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Project Title:	Determination of the optimum pruning time for fruit wall orchard systems for Gala apple
Project Leader:	Tim Biddlecombe Farm Advisory Services Team Ltd. Brogdale Farm Brogdale Road Faversham Kent ME13 8XZ
Contractor:	FAST Ltd.
Industry Representative:	Mark Holden Moat Farm Five Oak Green Tonbridge Kent TN12 6RR
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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.

CONTENTS

GROWER SUMMARY

Headline

- Work is ongoing to determine the optimum time to prune orchards planted as a fruit wall and to establish whether inter-tree pruning is necessary.

Background and expected deliverables

The fruit wall concept originated in France in 1986 where the system's potential to reduce pruning costs and increase yields was demonstrated. As UK growers consider adopting the fruit wall system, further work must be done to determine how the system needs to be adapted for use in the UK, particularly in establishing the optimum time to make the fruit wall cut. The timing of the cut will determine the amount of vegetative re-growth following the cut and also the formation of flower initials in the buds just behind the cut.

Determining the optimum time to perform the fruit wall cut will help to achieve maximum productivity from the fruit wall system and should also reduce pruning costs via the use of mechanical pruners. Impacts of the timing of the cut on the yield, fruit size and quality and vegetative re-growth will be assessed throughout the trial. The trial will be conducted over five years so that the long-term effects of fruit wall cut timings can be determined.

Summary of the project and main conclusions

The project was designed to test the effect of four timings of pruning a fruit wall mechanically, compared to a winter hand pruned control treatment. In addition, a further set of treatments designed to compare the effect of pruning between the trees by hand during winter will be included.

The timings of the fruit wall cut in the first year were based upon different growth stages: pink bud, six new leaves, nine new leaves and 12 new leaves (or when 50% terminal buds were present). In this first year of the trial no inter-tree pruning was necessary.

There was no significant effect on fruit weight, fruit size or percentage red colour of any treatment at harvest. However, overall yield was significantly affected with the winter hand pruned treatment giving a greater yield. The maturity of the fruit did appear to be affected by the fruit wall treatments and the length of re-growth and the number of leaves on these shoots differed significantly between the treatments.

The differences between the fruit wall treatments were observed in this, the trial's first year and must be considered preliminary until verified by results from subsequent years. The cumulative five year data will reveal more about the effects of the pruning treatments.

Financial benefits

The 2012 growing season was considered as an establishment period of the fruit wall and so the financial benefits are yet to be determined.

Action points for growers

- At this stage it is not possible to give definitive advice on the optimum timing for a fruit wall cut to be made.
- However, it was clear in this trial that the later the cut, the greater the reduction in subsequent growth.
- There appeared to be no advantage from establishing a fruit wall by cutting at pink bud and the later cuts gave better growth control and tree shape.
- The effect on subsequent crops from the different timings is yet to be determined.
- The trial indicated that fruit wall pruning cuts can potentially have adverse effects on fruit firmness and sugar levels. Growers should be aware of these before deciding on adopting the technique. The trial will establish whether these effects are a problem in subsequent years.

SCIENCE SECTION

Introduction

Growers in many countries are actively looking for ways to reduce labour inputs and increase mechanisation in a range of fruit crops. The fruit wall concept originated in France in 1986 when CTIFL began a project which aimed to reduce growing costs in top fruit production. Around the same time a harvesting robot known as the Magali was being developed and the CTIFL adapted an orchard to accommodate the robot to maximise the use of automation at harvest. As a result the work by CTIFL demonstrated the potential of the fruit wall growing system in reducing the costs associated with hand pruning and increasing class 1 yields.

The fruit wall is an example of a high density planting system where the trees are pruned mechanically during the growing season to attain a narrow A-shape tree.

The fruit wall system is now being considered as a viable option for commercial practice in the UK, not only because mechanical pruning is possible but also due to the potential for increasing yields. Results from the original work by CTIFL in France can be applied to growing areas further north, but only by adapting the methods to the local growing conditions.

There are three key manageable factors which influence total productivity from a fruit wall orchard:

- Planting density
- Tree architecture
- The timing of pruning

These factors all have an effect on the potential growth of each individual tree, flower initiation and fruit development. The management of these factors determines whether the fruit wall is able to provide increased and sustainable yields throughout the life of an orchard. All three factors influence both light interception and potential productivity.

Planting density is the first factor influencing the productivity of the fruit wall system. Hampson *et al*. (2002) demonstrated that planting density can have a greater influence on productivity than the training system (tree height and shape) used. It was observed that individual trees planted at lower density were more productive per tree than at a higher planting density due to reduced competition for resources, particularly light. However higher planting density systems tend to be more productive per hectare. Palmer *et al*. (1992)

suggested that Leaf Area Index (LAI) increases with increased planting density with a larger percentage of light interception as a result. Higher planting densities tend to increase fruit yields per unit area through more efficient use of ground area, however there is a natural limit to the increase in yield that can be achieved by increasing the planting density (Weber, 2001). For the fruit wall system to achieve greater productivity it should make improved use of the unit ground area than traditional orchard system designs.

As planting density increases, the Class 1 fruit quality can become compromised, an example of this is the red colouration of fruit, which can be an important indicator of fruit quality and maturity. Hampson *et al*. (2004) demonstrated in their study that the percentage of fruit of acceptable colour was reduced with increased planting densities, particularly when planting at or above 1,587 trees per hectare. This causes potential problems as a large proportion of orchards are now planted at densities higher than this and means that red colouration can become an issue (it should also be noted that there are red clones of *Gala* being planted where this problem does not arise).

The tree architecture of the fruit wall system has the potential to overcome issues such as reduced red colouration, as the trees tend to be narrower than in traditional orchards and therefore create less shading of fruit by laterals and allow for the greater red colouration of the fruit. It will be essential to maintain the narrow shape and size of the individual trees composing the fruit wall to preserve the maximum penetration of light throughout the tree. This can be achieved by effective pruning, and in the fruit wall system a fruit wall cut is made during the summer rather than in the winter to create an A-shaped tree, which is 40cm wide at the top and 80cm wide at the base.

However the aim of pruning is not only to achieve these narrow A-shape trees but also to encourage flower bud formation. Normally flower bud formation occurs during August (Abbot, 1974; cited in Dennis, 2003) and so conditions prior to this are important in determining its extent. There tends to be negative correlation between vegetative growth and flower bud formation and so treatments such as nitrogen application, which favour vegetative growth, tend to reduce flower bud formation; whereas treatments which retard vegetative growth, such as applications of Plant Growth Regulators (PGRs), tend to improve flower bud formation. In the fruit wall system, the fruit wall cut is made during the summer and the timing of the cut is critical in determining the amount of vegetative re-growth and the number of flowers which form in the buds behind the cuts. This is also true for other crops such as cherry, where Guimond *et al*. (1998) showed that flower initiation was stimulated by summer pruning in the buds behind the cut. Vegetative growth also increased due to the removal of apical dominance along the shoot. Therefore if the fruit wall cut is made too early

vegetative growth will be favoured, reducing flower bud formation. However, if the fruit wall cut is made too late the flower buds will have already formed and the cut will simply remove them. The optimal time for the fruit wall cut to be made will obviously vary between varieties and it is important to relate the time of the cuts to an easily identified growth stage.

Where trees are only pruned mechanically the branches in between the trees are left unpruned. These can become thick and intertwined, resulting in shading and adverse effects on fruit quality. It is important for growers to know whether inter-tree pruning is necessary and what effects it may have upon the vigour of the trees and fruit quality.

The trial described here aims to determine the optimum timing for the fruit wall cut to be made in a cv. Gala Galaxy fruit wall orchard and to evaluate the effect of inter-tree pruning. The results from 2012, which are described, are from the first year of the trial which should be considered as an establishment year. A winter hand pruning treatment was used as a control.

Materials and methods

The trial is based in an existing commercial orchard of cv. Gala Galaxy planted in the winter of 2010 at Parsonage Farm, Cobham, Kent on a clay loam soil type. The trees are trained on a post and wire system with bamboo cane supports. The planting distance is 0.5m between each tree with 10 trees between each post, forming a bay. Each plot consists of two bays. The alley width between each row is 3.5m. The trial area situated within this orchard consists of 800 trees organised in 20 bays of 10 trees in each of the four rows.

Block 1	Block 2	Block 3	Block 4
7	3	2	5
1	8	4	7
4	9	5	10
8	10	6	1
2	5	3	9
6	1	7	8
5	2	10	3
3	4	9	6
10	7	8	2
9	6	1	4

Figure 1. Plot layout of the fruit wall trial based at Parsonage Farm - see Table 1 for treatments.

The trial is a completely randomized block design with 10 treatments composed of two factors: fruit wall cut timing (five treatments) each of which have further sub-treatments for inter-tree pruning or no inter-tree pruning (two treatments). The plot consists of four replicate blocks, with the 10 treatments in each block. Six guard trees are left at each end of the plots leaving eight trees for sampling and recording:

	6 guard trees	**8 trees used for recording**	**6 guard trees**

Treatments

A description of each treatment in the trial is shown in Table 1. Each treatment consists of two parts: (a) a fruit wall cut and (b) inter-tree pruning. The fruit wall cut was performed by the farm's mechanical pruner at various developmental stages unless it was specified that winter hand pruning was to be undertaken (Treatments 1 and 2). The first fruit wall cut treatments were made at pink bud (Treatments 3 and 4). The next three fruit wall cuts were made when the new growth of the laterals had produced six new leaves, nine new leaves and 12 new leaves respectively (Treatments 5 and 6, 7 and 8, 9 and 10). The method of counting leaves for these stages is shown in Figure 2.

The inter-tree pruning is designed to remove branches between the trees along the plots which may grow into the gap and prevent light penetrating into the trees (inter-tree pruning). Excessively strong and/or weak branches will also be removed in these plots. The first cuts of this type will be made in the winter of 2012. The data for treatments 2, 4, 6, 8 and 10 are therefore presented for 2012.

Table 1. The fruit wall cut and pruning treatments undertaken for each treatment number.

Treatment number	Timing of fruit wall treatment	Inter-tree pruning
1	Winter by hand (Control)	Winter inter tree pruning
2		No inter tree pruning
3	Pink bud	Winter inter tree pruning
4		No inter tree pruning
5	6 new leaf stage	Winter inter tree pruning
6		No inter tree pruning
7	9 new leaf stage	Winter inter tree pruning
8		No inter tree pruning
9	12 new leaf stage	Winter inter tree pruning
10		No inter tree pruning

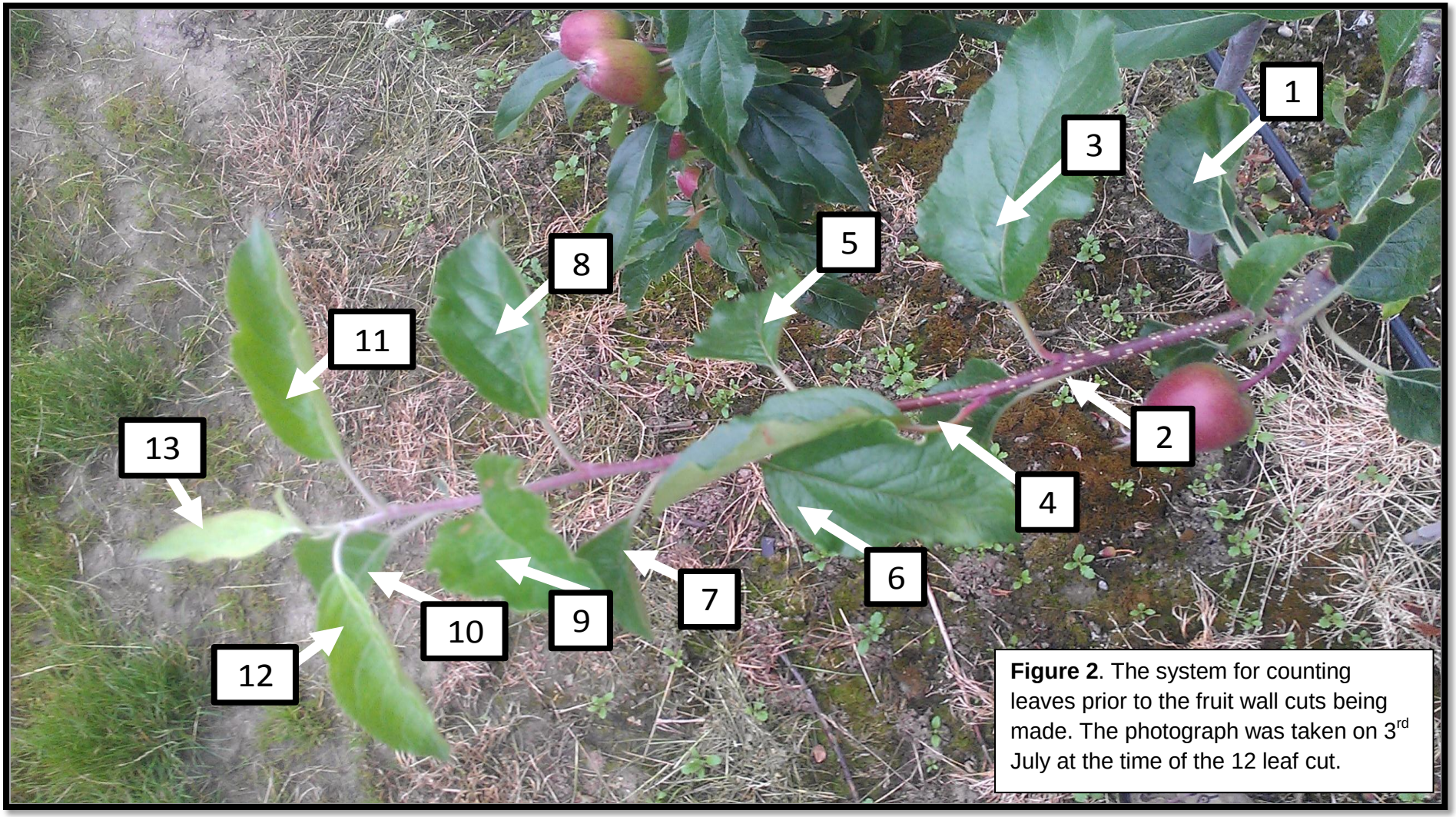

Figure 2. The system for counting leaves prior to the fruit wall cuts being made. The photograph was taken on 3rd July at the time of the 12 leaf cut.

Assessments

1. The number of new leaves produced on 25 laterals per plot, were counted every three to four days from 22 May to 3 July. The average number of leaves per lateral per plot was calculated to determine the timing of the six leaf cut, nine leaf cut and 12 leaf cut (Treatments 5 and 6, 7 and 8, 9 and 10) to be made using the farm's mechanical pruner.
2. The percentage of laterals where a terminal bud had formed was recorded from 26 June for the 12 leaf cut (Treatments 9 and 10) to be made. The timing of this cut was made either when 12 new leaves were produced on average per lateral or 50% of laterals had ceased growth and developed terminal buds, which ever occurred first.
3. The length of extension growth and leaf number produced by the shoots arising from the bud immediately behind the fruit wall cut were recorded in August and October. Where no fruit wall cut was made (Treatments 1 and 2 - winter hand pruning) the current season's growth was recorded.
4. The effects of treatments on leaf and fruit nutrient content were determined from samples collected on 23 August. Twenty-five leaves were selected per plot from shoots arising from fruit wall cuts made to the laterals, with leaves being selected which were two thirds along the length of the shoot. Twenty-five fruit were selected at random from each plot for analysis (not taken from the central eight trees used for the yield assessments).
5. The harvest assessments were conducted at the same time as the farm's commercial harvest. The assessments included:
    - All fruit from the central eight trees per plot were picked and the total weight recorded.
    - One hundred fruit from each plot were weighed to allow the average fruit weight (g) to be calculated.
    - The diameter of 100 fruit per plot was also measured to determine the effect on average fruit diameter.
    - From the same 100 fruit picked per plot, the percentage red colouration was assessed by estimating the percentage of the fruit surface coloured red.
    - Fruit maturity tests were conducted to determine the effect of the fruit wall cut treatments on fruit quality. The method used was as recommended by the UK Quality Fruit Group. Samples of 10 fruit from each plot were taken giving a total of 40 fruit tested per treatment. Fruit firmness was tested using a penetrometer mounted in a drill stand. Total soluble solids were tested using

a refractometer and starch was recorded by halving the fruit transversely and dipping the cut side in a potassium iodide solution. The purple/black colouration pattern was then compared to the standard CTIFL colour chart to estimate the percentage starch present.

Statistical analysis

Statistical analysis of the data was carried out using Analysis of Variance (ANOVA) to determine the overall significance of treatment followed by the use of multiple range tests to determine whether the differences between individual treatments were significant. Where data was not normally distributed, such as in the percentage red colouration or the percentage starch, the data was transformed using a logit transformation prior to the statistical analysis being calculated. Graphs are shown with standard error bars and the results of the multiple range tests are given where the effect of treatment was significant.

Results

Timing of pruning cuts

The earliest signs of budbreak were observed during mid March in 2012 for *Gala* on M9 rootstock, and the first fruit wall cut, at pink bud, was made on 3 May 2012 (Treatments 3 and 4). The assessment of leaf number is shown in Figure 3. These assessments determined the dates at which the six new leaf cuts (Treatments 5 and 6) and nine new leaf cuts (Treatments 7 and 8) were made (see Table 2).

The final developmental stage at which a fruit wall cut was made was when 12 new leaves were produced. (Treatments 9 and 10). However towards the end of June 2012, before an average of 12 leaves was produced on laterals, terminal buds began to form. By 3 July there were terminal buds formed in more than 50% of laterals recorded. Therefore the final fruit wall cut (Treatments 9 and 10) was made at this stage. It should be noted that treatments 9 and 10 are referred to as the 12 new leaf cut in this report. This change to the trial protocol was agreed with the HDC.

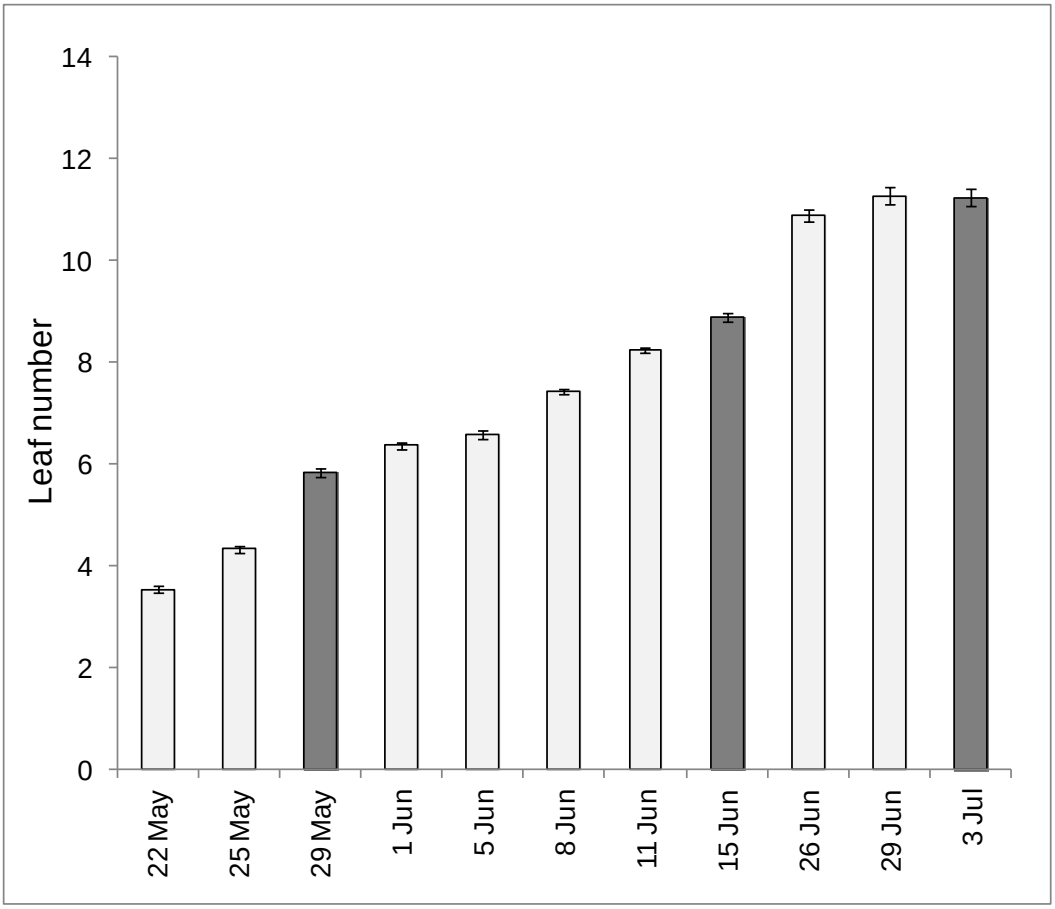

Figure 3. The average number of new leaves produced by laterals used to determine the point at which the fruit wall cut for each treatment was made (Treatments 5 and 6, 7 and 8, 9 and 10). The shaded bars indicate the dates at which the growth stages were achieved and when the cuts were made.

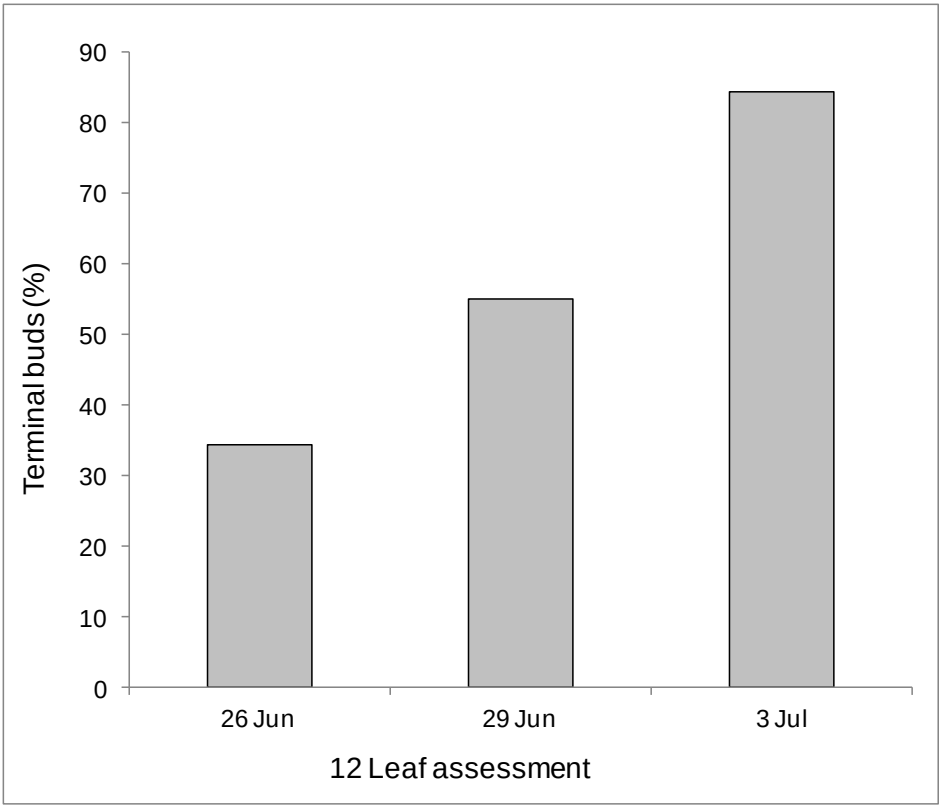

Figure 4. The percentage of laterals, which had formed terminal buds, assessed whilst determining when to make the fruit wall cut at the 12 leaf stage. (Treatments 9 and 10).

Table 2. Number of new leaves recorded at each assessment date and the dates of the pruning cuts.

Date	Number of leaves	Treatment
22 May	3.6	
25 May	4.3	
29 May	5.8	6 leaf cut
01 Jun	6.4	
05 Jun	6.6	
08 Jun	7.4	
11 Jun	8.3	
15 Jun	8.9	9 leaf cut
26 Jun	10.9	
29 Jun	11.3	
03 Jul	11.2	12 leaf cut

Fruit and leaf analysis

No significant differences were seen in the nutrient content of either the leaves or fruit, with the exception of leaf copper (p=0.048) - see Tables 4 and 5. The largest value for leaf copper was determined for the 12 new leaf fruit wall cut (Treatment 10) which was significantly larger than those found for the six new leaf and nine new leaf fruit wall cuts (Treatments 6 and 8) - see Table 3.

Table 3. The ANOVA and multiple range tests for the determination of leaf copper after fruit wall cuts/pruning treatments were made. Samples were taken on 23 August. The letters indicate which treatments differed from each other.

Treatment	**Leaf Copper levels (mg/kg)**
Winter hand pruning	7.9 **ab**
Pink bud	7.8 **ab**
6 Leaf	7.3 **a**
9 Leaf	7.1 **a**
12 Leaf	8.7 **b**
Significance	*0.048*

Table 4. Leaf analysis results sampled 23 August 2012. Standard errors are given in parenthesis and the significance of treatments determined through ANOVA is also shown**.**

Leaf analysis	(% dry weight)					(mg/kg)				
	N	**P**	**K**	**Mg**	**Ca**	**Mn**	**B**	**Cu**	**Zn**	**Fe**
T2 winter hand	2.37	0.20	1.86	0.16	1.23	56	30	7.9	12.7	202
	(0.06)	(0.005)	(0.12)	(0.05)	(0.08)	(15.9)	(0.70)	(0.09)	(0.06)	(5.5)
T4 pink bud	2.41	0.205	2.00	0.13	1.26	40	31	7.8	11.7	202
	(0.06)	(0.005)	(0.07)	(0.02)	(0.11)	(1.2)	(1.13)	(0.17)	(0.17)	(8.4)
T6 6 leaf	2.23	0.21	1.89	0.14	1.09	80.2	30	7.3	11.9	213
	(0.00)	(0.01)	(0.01)	(0.02)	(0.07)	(4.5)	(0.66)	(0.23)	(0.29)	(5.2)
T8 9 leaf	2.17	0.21	2.09	0.12	0.91	38	36	7.1	11.9	117
	(0.05)	(0.005)	(0.13)	(0.005)	(0.055)	(5.79)	(3.61)	(0.57)	(0.32)	(8.9)
T10 12 leaf	2.27	0.23	1.93	0.14	0.87	51	42	8.7	15.4	216
	(0.12)	(0.02)	(0.04)	(0.005)	(0.17)	(7.4)	(9.60)	(0.15)	(1.32)	(52)
Significance (P-value)	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*0.048*	*ns*	*ns*

Table 5. Fruit analysis results sampled on 23 August 2012. Standard errors are given in parenthesis and the significance of treatments determined through ANOVA is also shown

Fruit analysis	(mg/100g)					(mg/kg)		
	N	**P**	**K**	**Mg**	**Ca**	**B**	**Fe**	**Mn**
T2 winter hand	71.5	11.2	113.5	6.1	10.9	4.30	3.10	0.72
	(4.0)	(0.5)	(0.9)	(0.2)	(0.1)	(0.63)	(0.60)	(0.04)
T4 pink bud	78.0	12.5	122.3	6.8	11.5	5.09	2.53	0.78
	(2.3)	(0.1)	(3.1)	(0.3)	(0.9)	(0.17)	(0.20)	(0.09)
T6 6 leaf	76.0	11.2	113.5	6.6	12.6	4.21	2.89	0.97
	(4.7)	(0.7)	(1.6)	(0.1)	(0.4)	(0.54)	(0.03)	(0.24)
T8 9 leaf	75.5	11.9	122.5	6.9	11.5	4.30	2.87	0.77
	(5.0)	(0.6)	(3.0)	(0.2)	(0.4)	(0.59)	(0.10)	(0.04)
T10 12leaf	73.0	11.1	113.5	6.5	12.7	4.31	2.80	0.72
	(1.6)	(0.3)	(4.5)	(0.3)	(1.2)	(0.31)	(0.08)	(0.03)
Significance (P-value)	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

Fruit size and diameter

Average fruit size was between 58mm and 60mm at harvest and there were significant differences between treatments (see Figure 5). There was also no significant effect of treatment upon fruit weight (g) at harvest, which averaged between 107 and 112g (see Figure 6).

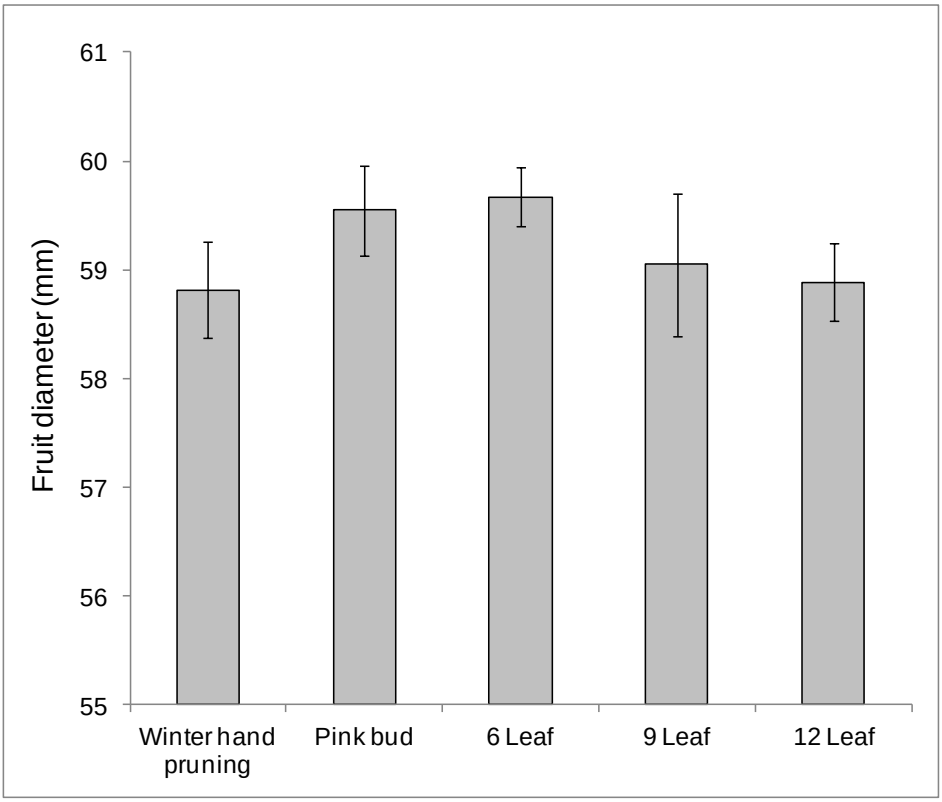

Figure 5. Average fruit diameter at harvest. Standard error bars are shown (P=0.32).

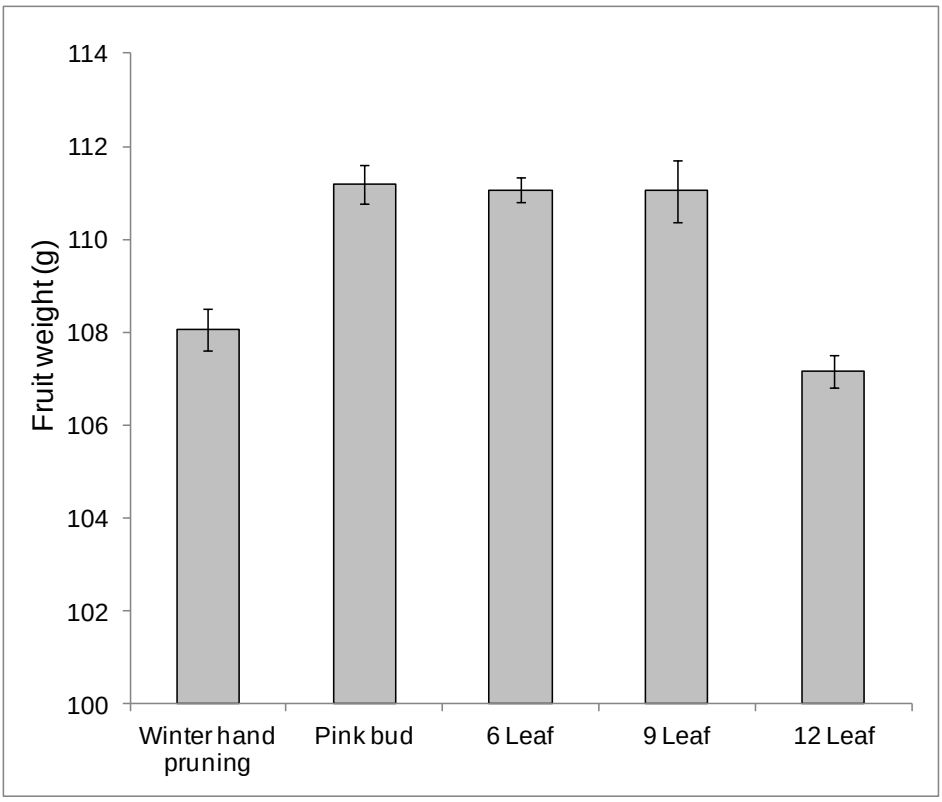

Figure 6. Average fruit weight (g) at harvest. Standard error bars are shown (P=0.20).

Fruit colour

There were no significant differences in the percentage red colour of the fruit in any of the treatments. The average block red colour was between 95 and 96% (P=0.94) - see Figure 7. It is worth noting that the clone used in this project, Gala Galaxy, is naturally well coloured.

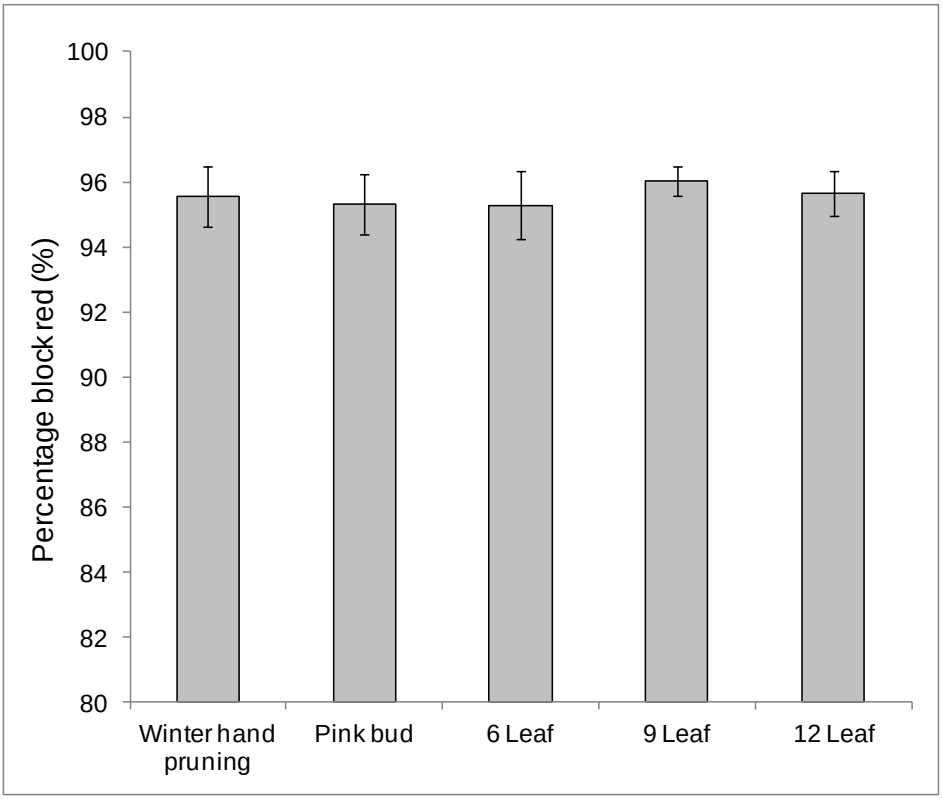

Figure 7. Percentage surface coloured block red at harvest. Standard error bars are shown (P=0.94).

Yield

The winter hand pruned control produced a significantly greater yield than all the other treatments except the six leaf stage cut. The differences between the summer pruned treatments were not significant - see Table 6 and Figure 8.

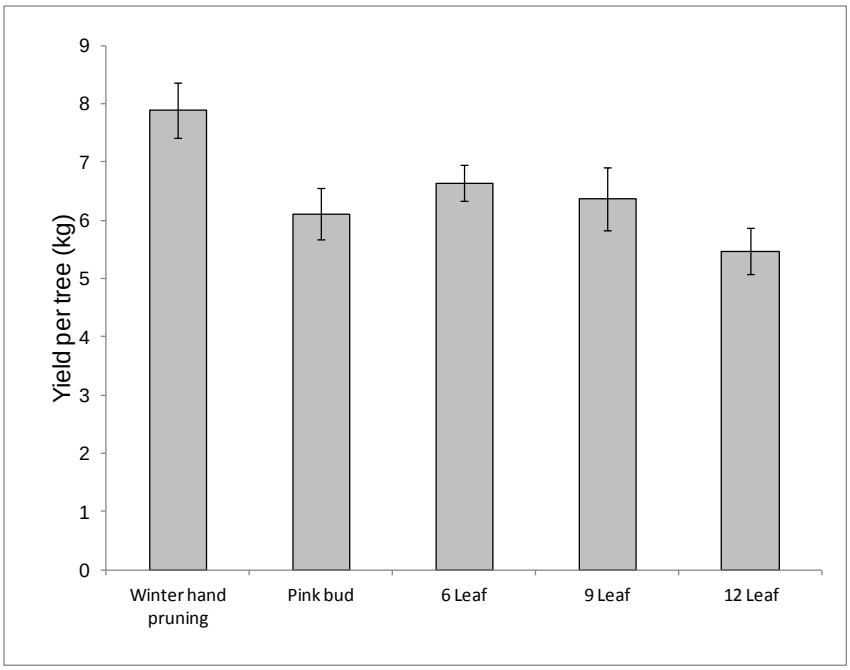

Figure 8. Average yield per tree (kg). Standard error bars are shown (P=0.024).

Table 6. Analysis of variance and multiple range test results for yield per tree. The letters indicate which treatments differed significantly.

Treatment	**Average yield per tree (kg)**
Winter hand pruning	7.88 **b**
Pink bud	6.11 **a**
6 Leaf	6.64 **ab**
9 Leaf	6.37 **a**
12 Leaf	5.47 **a**
Significance	*0.024*

Vegetative re-growth

The first measurement of re-growth was made on 16 August. However, the new shoots arising from buds behind the fruit wall cut had largely formed rosettes of leaves with very little internodal extension. To determine whether this was permanent or whether the shoots would elongate, a second measurement of re-growth was made on 1 October when shoot growth had ceased in all treatments. There were very few differences between the data collected in the two measurements (see Figures 9-12).

There was a significant difference of treatment effect on the number of leaves produced after the fruit wall cut or pruning event ($P<0.0001$). All treatments were significantly different from one another, with the exception of winter hand pruning (Treatment 2) and the fruit wall cut made at pink bud (Treatment 4), which both produced approximately 14 new leaves. The shoot length was also significantly different across treatments ($P<0.0001$), again with the exception of winter hand pruning (Treatment 2) and the fruit wall cut made at pink bud (Treatment 4), which again had comparable values. However, the assessment made on 1 October, whilst confirming the results from the earlier assessment, also revealed comparable levels of shoot re-growth for the fruit wall cuts made at nine and 12 new leaves (Treatments 8 and 10). The later that the fruit wall cuts were made, the more successful the treatment appeared to be at restricting the vegetative re-growth of shoots; which is desirable to maintain sufficient light penetration.

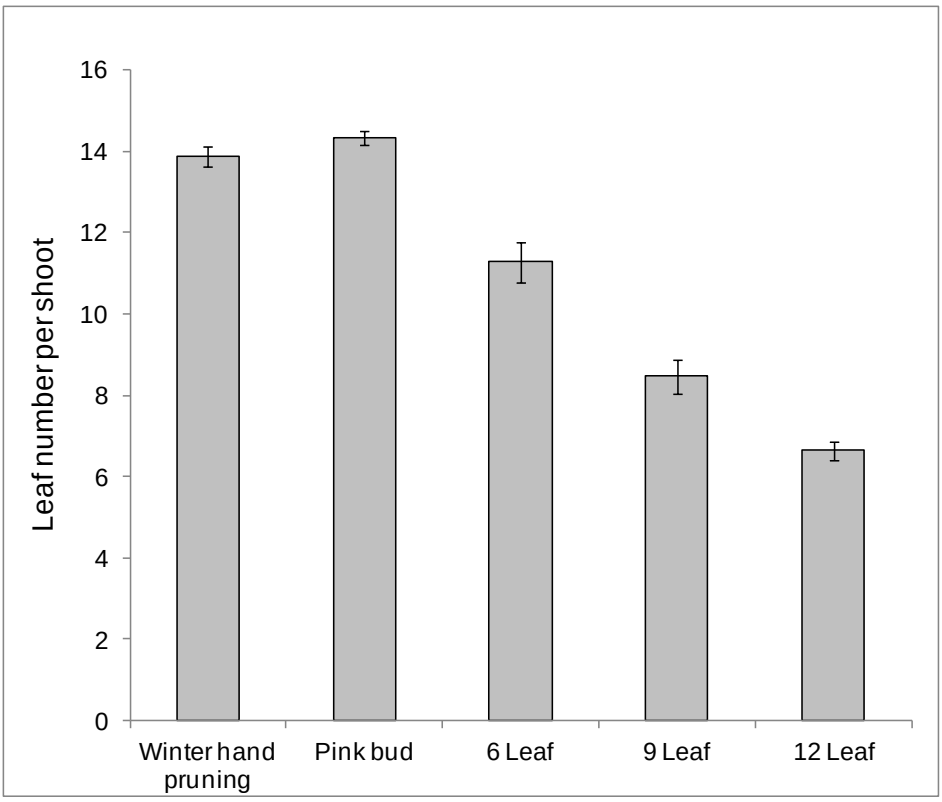

Figure 9. Average number of leaves produced by the shoots arising from the bud behind the pruning cut (assessed 16 August). Standard error bars are shown (P<0.0001).

Table 7. ANOVA and multiple range tests for the average number of leaves produced after pruning (assessed 16 August). The letters indicate which treatments differed from each other.

Treatment	**Average number of leaves per shoot**
Winter hand pruning	13.89 **d**
Pink bud	14.34 **d**
6 Leaf	11.28 **c**
9 Leaf	8.47 **b**
12 Leaf	6.65 **a**
Significance	*<0.0001*

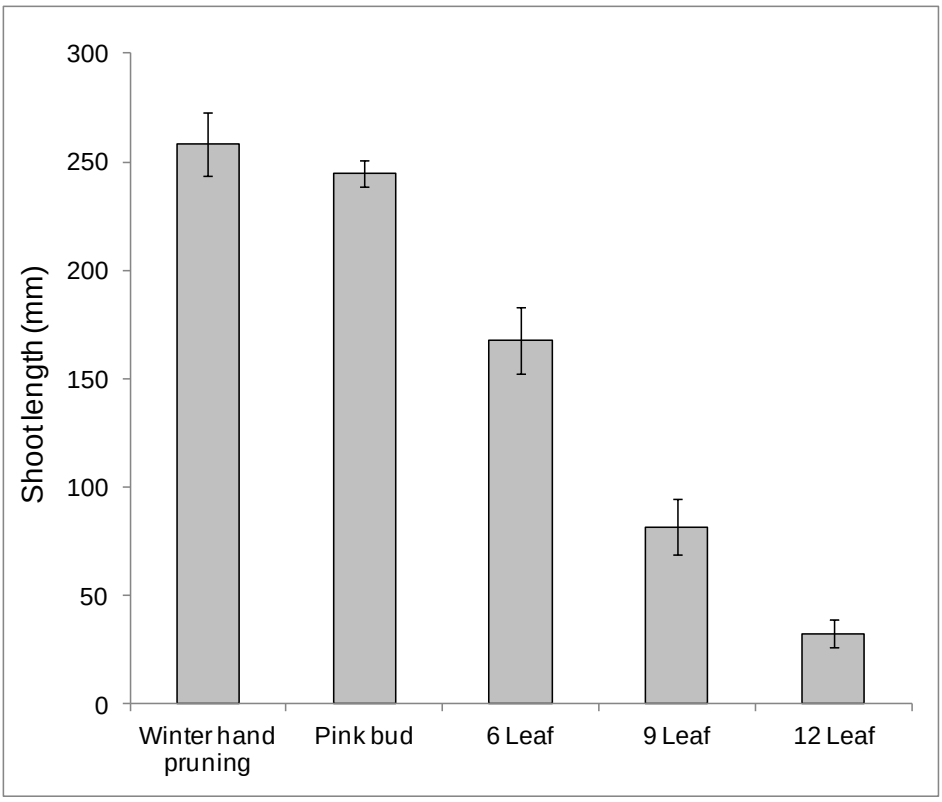

Figure 10. Average length of the shoots produced after the pruning cut for the different treatments (assessed 16 August). Standard error bars are shown (P<0.0001).

Table 8. ANOVA and multiple range tests for the average length of shoots produced after pruning (assessed 16 August). The letters indicate which treatments differed from each other.

Treatment	**Average length of re-growth (cm)**
Winter hand pruning	25.85 **a**
Pink bud	24.46 **a**
6 Leaf	16.78 **b**
9 Leaf	8.17 **c**
12 Leaf	3.26 **d**
Significance	*<0.0001*

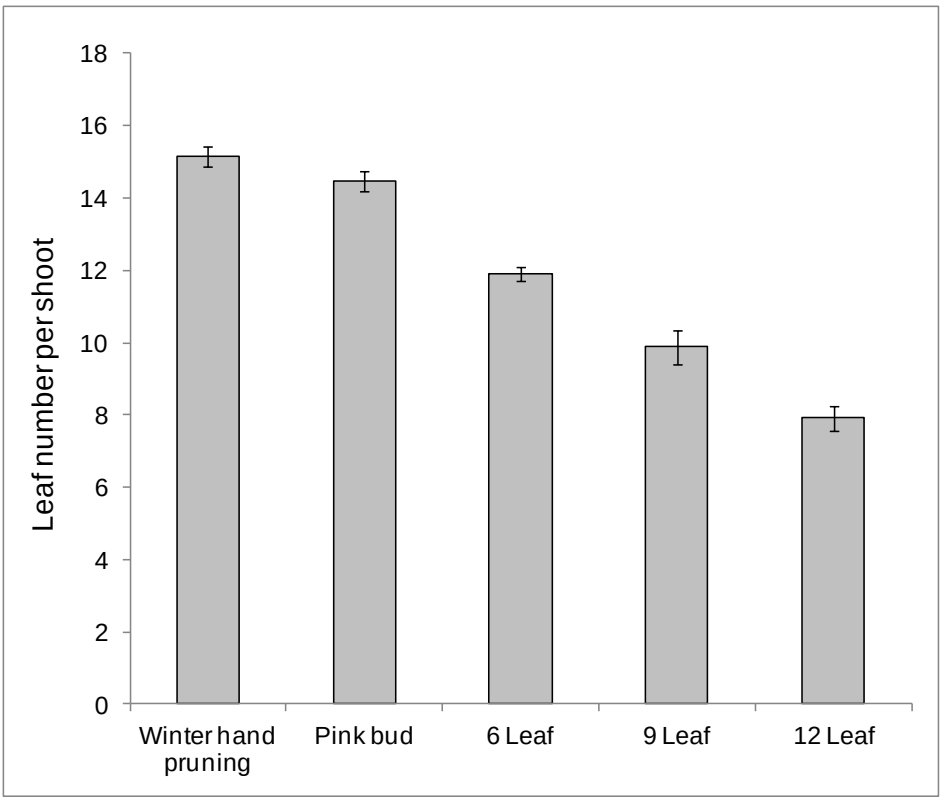

Figure 11. Average number of leaves produced by shoots arising from the bud behind the pruning cut (assessed 1 October). Standard error bars are shown (P<0.0001).

Table 9. ANOVA and multiple range tests for the average number of leaves produced after pruning (assessed 1 October). The letters indicate which treatments differed from each other.

Treatment	**Average number of leaves per shoot**
Winter hand pruning	15.14 **a**
Pink bud	14.47 **a**
6 Leaf	11.92 **b**
9 Leaf	9.88 **c**
12 Leaf	7.91 **d**
Significance	*<0.0001*

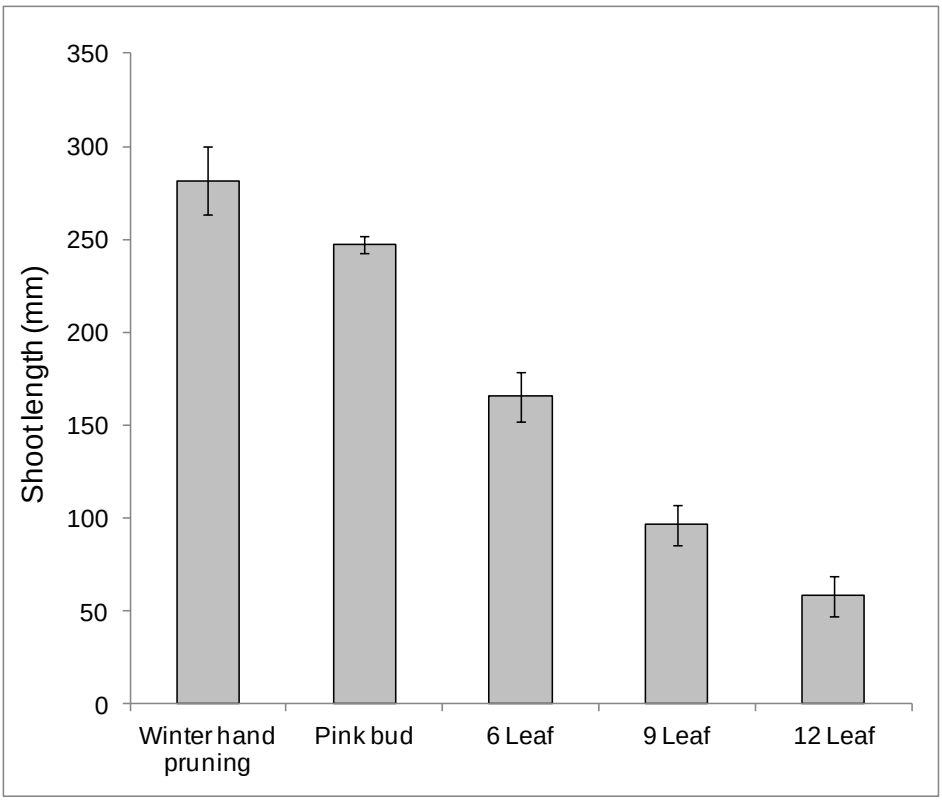

Figure 12. Average length of the shoots produced after pruning (mm) (assessed 1st October). Standard error bars are shown (P<0.0001).

Table 10. ANOVA and multiple range tests for the average length of shoots produced after pruning (assessed 1 October). The letters indicate which treatments differed from each other.

Treatment	**Average length of re-growth (mm)**
Winter hand pruning	282 **a**
Pink bud	247 **a**
6 Leaf	166 **b**
9 Leaf	97 **c**
12 Leaf	58 **c**
Significance	*<0.0001*

Fruit quality and maturity

There was a significant effect of treatment upon the fruit firmness (P=0.02) and average fruit firmness per treatment varied between 10.2 and 10.8 (see Figure 13). Fruit harvested from plots where a fruit wall cut was made at pink bud (Treatment 4) produced fruit with average fruit firmness significantly different from that of the fruit produced in plots where a fruit wall cut was made at nine new leaves (Treatment 8).

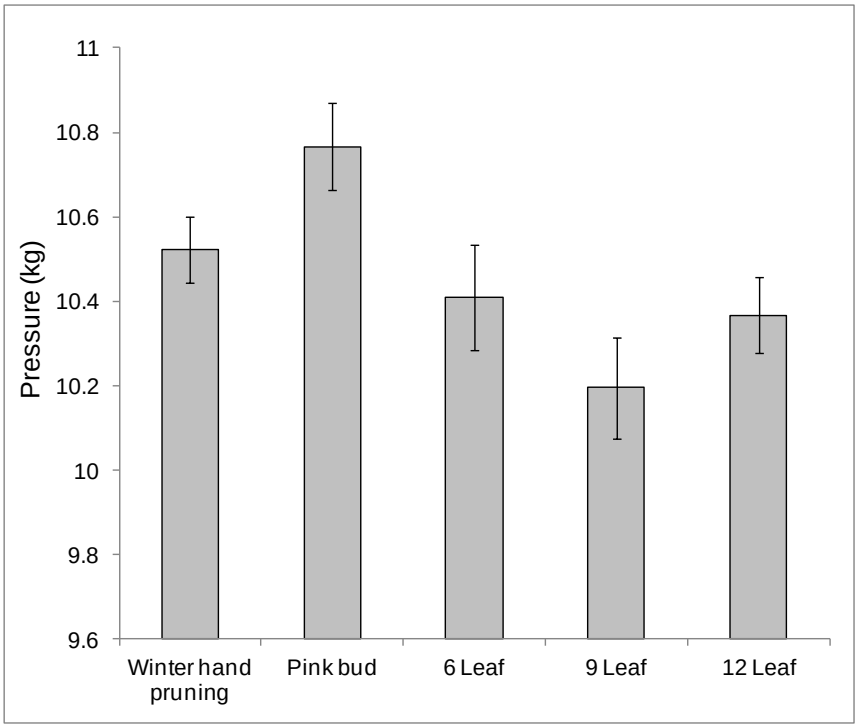

Figure 13. Average fruit flesh firmness on 21 September. Standard error bars are shown (P=0.02).

Table 11. ANOVA and multiple range tests for the average flesh firmness (kg). The letters indicate which treatments differed from each other.

Treatment	**Average fruit flesh firmness (kg)**
Winter hand pruning	10.52 **bc**
Pink bud	10.77 **c**
6 Leaf	10.41 **ab**
9 Leaf	10.20 **a**
12 Leaf	10.37 **ab**
Significance	*0.02*

As the fruit ripens, starch declines. By late September, the percentage starch had declined to between 70 and 80% with no significant differences between the treatments (see Figure 14).

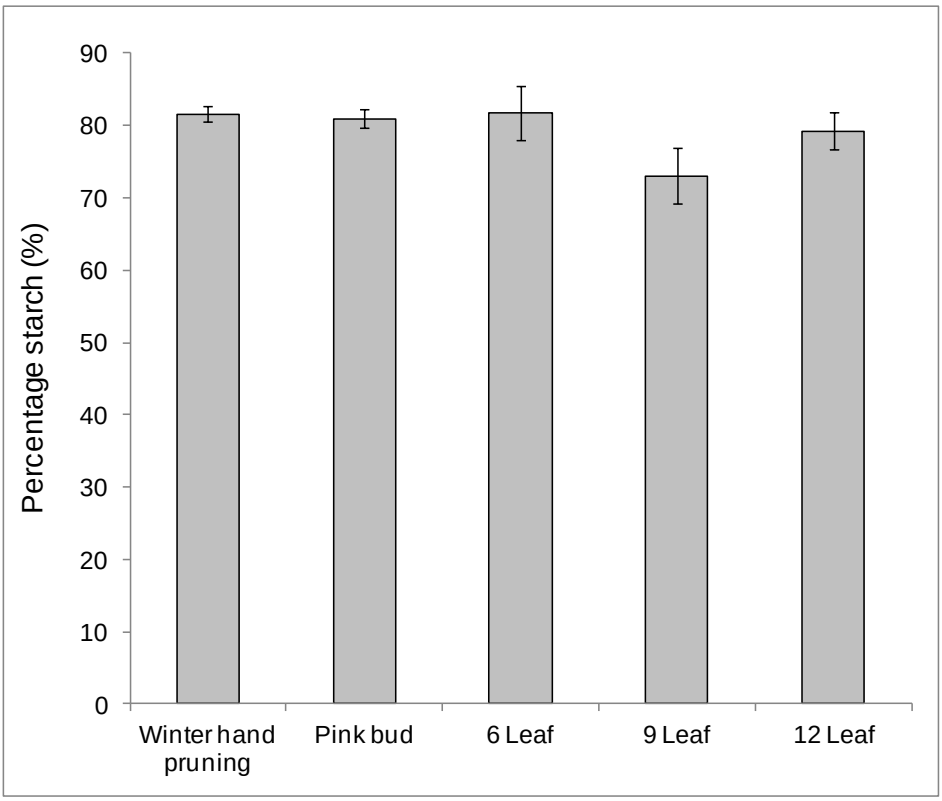

Figure 14. Average starch percentages on 21 September. Standard error bars are shown (P=0.13).

There was a significant effect of treatment upon the total soluble solids (P=0.007). See Table 12. Fruit produced by the plots where a fruit wall cut was made at pink bud (Treatment 4) had an average °Brix value of approximately 12.5° compared to 11.9° when the cut was made at the nine new leaves stage (Treatment 8). The average °Brix decreased to 11.4° when the cut was made at 12 new leaves (Treatment 10) - see Figure 15.

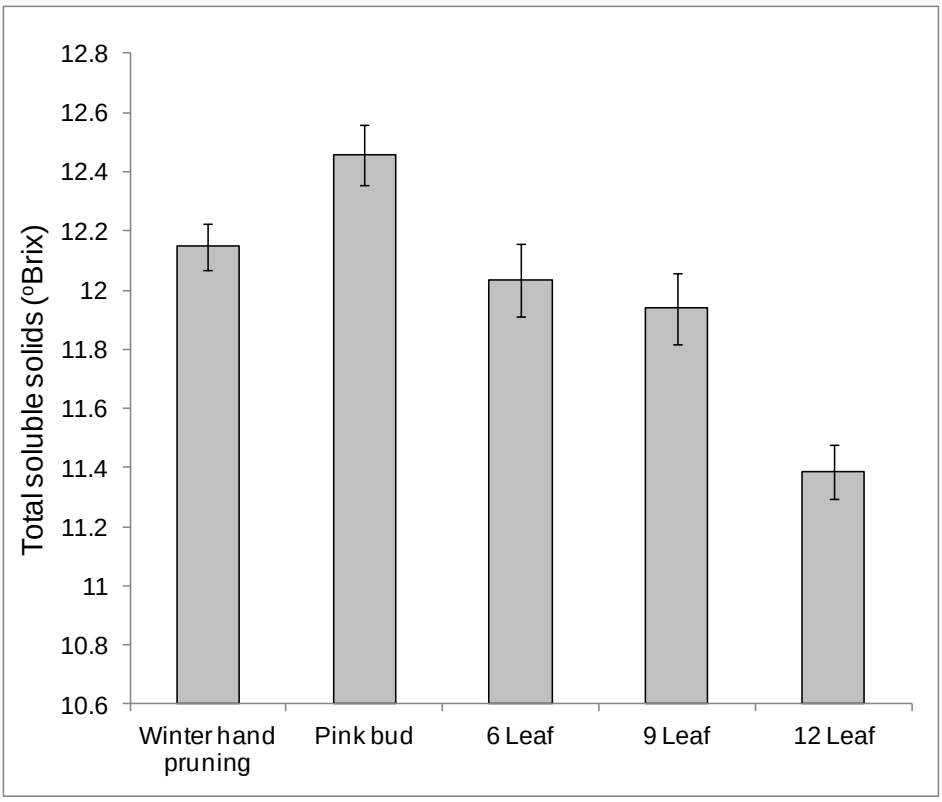

Figure 15. Average total soluble solids (°Brix) on 21 September. Standard error bars are shown (P=0.007).

Table 12. ANOVA and multiple range tests for average °Brix. The letters indicate which treatments differed from each other.

Treatment	**Average TSS (°Brix)**
Winter hand pruning	12.15 **bc**
Pink bud	12.46 **c**
6 Leaf	12.04 **bc**
9 Leaf	11.94 **b**
12 Leaf	11.39 **a**
Significance	*0.007*

Discussion

The trial produced several significant results in its first year.

Significant results:

- **Leaf Copper:** Copper levels in the leaf were higher in one treatment. There is no obvious explanation for this and mineral analysis in future years will determine if this is more than an anomaly in year one.
- **Yield:** This appeared to be as a result of a greater number of fruit produced by the winter hand pruning treatment as there were no significant differences in either fruit size or fruit diameter between any of the other treatments. 2012 is the first year during which the fruit wall cuts have been made and so in effect the summer fruit wall cuts removed more fruiting wood than the winter hand pruning, thereby reducing yield. In future years this may be balanced by the effect of the fruit wall cuts on fruit bud development within the narrower tree canopy. In future years therefore this decrease in yield compared to the winter hand pruning treatment may not be seen.
- **Shoot regrowth:** The different timings of the fruit wall mechanical pruning affected the amount of regrowth from behind the cut. The later the cuts the less the regrowth. Growers need to be aware of this effect and judge the timing of pruning according to the reduction in vigour that they wish to achieve. The effect of these different timings on the subsequent fruitfulness of the pruned branches will be assessed in future years.
- **Fruit firmness and sugar levels:** Any adverse effect of the fruit wall growing system and pruning time on fruit size and quality is potentially serious. In 2012, the first year of the trial, the summer cuts removed a relatively large amount of leaf, which is probably responsible for the reduction in fruit firmness and sugar levels in some of the summer pruned treatments. If this effect is repeated in subsequent years, it will need to be taken into account by growers planning on adopting the system. Other maturity factors (starch and background colour) were not affected in line with the °Brix and firmness measurements so this is not felt to be a maturity issue but rather a direct effect of the pruning treatments.
- **Fruit colour**: There was no significant effect of treatment on the percentage red colour of fruit. However, as the orchard is only in its first fruiting year, the tree canopies are not particularly dense and so effects of fruit wall treatments may be seen in future years where the canopy size is likely to have increased to such a stage where it may have a significant effect on fruit colour.

Conclusions

The effect of the timing of the fruit wall cut on re-growth of shoots was significant. As the cut was delayed, so the amount of re-growth was reduced. This was to be expected.

All fruit wall cut treatments, except at the six leaf stage, reduced yield compared to the winter hand pruning control treatment. This was because the fruit wall was in its first year of establishment and so the cuts removed a relatively large amount of fruiting wood.

The longer term effects of the fruit wall cuts will not be determined until next season when effects on flower bud formation and re-growth will become apparent.

The reduction in °Brix and fruit firmness in some of the summer cut treatments is a concern especially if it is confirmed in subsequent years.

Acknowledgements

We would like to thank Adrian Scripps Ltd. for hosting the trial at Parsonage Farm, Cobham.

Technology transfer

- An HDC open day was held in August 2012 for growers to view the site.
- Articles in Horticulture Week and The Fruit Grower highlighted the work being undertaken.
- Preliminary data was presented at the FAST Ltd. growers' conference in January 2013.
- A summary of the trial is to be placed in the 2013 HDC Tree Fruit Review.

References

Dennis, F. (2003). Flowering, pollination and fruit set and development. In: Ferree, D.C. and Warrington, I.J. Apples: Botany, production and uses. CAB International, Wallingford, U.K.

Ferree, D.C., Myers, S.C., Rom, C.R. and Taylor, B.H. (1984). Physiological aspects of summer pruning. Acta Horticulturae 146: 243-252.

Guimond, C.M., Lang, G.A. and Andrews, P.K. (1998). Timing and severity of summer pruning affects flower initiation and shoot regrowth in sweet cherry. Hortscience 33: 647-649.

Hampson, C.R., Quamme, H.A., and Brownlee, R.T. (2002). Canopy growth, yield and fruit quality of 'Royal Gala' apple trees grown for eight years in five tree training systems. HortScience 37: 627-631.

Hampson, C.R., Quamme, H.A., Kappel, F. and Brownlee, R.T. (2004). Varying density with Constant Rectangularity: I. Effects on Apple Tree Growth and Light Interception in Three Training Systems over Ten Years. HortScience 39: 501-506.

Li, K.T. and Lakso, A.N. (2004). Photosynthetic characteristics of apple spur leaves after summer pruning to improve exposure to light. Hortscience 39: 969-972.

Mika, A., Krawiec, A. and Krzewinska, D. (1997). Results of planting systems and density trials with dwarf and semi-dwarf apple trees grafted on Malling (M) and Polish (P) rootstocks. Acta Horticulturae 451: 479-786.

Palmer, J.W., Avery, D.J. and Wertheim, S.J. (1992). Effect of apple tree spacing and summer pruning on leaf area distribution and light interception. Scientia Horticulturae 52: 303-312.

Stover, E., Fargione, M.J., Watkins, C.B. and Lunderman, K.A. (2003). Harvest management of Marshall McIntosh apples. Effects of AVG, NAA, Ethephon and summer pruning on pre-harvest drop and fruit quality. Hortscience 38: 1093-1099.

Wagenmakers, P.S. and Callesen, O. (1995). Light distribution in apple orchard systems in relation to production and fruit quality. Journal of Horticultural Science 70: 935-948.

Weber, M.S. (2001). Optimizing the tree density in apple orchards on dwarf rootstocks. Acta Horticulturae 557: 229-234.

Wünsche, J.N., Lakso, A.N., Robinson, T.L., Lenz, F. and Denning, S.S. (1996). The Basis of productivity in apple production systems: The role of light interception by different shoot types. Journal of the American Society for Horticultural Science 121: 886-893.