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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.

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GROWER SUMMARY

Headline

Two years into this pruning trial, trees are beginning to react to their different pruning treatments.

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, this trial aims to establish the optimum time to make the pruning cut. The timing of the cut determines the amount of vegetative regrowth and also whether the bud behind the cut becomes floral or remains vegetative. Determining the optimum time to perform the pruning cut will help to achieve maximum productivity from the fruit wall system. The impact of the timing of pruning on the yield, fruit quality and vegetative regrowth are being assessed. The trial is being conducted over five years to assess the long-term effects of the treatments.

The trial was established to determine the optimum time to mechanically prune orchards planted as a fruit wall compared to a winter hand pruned control, and to establish the effects of inter tree pruning. The five year trial established in 2012 is laid out in an existing commercial orchard of dessert apple variety Gala (clone Galaxy). 2014 was the third year of timed pruning treatments.

Summary of the project and main conclusions

The project is designed to test the effect of four timings of pruning a fruit wall mechanically compared to a winter hand pruned control. In addition, a further set of treatments is being imposed to compare the effect of pruning between the trees by hand during the dormant period.

The pruning timings are based upon different growth stages: pink bud, 6 new leaves, 9 new leaves and 12 new leaves (or when 50% terminal buds were present).

As in previous years the winter and early season cuts produced the strongest regrowth in 2014 (approximately 25cm) and the latest timing the least regrowth (approximately 4cm).

There were no statistically significant differences in yields between the treatments in 2014 but the winter hand pruned control still had the highest cumulative yield. Small benefits in yield and quality in the plots with hand pruning between the trees are showing up but these were not significant. Small benefits in fruit size and sugar were recorded in the plots pruned at pink bud but these again were not statistically significant.

No differences were recorded in fruit colour or maturity between the treatments.

Financial benefits

If a system based mainly on mechanical pruning proves to be successful with minimal reduction in the yield of class I fruit, it holds the prospect for reducing the cost of pruning and for the need for skilled pruning labour. Both of these considerations are important for growers in the current conditions.

Action points for growers

It is important to "read the tree" before deciding on the timing of pruning. Where limited regrowth and improved fruit bud formation are required, pruning at the 9 leaf stage appears to be the optimum.

Where trees are not vigorous and are in balance, pruning at the pink bud stage may benefit fruit size and sugar content, but will encourage more growth.

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 developed and CTIFL adapted an orchard to create a narrow tall hedgerow (the fruit wall) to accommodate the robot and 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 I yields. However, differences in cropping were shown between the south and north of France, with the trial plots in the north performing less well than in the south.

The fruit wall system is now being considered as an option for commercial practice in the UK, as mechanisation of pruning and other operations (for example thinning) is possible and requires a modified tree architecture to be successful. Results from the original work by CTIFL in France can be applied to growing areas further north, but only by adapting the methods, particularly the time of pruning, to the local growing conditions.

Three key factors influence total productivity from a fruit wall orchard:

- Planting density;
- Tree architecture;
- The timing of pruning.

These factors all have an effect on extension growth, flower bud initiation and yield by influencing light interception and distribution by and through the canopy and the total amount of fruiting wood in the orchard. The management of these factors determines whether the fruit wall is able to provide increased and sustainable yields throughout the life of the orchard.

Hampson *et al*. (2002) demonstrated that planting density can have a greater influence on productivity than the training system (tree height and shape). Trees planted at lower density were more productive per tree than at a higher planting density due to reduced competition for resources, however higher planting densities tend to be more productive per hectare. Palmer *et al*. (1992) suggest that Leaf Area Index (LAI) increases with increased planting density with greater light interception as a result. Higher planting density systems tend to increase yields per unit area through more efficient use of ground area until a natural limit is reached (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.

Hampson *et al*. (2004) demonstrated in their study that the percentage of fruit with acceptable colour was reduced with increased planting densities. Red colouration is an indicator of fruit quality and therefore as planting density increases the percentage of Class I fruit may become compromised. 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 result in less shading of the fruit. It is essential to maintain the narrow shape and size of the trees composing the fruit wall to maximise the light distribution throughout the tree. In the fruit wall system a pruning cut is made by a tractor mounted mechanical cutter bar 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 narrow A-shaped trees but also to encourage flower bud formation. Flower bud formation usually 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 pruning treatments and management inputs e.g. nitrogen applications, which favour vegetative growth, tend to reduce flower bud formation; whereas plant growth regulators (PGRs) which retard vegetative growth tend to improve flower bud formation.

In the fruit wall system, the pruning cut is made during the summer and the timing of the cut is critical in determining the amount of vegetative regrowth and flower bud formation. This is also true for other crops such as cherry where Guimond *et al*. (1998) showed that flower initiation was stimulated by summer pruning and vegetative growth also increased due to the removal of apical dominance along the shoot. If the fruit wall cut is made too early then vegetative growth will be favoured, reducing flower bud formation. However, if the cut is made too late the flower buds will have already formed and the cut will simply remove them. The optimal date for the fruit wall cut to be made may vary between varieties and between different seasons and therefore it is essential to relate the time of the cuts to an easily identified growth stage.

With mechanical pruning the branches in between the trees are left unpruned and these can become thick and intertwined resulting in shading and adverse effects on fruit quality. It is important for growers to know the effect, if any, of removing these branches on yield and fruit quality.

The aim of the trial was to determine the optimum time for mechanical pruning the fruit wall of the apple cultivar Gala (clone Galaxy) and to evaluate the effect of inter tree pruning. The results from 2014 are presented in this report, together with the cumulative yields from the previous two years.

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. The trees are trained on a post and wire system with bamboo cane supports at a planting distance of 3.5 x 0.5m with 10 trees between each post, forming a bay and each plot consisting of two bays. The trial area is comprised of 800 trees in 20 bays of 10 trees in each of four blocks (see Fig 1a).

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 1a. Plot layout and treatment number.

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

Figure 1b. Plot recording and guard design.

The trial was a randomized complete block design with the 10 treatments replicated in four blocks. The treatments consisted of five different pruning timings each of which had two sub-treatments with either inter tree pruning or no inter tree pruning. Each plot was composed of 20 trees: six guard trees at each end and eight trees used for sampling and recording (see Fig. 1b).

Treatments

A description of the treatments is shown in Table 1. Each treatment consists of two parts: (a) the timing of the pruning cut and (b) +/- inter tree pruning. The pruning cut was made by a tractor mounted mechanical cutter bar (with the exception of the winter hand pruning treatments). The earliest mechanical cut treatment was made at pink bud (Treatments 3 and 4). The later mechanical cuts were made when the new extension growth had produced 6, 9 or 12 new leaves (Treatments 5 and 6, 7 and 8, and 9 and 10). The timing of pruning and number of leaves at pruning are shown in Figure 2 and Table 2 and the method of counting leaves to determine these stages is shown in Figure 3.

Inter tree pruning treatments were carried out from winter 2012/13 and in subsequent years at the same time as the winter prune treatment. The treatment consisted of removing one or two excessively strong, upright or long branches on each side of the tree which were causing shade. Any very weak or low branches were also removed.

Table 1. Fruit wall cut and pruning treatments

Treatment number	Timing of fruit wall cut	Inter tree pruning
1	Winter (by hand)	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

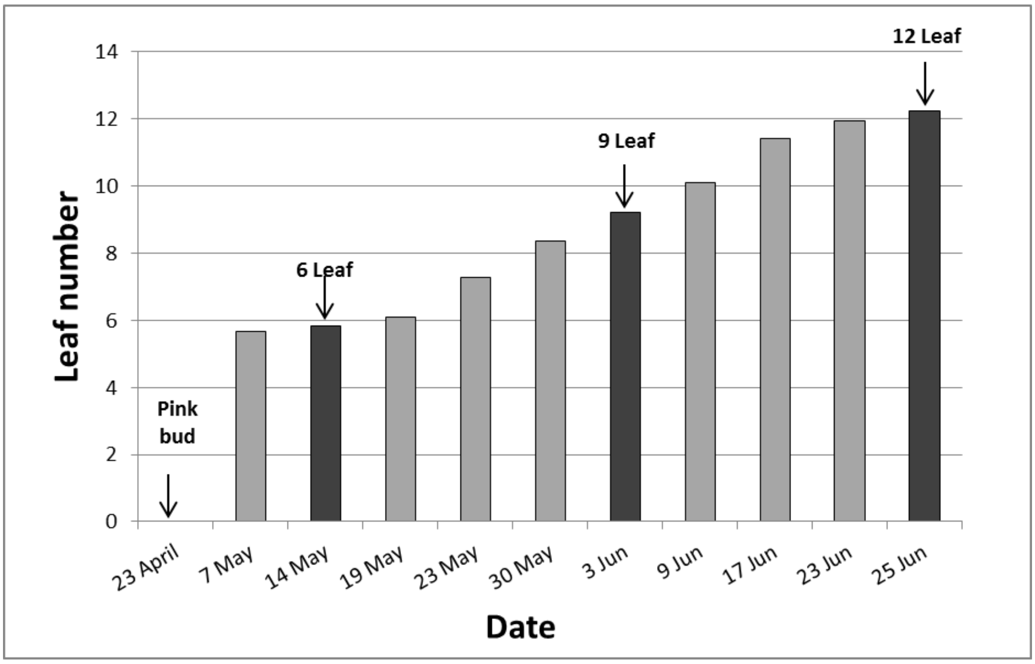

Figure 2. Average number of new leaves and timings of pruning cuts in 2014.

Table 2. Dates of the pruning treatments

Date	Number of leaves	Date of cut
7th March 2014	0	Winter hand pruning *(07-03-14)*
23rd April 2014	0	Pink bud *(23-04-14)*
7th May 2014	5.7	
14th May 2014	5.8	6 Leaf *(14-05-14)*
19th May 2014	6.1	
23rd May 2014	7.3	
30th May 2014	8.4	
3rd June 2014	8.5	9 Leaf *(03-06-14)*
9th June 2014	9.2	
17th June 2014	10.0	
23rd June 2014	11.9	
25th June 2014	12.2	12 Leaf *(25-06-14)*

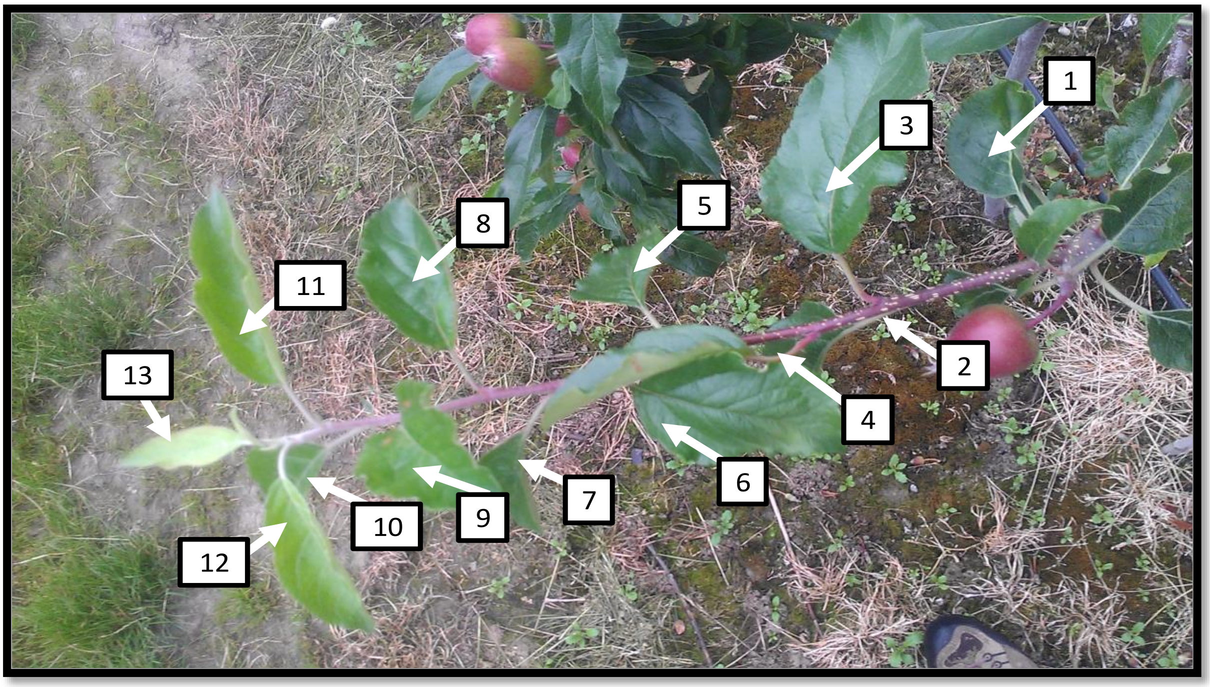

Figure 3. Showing the number of fully expanded leaves. Note that the basal whorl of small leaves are ignored.

Assessments

1. The number of new leaves produced on 25 shoots per plot, were counted weekly from the end of May, then twice weekly from mid-June until the end of July 2014 when growth ceased. The average number of leaves per shoot was calculated to determine the timing of the cuts.
2. The length of new extension growth and number of leaves produced on the shoots arising from the bud immediately behind the pruning cut were recorded on 14 August and 23 October 2014. Where no mechanical cut was made (winter hand pruning) the current season's growth was recorded.
3. The effect of treatments on leaf and fruit mineral content was determined on 2 September 2014. One leaf was selected from two thirds along the length of 25 extension shoots per plot. Twenty-five fruit were selected at random from the guard trees in each plot.
4. The harvest assessments were conducted at the same time as the farm's commercial harvest (9 until 11 September 2014). The assessments included:
    - Total yield from the eight experimental trees in each plot.
    - Average fruit weight (g), fruit diameter (mm) and percentage red colour (%) from 100 fruits in each plot.

- Fruit quality and maturity, using the same methodology as the UK Quality Fruit Group to assess the percentage starch, flesh firmness and Total Soluble solids (TSS).

Statistical analysis

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

Results

Vegetative regrowth

The greatest amount of regrowth occurred in the plots pruned by hand in the winter (see Figures 4, 5, 6 and 7). The level of regrowth was very similar to that in the plots pruned at the first mechanical cut carried out at pink bud. Subsequent mechanical cuts resulted in significant reductions in regrowth at each of the timings, with the last cut at the 12 leaf stage resulting in the least regrowth. The range in amount of regrowth was 27cm in the winter pruned treatment to less than 4 cm in the plots pruned at the 12 leaf stage.

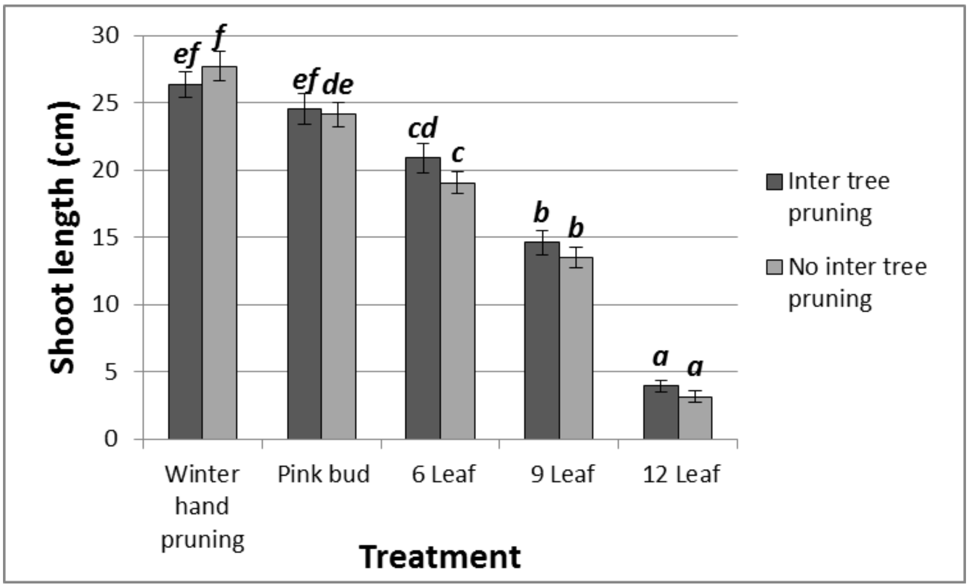

Figure 4. The effect of the pruning treatment on the extension growth arising from the bud behind the pruning cut (assessed 14 August 2014). Standard error bars are shown and the letters reflect statistical significance (P<0.0001).

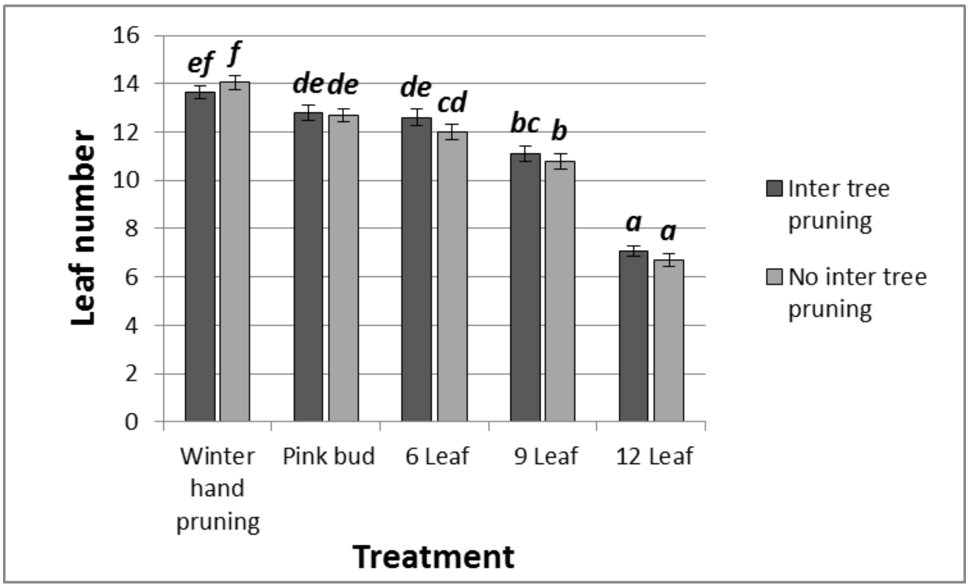

Figure 5. The effect of the pruning treatment on the number of leaves arising from the bud behind the pruning cut (assessed 14 August 2014). Standard error bars are shown and the letters reflect statistical significance (P<0.0001).

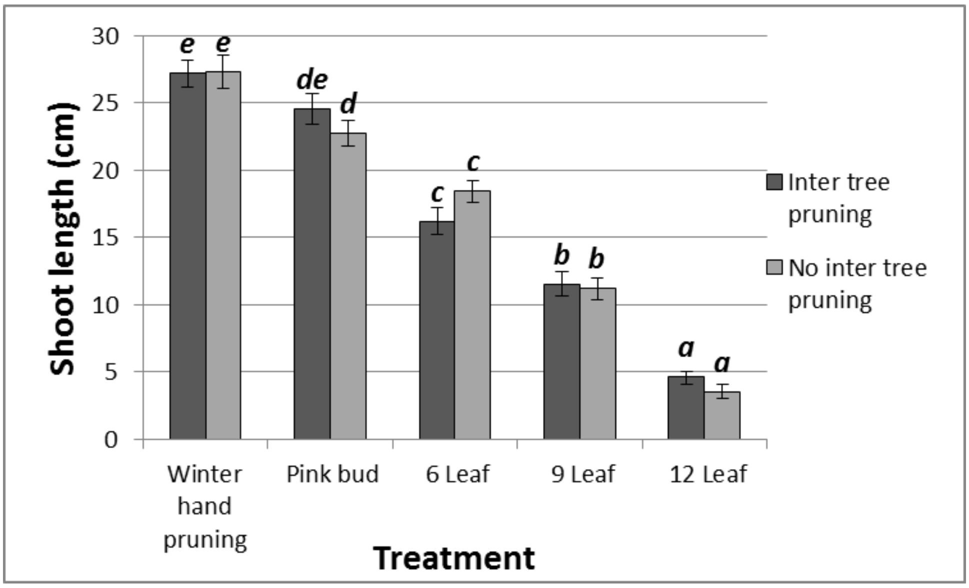

Figure 6. The effect of the pruning treatment on the extension growth arising from the bud behind the pruning cut (assessed 23 October 2014). Standard error bars are shown and the letters reflect statistical significance (P<0.0001).

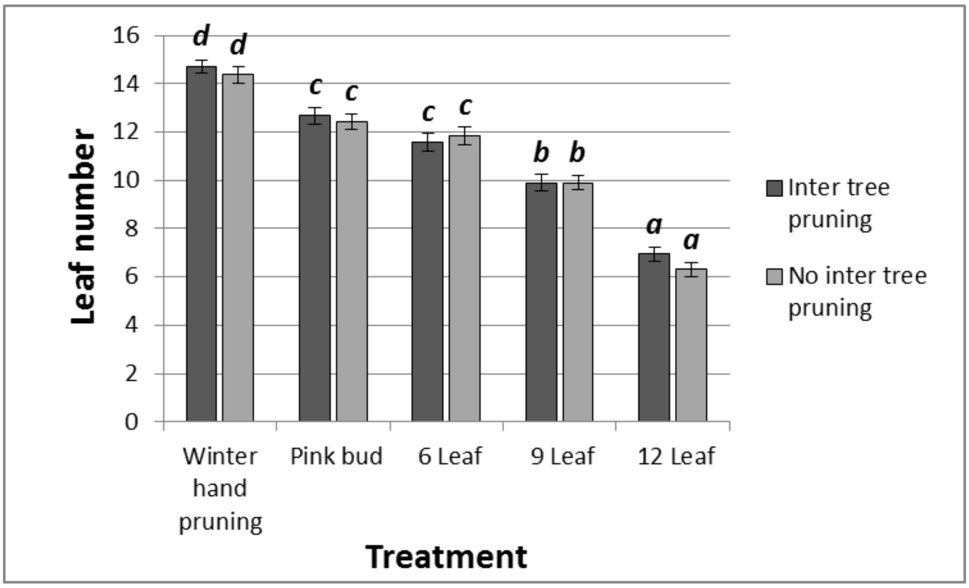

Figure 7. The effect of the pruning treatment on the number of leaves arising from the bud behind the pruning cut (assessed 23 October 2014). Standard error bars are shown and the letters reflect statistical significance (P<0.0001).

Yield

In 2014 yields varied between 10.35 kg per tree (12 leaf stage) and 13.1 kg per tree (winter pruned) but these differences were not statistically significant. In every treatment except the cut at the 6 leaf stage, the inter tree pruning reduced yield but not to a significant level (see Figure 8).

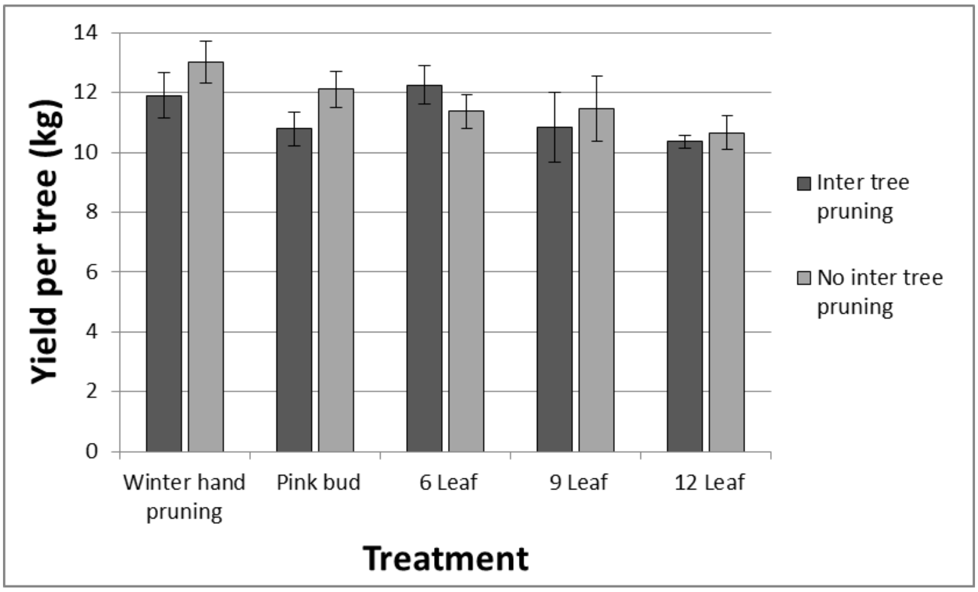

Figure 8. The effect of the pruning treatment upon the average yield per tree (kg) in 2014.

Cumulative yield

The cumulative yields for 2012 to 2014 varied between 41kg (12 Leaf) and 52kg (winter hand pruned). Inter pruning values for 2013 and 2014 have been averaged with the non inter pruned plots since this treatment variation was not introduced in 2012 (see Figures 9 and 10). The cumulative yields for 2013 to 2014 (including inter pruning treatments) varied between 17.5kg (12 Leaf inter pruned) and 23.0kg (winter hand pruned) following the same pattern as average yields - inter tree pruning reduced yield in each treatment except for the 6 Leaf cut.

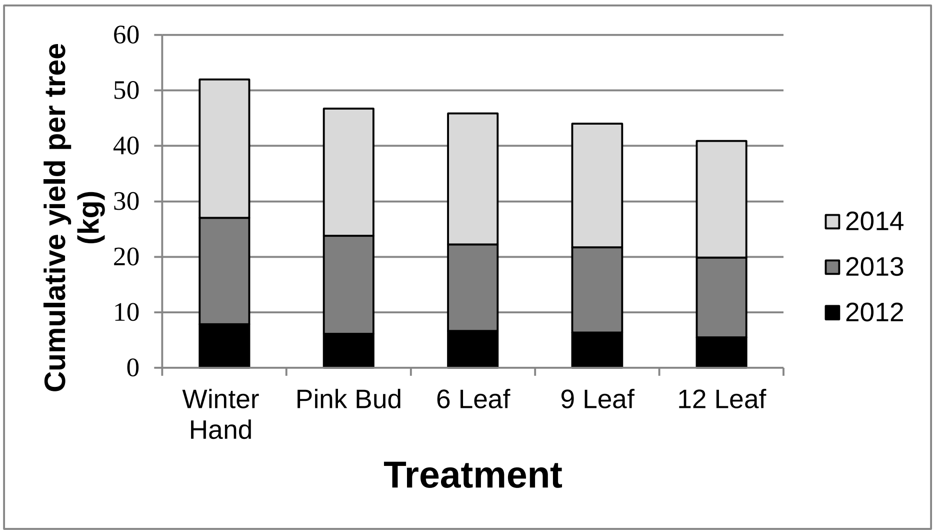

Figure 9. The cumulative yield per tree (kg) for pruning timing treatments – data averaged for different inter pruned treatments in 2013 and 2014 as inter pruning not initiated in 2012.

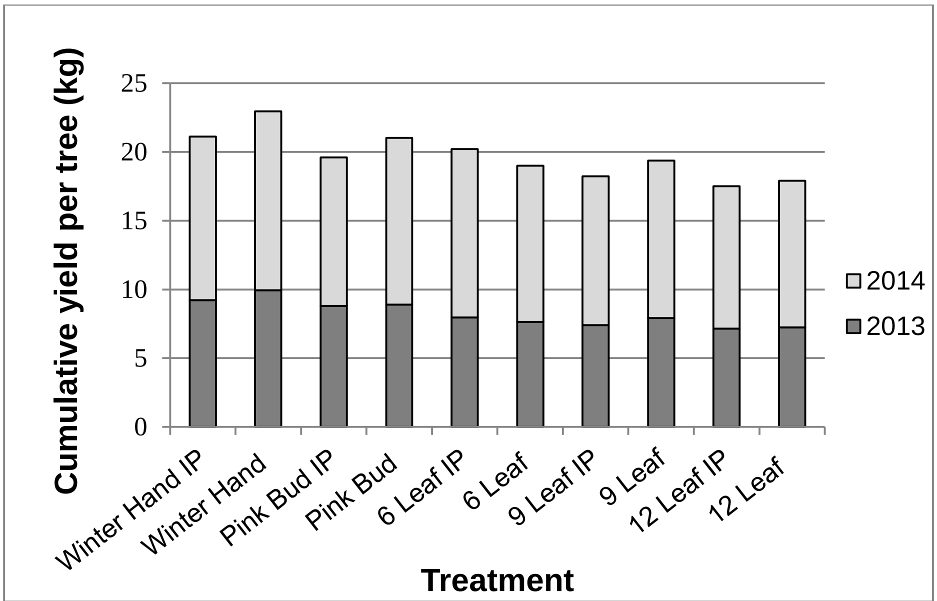

Figure 10. The cumulative yield per tree (kg) for pruning timing and inter pruning treatments – data for 2012 is omitted since inter pruning commenced in 2013.

Fruit diameter and weight

Average fruit diameter varied between 61mm and 65mm. Only the plots pruned at the pink bud stage with inter tree pruning, and those pruned at the 6 leaf stage, had fruit that was significantly larger than the winter hand pruned control.

The treatment with the lowest fruit weight (g) on average was in the plot pruned at the 12 leaf cut with no inter tree pruning (see Figure 12). Only the plots pruned at pink bud with inter tree pruning produced fruit significantly heavier than the controls. Average weight in this plot was 145g.

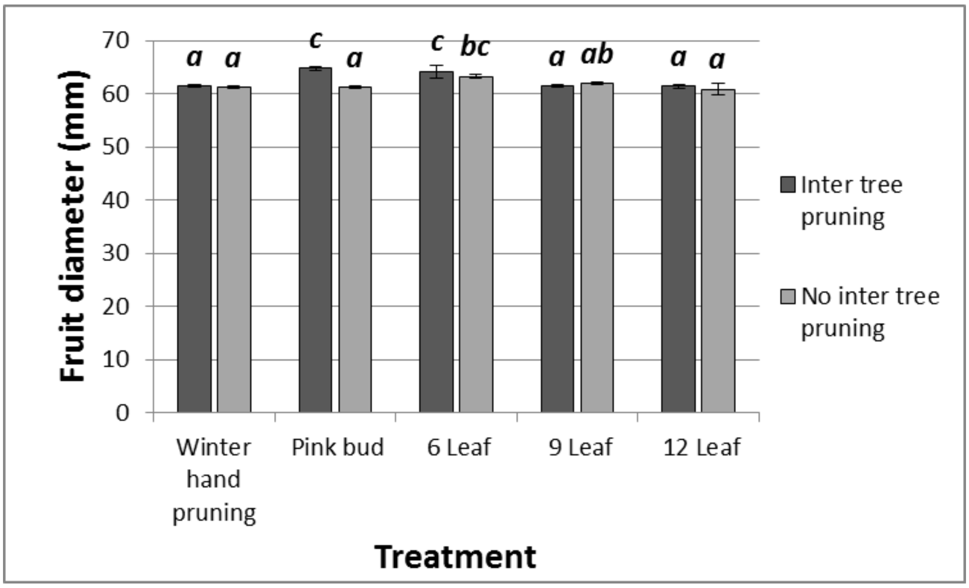

Figure 11. The effect of the pruning treatment on the average fruit diameter (mm) at harvest. Standard error bars are shown and the letters reflect the significance of treatments (P=0.0002).

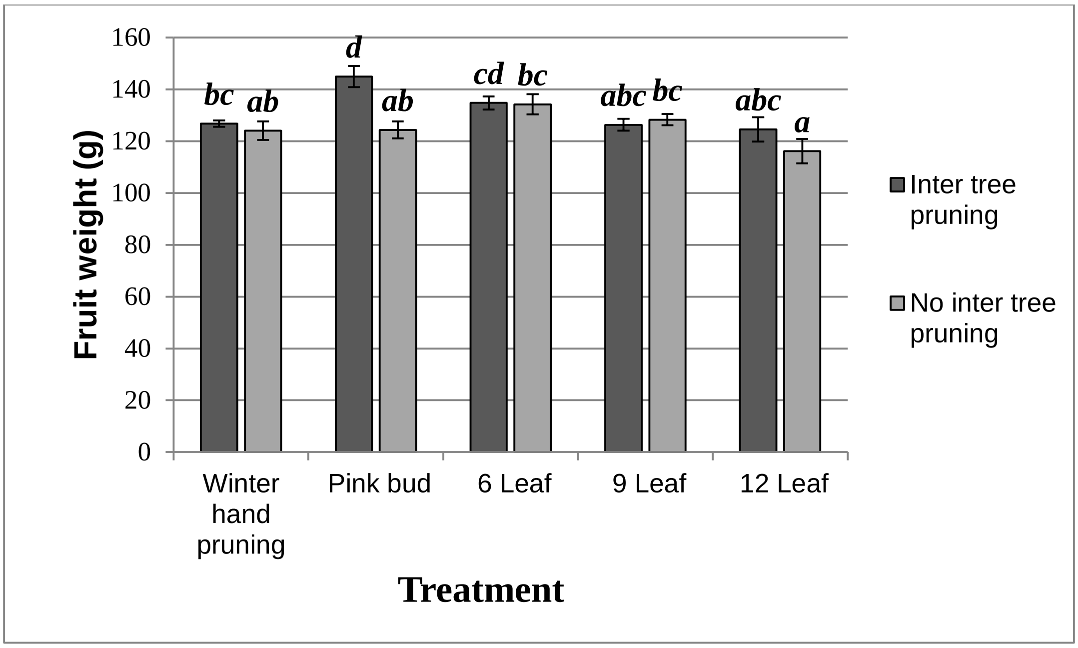

Figure 12. The effect of the pruning treatment on the average fruit weight (g) at harvest. Standard error bars are shown and the letters reflect the significance of treatments (P=0.0006).

Fruit colour

The Galaxy cone of cv. Gala, used in this project, is naturally a well coloured clone, and all the pruning treatments had sufficient colour to meet Class I standards. There were no significant differences in the percentage red colouration of the fruit between treatments or as a result of inter tree pruning (see Figure 13).

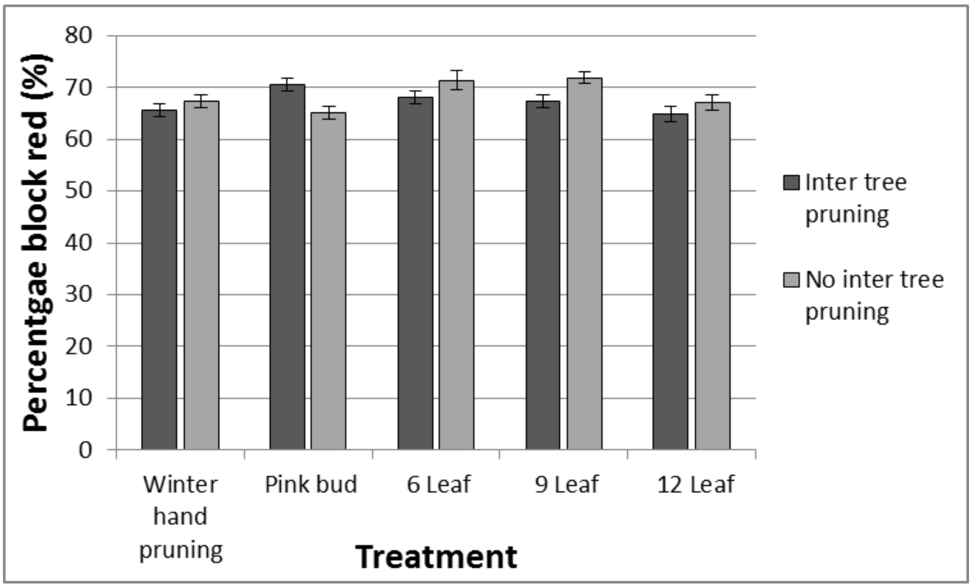

Figure 13. The effect of the pruning treatment on the percentage surface coloured block red at harvest. Standard error bars are shown.

Fruit quality and maturity

At harvest, the percentage of the fruit surface stained black with iodine ranged between 75% and 88%. There were no significant differences between the different pruning timings or in inter tree pruning treatments (see Figure 14). There was also very little difference in the firmness of fruit at harvest (see Figure 16).

The majority of treatments had °Brix levels between 10° and 11°. The highest °Brix value of 11.2°, was recorded in the plot pruned at pink bud with inter tree pruning, and was significantly greater than all other treatments (P=0.0106) (see Figure 15).

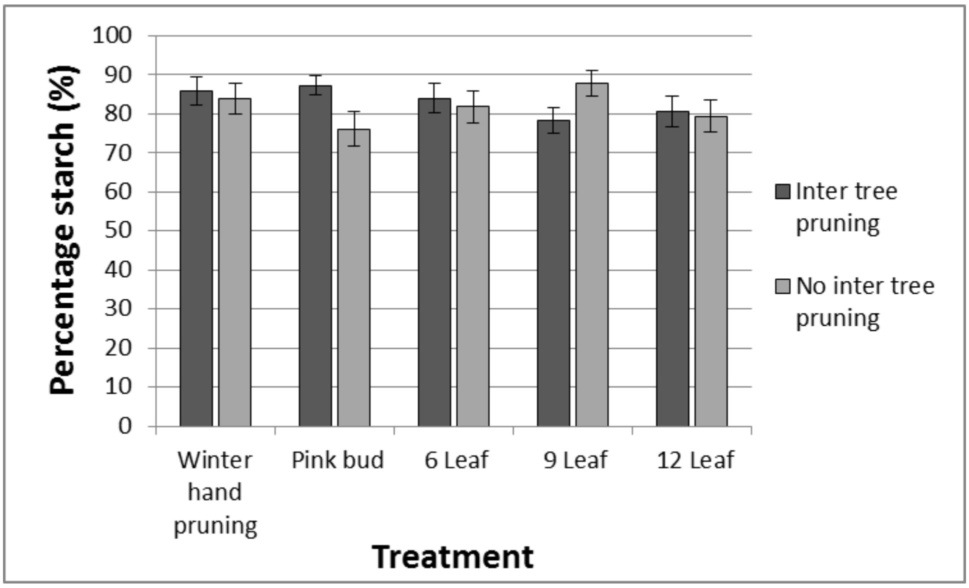

Figure 14. The effect of the pruning treatment on the average percentage starch, determined by standard iodine test, at harvest. Standard error bars are shown.

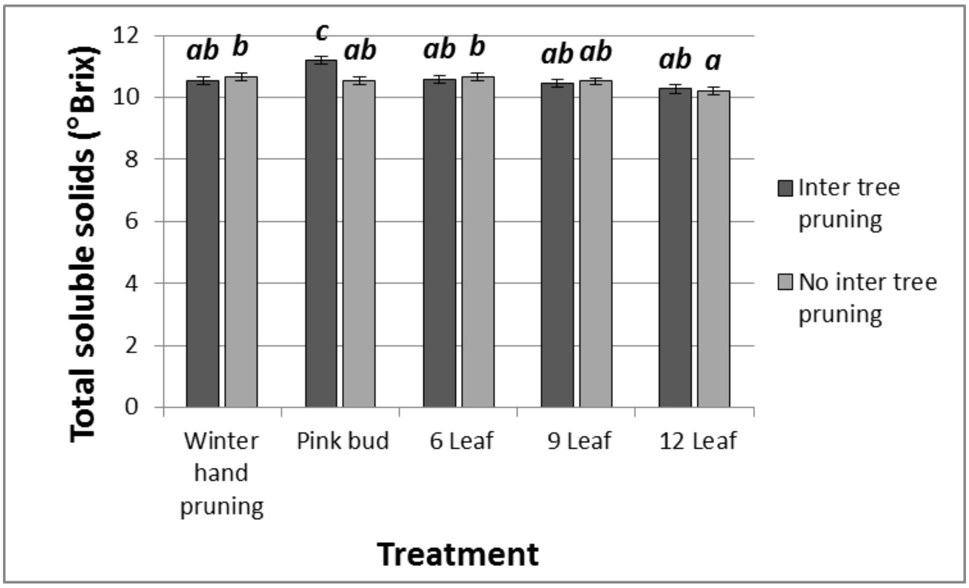

Figure 15. The effect of the pruning treatment on the average total soluble solids (Brix°) at harvest. Standard error bars are shown and the letters reflect statistical significance (P=0.0106).

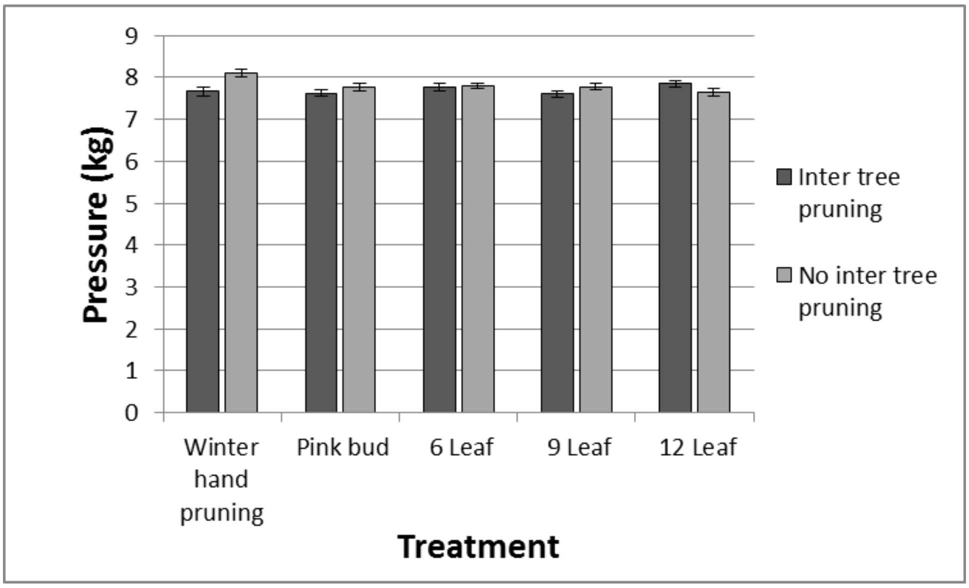

Figure 16. The effect of the pruning treatment on the average fruit firmness at harvest. Standard error bars are shown.

Fruit and leaf analysis

There were no significant treatment effects on fruit analysis for any elements except phosphorus, where the plot pruned at pink bud with inter tree pruning had higher levels.

There was a greater variation in the mineral levels in the leaves.

Nitrogen - There was a trend towards the winter hand pruned and the earlier mechanically pruned plots having higher leaf nitrogen levels than the later cuts.

Potassium and calcium - Differences between the treatments were recorded with no single treatment significantly higher or lower than all the others.

Copper and zinc - Significant differences between treatments were recorded but as with potassium and calcium no single treatment was significantly greater or lower than all the others.

Phosphorus, magnesium, manganese, boron and iron - No significant differences were recorded.

Table 3. Leaf analysis results from sampling on 2 September 2014. Standard errors are given in parenthesis and the letters reflect the significance of treatments determined through ANOVA

Leaf analysis	**(% dry weight)**					**(mg/kg)**				
	N	**P**	**K**	**Mg**	**Ca**	**Mn**	**B**	**Cu**	**Zn**	**Fe**
T1 Winter hand pruning-with inter tree pruning	2.43 ***(cdef)*** (0.04)	0.17 (0.00)	1.19 ***(a)*** (0.07)	0.18 (0.02)	1.89 ***(cd)*** (0.05)	67.42 (10.46)	21.60 (0.09)	61.10 ***(abcd)*** (4.32)	13.91 ***(cd)*** (0.39)	74.60 (1.07)
T2 Winter hand pruning- no inter tree pruning	2.39 ***(bcd)*** (0.06)	0.17 (0.00)	1.25 ***(ab)*** (0.06)	0.19 (0.03)	1.82 ***(bcd)*** (0.09)	59.84 (10.16)	21.54 (0.79)	64.15 ***(bcd)*** (2.59)	12.72 ***(bcd)*** (0.38)	73.81 (2.18)
T3 Pink bud- with inter tree pruning	2.50 ***(f)*** (0.04)	0.17 (0.00)	1.26 ***(ab)*** (0.06)	0.18 (0.01)	1.39 ***(a)*** (0.07)	56.34 (4.71)	22.04 (0.40)	81.92 ***(f)*** (1.20)	9.72 ***(a)*** (0.60)	77.54 (5.62)
T4 Pink bud- no inter tree pruning	2.46 ***(def)*** (0.03)	0.17 (0.01)	1.40 ***(c)*** (0.02)	0.14 (0.01)	1.56 ***(abc)*** (0.09)	62.51 (11.06)	22.44 (0.26)	67.55 ***(cd)*** (2.74)	11.79 ***(abc)*** (1.35)	72.93 (2.74)
T5 6 Leaf- with inter tree pruning	2.50 ***(f)*** (0.01)	0.18 (0.00)	1.35 ***(bc)*** (0.04)	0.18 (0.01)	1.56 ***(ab)*** (0.11)	65.33 (6.77)	21.84 (0.53)	69.52 ***(de)*** (3.92)	12.76 ***(bcd)*** (1.20)	76.39 (2.14)
T6 6 Leaf- no inter tree pruning	2.39 ***(bcde)*** (0.04)	0.18 (0.00)	1.41 ***(c)*** (0.05)	0.15 (0.03)	1.61 ***(abc)*** (0.14)	42.78 (3.53)	21.99 (1.05)	79.23 ***(ef)*** (6.12)	10.63 ***(ab)*** (0.94)	76.71 (2.34)
T7 9 Leaf- with inter tree pruning	2.34 ***(bc)*** (0.04)	0.17 (0.00)	1.26 ***(ab)*** (0.04)	0.17 (0.00)	1.59 ***(abc)*** (0.09)	65.55 (11.44)	22.25 (0.36)	58.14 ***(abc)*** (2.27)	13.58 ***(cd)*** (1.10)	71.52 (1.46)
T8 9 Leaf- no inter tree pruning	2.34 ***(bc)*** (0.06)	0.18 (0.00)	1.36 ***(bc)*** (0.04)	0.15 (0.02)	1.51 ***(ab)*** (0.07)	50.18 (4.45)	21.65 (0.58)	58.99 ***(abc)*** (2.00)	13.22 ***(bcd)*** (0.82)	72.04 (2.81)
T9 12 Leaf- with inter tree pruning	2.29 **(ab)** (0.07)	0.17 (0.01)	1.24 ***(ab)*** (0.04)	0.16 (0.03)	2.09 ***(d)*** (0.17)	45.86 (5.66)	21.94 (0.95)	50.88 ***(a)*** (3.94)	14.77 ***(de)*** (1.36)	65.55 (2.11)
T10 12 Leaf- no inter tree pruning	2.22 ***(a)*** (0.01)	0.18 (0.01)	1.31 ***(abc)*** (0.02)	0.16 (0.02)	2.08 ***(d)*** (0.22)	50.84 (13.15)	22.09 (0.20)	54.17 ***(ab)*** (4.88)	16.64 ***(e)*** (0.78)	68.13 (2.06)
Significance (P-value)	***0.0003***	*n.s*	***0.0252***	*n.s*	***0.0009***	*n.s*	*n.s*	***0.0000***	***0.0008***	*n.s*

Table 4. Fruit analysis results sampled 2 September 2014. Standard errors are given in parenthesis and the letters reflect the significance of treatments determined through ANOVA

Fruit analysis	**(mg/100g)**					**(mg/kg)**		
	N	**P**	**K**	**Mg**	**Ca**	**B**	**Fe**	**Mn**
T1 Winter hand pruning- with inter tree pruning	46.69 (1.89)	9.12 ***(ab)*** (0.13)	94.04 (1.83)	5.42 (0.06)	10.61 (0.18)	3.33 (0.17)	1.90 (0.12)	0.63 (0.05)
T2 Winter hand pruning- no inter tree pruning	44.16 (1.85)	8.74 ***(a)*** (0.20)	96.01 (4.07)	5.30 (0.29)	10.79 (0.53)	3.03 (0.40)	1.83 (0.09)	0.60 (0.04)
T3 Pink bud- with inter tree pruning	52.85 (3.43)	10.20 ***(c)*** (0.19)	97.71 (1.74)	5.52 (0.12)	9.73 (0.47)	3.49 (0.23)	1.71 (0.07)	0.56 (0.02)
T4 Pink bud- no inter tree pruning	54.36 (3.91)	9.50 ***(bc)*** (0.34)	103.38 (1.47)	5.75 (0.28)	10.11 (0.44)	3.42 (0.12)	1.86 (0.04)	0.67 (0.04)
T5 6 Leaf- with inter tree pruning	46.30 (1.82)	9.23 ***(ab)*** (0.43)	98.18 (2.84)	5.57 (0.26)	9.56 (0.72)	3.00 (0.22)	1.84 (0.17)	0.61 (0.06)
T6 6 Leaf- no inter tree pruning	47.54 (4.20)	8.93 ***(ab)*** (0.22)	95.15 (1.65)	5.32 (0.07)	9.47 (0.42)	2.96 (0.28)	1.62 (0.17)	0.52 (0.02)
T7 9 Leaf- with inter tree pruning	48.66 (0.92)	8.94 ***(ab)*** (0.15)	91.99 (1.99)	5.24 (0.05)	9.90 (0.24)	3.27 (0.03)	1.87 (0.13)	0.63 (0.06)
T8 9 Leaf- no inter tree pruning	49.51 (3.08)	9.18 ***(ab)*** (0.31)	98.76 (3.03)	5.65 (0.23)	10.15 (0.61)	3.13 (0.41)	1.89 (0.17)	0.61 (0.03)
T9 12 Leaf- with inter tree pruning	48.37 (1.86)	9.06 ***(ab)*** (0.25)	93.00 (2.42)	5.35 (0.16)	10.68 (0.64)	3.23 (0.38)	1.47 (0.13)	0.54 (0.03)
T10 12 Leaf- no inter tree pruning	46.02 (1.68)	9.09 ***(ab)*** (0.12)	95.27 (3.02)	5.43 (0.13)	10.89 (0.83)	3.27 (0.23)	1.90 (0.07)	0.61 (0.04)
Significance (P-value)	*n.s*	***0.0281***	*n.s*	*n.s*	*n.s*	*n.s*	*n.s*	*n.s*

Discussion

As the trial progresses the trees are reacting to the pruning treatments. It should be noted that the orchard is not vigorous and the differences in growth response and yield could be much greater in orchards that are stronger. The inter tree pruning plots are tending to have slightly more growth, lower yields, larger fruit and sweeter fruit but these differences were not significant in 2014.

Shoot growth was again reduced as the timing of the mechanical cuts was delayed, with the latest cut at the 12 leaf stage only producing 3-4cm of new growth compared to over 25cm for the winter pruned control and 18-19cm in the plots pruned at pink bud.

Where tree control is the major consideration delayed pruning is advised.

This year there were no statistical differences in yield between any of the plots. This is in contrast to previous years when the winter pruned control plots have yielded significantly higher yields. In the first year of the trial the volume of cropping wood in the mechanically pruned plots was reduced by the treatments. As the trees have responded to the treatments, more fruit wood has built up and the mechanically pruned trees are better furnished now resulting in more cropping within the narrower tree canopy. Cumulative yields are still highest in the hand pruned controls.

Where trees are well controlled and not vigorous the timing at which pruning is carried out appears to be less critical in terms of yield, but growers must be aware that more regrowth results from cuts close to blossom.

This year the pruning cuts at pink bud, where inter tree pruning was carried out, appeared to have a benefit in terms of improved fruit size and sugars. The significant reduction of fruit sugar levels seen in the later summer cuts in the early years of the trial was not repeated in 2014.

The plots pruned at pink bud had higher nitrogen and potassium levels in the leaves but whether these had a direct influence on fruit size and sugar levels is not understood.

Fruit ripened at a similar time in all the plots.

Conclusions

The large differences in yield and °Brix levels are beginning to even out as the trees settle down.

The large significant differences in growth response to the cuts at the different stages through the season are consistent through the years and must be taken into account by growers contemplating mechanical pruning.

As with all pruning interventions it is critically important that the grower and his staff "read the tree" each year and understand the implications of the degree and the timing of the pruning, in terms of their effects on yield, growth and fruit bud development.

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Technology Transfer

- Results from the 2014 season were presented at the FAST LLP growers' conference in February 2015 by Ivan Velasco.

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.