf N and petiole sap NO_3-N tests, to ascertain changes with leaf maturity. Fruit nutrient analysis and some stem analysis was also undertaken in 2005/06.

Crop vigour, fruit set and size were also measured. However it was difficult to obtain accurate yield data. As a consequence the NZ Boysenberry Council is sponsoring some extra work for the 2007/08 season using this site and three other sites.

4.2 RESULTS AND DISCUSSION

The winter of 2005 was mild and the spring warm. This suited boysenberries so most crops had good yields. All crops had access to irrigation, so the early summer dry had little effect.

The 2006/07 season followed a much wetter and colder winter, causing some winter leaching and poor spring growth. The cool and late spring weather prolonged flowering, so most yields were down. Cold southerly winds in December affected the more exposed blocks.

Results for both seasons are given in Appendix 4, Table 4a.

General soil fertility and pH was good on most sites in both years. The exception was that SO_4-S values were generally low, particularly in 2006/07.

Soil N results were also good on most sites. Nitrogen fertility was much greater than on blackcurrant blocks. Soil AMN values were generally above 110 kgN/ha (low to medium), soil OM from 3-12% (low to medium) and soil TN from 0.17-0.59% (low to high). All values were lower in 2006 compared to 2005, particularly OM and TN. For a full explanation of what these different soil tests measure refer to the blackcurrant section, part 3.

Leaf N values in primocane were 3.3-4%N in 2005, in general at or above typical values of 3-3.7%N (Kay and Hill 1998). As 2006 had a cooler spring, growth was slow so many growers used extra N to encourage growth. Nitrogen use in 2006/07 ranged from 38-95 kgN/ha during the season with several also receiving 45-55 kgN/ha at harvest or post harvest. This compares with 33-72 kgN/ha applied during the 2005/06 season. As a consequence leaf N values were higher in 2006/07 (3.3-4.8%N). The highest values in both years were on the highest yielding site, a site which received only moderate fertiliser N inputs.

In 2005/06 leaf sap nitrate values were barely measurable in January 06 despite rapid growth. In 2006/07 earlier sampling of florocane in October 06 showed much higher values in young petiole growth.

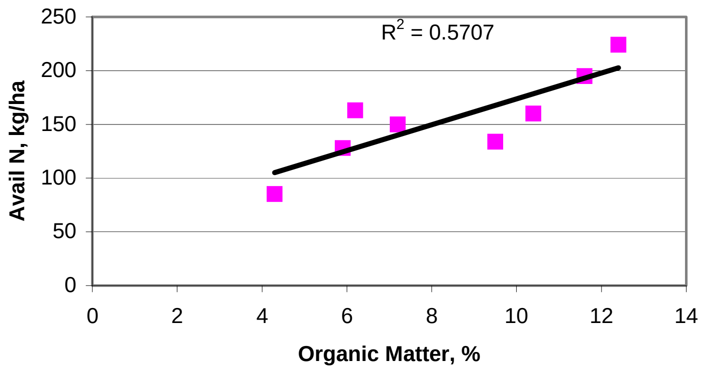
Yields in 2005/06, averaging 19 t/ha. The cooler spring and prolonged flowering reduced yields in 2006/07 to 16.5 t/ha, although some sites yielded as well or better than the previous year.

4.2.1 Relationships between soil and plant N parameters and yield

In 2005/06 and 2006/07 the relationships between most soil N parameters and yield were poor (R^2 <0.1). In 2005/06, there were some trends between yield and the soil AMN:TN ratio, (R^2 = 0.43) and yield and fertiliser N, (R^2 = 0.46). However these trends were much weaker and different in 2006/07.

Although the weather influenced yield and pests and diseases would also have contributed to yield on some sites, a major reason for these poor relationships is the moderate level of OM in these soils. Sufficient nitrogen is present for a yield of 15-16 t/ha on most sites, so based on the yields produced, many might not have responded to fertiliser N. As many of these blocks are on lighter stony soils, eg. Ranzau stony silt loams, OM must have accumulated through previous cultural practices and the recycling of canes. Only 20-25 primocanes are tied up for next season, so a considerable portion of the primocane plus last year's florocane is mulched. This generally leads to better soil available N (AMN) values as evidenced by the relationship in 2005/06 below, Figure 4b.

Figure 4b. Boysenberry 2005/06 Soil AMN vs OM%



However this relationship was not evident in the wetter and cooler 2006/07 season as winter N leaching reduced the soil AMN values. This result, coupled with the poor individual soil N measurement relationships to yield, highlights that more than one measurement may be needed when making recommendations. In wet years the value of soil AMN testing and fertiliser N and its timing is likely to be more important than in drier years.

The leaf petiole NO_3-N values in florocane measured in 2006 showed a weak trend, declining with increasing yield. This is likely to reflect a dilution effect caused by better yielding crops having more vigorous cane growth. Equally even low NO_3-N levels may be sufficient to optimise yield, and/or boysenberries may prefer to take up ammonium-N.

The most consistent relationship observed was between leaf N values of primocane after harvest and that season's yield. Although these relationships were not strong, they were similar in both years, Figures 4c and 4d.

This indicates that the better yielding crops tended to have sufficient nitrogen left over to promote better cane growth for the next season. Any higher N cane not subsequently tied up would be mulched back in for future N cycling.

Figure 4c. Boysenberry leaf N vs Yield 2005/06

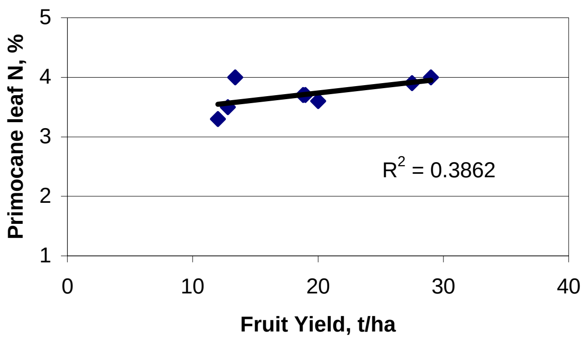
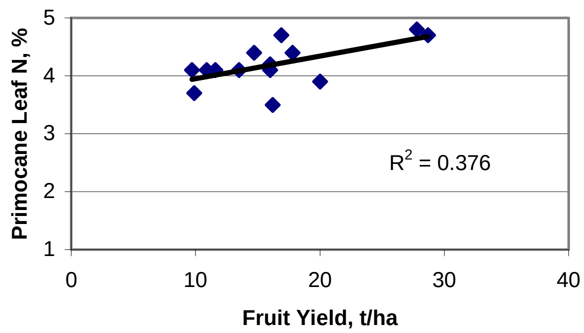
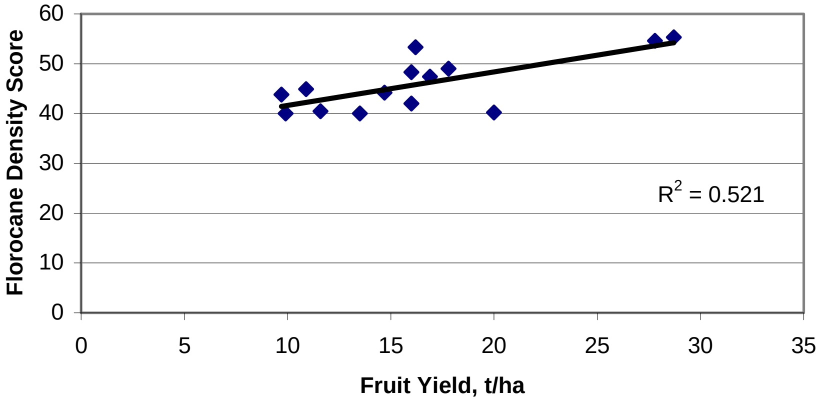


Figure 4d. Boysenberry leaf N vs yield 2006/07



The downside of sampling at this time is that leaf N values in primocane do not give much indication of nitrogen issues facing the current crop. In an attempt to overcome this internode length and stem thickness of florocane were assessed in November 2006. Individually these measurements did not strongly reflect yield, however the combination of these two measurements, termed cane density, showed some relation to yield, Figure 4e. A previous survey by HortResearch (Langford and Harris-Virgin 1998) had indicated cane quality as determined by number, size, bud and flower number, to be indicative of higher yields. These extra measurements will also be used in the coming season to help assess any yield responses to N.

Figure 4e. Boysenberry Leaf vs Cane density 2006/07

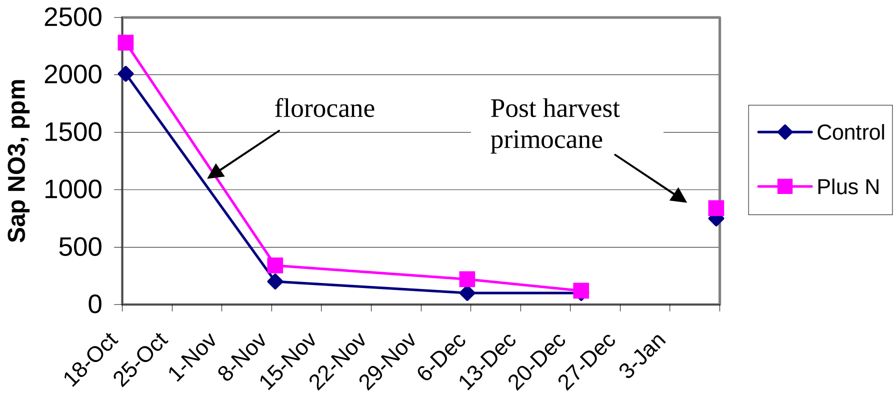


4.2.2 Boysenberry Additional N Plot

Data is presented in Table 4b comparing an additional 50 kgN/ha applied in late winter with the grower practice, on 20 year old 'Mapua' boysenberries.

Allowing for sampling and laboratory error there was little difference in soil or plant values between the two treatments. Soil AMN values were lower in 2006, more so than on other sites. This is probably because this crop was on a heavy gley soil, so it was more affected by the cooler spring in 2006. Fertiliser N did however increase leaf sap NO_3-N levels throughout the season, Figure 4f, and generally increased the amount and thickness of cane. While crop vigour may benefit yield, excessive vegetation can also increase crop humidity and therefore its predisposition to disease.

Figure 4f. Sap NO3 levels with and without additional 50kgN/ha Boysenberries 2006/07



It was unclear whether additional N benefited yield. In year 1, no data was collected, and in year 2 only harvester yield data was available, to which there was no response to N. Prior to machine harvesting some punnet picking of the best and largest fruit was undertaken (estimated at 25% of the machine harvested yield), so total yields may differ. The number of fruit set and one off fruit weights were better where additional N was used. To better address this issue, further work is to be financed by the Boysenberry growers in 2006/07.

Fruit quality was also measured in 2005/06. As expected fruit nutritional levels fell where N was added (data not presented), probably as a consequence of more fruit and/or cane being produced. When brix levels were measured on a cross section of fruit in 2006/07, levels were 10% lower where additional N was added, highlighting it would take this fruit several extra days to ripen. These changes are typical of what happens when additional N is used on other arable and horticultural crops.

CONCLUSIONS AND RECOMMENDATIONS

Blackcurrants

Nutrient deficiency work in pot trials has demonstrated that the major nutrient blackcurrants respond to is **nitrogen**. As the soil already contains some nitrogen then fertiliser nitrogen requirements should reflect the crop demand less soil nitrogen inputs.

To date crop removal data has suggested that a 10-12 t/ha crop grown on a moderate sized bush should remove between 55-65 kgN/ha. Therefore allowing for 65-70% utilisation of soil and fertiliser N this might relate to a requirement of 80-100 kgN/ha. The amount of fertiliser nitrogen required would vary with the soil reserves of nitrogen and the degree of leaching the soil receives, usually each winter. Also extra nitrogen may be required to grow additional foliage and if high rainfall events occur during the growing season especially following fertiliser N application.

The field work has not been very successful in relating various soil N tests to yield. This is because many other factors in particular the weather (winter chill, frost and wind) as well as pests (clearwing, mites) and disease (botrytis) contribute to yield variation. The best soil test to use is the soil AMN (sometimes called soil available N) test taken at the end of winter, as this gives an indication of the soil N that will be mineralised and available for plant growth during the season. This will vary between seasons, depending on the degree of nitrogen lost by leaching. This is a standard soil test available on request from most New Zealand soil laboratories. As it requires a 7 day incubation, results will take longer than for a normal soil test.

Soil Organic Matter/Total Carbon or Total Nitrogen tests were also found to be useful for characterising the soil as they give an indication of the size of the soil N pool. Soils with more OM, particularly >4% OM (2.3% TC) are likely to require less fertiliser N. This test should not vary greatly between seasons, so it only needs to be used every 3-4 years. It might be expected to pick up gradual changes provided significant crop prunings and inter row ground cover are mulched back in and recycled. These tests would also be useful when planting a new block. It is important to improve soil OM as this will improve soil structure. A previous survey of Canterbury blackcurrants (Officer *et al*., 2004) indicated that soil structure appears to decline with crop age. This suggests growers have limited prunings to recycle and that ground cover clippings are not preferentially thrown into the row where more roots can ultimately access the released nitrogen.

The ratios of soil C:N and AMN:TN fell in a narrow range irrespective of soil, site and cultivar so were not considered sensitive enough to easily differentiate requirements of different crops. The ratio AMN:TN in particular varied with the soil AMN value so gave no agronomic (or economic) advantage over just using the soil AMN test.

Soil Tests – in addition to standard soil tests

- Annually: soil AMN test
- Every three years and on new blocks: soil OM test

Sample at the end of winter, 0-15 cm samples sampling specific rows on representative blocks

Adding grower fertiliser N inputs to the soil AMN value for those sites where N utilisation was considered good (ie. sites where other factors were considered to minimally impact on yield) shows there is some relationship (R^2=0.43) between N supplied and yield, Figure 3b. This relationship was stronger in the drier/warmer year 2005/06, (R^2=0.56), suggesting that frost and/or cool spring conditions caused greater problems than first thought. Using this relationship a 10 t/ha crop might be expected to need 95-100 kgN/ha, which if related to the crop removal data indicates a utilisation of soil and fertiliser N by the crop of 60-65%.

> Therefore using the example of a soil AMN of 80 kgN/ha then a 10 t/ha crop would need an extra 15-20 kgN/ha which after allowing for some utilisation requires 25-30 kgN or 90-110 kg/ha of CAN (calcium ammonium nitrate). A 20 t/ha crop should not require a great deal more as it only has to meet fruit N rather than extra bush N requirements. It may only require 45-60 kgN/ha depending on the size of its soil reserves (eg. its OM content).

Ideally for a 10-12 t/ha crop;

- Soil AMN values should be >100 kgN/ha (and soil OM >4%), with up to 150 kgN/ha for higher yield potentials

December leaf N testing in the field proved of limited value because the range of results was narrow irrespective of the observed crop vigour. This was because nitrogen was often diluted by bush volume. Therefore, for a given site larger bushes generally had lower N values than smaller bushes. On average results were lower in 2006 reflecting winter leaching and lower soil AMN values. The pot trials gave similar results when nitrogen rates were altered. Data from the additional N plot in the field showed that leaf N values change rapidly in November as leaves expand and fruit are set. Therefore there is a case for evaluating the use of leaf N tests earlier in the season to identify a potential N shortage, if a shortfall is to be rectified in the current season.

Preliminary work in 2006 on bush light interception and new growth (Figure 3c), shows it is not necessary to have a large bush to produce good yields. Rather a moderate size bush appears more than adequate. Excessive foliage is often associated with older insect damaged wood that leads to little fruit and higher disease risk. A one year project is looking at various parameters that may be useful to relate bush size to yield and leaf N.

Leaf N tests – preliminary findings

- December sampling is of limited value unless used in conjunction with bush size
- Consideration given to earlier herbage sampling in October

Sap nitrate concentrations were found to decline with crop maturity and consequently at any time also varied between cultivars. It was also necessary to sample younger growth as the crop matured. Given also the time consuming nature of preparing the samples, the natural variability between individuals taking the readings and the practice required and the equipment costs, it would be difficult to calibrate this accurately for growers to use. Sap nitrate testing is best used as a research tool.

Sap nitrate N testing is not a practical tool for growers to base N recommendations

Regarding other soil fertility issues, neither the pot trial or field crop data suggested phosphorus (P) was limiting where P levels were below optimum. However the crop removal data did highlight in the first year that P removal was significant due to root development. Provided growers use P in the early years, and depending on previous land use, many will have little or no P requirement in the later years.

The pot trial work also indicated that reducing potassium (K) levels had little effect on growth despite herbage levels being lower than the standards. Herbage results were variable on most sites in the field, and did not necessarily relate to soil K values. There is a strong case for reducing the soil standards from QTK 10-20 to 8-15 and the herbage standards (December sampling) from 1.5-2.0% to 1.3-1.8% although in some years, herbage results may be lower. Potassium inputs are needed as fruit yields become significant as 70-80% of K is in the fruit. Nelson growers may need to apply 30-60 kgK/ha as their soil K reserves are lower than those in Canterbury, where growers may only need 0-30 kgK/ha.

Soil sulphate sulphur (SO_4-S) levels were low in the field in most crops in both years. This is not surprising as soil S reserves are low in much of the South Island. Despite most crops only receiving minimal S through the use of potassium sulphate and/or fine elemental S sprays, herbage levels were good. Even the low S treatments in the pot trials failed to reduce herbage levels below 0.2%. The soil SO_4-S standards could be reduced from 20-50 to 10-20. The occasional use of a sulphur super fertiliser (which contains elemental S) would help maintain S supply on lighter soils.

Boron (B) levels in Nelson and many Canterbury soil are low so crops would be expected to respond to B. Low B levels were shown in the pot trials to cause premature fruit drop although the individual plant variability and a lack of plant numbers meant this could not be related to yield. There is insufficient evidence to suggest modifying herbage standards, although many crops appear to be at the lower end of the standards. Leaves appear to remove more B than other plant parts so if these blow off site in autumn, significant B is being removed from the site. Certainly those growers who use B can maintain higher but moderate levels of 25-30 mg/kg.

Soil and Herbage standards

Consideration given to;

- Reducing optimal soil K standards to QTK 8-15
- Reducing optimal herbage K standards to 1.3-1.8%K
- Reducing optimal soil SO_4-S standards to 10-20

Boysenberries

Soil AMN and OM levels were higher in boysenberries than in blackcurrants, despite many being on light stony soils. As most of the vine is cutdown and mulched back every year and these prunings are softer than blackcurrant wood, soil OM levels have built up to sufficient levels to slowly release N to the plant. In addition in the past much of the mulched material was preferentially swept under the vines, although now most is evenly spread between rows. Therefore there was a good relationship between soil AMN and soil OM in 2005/06. This relationship was much poorer in 2006/07 when leaching and cool conditions continued on some sites after sampling. This suggests in some seasons, some early fertiliser N may be required irrespective of OM levels.

As a consequence of the high soil N levels it is difficult to suggest optimum levels. When fertiliser N inputs were also considered, then better yields were more likely at soil AMN plus fertiliser N values of at least 130-160 kgN/ha and >6% OM. This depended on the season and sometimes good yields were found at lower levels. Post harvest N the previous season could also contribute to some of this variation.

There is no evidence to suggest soil C:N or AMN:TN ratios are any better than soil AMN and OM tests for aiding with recommendations. In most cases their range is very small.

Soil Tests – in addition to standard soil tests

- Annually: soil AMN test
- Every three years and on new blocks: soil OM test

Sample at the end of winter, 0-15 cm samples sampling specific rows on representative blocks

Sap nitrate levels were a poor indicator of yield, perhaps reflecting dilution through extra growth. However herbage N post harvest did not show the same trend, rather in both years it showed a positive relationship between primocane N levels and the fruit yield just removed. This was reinforced by a higher cane density (thicker, longer canes) also showing an increasing trend to improved yield. Where extra N was applied to one site the crop was more vigorous and set more fruit, although there is as yet no evidence to suggest this benefited final yield. This is currently being tested in replicated trials.

Fertiliser N inputs varied with the poorer crops often receiving more nitrogen in response to poorer vigour, highlighting other factors are influencing yield. Certainly yield is reduced in cooler conditions when flowering is prolonged and disease pressure is increased. Tentatively growers are likely to need 40-60 kg of fertiliser N/ha unless soil AMN levels are above 130-160 kgN/ha and more if soil AMN levels are below 110 kgN/ha.

- Ideally soil AMN values should be 130-160 kgN/ha and soil OM >6%
- However herbage N post harvest and cane thickness and vigour are also useful indicators of past yield and need to be considered when making recommendations

As general fertility is high on most boysenberry crops it is difficult to make judgements as to critical soil levels. Like blackcurrants soil SO_4-S levels are low, although this may be less of a problem on boysenberries as potassium sulphate is used at higher application rates than on blackcurrants. Fruit will remove large amounts of potassium and there is a need for crop removal work to be carried out on boysenberries to establish its removal and that of the other major nutrients.

One concern is the availability of potassium to the plant on sites with high magnesium levels, so although QTK of 8-15 may be adequate on some soils, the values may need to be higher on soils where the base saturation ratios of K:Mg are <0.5.

> There is a need for crop nutrient removal work to be carried out on boysenberries

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nutrient solutions MAF Sustainable Farming Fund HortResearch

SUPPLEMENT:

SAP NITRATE TESTING PROCEDURE FOR BERRYFRUIT

Sap testing measures the nitrate concentration of leaf petiole sap using Reflectoquant Nitrate Test strips. The method is by reflectometric determination after reduction of nitrate to nitrite and reaction with Griess reagent.

For blackcurrants the sap was extracted from chopped soft leaf petiole. In early spring this was the third to fourth expanding leaf, but by late spring this was the first to second semi-expanded leaf. By December when leaf analysis is normally carried out and leaves were more mature it was difficult to extract sap from the petiole. Accordingly the growth tip or first leaf petiole was used for analysis.

For boysenberries the sap was extracted in spring from the soft petiole of the youngest fully expanded florocane leaf, and in late spring from the youngest leaf. From harvest in December the petiole from the youngest expanded primocane leaf was used. The active growth tip had very little nitrate activity.

Early season

Mid spring

December

Blackcurrant

Boysenberry

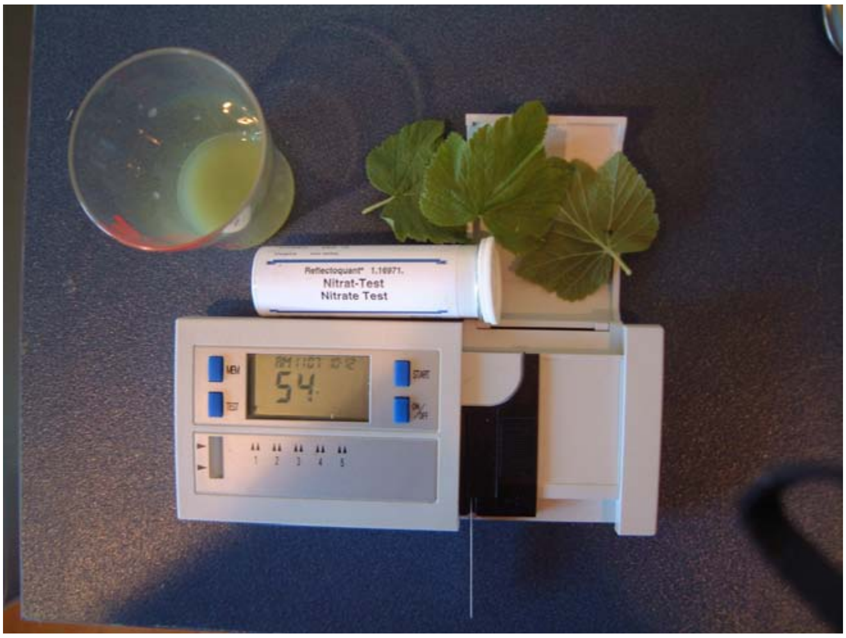
Early season

Mid spring

December

Ideally sampling should occur in the middle part of the day, although in practice samples taken earlier or later in the day often produce similar results. Rather, cool, overcast days produce lower activity than warm, sunny days.

Sufficient petioles are removed for 1 or 2 gms to be ground in a mortar with a pestle and a few mls of deionised water. Alternatively sap can be extracted from softer tissue by finely chopping a given weight and squeezing it with a garlic crusher. The extracted juice was made up to 10 or 20 mls after squeezing through cheesecloth. A nitrate test strip was immersed in the liquid for 5 seconds before leaving a further 55 seconds and reading the change in colour intensity using a RQ Flex reflectometer (Merck Ltd). The colour change is reflected as increasing intensity of pink. Measurements were multiplied by 10 to express in mg/l NO_3-N. Highly concentrated samples were diluted further before measurement.



APPENDIX TO PART ONE

Table 1a: Concentration of major and minor nutrients (ppm) in treatments in the 'Ben Ard' blackcurrant nutrition pot trials, 2005/06 (includes nutrients present in water and in the acid used for pH control). Red (dark) are treatment effects, light shading reflects nutrient limitations caused by the chemicals used.

Treatment	N	P	K	Mg	Ca	S	Na	Cl	B	Fe	Mn	Cu	Zn	Mo
1. Control	174	42	155	36	156	48	54	31	0.54	10.8	1.02	0.064	0.165	0.048
2. Low N	46	42	157	36	153	130	0	87	0.54	10.8	1.02	0.064	0.165	0.048
3. Med N	90	42	157	36	157	105	0	31	0.54	10.8	1.02	0.064	0.165	0.048
4. High N	259	42	155	36	156	47	39	31	0.54	10.8	1.02	0.064	0.165	0.048
5. Low K	176	42	38	36	156	48	39	31	0.54	10.8	1.02	0.064	0.165	0.048
6. Med K	175	42	77	36	156	48	39	31	0.54	10.8	1.02	0.064	0.165	0.048
7.Low Ca	167	42	156	36	46	47	39	31	0.54	10.8	1.02	0.064	0.165	0.048
8 Med Ca	170	42	156	36	80	47	39	31	0.54	10.8	1.02	0.064	0.165	0.048
9.Shell Ca[1]	167	42	156	36	156	47	39	31	0.54	10.8	1.02	0.064	0.165	0.048
10 Low S	175	42	155	36	156	12	0	31	0.54	10.8	1.02	0.064	0.165	0.048
11.Med S	176	42	156	36	156	26	0	31	0.54	10.8	1.02	0.064	0.165	0.048
12.NH_4-N	174	42	157	36	126	128	0	87	0.54	10.8	1.02	0.064	0.165	0.048
13. No B	174	42	155	36	156	48	24	31	0.00	10.8	1.02	0.064	0.165	0.048
14 Low B	174	42	155	36	156	48	24	31	0.27	10.8	1.02	0.064	0.165	0.048

Table 1b: Ben Ard leaf analysis in Pot trial, 2005

Treatment	N	P	K	S	Ca	Mg	Fe	Mn	Zn	Cu	B
			%						mg/kg		
1. Control	3.55	0.72	2.40	0.34	1.49	0.33	109	71	23	5	24
2. Low N	2.75	0.62	2.05	0.29	2.08	0.47	97	90	23	5.5	34
3. Med N	3.20	0.79	2.50	0.33	1.60	0.38	102	68	22	5.5	24
4. High N	3.50	0.60	2.35	0.30	1.20	0.30	108	94	20	5	20
5. Low K	3.75	0.76	1.90	0.34	1.45	0.39	108	105	30	5	19
6. Med K	3.85	0.78	2.35	0.38	1.42	0.36	110	92	27	5	21
7. Low Ca	3.55	0.72	2.60	0.30	0.95	0.39	102	140	24	5.5	19
8. Med Ca	3.70	0.74	2.80	0.33	1.14	0.37	115	125	26	6	22
9. Shell Ca	3.85	0.76	2.60	0.37	1.37	0.34	116	65	25	5.5	19
10. Low S	3.45	0.71	2.45	0.24	1.29	0.31	101	55	23	5.5	20
11. Med S	3.70	0.71	2.50	0.32	1.34	0.32	105	64	23	5	25
12. NH_4-N	3.35	0.68	2.60	0.32	1.18	0.30	101	150	24	5	20
No B	3.45	0.65	2.55	0.32	1.18	0.31	94	52	25	5.5	7
Low B	3.40	0.67	2.35	0.33	1.43	0.34	107	68	27	6	17
Optimum	2.9-3	0.26-3	1.5-2	0.2-0.4	1.3-2.5	0.15-0.6	50-100	30-100	20-40	5-10	20-40

Table 1c: Ben Ard leaf analysis, Pot trial 2006

Treatment	N	P	K	S	Ca	Mg	Fe	Mn	Zn	Cu	B
			%						mg/kg		
1. Control	2.38	0.42	1.63	0.20	1.59	0.39	77	70	14.3	3.3	28.8
2. Low N	2.15	0.50	1.60	0.25	2.01	0.51	73	69	16.0	3.0	35.5
3. Med N	2.45	0.43	1.60	0.25	1.84	0.46	82	59	15.0	3.5	30.5
4. High N	2.75	0.37	1.60	0.22	1.56	0.38	78	82	15.5	3.5	24.0
5. Low K	2.55	0.45	1.25	0.22	1.75	0.46	79	81	19.0	3.5	27.5
6. Med K	2.60	0.45	1.55	0.23	1.61	0.45	80	75	16.0	3.0	28.5
7. Low Ca	2.55	0.45	1.80	0.23	1.34	0.45	74	92	15.5	4.0	25.5
8. Med Ca	2.65	0.44	1.70	0.24	1.57	0.45	79	90	15.0	3.5	31.5
9. Shell Ca	2.45	0.30	1.55	0.24	1.77	0.42	76	64	15.5	3.0	33.5
10. Low S	2.55	0.42	1.65	0.20	1.72	0.41	80	62	16.5	4.0	28.5
11. Med S	2.50	0.41	1.60	0.21	1.60	0.40	78	68	15.5	3.5	29.5
12. NH_4-N	2.50	0.39	1.65	0.23	1.50	0.38	86	125	16.0	3.5	27.0
No B	2.30	0.38	1.65	0.21	1.41	0.37	78	62	13.5	3.5	7.0
Low B	2.55	0.38	1.55	0.23	1.56	0.41	82	69	16.0	4.0	19.0
Optimum	2.9-3	0.26-3	1.5-2	0.2-0.4	1.3-2.5	0.15-0.6	50-100	30-100	20-40	5-10	20-40

APPENDIX TO PART THREE

Table 3a. Blackcurrants. Primary Sites Soil and Crop Data 2005

Site	Cultivar	Soil pH	Soil Olsen P	Soil QTK	Soil QTCa	Soil QTMg	Soil QTNa	Soil SO4-S	Soil AMN	Soil OM	Soil TC	Soil TN	Soil C/N ratio	Soil AMN/TN	leaf N	leaf sap	Yield Estimate
PN1	Ben Ard	6.5	54	10	6	22	4	1	24	1.3	0.8	0.09	8.5	1.5	3.0	240	8.5
PN2	Ben Rua	6.3	62	11	6	29	4	2	52	2.2	1.3	0.15	8.8	2.4	2.8	720	7.0
PN3	Ben Ard	5.9	14	8	12	37	5	20	99	8.5	5	0.46	10.7	1.6	3.1	630	6.0
PN4	Magnus	6.1	41	12	10	31	5	7	100	3.7	2.2	0.21	10.4	3.2	3.1	520	9.0
PN5	Ben Ard	6.3	59	9	7	16	4	3	77	2.9	1.7	0.17	9.8	2.8	2.8	280	13.9
PN6	Magnus	6.1	26	8	9	16	5	5	99	3.7	2.1	0.23	9.3	3.0	2.9	70	8.8
PN7	Ben Ard	6.1	33	16	9	29	4	14	164	7.7	4.4	0.42	10.6	3.1	2.9	220	11.5
PN8	Magnus	6.4	34	23	12	37	3	7	116	4.3	2.5	0.24	10.4	3.6	2.7	210	5.1
PC1	Ben Ard	6.8	52	19	10	33	8	3	49	2.2	1.3	0.14	9.1	2.0	2.9	200	9.4
PC2	Magnus 02	6.6	39	17	20	57	12	5	157	5.5	3.2	0.28	11.3	4.0	3.3	210	7.4
PC3	Magnus 03	6.3	46	25	16	64	10	15	125	7.9	4.6	0.41	11.2	2.4	3.2	420	3.6 1st after cutdown
PC4	Murchison	6.2	76	26	13	50	11	3	102	5.8	3.4	0.29	11.5	2.4	3.5	990	5.0
PC5	Ben Ard	6.4	21	13	16	49	13	29	104	4.6	2.7	0.26	10.0	2.6	3.2	160	13.5
PC6	Magnus	6.6	30	15	13	31	14	14	107	3.7	2.1	0.21	9.9	3.1	3.0	230	6.6
PC7	Ben Ard	6.2	20	14	16	65	12	14	115	6.0	3.5	0.37	9.6	2.3	3.2	180	20.0
PC8	Magnus	6	27	14	14	48	12	13	122	4.7	2.7	0.28	9.6	3.0	3.1	180	6.8
PC9	Ben Ard	6.1	31	13	8	23	7	14	77	3.0	1.8	0.19	9.2	2.6	3.2	230	18.0
PC10	Ben Rua	6.1	33	13	10	16	6	16	112	5.0	2.9	0.29	10.2	2.7	2.7	85	24.7
PC11	Ben Ard	6.4	27	15	16	31	8	13	111	6.1	3.5	0.35	10.0	2.4	3.0	360	8.0
PC12	Magnus	6.2	39	22	11	27	6	9	116	4.2	2.5	0.22	11.1	3.5	3.2	500	6.0
PC13	Ben Ard	6.2	14	14	12	29	11	8	102	4.3	2.5	0.26	9.5	2.6	3.0	90	4.9
PC14	Ben Rua	6.2	12	11	12	30	12	6	109	4.4	2.6	0.27	9.4	2.7	2.7	240	10.6
Optimum		5.8-6.5	15-30	10-20	7-14	20-60	0-20	20-50									

Table 3b. **Blackcurrants. Primary Sites Soil and Crop Data 2006.**

Site	Cultivar	Soil pH	Soil Olsen P	Soil QTK	Soil QTCa	Soil QTMg	Soil QTNa	Soil SO4-S	Soil AMN	Soil OM	Soil TC	Soil TN	Soil C/N ratio	Soil AMN/TN	leaf N	leaf sap	Yield Estimate
PN1	Ben Ard	6.5	53	10	5	16	2	2	36	1.4	0.8	0.08	9.7	2.6	3.0	355	8.0
PN2	Ben Rua	6.3	51	12	6	26	3	5	77	2.2	1.3	0.15	8.7	3.5	2.9	1095	2.7 mites
PN3	Ben Ard	6.0	13	5	13	33	4	9	66	3.8	2.2	0.23	9.6	2.0	2.9	810	5.3
PN4	Magnus	6.2	29	6	10	23	3	5	93	3.2	1.9	0.20	9.4	3.1	2.8	1560	6.5
PN5	Ben Ard	6.4	50	7	7	21	2	4	115	4.0	2.3	0.24	9.8	3.1	2.7	360	11.2
PN6	Magnus	6.1	23	8	8	19	2	6	109	4.2	2.5	0.26	9.4	3.2	2.9	300	12.9
PN7	Ben Ard	6.0	34	13	8	24	2	13	119	8.8	5.1	0.43	11.7	2.2	3.4	580	4.7
PN8	Magnus	6.3	40	20	11	35	2	6	131	9.5	5.5	0.47	11.6	2.2	2.9	550	2.6
PC1	Ben Ard	6.6	58	17	9	30	5	2	64	3.0	1.7	0.19	9.0	2.1	2.6	1350	3.5
PC2	Magnus 02	6.5	46	15	17	50	9	4	122	8.1	4.7	0.41	11.5	2.2	2.9	860	6.0
PC3	Magnus 03	6.2	48	22	15	59	8	3	76	4.7	2.7	0.28	9.9	2.1	3.1	820	5.7
PC4	Murchison	6.5	70	17	17	58	9	3	110	7.1	4.1	0.38	10.8	2.3	3.2	2240	9.8
PC5	Ben Ard	6.2	21	10	13	41	7	5	83	4.5	2.6	0.28	9.4	2.1	2.7	410	13.6
PC6	Magnus	6.4	36	11	11	26	7	5	96	4.0	2.3	0.22	10.2	2.8	2.8	270	11.1
PC7	Ben Ard	6.2	21	13	16	61	9	6	93	5.3	3.1	0.33	9.4	2.0	2.8	560	10.8
PC8	Magnus	6.0	30	11	13	45	9	3	70	5.0	2.9	0.30	9.6	1.7	2.7	820	12.0
PC9	Ben Ard	6.1	31	10	7	18	3	3	72	3.8	2.2	0.22	10.1	2.1	2.7	540	12.2
PC10	Ben Rua	6.2	37	12	10	11	3	4	89	5.1	3.0	0.31	9.7	2.0	2.6	1070	11.5
PC11	Ben Ard	6.4	26	16	16	31	6	7	97	4.8	2.8	0.28	10.0	2.6	2.9	760	3.2
PC12	Magnus	6.4	32	22	11	27	3	3	107	4.1	2.4	0.24	10.0	3.2	2.5	590	4.4
PC13	Ben Ard	6.2	15	10	11	22	4	4	87	4.5	2.6	0.28	9.2	2.1	2.6	470	11.9
PC14	Ben Rua	6.2	13	7	11	23	5	7	80	4.1	2.4	0.26	9.1	2.2	2.7	1290	11.3
Optimum		5.8-6.5	15-30	10-20	7-14	20-60	0-20	20-50									

Table 3c. Blackcurrants. Secondary Sites Soil and Crop Data 2006.

Site	Cultivar	Soil pH	Soil Olsen P	Soil QTK	Soil QTCa	Soil QTMg	Soil QTNa	Soil SO4-S	Soil AMN	Soil OM	Soil TC	Soil TN	Soil C/N ratio	Soil AMN/TN	leaf N	leaf sap	Yield Estimate
SN9	Ben Ard	5.9	103	11	6	25	2	3	86	2.6	1.5	0.15	9.8	3.7	2.4	140	2.8 frosted
SN10	Magnus	6.0	90	9	5	26	2	3	119	2.2	1.3	0.15	8.1	5.0	2.2	120	4.1
SN11	Ben Ard	5.7	33	7	9	28	2	13	88	3.6	2.1	0.19	10.9	3.4	2.7	1530	7.5
SN12	Magnus	5.4	41	7	7	23	2	12	100	4.6	2.7	0.28	9.6	2.9	2.5	830	7.1
SN13	Ben Ard	6.3	33	15	9	11	2	12	206	7.4	4.3	0.41	10.4	3.8	3.0	810	9.5
SN14	Magnus	5.9	69	11	9	15	2	9	103	4.6	2.6	0.25	10.5	3.0	3.1	1090	7.3
SN15	Ben Rua	6.3	37	8	6	119	2	4	95	3.6	2.1	0.22	9.5	3.0	2.9	540	9.3
SC15	Ben Ard	6.5	22	7	16	52	10	7	120	6.0	3.5	0.37	9.4	2.5	2.8	285	8.5
SC16	Ben Rua	6.2	24	6	15	41	9	7	140	7.7	4.5	0.42	10.6	2.7	2.5	1850	2.0 frosted
SC17	Ben Ard	6.1	34	27	13	33	6	5	114	5.2	3.0	0.32	9.4	2.7	2.9	910	11.3
SC18	Ben Rua	5.6	31	15	8	26	7	6	97	4.2	2.5	0.25	9.8	2.7	2.4	860	9.4
SC19	Ben Ard	6.3	23	13	10	11	3	8	62	3.9	2.3	0.22	10.3	2.0	2.9	1450	5.6
SC20	Ben Rua	6.1	77	13	10	16	4	4	78	4.6	2.7	0.28	9.5	2.2	cutdown	1420	
SC21	Ben Ard	6.2	22	13	10	26	5	4	97	5.7	3.3	0.31	10.5	2.3	2.7	1110	9.3
SC22	Magnus	6.0	45	16	10	26	5	4	96	6.0	3.5	0.33	10.7	2.2	3.0	470	4.7
SC23	Ben Ard	5.8	36	13	9	21	2	4	88	4.3	2.5	0.26	9.5	2.3	2.7	310	9.6
SC24	Ben Rua	6.2	38	22	15	36	5	4	96	5.4	3.1	0.27	11.6	2.5	2.9	1520	8.6
SC25	Ben Ard	6.8	20	9	14	29	4	6	81	4.4	2.6	0.27	9.4	2.0	2.7	195	11.7
SC26	Ben Rua	6.6	13	11	12	29	6	4	69	4.2	2.5	0.27	9.0	1.8	2.7	830	14.1
Optimum		5.8-6.5	15-30	10-20	7-14	20-60	0-20	20-50									

Table 3d. Ben Ard leaf status, December 2005

	N	P	K	S	Ca	Mg	Na	Fe	Mn	Zn	Cu	B
				%						**mg/kg**		
PN1	3.0	0.26	1.3	052	1.81	0.38	<0.01	65	33	54	4	24
PN3	3.1	0.25	1.7	0.42	1.46	0.34	<0.01	221	130	110	6	23
PN5	2.8	0.24	1.6	0.44	1.81	0.35	<0.01	64	61	54	5	34
PN7	2.9	0.27	1.5	0.41	1.73	0.32	<0.01	56	59	110	5	19
PC1	2.9	0.34	1.7	0.53	2.21	0.39	<0.01	134	33	71	5	26
PC5	3.2	0.25	1.2	0.66	2.75	0.61	0.02	81	64	120	7	23
PC7	3.2	0.26	1.4	0.47	2.02	0.49	0.02	67	39	120	6	22
PC9	3.2	0.25	1.6	0.47	1.97	0.33	<0.01	68	47	140	6	15
PC11	3.0	0.29	1.6	0.47	2.34	0.39	<0.01	90	70	120	6	18
PC13	3.0	0.33	1.7	0.51	1.89	0.38	<0.01	69	67	65	6	14
Optimum	2.9-3.0	0.26-0.3	1.5-2.0	0.2-0.40	1.3-2.5	0.15-0.6	0-0.05	50-100	30-100	20-40	5-10	20-40

Elevated zinc levels reflect water (washing) contamination

Table 3e. Ben Ard Leaf status, December 2006

	N	P	K	S	Ca	Mg	Na	Fe	Mn	Zn	Cu	B
				%						mg/kg		
SN1	2.4	0.45	1.7	0.27	1.10	0.31	<0.01	45	59	47	4	20
PN1	3.0	0.32	1.9	0.48	1.34	0.35	<0.01	61	34	110	5	20
PN3	2.9	0.40	2.0	0.49	1.51	0.31	<0.01	55	100	85	6	22
SN11	2.7	0.44	1.8	0.39	1.23	0.31	<0.01	51	110	86	6	19
PN5	2.7	0.22	1.5	0.46	1.39	0.30	<0.01	50	56	72	4	28
SN13	3.0	0.23	1.7	0.51	1.64	0.25	<0.01	56	74	81	6	20
PN7	3.4	0.42	1.9	0.33	0.97	0.22	<0.01	49	43	81	6	16
PC1	2.6	0.34	1.7	0.39	1.40	0.31	<0.01	70	32	100	3	28
SC15	2.8	0.24	1.4	0.33	1.70	0.35	0.02	54	40	70	6	24
PC7	2.8	0.24	1.4	0.40	1.62	0.39	0.02	53	33	100	5	32
PC5	2.7	0.32	1.2	0.43	2.31	0.49	0.02	63	46	73	6	18
SC17	2.9	0.28	1.4	0.45	1.84	0.39	0.02	57	41	73	6	18
SC19	2.9	0.27	1.2	0.72	2.72	0.32	0.02	69	48	120	6	21
PC9	2.7	0.24	1.2	0.57	2.28	0.37	0.03	70	71	130	6	20
PC11	2.9	0.34	1.6	0.56	1.94	0.37	0.03	62	64	160	6	20
SC21	2.7	0.23	1.2	0.61	2.46	0.42	0.02	58	57	64	6	19
SC23	2.7	0.24	1.1	0.59	2.31	0.42	0.02	59	87	200	5	18
SC25	2.7	0.29	1.2	0.78	2.55	0.46	0.04	61	52	140	6	20
PC13	2.6	0.26	1.4	0.68	2.02	0.41	0.02	57	87	54	5	17
Optimum	2.9-3.0	0.26-0.3	1.5-2.0	0.2-0.40	1.3-2.5	0.15-0.6	0-0.05	50-100	30-100	20-40	5-10	20-40

Elevated zinc levels reflect water (washing) contamination

Table 3f. Additional Nitrogen Site, Ben Ard Blackcurrants, Soil and leaf nutrient values 2005 and 2006.

Soil Data

	Soil pH	Soil Olsen P	Soil QTK	Soil QTCa	Soil QTMg	Soil QTNa	Soil SO4-S	Soil AMN kg/ha	Soil OM %	Soil TC %	Soil TN %	Soil C/N ratio	Soil AMN/TN	leaf N %	leaf sap mg/kg	Yield Estimate t/ha
2005																
Control	6.8	52	19	10	33	8	3	49	2.2	1.3	0.14	9.1	2.9	2.9	200	8.7
Plus N	6.6	56	21	10	33	9	3	65	2.6	1.5	0.16	9.4	2.5	3.4	240	10.1
2006																
Control	6.6	58	17	9	30	5	2	64	3.0	1.7	0.19	9.0	2.1	2.6	300	3.7
Plus N	6.4	71	18	9	26	4	1	69	3.0	1.8	0.18	9.7	2.3	2.6	550	4.1

Leaf Data

	N	P	K	S	Ca	Mg	Na	Fe	Mn	Zn	Cu	B
				%						mg/kg		
2005												
Control	2.9	0.34	1.7	0.53	2.21	0.39	0.01	134	33	71	5	26
Plus N	3.4	0.38	1.7	0.48	2.08	0.37	0.02	120	38	130	6	25
2006												
Control	2.6	0.34	1.7	0.39	1.40	0.31	0.01	70	32	100	3	28
Plus N	2.6	0.31	1.6	0.34	1.39	0.29	0.02	64	31	84	3	22

APPENDIX TO PART FOUR

Table 4a. Boysenberry. Soil and Plant Data 2005 and 2006

Site	Cultivar	Soil pH	Soil Olsen P	Soil QTK	Soil QTCa	Soil QTMg	Soil QTNa	Soil SO4-S	Soil AMN kg/ha	Soil OM %	Soil TC %	Soil TN %	Soil C/N ratio	Soil AMN/TN	leaf N %	leaf sapNO3 mg/kg	Yield Estimate t/ha
Boysenberries – 2005/06 data																	
5/01	Mapua	6.2	36	21	16	57	8	7	163	6.2	3.6	0.35	10.2	3.5	3.6	32	20.0
5/02	Riwaka Choice	6.4	50	27	22	66	6	9	224	12.4	7.2	0.59	12.3	3.1	3.7	20	19.0
5/03	Mapua	6.2	40	15	12	77	5	22	85	4.3	2.5	0.24	10.3	2.4	3.7	24	18.8
5/04	lates	6.3	71	18	15	81	7	19	128	5.9	3.4	0.29	11.7	3.1	3.5	15	12.8
5/05	Mapua	6.2	56	22	16	86	6	7	160	10.4	6.0	0.54	11.1	2.4	4.0	32	29.0
5/06	Tasman	6.2	62	20	18	62	4	7	134	9.5	5.5	0.46	11.8	2.1	3.9	28	27.5
5/07	Riwaka Choice	6.7	68	14	18	27	4	5	150	7.2	4.2	0.4	10.5	2.9	4.0	65	13.4
5/08	lates	5.9	58	24	17	40	6	3	195	11.6	6.7	0.56	12.1	3.2	3.3	45	12.0
Boysenberries – 2006/07 data																	
6/01	Mapua	6.3	36	14	15	45	3	5	117	6.4	3.7	0.35	10.6	2.6	3.1	2010	17.8
6/02	Riwaka Choice	6.5	38	18	20	42	3	5	153	11.5	6.6	0.58	11.5	2.2	4.2	1580	16.0
6/03	Mapua	6.2	40	10	12	64	2	3	95	4.6	2.7	0.25	10.5	2.8	4.7	1760	16.9
6/04	lates	6.3	62	13	13	62	2	3	104	6.5	3.8	0.32	11.7	2.4	4.1	1700	9.7
6/05	Mapua	6	67	20	16	70	2	6	170	9.2	5.3	0.47	11.3	2.7	4.8	1140	27.8
6/06	Tasman	6.4	57	19	20	56	3	5	142	8.7	5.0	0.45	11.2	2.4	4.7	1180	28.7
6/07	Riwaka Choice	6.5	64	11	16	25	3	5	168	6.7	3.8	0.36	10.7	3.4	4.1	2900	10.9
6/08	lates																
New Sites																	
6/09	Tasman	6.3	40	8	13	21	3	4	136	6.8	4.0	0.37	10.8	2.7	4.4	2840	14.7
6/10	Tasman	6.3	23	7	13	29	2	3	148	6.2	3.6	0.34	10.6	3.2	4.1	2180	11.6
6/11	Lates	6.3	53	11	13	24	2	4	135	6.2	3.6	0.37	9.8	2.7	3.7	1700	9.9
6/12	Riwaka Choice	6.3	73	8	12	24	3	4	169	5.3	3.1	0.30	10.2	4.0	4.1	800	16.0
6/13	Tasman	6.9	51	7	11	18	3	3	210	3.8	2.2	0.22	10.0	6.3	3.9	1200	20.0
6/14	Tasman	6	73	10	6	25	2	9	115	2.8	1.6	0.17	9.5	4.4	4.1	1380	13.5
6/15	LDE2	5.9	69	10	9	24	2	11	99	3.7	2.1	0.19	11.2	3.7	3.5	1800	16.2
Optimum		5.8-6.5	40-60	10-16	8-15	20-60	0-25	20-50									

Table 4b. Additional Nitrogen site. Mapua boysenberries Soil, leaf and vigour, fruit parameters 2005 and 2006.

Soil Data

		Soil pH	Soil Olsen P	Soil QTK	Soil QTCa	Soil QTMg	Soil QTNa	Soil SO4-S	Soil AMN kg/ha	Soil OM %	Soil TC %	Soil TN %	Soil C/N ratio	Soil AMN/TN	leaf N %	leaf sap mg/kg
	2005															
	Control	6.2	36	21	16	57	8	7	163	6.2	3.6	0.35	10.2	3.5	3.6	200
	Plus N	6.2	32	28	16	56	6	8	157	6.9	4.0	0.37	10.6	3.1	3.8	240
	2006															
	Control	6.3	36	14	15	45	3	5	117	6.4	3.7	0.35	10.6	2.6	4.4	750
	Plus N	6.3	32	21	14	44	3	6	114	6.1	3.5	0.37	9.6	2.4	4.4	840

Leaf Data - late Dec primocane

		N	P	K	S	Ca	Mg	Na	Fe	Mn	Zn	Cu	B
					%						mg/kg		
	2005												
late Dec	Control	3.6	0.31	1.4	0.2	0.62	0.32	0.02	85	22	98	10	29
	Plus N	3.8	0.3	1.2	0.21	0.62	0.31	0.03	69	30	110	10	31
late Jan	Control	3.1	0.21	1.2	0.14	0.87	0.39	0.02	68	27	78	7	32
	Plus N	3.0	0.22	1.1	0.16	0.70	0.33	0.02	59	26	100	7	25
	2006												
late Dec	Control	4.4	0.35	1.5	0.24	0.50	0.29	0.02	74	30	220	11	33
	Plus N	4.4	0.36	1.7	0.23	0.53	0.32	0.02	74	39	210	11	31
late Jan	Control	3.1											
	Plus N	3.1											

Other data	**New Cane Density % Apr-06**	**Stem thickness 1-10 Score Jul-06**	**Internode Length cm Aug-06**	**Early flower no. /vertical m Nov-06**	**Relative Growth 1-10 Score Dec-06**	**Final fruit sites /1.6m grid Feb-07**	**Late Fruit Wt. gms Jan-07**
Control	80	4.4	7.0	29	6.5	350	6.7
Plus N	83	4.9	7.4	33	7.0	395	8.2