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The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

Principle worker

John G Atwood B.Sc. (Hons) (Hort), MRPPA (Hort) Author of report

Authentication

I declare that this work was undertaken either, directly by me, or under my personal supervision according to the procedures described herein and that this report represents a true and accurate record of the results obtained.

……. J Atwood
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GROWER SUMMARY

COMMERCIAL BENEFITS OF THE PROJECT

By assessing the chilling response of existing and potential cultivars in a formalised manner, it will be possible to predict their performance in seasons where low levels of chilling may be received. It is possible that with the onset of global warming, warmer winters could be more frequent and the selection of cultivars with a low winter chill requirement will be important.

BACKGROUND AND OBJECTIVES

There is increasing evidence that the amount of cold experienced by blackcurrant cultivars, in some regions, in some winters, is inadequate, leading to delayed and uneven bud break, with consequent adverse effects on yield and quality.

Following assessment of the chilling response, at the end of the trial it will be possible to rank all of the cultivars that are growing at the Bradenham Hall trial site, with respect to their winter chilling requirement. This information, taken together other parameters, will help growers to assess the suitability of a given cultivar for growing on a given site.

SUMMARY OF RESULTS AND CONCLUSIONS

Branches from each cultivar in the trial were cut twice weekly from January to March 2003 and 2004, and kept at 20^{o}C for 21 days. Branches were assessed using 75% bud break as the criteria for the chill requirement having been met, the heat units required for further development were recorded from point of chill achievement to mid flower.

Table 1: Cultivar Chill and Heat Unit Requirement 2003/4

Row	Cultivar	Date sufficient chill received for 75% bud break		Chill Units		Heat Units		50% Flower	
		2003	2004	2003	2004	2003	2004	2003	2004
32	9032-1	16/1/03	13/1/04	1331	1312	318.9	280.7	18/4	19/4
22	88111-4	20/1/03	16/1/04	1409	1370	312.5	328.1	18/4	26/4
31	Ben Gairn	20/1/03	19/1/04	1409	1440	312.5	326.7	18/4	26/4
21	Ben Hope	28/1/03	23/1/04	1577	1495	313.0	361.6	20/4	3/5
23	8922-11	28/1/03	16/1/04	1577	1370	290.9	328.1	18/4	26/4
9	S18-10-18	31/1/03	9/2/04	1647	1721	343.0	251.0	23/4	26/4
12	8944-13	3/2/03	3/2/04	1719	1683	342.6	239.2	23/4	19/4
18	8972-1	3/2/03	3/2/04	1719	1683	289.4	290.2	18/4	26/4
5	903-1	13/2/03	13/2/04	1918	1765	365.2	267.2	28/4	30/4
17	Baldwin	13/2/03	6/2/04	1918	1683	237.6	259.9	15/4	26/4
36	8999-9	13/2/03	30/1/04	1918	1657	299.1	309.2	20/4	26/4
27	Ben Dorain+	17/2/03		2014		-		-	
30	896-4	17/2/03	9/2/04	2014	1721	329.3	200.1	23/4	19/4
14	S18-25-20+	21/2/03		2104		-		-	
15	S30-13-35	21/2/03	17/2/04	2104	1824	327.0	256.3	23/4	30/4
24	Ben Lair+	21/2/03		2104		-		-	
3	8814-2	24/2/03	1/3/04	2157	2119	321.2	194.1	23/4	23/4
26	Ben Avon+	24/2/03		2157		-		-	
28	894-2	24/2/03	16/1/04	2157	1370	309.6	277.1	22/4	19/4
33	8949-15	24/2/03	17/2/04	2157	1824	320.7	177.6	23/4	19/4
20	Ben Lomond	28/2/03	17/2/04	2221	1824	309.6	256.3	23/4	30/4
2	8962-1	3/3/03	12/3/04	2250	2348	481.9	312.5	8/5	13/5
35	8942-5	3/3/03	1/3/04	2250	2119	299.0	249.8	23/4	30/4
37	8966-9	3/3/03	17/2/04	2250	1824	287.8	256.3	22/4	30/4
4	871-5	7/3/03	12/3/04	2296	2348	318.6	258.4	28/4	3/5
8	8982-6	7/3/03	17/2/04	2296	1824	385.6	276.3	2/5	3/5
10	S18-3-70	7/3/03	22/3/04	2296	2436	441.6	243.5	6/5	10/5
11	S18-2-23	7/3/03	1/3/04	2296	2119	441.6	306.3	6/5	10/5
7	8986-13	10/3/03	1/3/04	2328	2119	307.1	249.8	28/4	30/4
19	8955-2+	10/3/03		2328		-		-	
38	Ben Tirran	14/3/03	8/3/04	2397	2260	428.2	243.3	7/5	15/5
39	Ben Alder	24/3/03	13/2/04	2550	1765	396.2	323.6	7/5	10/5
40	Ben Vane		1/3/04		2119				

Chill Units – Total number of hours below 7^{o}C recorded from 1st October 2002 to the date on which sufficient chilling had been received for >75% bud break after 21 days at 20^{o}C

Heat Units – Total number of day degrees (base temperature 4^{o}C, hourly averaged) accumulated from the date of sufficient chill to the date of 50% flower open in the field.

At the start of the 2004 recording period, 16 January, slightly more chill units had been recorded in 2004 (1370) than in 2003 (1331). Subsequently, however, fewer chill units were accumulated in 2004 than in 2003, so that by 24 February, 2157 units were recorded in 2003, and 1978 units in 2004. At the end of the period, by 24 March, 2550 units were recorded in 2003 and 2478 in 2004. Although average temperatures in January and February were respectively 1 and 2 deg C warmer in 2004 compared with 2003, March average temperatures were cooler in 2004 by 0.8 deg C compared with 2003. In spite of this, more chill units were recorded in March 2003 compared with March 2004. Although there were fewer hours <7 deg in March 2004, the overall temperature was lower.

For most cultivars the chill unit requirement was broadly similar, albeit slightly lower than that recorded in 2003, and a similar ranking resulted. There were however two cultivars that appeared to differ markedly in response between the two years. Ben Alder and 894-2 required respectively 37% and 31% fewer chill units in 2004 compared with 2003. Taking into account the results from 2003 an average chilling requirement was derived for the two years studied.

ACTION POINTS FOR GROWERS

- Cultivars Ben Gairn, Ben Hope, 9032-1, 88111-4, 8922-1, S18-10-18, 8944-13, and 8972-1 could be classified as having a low winter chill requirement and would be suitable for use in areas of minimal winter chill.
- Cultivars Baldwin, 894-2, 8999-9, , 903-1, 896-4, S30-13-35 and 8949-15 could be classified as having a low moderate winter chill requirement
- Cultivars Ben Lomond, Ben Dorain, Ben Alder, Ben Vane, Ben Lair, 8966-9, 8982-6, S18-25-20, 8814-2 and 8942-5 could be classified as having a moderate high winter chill requirement and would be likely to under perform on occasions in areas where minimal winter chilling is likely to be received.

- Cultivars Ben Tirran, S18-2-23, 8986-13, 8962-1, 871-5, 8955-2,S18-3-70, could be classified as having a high winter chill requirement and should not be planted in areas where minimal winter chilling is likely to be received.

Table 2: Cultivar Ranking - Average of 2003/4

Row	Cultivar	Average Chill Unit Required 2003/4
32	9032-1	1321.5
22	88111-4	1389.5
31	Ben Gairn	1424.5
23	8922-11	1463.5
21	Ben Hope	1526
9	S18-10-18	1684
12	8944-13	1701
18	8972-1	1701
28	894-2	1763.5
36	8999-9	1787.5
17	Baldwin	1800.5
5	903-1	1841.5
30	896-4	1867.5
15	S30-13-35	1964
33	8949-15	1990.5
27	Ben Dorain+	2014
20	Ben Lomond	2022.5
37	8966-9	2037
8	8982-6	2060
14	S18-25-20+	2104
24	Ben Lair	2104
40	Ben Vane	2119
3	8814-2	2138
26	Ben Avon+	2157
39	Ben Alder	2157.5
35	8942-5	2184.5
11	S18-2-23	2207.5
7	8986-13	2223.5
2	8962-1	2299
4	871-5	2322
19	8955-2+	2328
38	Ben Tirran	2328.5
10	S18-3-70	2366

+ These cultivars were grubbed due to reversion before completion of the trial, only 2003 results are available.

ANTICIPATED PRACTICAL AND FINANCIAL BENEFITS

The winter chill ranking could be used to decide suitability of existing and potential new cultivars for planting in areas with different winter climates. Planting unsuitable cultivars can result in uneven bud break, uneven ripening and poor yields.

SCIENCE SECTION

INTRODUCTION

The need for plants to experience a period of cold is well established. There is increasing evidence that the amount of cold experienced by blackcurrant cultivars, in some regions, in some winters, is inadequate, leading to delayed and uneven bud break, with consequent adverse effects on yield and quality.

The GSK growers association is investigating the problem in a number of ways, and one branch of the research is aimed at assessing the chilling response of existing and potential cultivars in a formalised manner.

OBJECTIVES

At the end of the trial it will be possible to rank all of the cultivars that are growing at the Bradenham Hall trial site, with respect to their winter chilling requirement. This information, taken together other parameters, will help growers to assess the suitability of a given cultivar for growing on a given site.

MATERIAL AND METHODS

Method

The procedure adopted is similar to that employed by Lantin (1973). From early January, twice weekly, one or two branches were cut from a bush of each cultivar in the Bradenham Hall Cultivars trial. Care was taken to ensure that branches were selected with both two year old and one year old extension growth. The extension growth being selected to have at least 13 buds. Branches arising from previous years pruning or laterals from the base of a branch were not used. As far as possible, bushes a similar distance from the windbreak were used on each occasion. Where there was sufficient bushes and growth, two branches were taken, where the rows were short or the growth poor, only one branch was selected.

Following cutting, branches were labelled with date and code and placed in a warm (20˚C) insulated building in a plastic flower buckets with sufficient water to cover the base of the shoot.

Assessments

After 21 (+ or - 1) days branches were examined and the top 3 and following 10 buds were recorded as broken or not. The definition of bud break being growth stage B1 (a distinctive appearance of green that can clearly be identified as something that will develop into a leaf). The total number of buds broken was recorded.

As a guide to the speed of development, in 2003 only, branches were observed for a further 3 weeks and another similar record taken at 42 (+ or - 1) days.

A record was also taken of root development on 28/2/03 in which a score of 0-5 was used to record the volume of root growth.

Experiment design

The cultivar trial consists of single non-replicated rows of individual cultivars. Because of the non-replicated nature of the trial, assessments were not statistically analysed. Material for Ben Tirran and Ben Alder was taken from another plantation on the farm as these cultivars were not in the cultivar trial. These cultivars were allocated notional row numbers 38 and 39 respectively. Material for Ben Vane was cut from the cultivar trial at Newent, and posted to Bradenham for inclusion in the experiment, in 2004 only.

RESULTS AND DISCUSSION

Budbreak

The full records of bud break for 2003 after 21 and 42 days are shown in Appendix 1, Tables 1 and 2 respectively, and for 2004 after 21 days in Table 3.

Using this data a ranking has been drawn up for all cultivars in the trial to show the first cutting date for which sufficient chilling had been received to give either 8 out of

10 buds breaking after 21 days (buds 4-13) or 9 out of 13 buds breaking after 21 days (all buds, 1-13). (Table 1) below.

Observations of the branches over the period showed that:

- The 1st terminal bud broke readily, typically requiring one months' less chilling than other buds.
- Buds 2 and 3 were more variable, tending to break much later than the terminal. These buds were often relatively small and it could be difficult to detect bud break. If bud 3 was particularly small, it sometimes did not break until most of the other buds had broken.
- There was a tendency for a few buds to break ahead of the 75% bud break stage.
- The 75% target bud break date was for most varieties clear cut with later cutting dates giving similar or more bud break.
- Where 2 branches were taken from a cultivar, there were slight differences in response even though branches were apparently similar.

However these differences were often limited to + or - 2 buds breaking and did not affect interpretation of the general trend.

- Observation from 21-42 days showed that for cultivars that had not received sufficient chilling, a few more buds would develop slowly by 42 days.
- In most cases, recording bud break after 42 days would not have given a different 'chill achieved' date from 21 days.
- For a few low chill requirement varieties 8 (8982-6), 12 (8944-13) and 36 (8999-9) buds continued to develop after 21 days and an even earlier 'chill achieved' date would have been recorded by allowing 42 days for development.

Table 1: Cultivar Chill and Heat Unit Requirement 2003/4

Row	Cultivar	Date sufficient chill received for 75% bud break		Chill Units		Heat Units		50% Flower	
		2003	2004	2003	2004	2003	2004	2003	2004
32	9032-1	16/1/03	13/1/04	1331	1312	318.9	280.7	18/4	19/4
22	88111-4	20/1/03	16/1/04	1409	1370	312.5	328.1	18/4	26/4
31	Ben Gairn	20/1/03	19/1/04	1409	1440	312.5	326.7	18/4	26/4
21	Ben Hope	28/1/03	23/1/04	1577	1495	313.0	361.6	20/4	3/5
23	8922-11	28/1/03	16/1/04	1577	1370	290.9	328.1	18/4	26/4
9	S18-10-18	31/1/03	9/2/04	1647	1721	343.0	251.0	23/4	26/4
12	8944-13	3/2/03	3/2/04	1719	1683	342.6	239.2	23/4	19/4
18	8972-1	3/2/03	3/2/04	1719	1683	289.4	290.2	18/4	26/4
5	903-1	13/2/03	13/2/04	1918	1765	365.2	267.2	28/4	30/4
17	Baldwin	13/2/03	6/2/04	1918	1683	237.6	259.9	15/4	26/4
36	8999-9	13/2/03	30/1/04	1918	1657	299.1	309.2	20/4	26/4
27	Ben Dorain+	17/2/03		2014		-		-	
30	896-4	17/2/03	9/2/04	2014	1721	329.3	200.1	23/4	19/4
14	S18-25-20+	21/2/03		2104		-		-	
15	S30-13-35	21/2/03	17/2/04	2104	1824	327.0	256.3	23/4	30/4
24	Ben Lair+	21/2/03		2104		-		-	
3	8814-2	24/2/03	1/3/04	2157	2119	321.2		23/4	23/4
26	Ben Avon+	24/2/03		2157		-		-	
28	894-2	24/2/03	16/1/04	2157	1370	309.6	277.1	22/4	19/4
33	8949-15	24/2/03	17/2/04	2157	1824	320.7	177.6	23/4	19/4
20	Ben Lomond	28/2/03	17/2/04	2221	1824	309.6	256.3	23/4	30/4
2	8962-1	3/3/03	12/3/04	2250	2348	481.9	312.5	8/5	13/5
35	8942-5	3/3/03	1/3/04	2250	2119	299.0	249.8	23/4	30/4
37	8966-9	3/3/03	17/2/04	2250	1824	287.8	256.3	22/4	30/4
4	871-5	7/3/03	12/3/04	2296	2348	318.6	258.4	28/4	3/5
8	8982-6	7/3/03	17/2/04	2296	1824	385.6	276.3	2/5	3/5
10	S18-3-70	7/3/03	22/3/04	2296	2436	441.6	243.5	6/5	10/5
11	S18-2-23	7/3/03	1/3/04	2296	2119	441.6	306.3	6/5	10/5
7	8986-13	10/3/03	1/3/04	2328	2119	307.1	249.8	28/4	30/4
19	8955-2+	10/3/03		2328		-		-	
38	Ben Tirran	14/3/03	8/3/04	2397	2260	428.2	243.3	7/5	15/5
39	Ben Alder	24/3/03	13/2/04	2550	1765	396.2	323.6	7/5	10/5
40	Ben Vane		1/3/04		2119				

+ These cultivars were grubbed due to reversion before completion of the trial, at 10/3/03 insufficient chilling had been received on 8955-2.

Chill Units – Total number of hours below 7^{o}C recorded from 1st October 2002 or 2003 to the date on which sufficient chilling had been received for >75% bud break after 21 days at 20^{o}C

Heat Units – Total number of day degrees (base temperature 4^{o}C) accumulated from the date of sufficient chill to the date of 50% flower open, hourly averaged method.

At the start of the 2004 recording period, 16 January, slightly more chill units had been recorded in 2004 (1370) than in 2003 (1331). Subsequently, however, fewer chill units were accumulated in 2004 than in 2003, so that by 24 February, 2157 units were recorded in 2003, and 1978 units in 2004. At the end of the period, by 24 March, 2550 units were recorded in 2003 and 2478 in 2004. Although average temperatures in January and February were respectively 1 and 2 deg C warmer in 2004 compared with 2003, March average temperatures were cooler in 2004 by 0.8 deg C compared with 2003. In spite of this, more chill units were recorded in March 2003 compared with March 2004. Although there were fewer hours <7 deg in March 2004, the overall temperature was lower.

For most cultivars the chill unit requirement was broadly similar, albeit slightly less than that recorded in 2003, and a similar ranking resulted. There were however two cultivars that appeared to differ markedly in response between the two years. Ben Alder and 894-2 required respectively 37% and 31% fewer chill units in 2004 compared with 2003. Taking into account the results from 2003 an average chilling requirement was derived for the two years studied (Table 2)

Heat unit requirements (from chill achievement to mid flower) were not consistent between the two years for some of the cultivars, suggesting that the simple model used, may not be appropriate for all cultivars. Whereas in 2003 there was a trend for the cultivars with low winter chill requirement to have lower heat unit requirement for further development, in 2004 no clear trend emerged.

Table 2: Cultivar Ranking - Average of 2003/4 Chill Unit Requirement

Row	Cultivar	Average Chill Unit Required 2003/4
32	9032-1	1321.5
22	88111-4	1389.5
31	Ben Gairn	1424.5
23	8922-11	1463.5
21	Ben Hope	1526
9	S18-10-18	1684
12	8944-13	1701
18	8972-1	1701
28	894-2	1763.5
36	8999-9	1787.5
17	Baldwin	1800.5
5	903-1	1841.5
30	896-4	1867.5
15	S30-13-35	1964
33	8949-15	1990.5
27	Ben Dorain+	2014
20	Ben Lomond	2022.5
37	8966-9	2037
8	8982-6	2060
14	S18-25-20+	2104
24	Ben Lair	2104
40	Ben Vane	2119
3	8814-2	2138
26	Ben Avon+	2157
39	Ben Alder	2157.5
35	8942-5	2184.5
11	S18-2-23	2207.5
7	8986-13	2223.5
2	8962-1	2299
4	871-5	2322
19	8955-2+	2328
38	Ben Tirran	2328.5
10	S18-3-70	2366

+ These cultivars were grubbed due to reversion before completion of the trial, only 2003 results are available.

CONCLUSIONS

The results obtained from the 2003 and 2004 seasons have enabled an average ranking of cultivars to be drawn up for winter chilling requirement.

In many cases the point where sufficient winter chill was received was clear cut, with a transition from a low percentage bud burst to over 75% on subsequent cutting dates.

Observation of the cuttings for the full 42 days indicated that 21 days at 20 ^{o}C was an appropriate period for observing bud burst. There was little advantage in observing over the longer period and for 2004 records were only taken for 21 days.

The performance of the top three buds was often different from the next 10 buds. The terminal bud showed a more ready tendency to burst after relatively little chilling, however the 2nd and 3rd buds were sometimes very small and sometimes did not burst even after the normal chilling requirement was achieved. It is possible that the criteria for achievement of bud burst could be assessed purely on the next 10 buds after the first 3.

For most cultivars the chill unit requirement in 2004 was broadly similar, albeit slightly lower than that recorded in 2003, and a similar ranking resulted. There were however two cultivars that appeared to differ markedly in response between the two years. Ben Alder and 894-2 required respectively 37% and 31% fewer chill units in 2004 compared with 2003. It would be desirable to test alternative chill models to the two years' results to see if closer correlation between the years could be achieved.

By using the chill requirement averaged between the two years, it is possible to categorise the cultivars:

- Cultivars Ben Gairn, Ben Hope, 9032-1, 88111-4, 8922-1, S18-10-18, 8944-13, and 8972-1 could be classified as having a **low** winter chill requirement and would be suitable for use in areas of minimal winter chill.
- Cultivars Baldwin, 894-2, 8999-9, 903-1, 896-4, S30-13-35 and 8949-15 could be classified as having a **low-moderate** winter chill requirement

- Cultivars Ben Lomond, Ben Dorain, Ben Alder, Ben Vane, Ben Lair, 8966-9, 8982-6, S18-25-20, 8814-2 and 8942-5 could be classified as having a **moderate-high** winter chill requirement and would be likely to under perform on occasions in areas where minimal winter chilling is likely to be received.
- Cultivars Ben Tirran, S18-2-23, 8986-13, 8962-1, 871-5, 8955-2,S18-3-70, could be classified as having a **high** winter chill requirement and should not be planted in areas where minimal winter chilling is likely to be received.

From the 2003 ranking, it was noted that cultivars with a low chill requirement also tended to have a relatively low heat unit requirement for subsequent development and were consequently relatively early to flower. There was however some variation; Ben Hope, S18-10-18 and 8944-13 were mid season flowering cultivars with relatively low chill requirements – a desirable combination, conversely 8966-9, 8942-5 and Ben Lomond were also mid season flowering cultivars but with a much higher chill requirement. This trend however was not so clear cut in 2004, and for a number of cultivars the heat unit requirement (as measured) appeared to differ markedly between the two years. Ben Hope however still continues to stand out as having a relatively low chill requirement and later flowering.

From these results it would appear that the simple method of calculation for heat units with a 4 ^{o}C base temperature may not be appropriate for all the cultivars tested. For proper validation, crop growth and temperature records would need to be taken for a number of seasons, and a number of alternative models tested for best correlation

Records of root development were taken on one occasion in 2003 and were reported in the 2003 annual report. It was noted that root development may have been influenced by relative dormancy of the cuttings, with those cuttings at bud burst being less liable to develop roots. For a more accurate assessment of rooting potential of each cultivar it would therefore be necessary to take records on several occasions throughout the experiment.

REFERENCES

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APPENDICES

Fig 1: Ben Gairn 11/2/03, 3 weeks after cutting, one of the earliest cultivars to achieve sufficient winter chill

Fig 2: Ben Hope 11/2/03, 3 weeks after cutting, almost had sufficient chill, top buds breaking

Fig 3: 8962-1 11/2/03, 3 weeks after cutting, tight bud, this cultivar required maximum winter chill

Fig 4: Ben Lair, 11/2/03, 3 weeks after cutting, tip buds only breaking, not sufficient winter chill

Fig 5: Baldwin, 11/2/03, 3 weeks after cutting, tip buds only breaking, not sufficient winter chill

Fig 6: 8972-1, 11/2/03, 3 weeks after cutting, more than 75% bud break

Fig 7: Ben Gairn, 7/3/03, 6 weeks after cutting, all buds burst

Fig 8: Ben Alder 7/3/03, 6 weeks after cutting, buds still tight

Fig 9: 9032-1 17/2/03, 3 weeks after cutting, this cultivar required the least winter chilling

Fig 10: 8962-1, 27/3/03, 3 weeks after cutting, still not breaking

Fig 11: 8972-1, 27/3/03, 3 weeks after cutting, fully open

Fig 12: 871-5, 27/3/03, 3 weeks after cutting, tip buds open only

Appendix 1 Bud Break after 21 Days 2003
Date Cut

Row	Variety	6/1	10/1	13/1	16/1	20/1	24/1	28/1	31/1	3/2	6/2	11/2	13/2	17/2	21/2	24/2	28/2	3/3	7/3	10/3	14/3	17/3	20/3	24/3	27/3
2	8962-1	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	2 0 0 0 0	0 0 0 0 0	0 0 0 0 0	1 0 2 0	2 4 3 6	1 9 2 9	- -	- -	- -	- -	- -	- -	- -
3	8814-2	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	1 5 0 0	0 0 0 0	0 0 0 0	3 0 1 1	0 0 0 0	0 1 1 0	1 0 1 1	2 4 2 4	3 8 3 10	- -	- -	- -	- -	- -	- -	- -	- -	- -
4	871-5	0 0	1 1	0 0	0 0	0 3	0 6	0 0	0 0	0 0	0 1	0 0	1 0	3 6	2 1	3 2	3 5	2 1	3 6	3 3	1 6	- -	- -	- -	- -
5	903-1	0 0	0 0	0 0	0 0	0 0	0 0	1 0	0 0	0 1	0 0	0 0	2 7	3 8	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
7	8986-13	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	1 4 0 0	0 0 0 0	1 4 1 0	0 0 0 0	0 0 0 0	0 0 0 0	1 2 0 0	1 0 1 1	3 7 * *	1 0 * *	1 7 1 2	1 0 1 0	1 1 0 6	1 2 2 5	1 6 1 6	1 8 1 7	- -	- -	- -	- -	- -
8	8982-6	0 0	0 0	0 0	0 0	1 1 1 5	0 0 0 0	0 0 0 0	0 0 0 0	1 2 0 0	1 3 1 0	0 7 1 6	0 0 1 7	1 2 * *	1 4 1 0	1 2 0 0	1 5 1 0	1 3 1 2	1 6 1 9	1 6 0 8	2 4 2 5	2 7 2 7	3 9 2 6	- -	- -
9	518-10-18	0 0	1 0	1 1	0 0	0 0	1 0	1 3	2 7	2 3	0 2	2 3	3 7	2 9	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
10	518-3-70	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 1	1 0	0 0	1 0	0 0	3 2	3 4	1 0	3 8	0 2	1 2	1 3	1 5	2 9	2 7
11	518-2-23	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 1 1	0 0 1	2 2 1	0 4 1	2 4 0	1 5 3	0 3 3	2 7 1	1 1 1	3 6 2 6	2 2 2 1	2 5 2	2 6 3	2 7 3

		0	0	0	0	0	0	0	0	0	1	0	0	0	2	3	4	6	10	2			6	10	7
12	8944-13	0 0	0 0	0 0	0 0	0 0	2 5	1 0	0 0	2 7	1 7	1 1	1 8	2 8	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
14	518-25-20	0 0	0 0	0 0	1 0 2 1	0 0 0 0	2 0 1 0	2 1 0 0	1 2 0 0	1 0 3 0	1 4 0 0	2 4 2 5	1 0 1 0	1 0 1 2	* * * *	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
15	530-18-35	0 0	0 0	0 0	0 0	0 0	0 0	0 3	1 2	0 0	0 0	1 0	1 7	2 4	2 7	1 3	3 6	* *	1 7	- -	- -	- -	- -	- -	- -
17	Baldwin	0 0	0 0	0 0	0 0	1 1	2 9	1 1	3 2	3 1	2 1	2 5	3 10	3 8	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
18	8972-1	0 0	0 0	0 0	0 0	1 4 1 2	2 1 1 0	1 0 1 5	2 6 2 7	2 7 2 9	3 10 3 10	3 10 3 10	3 8 3 7	3 8 3 7	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
19	8955-2	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	1 0 0 0 0	0 0 0 0 0	1 0 0 0 0	1 0 0 0 0	2 0 3 2	1 0 2 3	1 0 3 4	1 0 1 1	* *	* *	* *	* *	* *
20	BLomond	0 0	0 0	1 0	0 0	0 0	2 2	0 0	3 2	0 0	2 0	1 0	1 0	1 1	1 1	3 2	2 7	2 9	- -	- -	- -	- -	- -	- -	- -

Row	Variety	6/1	10/1	13/1	16/1	20/1	24/1	28/1	31/1	3/2	6/2	11/2	13/2	17/2	21/2	24/2	28/2	3/3	7/3	10/3	14/3	17/3	20/3	24/3	27/3
21	B. Hope	0 0	3 1	0 1	1 4	0 6	3 4	2 7	* *	3 7	3 4	3 6	3 4	3 4	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
22	88111-4	0 0	0 1	1 0	1 1	1 9	3 9	3 9	2 8	2 10	2 9	3 10	3 10	3 10	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
23	8992-11	1	0	1	1	1	1	1	2	1	2	3	1	1	2	-	-	-	-	-	- -	- -	-	-	-

		0	0	0	1	0	1	9	5	0	4	3	6	3	8	-	-	-	-	-			-	-	-
24	B. Lair	0 0	1 2	0 1	1 2	1 0	1 4	1 1	3 5	1 2	2 5	2 2	1 2	2 2	2 9	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
26	B. Avon	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	1 0	0 0	0 0	0 0	0 0	3 9	2 4	- -	3 9	- -	- -	- -	- -	- -	- -
27	B. Dorain	0 0	0 0	0 0	0 0	1 0	0 0	1 2	2 2	2 4	1 2	1 1	0 0	2 7	2 10	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
28	894 -3	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	1 3	1 1	0 0	0 0	1 0	1 4	3 10	- -	- -	- -	- -	- -	- -	- -	- -	- -
30	896 - 4	0 0	0 0	0 0	1 0	0 0	0 0	1 0	1 2	1 0	1 0	2 5	1 1	2 6	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
31	B. Gairn	3 0 2 5	* * * *	1 8 1 3	1 6 2 6	2 10 * *	1 6 3 6	3 2 3 1	0 4 3 9	3 10 1 9	3 10 2 5	3 9 1 9	3 10 3 9	2 1 2 6	- - - -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
32	9032 - 1	0 0	0 0	2 4	3 9	2 3	3 9	3 10	0 0	2 9	3 10	3 10	3 3	3 10	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
33	8949 - 15	0 0 0 0	0 0 0 0	2 1 2 0	1 0 1 0	2 1 0 0	0 0 0 0	1 0 1 0	1 0 1 6	1 0 1 1	1 1 2 0	2 2 2 0	1 0 1 3	* * * *	1 0 1 2	2 6 3 9	1 6 2 9	3 9 3 10	- -	- -	- -	- -	- -	- -	- -
35	8942 - 5	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	1 0 2 4	0 3 * *	0 0 1 2	1 0 1 5	1 0	1 2 1 4	1 2 1 4	2 6 * *	3 6 * *	3 10 * *	3 5 3 6	- -	- -	- -	- -	- -
36	8999 - 9	0 0	0 0	0 3	0 0	0 0	1 5	1 2	1 7	1 1	1 4	1 5	3 8	3 10	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
37	8966 - 9	0 0	0 0	0 0	0 0	0 0	0 0	1 0	0 0	1 1	1 2	2 0	1 0	1 0	1 1	3 4	1 3	3 9	- -	- -	- -	- -	- -	- -	- -

38	B. Tirran	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	3 5 2 4	0 0 0 0	0 0 0 0	1 0 0 0	1 1 2 2	3 1 0 0	1 0 0 0	3 0 1 0	3 10 3 2	3 2 0 0	3 3 1 4	1 4 2 8	3 6 0 5	1 4 2 2	2 2 3 7	2 9 3 5	3 6 3 5	2 9 3 5	1 8 2 7	- -
39	B. Alder	0 0 0 0	0 0 0 0	1 0 0 1	1 0 0 0	3 2 5 2	0 0 0 0	0 0 0 0	0 1 0 0	0 0 1 0	0 0 1 1	0 0 0 0	1 0 0 0	2 0 0 0	1 2 0 2	1 2 0 2	1 2 1 2	2 3 1 8	2 0 1 5	1 5 3 6	3 9 1 4	3 5 2 4	3 9 1 4	1 8 1 9	- -

* = missing data

Appendix 2 Bud Break after 42 Days 2003

Date Cut

Row	Variety	6/1	10/1	13/1	16/1	20/1	24/1	28/1	31/1	3/2	6/2	11/2	13/2	17/2	21/2	24/2	28/2	3/3	7/3	10/3	14/3	17/3	20/3	24/3	27/3
2	8962-1	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 1	0 2 1 1	3 1 0 0	0 3 0 0	0 3 0 3	2 1 3 3	1 3 0 6	1 3 2 3	1 3 3 5	- -	- -	- -	- -	- -	- -	- -	- -	- -
3	8814-2	0 0 0 0	0 0 0 0	0 0 2 0	0 0 0 0	1 1 0 1	1 0 0 1	1 0 2 5	1 0 0 0	1 0 0 0	3 2 1 0	1 0 1 2	1 2 1 0	1 1 1 2	2 1 1 3	2 3 3 6	- -	- -	- -	- -	- -	- -	- -	- -	- -
4	871-5	0 0	3 6	2 5	0 0	0 4	3 4	0 0	0 2 1 3	1 2	2 1	1 2	1 0	3 4	2 1	3 1	3 6	2 1	3 5	3 2	3 6	- -	- -	- -	- -
5	903-1	0 0	0 1	0 1	0 0	3 3	1 2	1 0	2 2	1 1	1 1	2 3	2 7	3 8	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
7	8986-13	0 0 0 0	0 0 0 1	0 0 0 0	1 1 1 4	1 1	2 3 1 1	1 1 2 1	1 2	1 0 0 0	1 2 2 2	1 0 1 1	3 7 0 1	1 0	2 6 1 2	1 0 2 3	1 0 0 8	1 1 2 8	1 5 1 6	- -	- -	- -	- -	- -	- -

8	8982-6	0 0 0 0	2 2 2 2	3 0 2 0	2 1 2 5	2 6 2 3	0 0 0 0	2 3 2 4	2 10 1 5	2 1	1 8 1 7	0 7 2 7	2 7 0 0	1 1 1 3	1 3 1 0	1 3 1 3	1 1 2 6	1 6 2 7	1 3 1 7	- -	2 8 2 6	2 8 2 1	- -	- -	- -
9	518-10-18	0 0	2 0	2 6	2 1	0 0	2 2	1 5	2 7	3 10	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
10	518-3-70	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	2 1	1 2	0 0	* *	2 0	1 0	1 3	3 4	2 6	3 6	0 2	0 4	2 5	- -	- -	- -
11	518-2-23	0 0 0 0	0 1 1 1	0 0 0 0	0 0 0 0	3 2	1 1 0 1	0 0	0 3 0 0	3 3 0 3	3 4 0 4	0 2 1 4	3 1 1 1	3 5 1 0	2 1 0 5	3 3 2 5	1 5 2 3	3 8 0 4	2 5 1 7	0 1 2 4	2 8 2 6	3 3 2 2	- -	- -	- -
12	8944-13	0 0	1 6	2 7	2 6	1 5	2 7	1 8	3 3	3 7	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
14	518-25-20	1 0 0 0	2 7 1 0	3 2 1 1	1 0 2 2	1 1 1 3	2 1 1 0	2 1 2 0	1 0 1 1	2 0 3 2	1 3 1 0	1 4 1 5	1 0 1 1	1 0 1 2	3 6 3 5	1 0 2 1	- -	- -	- -	- -	- -	- -	- -	- -	- -
15	530-18-35	0 0	0 0	2 0	2 3	1 2	3 1	2 9	3 4	1 3	1 2	1 0	1 7	1 5	2 5 2 5	2 5	- -	- -	- -	- -	- -	- -	- -	- -	- -
17	Baldwin	3 0	3 3	0 0	3 2	1 1	3 9	3 3	3 1	1 0	3 0	3 4	3 10	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
18	8972-1	0 1	3 6 0 2	1 0 2 0	3 6 2 5	2 5 2 4	1 1 1 1	2 1 1 1	1 2 1 1	3 8 3 5	3 8 3 10	3 10 3 10	3 10 3 10	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
19	8955-2	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	1 0 1 0	1 0 0 0	1 0 0 0	1 0 2 0	0 0 3 2	1 0 0 1	2 1 1 0	1 0 1 0	2 0 3 0	2 1 0 0	1 0 1 0	2 4 2 1	1 0 2 5	3 6 2 1	2 4 1 0	* *	* *	- -	- -	- -

Row	Variety	6/1	10/1	13/1	16/1	20/1	24/1	28/1	31/1	3/2	6/2	11/2	13/2	17/2	21/2	24/2	28/2	3/3	7/3	10/3	14/3	17/3	20/3	24/3	27/3
20	Blomond	0 0	2 2	3 2	1 3	0 0	3 3	2 0	2 1	* *	2 0	1 0	1 1	2 1	1 3 2 1	3 4	2 7	- -	- -	- -	- -	- -	- -	- -	- -
21	B. Hope	1 0	3 3	2 7	1 4	1 7	3 6	3 4	2 8	* *	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
22	88111-4	1 0 1 0	1 1	3 5	1 5	1 10	3 10	3 10	2 8	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
23	8992-11	1 0	1 4	2 2	2 4	2 3	1 2	2 3	2 8	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
24	B. Lair	0 0	2 3	1 3	2 2	1 1	0 0	1 1	3 4	1 2	2 4	1 5	1 2	1 3	2 3	3 5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
26	B. Avon	0 0	3 1	1 3	0 0	0 0	1 0	0 0	0 0	1 3	1 0	1 1	0 0	0 0	2 2	3 6	1 4	- -	- -	- -	- -	- -	- -	- -	- -	- -
27	B. Dorain	0 0	0 0	0 7	0 0	1 0	0 0	1 2	2 1	3 2	1 1	1 1	* *	3 10	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
28	894 -3	0 0	0 0	0 0	1 1	0 2	0 0	0 5	0 0	2 2	2 2	1 0	0 1	1 0	2 3	3 7	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
30	896 - 4	0 0	0 0	3 4	2 1	2 2	1 1	1 0	3 4	2 1	1 0	1 7	1 1	2 8	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
31	B. Gairn	3 3 2 8	* * * *	2 2 5 7	1 5 2 5	2 10	3 5 1 6	3 5 3 1	3 9 0 4	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

32	9032 - 1	32	13	310	310	39	39	31030	11	29	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
33	8949 - 15	0000	2221	3222	1012	21	10	1016	1017	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
35	8942 - 5	00	00	01	0200	0003	1310	3212	0200	0524	0202	1012	0015	11	1513	13	1015	1236	3217	310310	- -	- -	- -	- -	- -
36	8999 - 9	00	10	17	07	35	29	23	28	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
37	8966 - 9	00	21	31	11	10	20	32	10	32	12	21	**	13	20	3335	23	- -	- -	- -	- -	- -	- -	- -	- -
38	B. Tirran	0000	2050	2501	2100	2613	1111	1000	3002	2222	1223	0100	0213	34310	3701	2623	2428	2604	3413	3926	3727	- -	- -	- -	- -
39	B. Alder	0000	****	11**	1020	3723	0102	1511	3212	1111	1111	1020	1001	1410	0513	1011	1001	1826	2312	3517	1112	- -	- -	- -	- -

Note – in a few cases there are fewer bud recorded as burst after 42 days compared with 21 days, this was due to a number of very small buds which appeared to be developing after 21 days but which subsequently failed to develop.

Appendix 3 Bud Break after 21 Days 2004

Date Cut

Row	Variety	8/1	13/1	16/1	19/1	23/1	26/1	30/1	3/2	6/2	9/2	13/2	17/2	21/2	24/2	27/2	1/3	5/3	8/3	12/3	15/3	19/3	22/3		
2	8962-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	1	17	29	2		

		0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 1	1 0 0	0 0 0	0 2 2	0 0 0	0 0 1	0 1 3	0 0 1	0 0 2	6 0 1	8 3 5	1 5	2 8	5 3 6		
3	8814-2	0 0 0 0	0 0 0 0	0 0 0 0	1 0 0 0	0 1 0 0	0 1 0 0	0 0 0 0	1 0 2 4	1 8 1 0	2 8 1 2	2 8 1 5	0 0 2 1	2 4 1 3	1 1 1 4	1 4 1 6	2 7 2 10	1 0 1 2							
4	871-5	0 0	0 0	0 0	0 0	2 2	0 0	1 0	1 1	2 3	3 4	2 1	1 1	1 2	*	3 4	3 3	3 7	1 4	3 8	1 8				
5	903-1	0 0	0 0	0 1	2 8	0 0	0 6	1 1	0 0	0 0 1 2	3 4 0 2	3 7	3 10												
7	8986-13	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 1 0	0 0 0 0	0 1 0 0	1 2 1 0	1 0 0 0	2 4 1 1	1 2 2 0	1 0 1 0	3 6 2 7	2 3 2 8	2 5	2 9 2 10					
8	8982-6	0 0 0 0	0 5 0 0	0 1 0 2	0 1 2 5	0 0 0 1	2 3 1 5	3 9 0 8	1 0 1 4	1 2 1 2	1 3 1 3	1 8 2 2	2 7 2 6	2 6 2 6											
9	518-10-18	0 0	1 2	1 3	0 5	0 6	1 5	1 0	1 0	1 5	1 6	3 0 2 5	2 6	2 7											
10	518-3-70	0 0	0 0	0 0	0 0	0 0 0 0	0 0	0 0	0 0	0 1	0 0	1 0	1 2	0 3	0 3	0 0	3 0	0 3	1 1	3 2	1 2	1 1	2 8		
11	518-2-23	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	1 2 0 0	0 0 0 0	0 1 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 2 0 1	0 0 0 0	2 2 1 5	3 8 2 8	2 4 0 5	1 8 2 5	2 4 2 3	1 7 2 9				
12	8944-13	0 1 0	0 0 0	0 1 0	1 0 0	1 6 2	1 0 1	1 1 3	2 7 1	1 7 1	2 8 2														

		0	0	0	0	3	0	4	7	5	8													
15	530-18-35	0 0	0 0	0 0	0 3	0 0	1 4	0 6	0 7	1 3	1 8	1 3	2 8	2 8											
17	Baldwin	2 7 0 0	0 0 0 0	1 3 0 0	1 1 1 0	2 2 1 1	1 0 2 4	3 4 3 0	3 0 3 3	3 8 2 6	3 7 2 2													
18	8972-1	0 0 0 0	0 3 0 0	0 0 0 0	1 2 0 0	2 4 1 9	1 4 1 7	1 4 1 4	3 10 2 9	3 10 3 10														
20	BLomond	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 1 2 3	3 7 0 2	1 0 2 3	2 2 1 4	0 1 2 3	1 2 1 1	3 5 2 5	2 8 2 9											
21	B. Hope	1 7 0 0	2 7 0 0	3 6 0 0	0 0 3 6	3 6 1 6																		

Row	Variety	8/1	13/1	16/1	19/1	23/1	26/1	30/1	3/2	6/2	9/2	13/2	17/2	21/2	24/2	27/2	1/3	5/3	8/3	12/3	15/3	19/3	22/3		
22	88111-4	1 4 1 6	3 6 1 2	3 8 2 7	3 10 3 10																				
23	8992-11	1 5	1 6	1 9	2 9																				
28	894 -3	0 0	0 0	3 6	2 9																				
30	896 - 4	0 0	0 0	0 0	0 0	0 0	2 4	3 4	3 5	2 4	3 8														

										20															
31	B. Gairn	3900	2517	1000	3934	18310																			
32	9032 - 1	00	310	*	31039																				
33	8949 - 15	0012	0000	0000	0000	1001	1212	1111	2211	2625	1210	1111	2735	3723	3826										
35	8942 - 5	0200	0600	3500	0000	0000	0911	11	00	00	15	10	13	12	12	43	35								
36	8999 - 9	12	0000	*	34	2323	24	35	310																
37	8966 - 9	00	00	10	13	00	*	32	36	10	13	25	37												
38	B. Tirran	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0100	0100	0002	0104	0708	1604	1503	27110	2938					
39	B. Alder	0000	0000	0000	0000	0135	3235	3002	3213	2502	0114	3717	1828												
40	B. Vane	001	211	002	222	220	132	*	203	14	120	*	222	222	121	231	262	362	*	1101	3 10 1 7				

		1	1	3	4	0	1		0		0		2	3	3	2	6	1		9					

- = missing data