Project title:	Comparison of different planting material for fruit wall orchard systems for apple
Project number:	TF 206
Project leader:	Tim Biddlecombe, Fruit Advisory Services Team LLP
Report:	Annual report 2015
Previous report:	Annual report 2014
Location of project:	Fruit Advisory Services Team LLP, Brogdale Farm, Brogdale Road, Faversham, Kent, ME13 8XZ
Industry Representative:	Mark Holden, Adrian Scripps Ltd.
Date project commenced:	01 December 2012
Date project completed (or expected completion date):	31 March 2019

DISCLAIMER

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.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

Tim Biddlecombe

Managing Partner

Fruit Advisory Services Team LLP

Signature .... Date ....

Report authorised by:

Dr William E Parker

Director of Horticulture

The Agriculture and Horticulture Development Board

Signature .... Date ....

CONTENTS

GROWER SUMMARY

Headline

- Records and assessments of five different tree types for establishing Fruit Wall orchards commenced in 2014 and showed that the larger two year old tree types yielded most fruit and one year un-feathered trees the least.

Background and expected deliverables

Growers in many countries are actively looking for ways to reduce labour inputs and increase the use of mechanical aids in a range of fruit crops. With a general decline in skilled labour, ease of management is another requirement, but in all these developments it is essential that there is no loss of yield or quality. In fact, an increase in yields will be required to enable growers to maintain profitability.

Following the successful development and commercial uptake of the Concept Orchard (AHDB Horticulture Project TF 151) by many UK growers, further evolution and development of more intensive planting systems is being considered. In TF 151, reference was made to 'Le Mur Fruitier', a newly developed orchard system in France. Further developments of this system have been carried out privately and at the PC Fruit Research Station in Sint Truiden, Belgium. Generally this work has been done in existing orchards that have been adapted to the new pruning regime and generally on varieties not grown in the UK. Results have shown that the principles developed in the work by CTIFL in France can apply in more northern growing areas. However, they need to be adapted to local growing conditions and varieties, as the timing of pruning is critical and specific to individual varieties, whilst the length of the growing season varies in different geographical areas.

Little work has been done on ways of establishing Fruit Wall orchards and which type of tree gives the best results. Conventionally produced trees have a form and structure ideally suited to wider spacings, where a branch framework is necessary, but they can be adapted to be managed in a Fruit Wall planting. However, other tree types may be more suitable, either because they are cheaper and can be planted more intensively at the same cost per hectare, or because they have been specifically grown in the nursery to form a narrow, tall tree potentially giving higher, early yields.

Several specialist nurseries are developing tree types designed and grown especially for Fruit Wall orchards. These include 'grow through trees' from several nurseries, and

Bibaum® trees from Mazzoni nurseries. Other nurseries recommend that using a maiden tree or an 8 month tree at a close planting distance can give better results. This project will provide a comparison of five different tree types using a standard variety/ rootstock and spacing, and provide growers with comparable data to allow them to make informed decisions about the best tree type to use for their own situation.

Summary of the project and main conclusions

The trial was established to compare the performance (yield and grade out) of different nursery tree types when planted in an intensive orchard managed using the Fruit Wall system. Trees were planted and established during 2013.

2014 was the first fruiting season of the trial when records and assessments commenced.

There were statistically significant differences between yields - two year old tree types yielded most fruit and one year un-feathered the least.

A delay in applying one spray for scab resulted in an infection at the fruitlet stage which resulted in a high incidence of fruit scab at harvest. As the infection affected the whole area, the results from 2014 can still be used to compare the different tree types.

Most waste fruit was caused by scab rather than tree type or Fruit Wall pruning effects.

The trees have yet to fill their space and develop lateral branches, but the two year old trees are more advanced in this respect.

Financial benefits

It is too early in the trial to determine any financial benefits.

The trial is responding to the industry’s need to shorten payback periods and to produce guidance on the cropping potential of different tree types in the early years.

The cost of establishing an intensive orchard is currently between £22k and £28k per hectare. In particular:

- The differences in cost of the various tree types available is quite small (typically around £0.50 per tree or £1,500 per ha), but a reduction in yield of 5% in each of the first four cropping years can reduce net returns by around £3,000 per ha. Some tree types have the potential to fill their space, vertically and horizontally, much more quickly, leading to increases in early yields, whilst others require more inputs in terms of pruning and thinning in order to achieve successful establishment.

- Although new intensive orchard systems are simpler and easier to prune than lower density traditional orchards, it can still take between 25 and 40 man hours to prune a 1 hectare orchard. Rates of mechanical pruning are between 1.5 and 2.5 hours per ha depending on planting distance. Some hand pruning will be needed even where mechanical pruning is used but net savings of around £3,000 per ha over a 15 year orchard life are envisaged (net of machinery cost).

- Anecdotal evidence from experimental plots in Northern Europe suggests that annual yields from Fruit Wall plantings can be around 20 tonnes per ha greater than orchards of a similar density managed conventionally. The value to the grower of this increase would be approximately £21,000 net of all post harvest costs over 15 years.

- For growers to implement the system, they would have to rent or buy specialist pruning equipment. Current costs for this type of equipment are in the region of £14,000, but the machine also has the capability of being used for other operations on the farm such as hedge and windbreak cutting.

- There will be a need for good technology and knowledge transfer and possibly further development work. This is because the interaction between the Fruit Wall growing system and other orchard management operations (such as use of growth regulators for fruit setting and thinning) could well be different (possibly due to the effects of late pruning on leaf metabolism at a critical time of year during the early fruit development phase). As the leaf to fruit ratio is altered in the Fruit Wall, more attention to crop nutrition and leaf health will be necessary.

Action points for growers

- The 2014 season was the first fruiting season of the trial.
- The Fruit Wall cut was carried out when 9 new leaves had emerged on the current season's growth. To determine this, growers need to make random leaf counts regularly to establish the growth stage before making the cut.
- Other actions points will be determined in future years when it is established which tree type may be most suitable to Fruit Wall management in terms of early yield build up and highest yield of class 1 fruit.

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 1 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 it requires 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 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 a 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 1 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 will be 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 the narrow A-shape 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 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 re-growth and flower bud formation. This is also true for other crops such as cherry - 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 the bud behind the cut will form a shoot, reducing flower bud formation. However, if the cut is made too late the buds do not have enough time and resources to form a fruit bud and will then remain vegetative. The optimal date for the Fruit Wall cut to be made may vary between varieties and between different seasons. Therefore, it is essential to relate the time of the cuts to an easily identified growth stage.

The aim of the trial is to compare different planting material for Fruit Wall orchard systems for apple by assessing performance (yield and grade out) and tree volume.

Materials and methods

The six year trial was established in 2013.

Gala trees (clone Royal Beaut) were sourced from specialist nurseries.

The trees were planted in March 2013 at Brogdale Farm, Faversham.

The site, soil type clay loam with flint, had been fallow for at least 10 years.

The trees were planted at a distance of 3.5m by 0.8m.

A post and wire system with bamboo canes supports the trees.

The trees were not irrigated during establishment.

A standard commercial programme of foliar nutrition, disease and pest sprays plus herbicides has been applied since establishment.

The five different tree types selected were:

1. 1 year 5 + branches
2. 1 year unfeathered
3. 2 year old (grow through)
4. Standard knip
5. Twin stem

The trial area consists of a randomized complete block with each of the five growing systems replicated in 6 blocks (rows) – see Figure 1.

Figure 1. Trial plan

Twin stem	2 year old grow through	1 Year 5 + branches	1 year unfeathered	Standard knip	1 year unfeathered
2 year old grow through	1 Year 5 + branches	Standard knip	2 year old grow through	1 year unfeathered	Twin stem
1 year unfeathered	Twin stem	2 year old grow through	Standard knip	1 Year 5 + branches	Standard knip
1 Year 5 + branches	Standard knip	1 year unfeathered	Twin stem	2 year old grow through	1 Year 5 + branches
Standard knip	1 year unfeathered	Twin Stem	1 Year 5 + branches	Twin stem	2 year old grow through
Block 1	**Block 2**	**Block 3**	**Block 4**	**Block 5**	**Block 6**

Each row has one plot of 10 trees of each tree type (except for twin stems which have five trees but 10 stems), making 300 trees in total on approximately 0.09ha. The middle eight trees (three trees for twin stems) were used for recording and sampling and the end two trees in each plot are guards – see Figures 2 and 3.

Figure 2. Plot layout –except twin stems

	1 guard tree	**8 trees used for recording**	**1 guard tree**	

Figure 3. Plot layout – twin stems

	1 guard tree	**3 trees used for recording (6 stems)**	**1 guard tree**	

During 2013 the trees received minimal pruning by hand to remove excess branches (any that were too strong or too weak) and all fruit was removed in order to ensure that the trees established well.

Growth stages were monitored regularly during early 2014 and shoot growth assessments commenced in May in order to establish when to prune at the 9-leaf stage. This occurred on 10 June.

Photographs of trees before and after the 9-leaf cut in 2014 cut are included in Appendix 1.

In summer 2014, all trees were thinned to two fruit per cluster on branches below 1.5m and one fruit per cluster on branches above 1.5m. Trees also received minimal summer pruning, mainly removal of double leaders on most tree types except twin stems.

Fruit was harvested on 25 September 2014 according to industry guidelines (Quality Fruit Group predictions), placed into cold store and assessed later for quality and size.

Height and spread were measured during the winter of 2104/2015 and tree volume calculated. NB – each twin stem tree was treated as two trees and height and spread for each stem measured separately (making six in total rather than eight for the other tree types).

Assessments

In order to determine the correct date to carry out the Fruit Wall cut at the 9-leaf stage an initial assessment of extension growth was made on 19 May. Detailed measurements were carried out on the 28 May and 10 June. One shoot on both sides of each tree or stem was assessed (20 shoots per plot). Average numbers of leaves were calculated and are shown in Table 1 below.

Table 1. Leaf counts

Date	**Tree type**	**Mean leaf count**	**Overall mean**
19 May	All	6	**6**
28 May	1 year 5 + branches	6.7	**6.5**
	1 year unfeathered	6.4	
	2 year old grow through	6.5	
	Standard knip	6.5	
	Twin stem	6.4	
10 June	1 year 5 + branches	9.3	**9.1**
	1 year unfeathered	8.9	
	2 year old grow through	9	
	Standard knip	9.1	
	Twin stem	9.1	

The Fruit Wall cut was made on 13 June 2014 when the shoot extension growth had reached a mean of 9.1 leaves. The branches were cut back by hand (simulating a mechanical cut) to a maximum length of 40cm each side at the base of the tree and 20cm at the apex (giving a total width per tree of 80cm and 40cm respectively).

The total yield (kg) was recorded in each plot at harvest on 25 September 2014. Average yield per tree and average yield per stem were calculated. A random sample of 100 fruits from each plot was collected at harvest, placed in cold storage and measured during the autumn for fruit size and quality (Class 1; Class 2 and Waste). The average fruit weight (g) was calculated. The percentage of total yield by size category was calculated together with percentages of fruit within each class category (weight (g)).

Tree heights and spreads were measured in winter 2015 and tree volume calculated.

Statistical analysis

Statistical analysis was carried out using Analysis of Variance (ANOVA) and multiple range tests (MRTs) used to determine whether the differences between individual treatments were statistically significant. Graphs are shown with standard error bars (where applicable) and the results of the MRTs are indicated by letters (homogenous groups) where statistically significant effects were shown (and where the P value = < 0.05).

Results

Yield

Yield data was recorded at harvest on 25 September 2014 – see Table 5 and Figures 4, 5 and 6.

Table 2. Total yield per tree type, mean yield per tree and per stem (kg)

TREE TYPE	Total yield per tree type (kg)	Mean yield per tree (kg)	Mean yield per stem (kg)
1 year 5 + branches	235.5	3.9	3.9
1 year unfeathered	89.4	1.5	1.5
2 year old	319.8	5.3	5.3
Standard knip	200.7	3.3	3.3
Twin stem	136.8	4.6	2.3

The total yield of all plots for each tree type was between 319.8kg and 89.4kg. The 2 year old trees had the highest yields and the 1 year unfeathered trees had the lowest yields. The results were statistically significant.

The differences in average yields per tree were statistically significant. The highest average yield per tree was 5.3kg for 2 year old trees. The lowest average yield per tree was 1.5kg for 1 year unfeathered trees.

The differences in the average yield per stem were statistically significant. The highest yields per stem, 5.3 kg, were for 2 year old trees and the lowest, 1.5kg, for 1 year unfeathered trees.

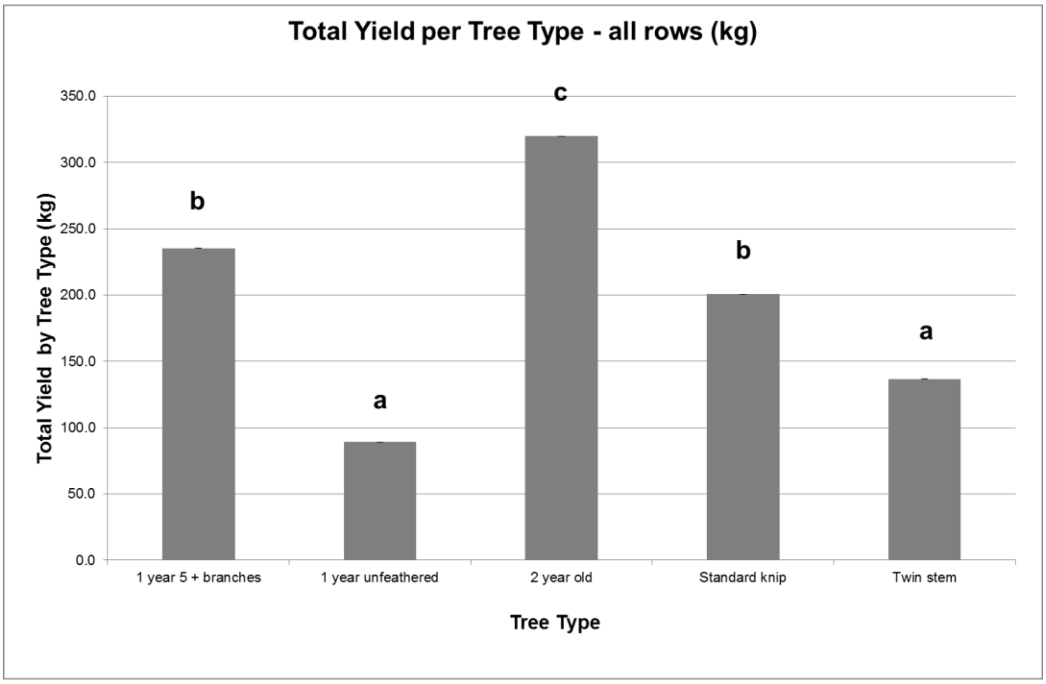

Figure 4. Total Yield per Tree Type (kg). Standard error bars are shown (and are very small in this instance). Letters indicate homogenous groups reflecting statistically significant differences. For this analysis P<0.0001

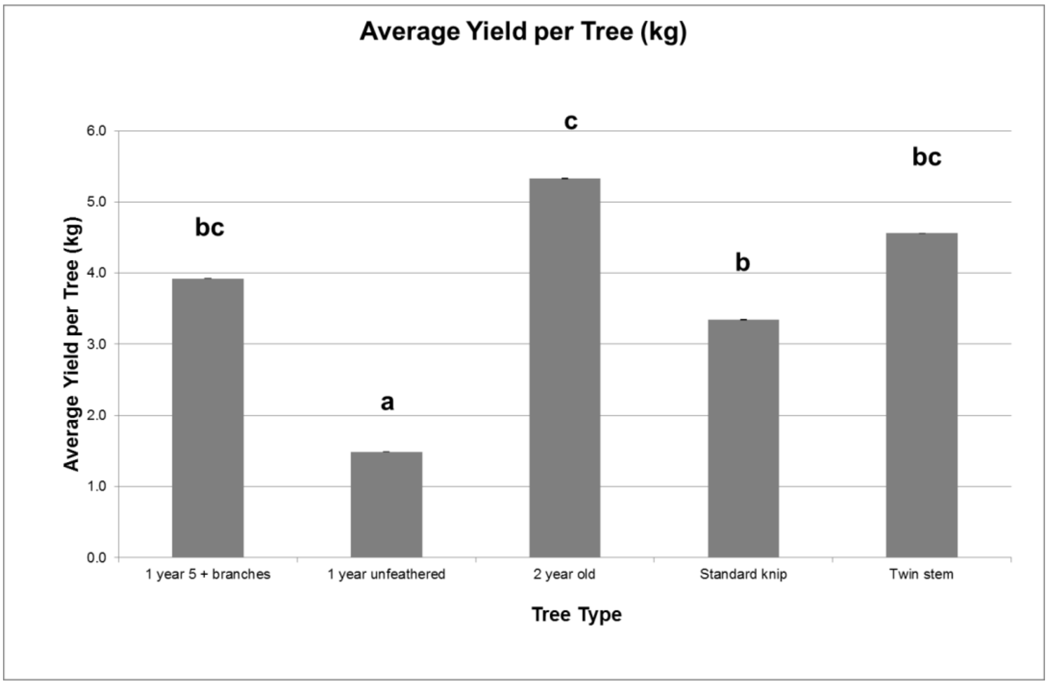

Figure 5. Average Yield per Tree (kg). Standard error bars are shown (and are very small in this case). Letters indicate homogenous groups reflecting statistically significant differences. For this analysis P=0.0005.

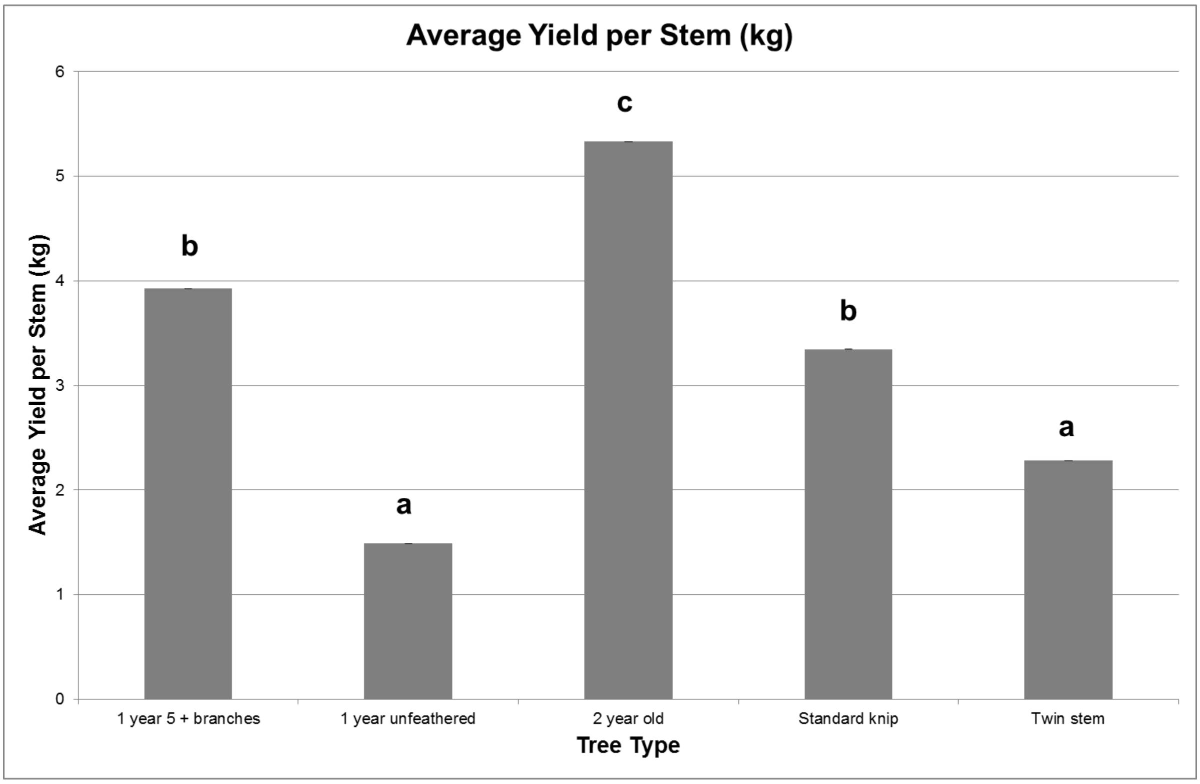

Figure 6. Average Yield per Stem (kg). Standard error bars are shown (and are very small in this instance). Letters indicate homogenous groups reflecting statistically significant differences. For this analysis P<0.0001.

Fruit weight

Average fruit weight was calculated from the 100 fruit randomly sampled at harvest – see Table 3.

Table 3. Average fruit weight

Tree type	**Average fruit weight (g)**
1 year 5 + branches	132.8
1 year unfeathered	130.3
2 year old	135.1
Standard knip	128.5
Twin stem	147.7

Average fruit weight was between 147.7g and 128.5g. Twin stem trees had the largest fruit and standard knip trees the smallest. There were statistically significant differences between twin stem average fruit weight and the other tree types –see Figure 7.

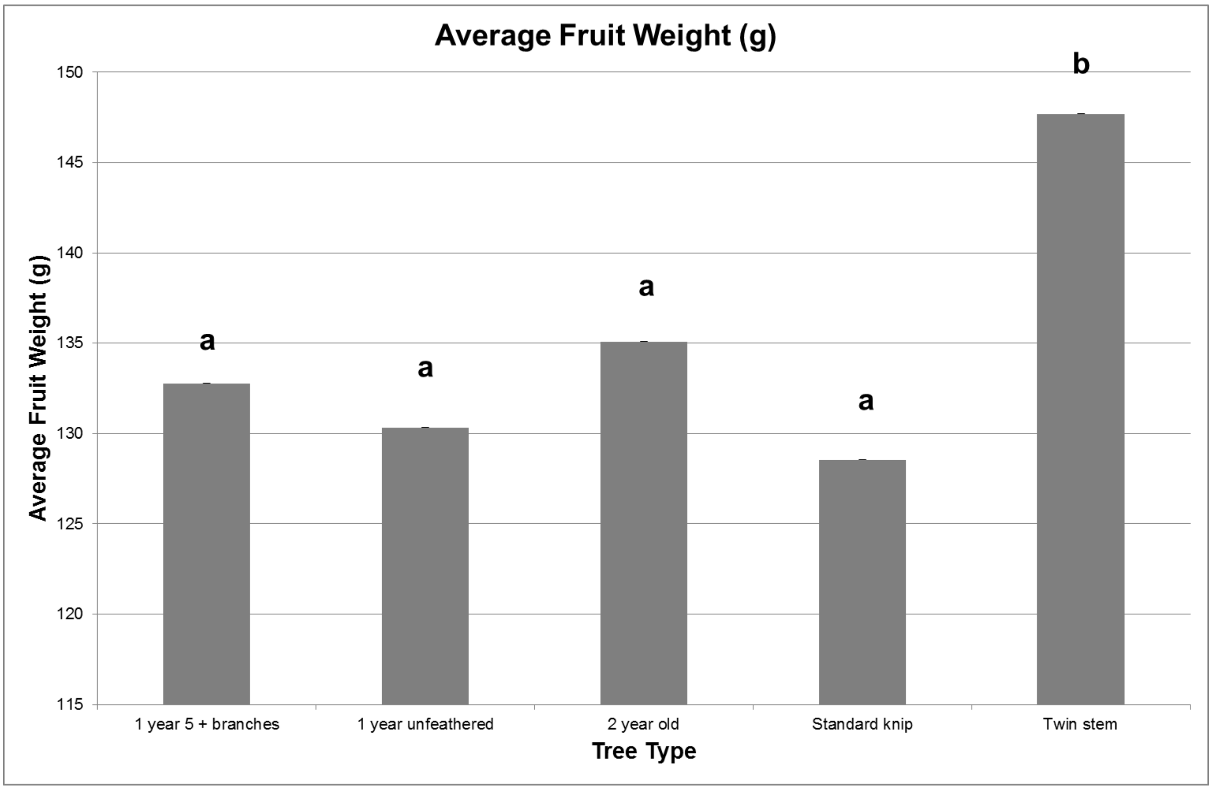

Figure 7. Average Fruit Weight (g). Standard error bars are shown (and are very small). Letters indicate homogenous groups reflecting statistically significant differences. For this analysis P=0.0019.

Fruit size

Fruit was assessed for size after harvest – see Table 4 and Figure 8.

Table 4. Percentage of total yield by weight within size categories

Size / tree type	1 Year 5 +	1 year unfeathered	2 year old	Standard knip	Twin stem
< 55mm	1.5	1.7	1.8	2.4	0.7
55-60mm	6.5	5.9	5.4	8.4	2.9
60-65mm	19.1	17.3	16.6	19.2	10.2
65-70mm	31.8	33.4	33.1	30.3	28.3
70-75mm	29.0	27.7	31.0	31.3	31.2
>75mm	12.1	13.9	12.1	8.3	26.7

The tree type with largest percentage of oversized fruit (>75mm) by weight within total yield was twin stem (26.7%) and the smallest percentage was standard knip (8.3%).

The tree type with the greatest percentage of undersized fruit (<60mm) by weight within total yield was standard knip with 10.8% and the least was twin stem with 3.6%.

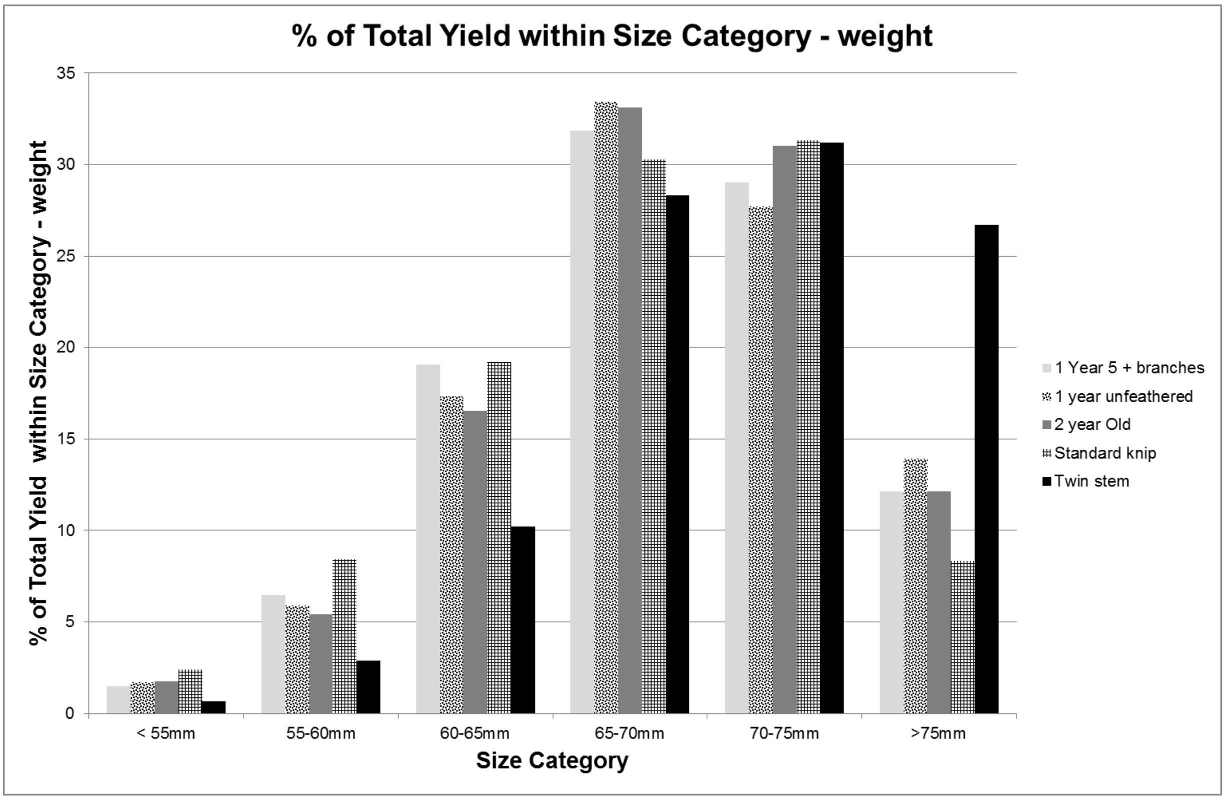

Figure 8. % of Total Yield within Size Category by weight.

Quality

Quality assessments were made after harvest during autumn of 2014 – see Figures 9 and 10.

When comparing Class 1 and Class 2 fruit, 1 year 5 + trees had the highest percentage of Class 1 fruit (59.3%) and twin stem the lowest (38.1%).

Overall quality was poor with a large percentage of waste in the total yield. The highest percentage of waste within total yield was for 2 year old trees (57.9%) and the lowest for 1 year unfeathered trees (39.2%).

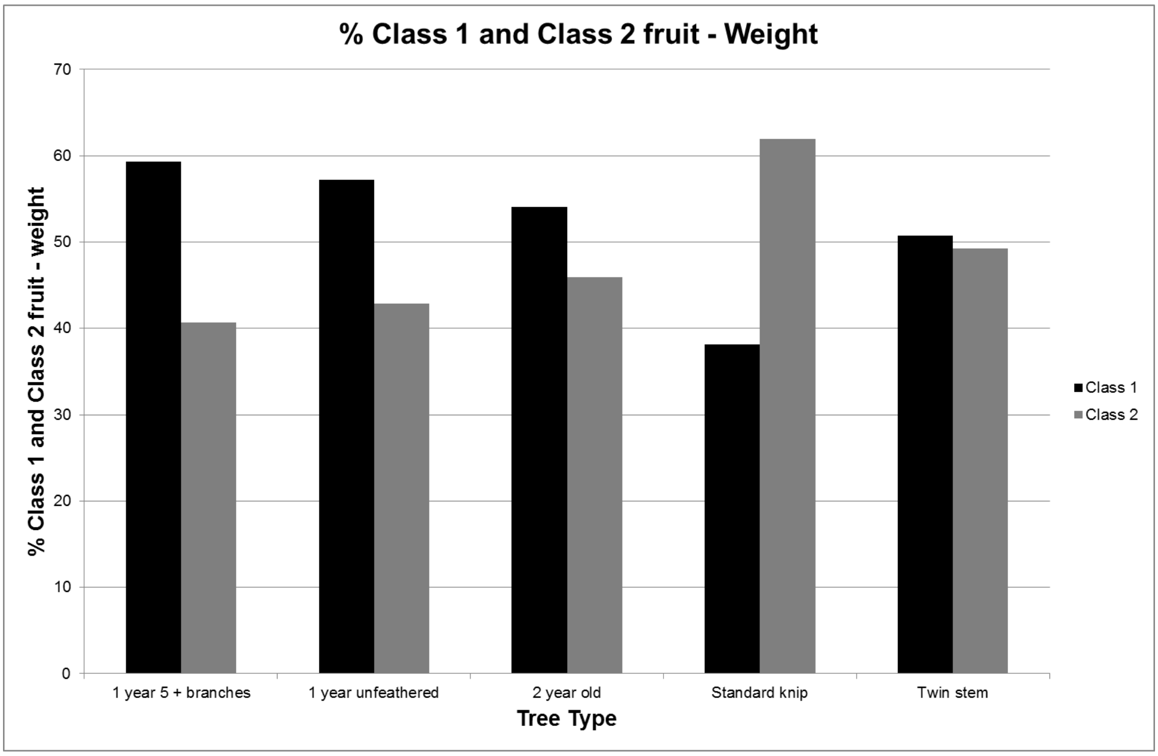

Figure 9. % of Class 1 and Class 2 fruit - weight.

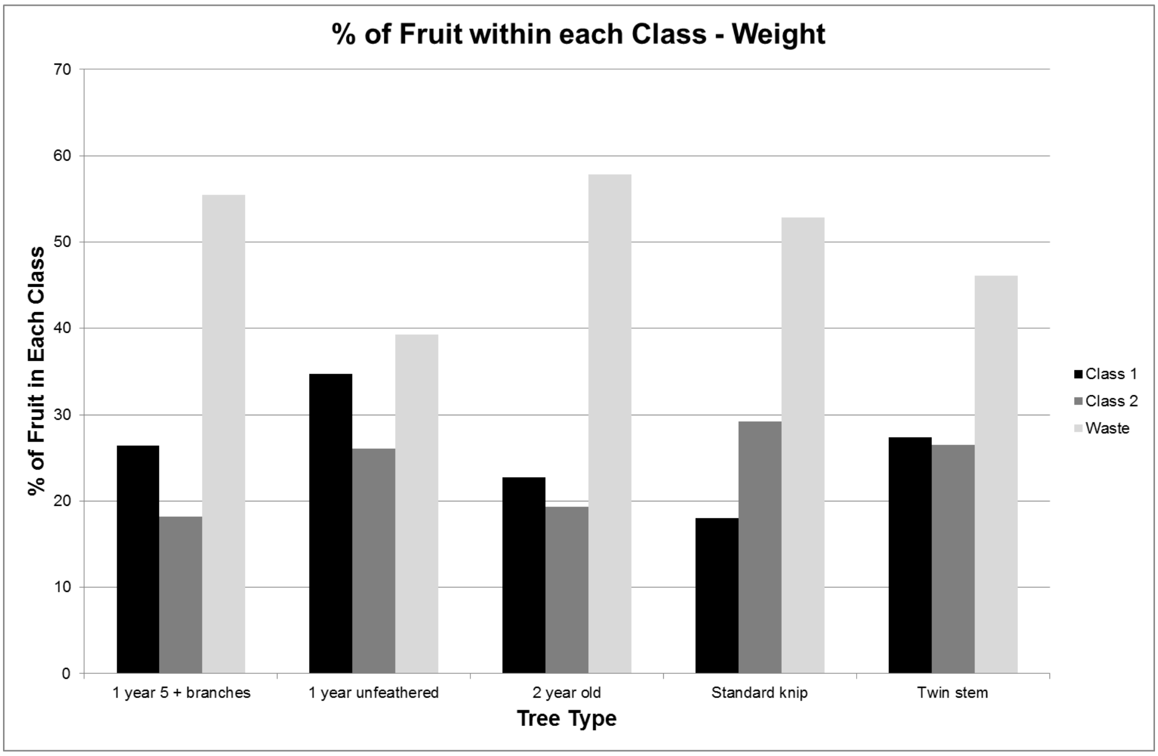

Figure 10. % of Fruit within each Class - weight.

Tree height, spread and volume

Tree height and spread were measured during winter of 2014/2015 and the volume calculated.

The average tree height varied between 245.5cm for 2 year old trees and 197.3cm for twin stem trees. The differences in the average tree height were statistically significant– see Figure 11.

The average spread varied between 111.2cm for 2 year old trees and 65.7cm for twin stem trees. Statistically significant differences between tree types were noted– see Figure 12.

The average tree volume varied between 0.70m³ for 2 year old trees and 0.24m³ for twin stem trees. There were statistically significant differences between tree types for tree volume– see Figure 13.

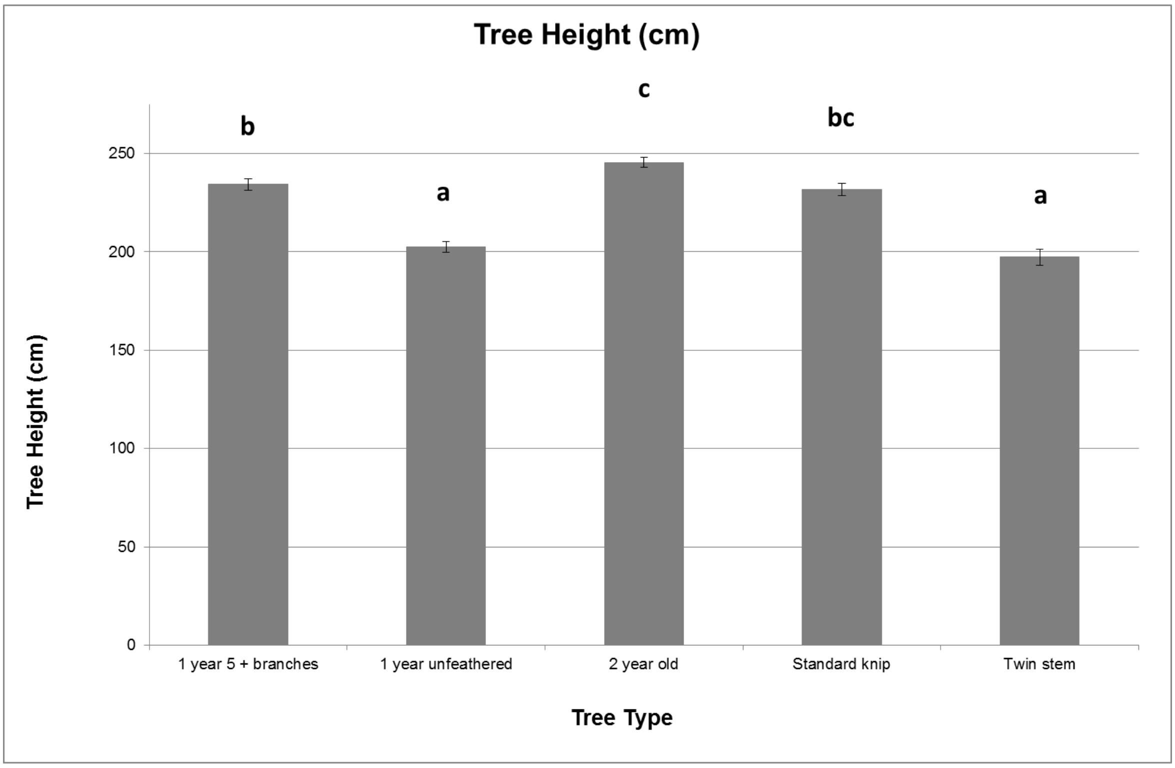

Figure 11. Tree Height (cm). Standard error bars are shown. Letters indicate homogenous groups reflecting statistically significant differences. For this analysis P<0.0001.

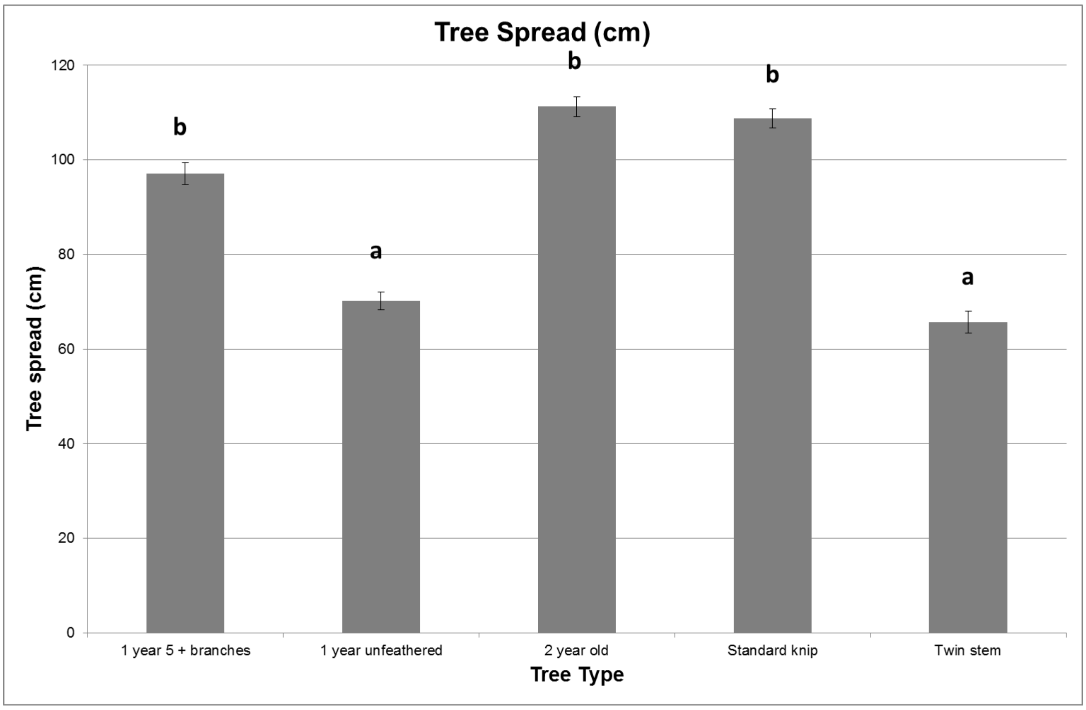

Figure 12. Tree Spread (cm). Standard error bars are shown. Letters indicate homogenous groups reflecting statistically significant differences. For this analysis P=0.0003.

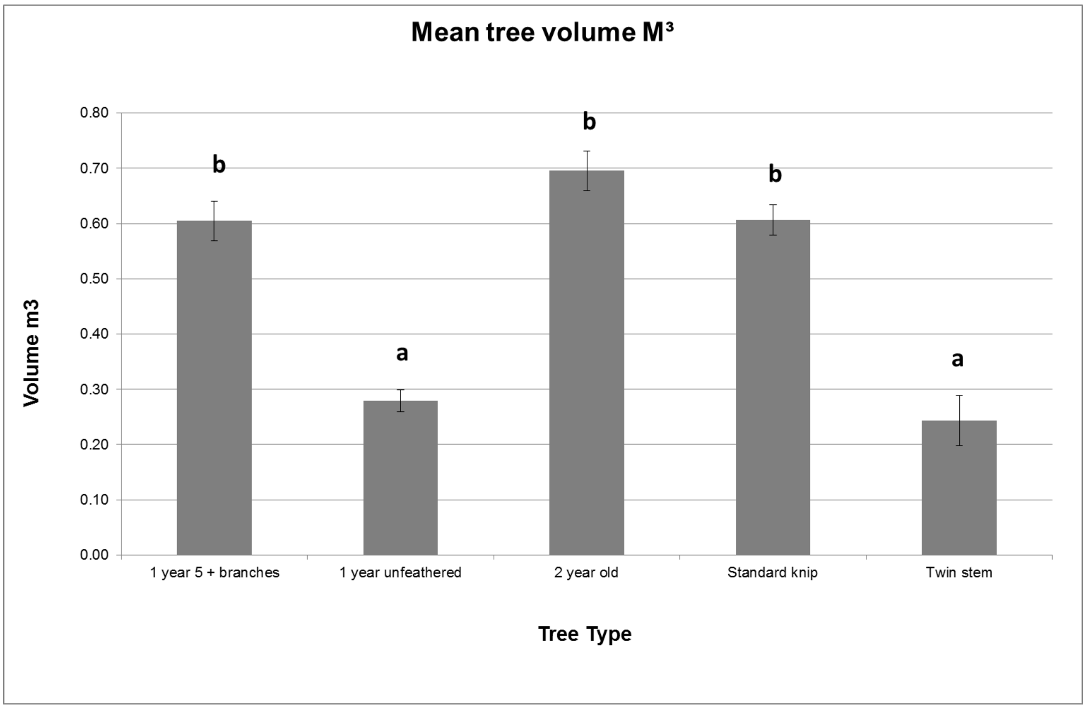

Figure 13. Tree Volume (m^3). Standard error bars are shown. Letters indicate homogenous groups reflecting statistically significant differences. For this analysis P<0.0001.

Discussion

In 2014 yields were variable. This is to be expected with trees of different ages and growing methods in the nursery. It is not surprising that 2 year old trees had the greatest yield, nor that the 1 year unfeathered yielded the least because of their ages and treatment in the nursery.

Average fruit weight differences were statistically insignificant between all tree types except twin stem. This may be due to the twin stem trees having a more open tree structure in 2014 compared to the others and fewer, therefore larger, fruit.

The percentage of oversize fruit for all tree types in 2014 was quite high. This may be expected with immature trees which have yet to fill their space, having fewer fruit and yet to achieve a full crop load.

Quality was very poor in 2014. It was a high risk year for scab with multiple and severe infection periods (see Appendix 1). A delay in applying one spray for scab allowed an infection in at the fruitlet stage which resulted in a high incidence of fruit scab at harvest and a high percentage of waste within total yields. Most waste fruit was due to scab. The infection affected the whole trial area and so the results from 2014 can still be used to compare the different tree types.

Tree heights for less mature trees (e.g. 1 year unfeathered) and twin stems were less during the first year of fruiting because of their structure and treatment in nursery. The difference in tree spread between tree types is also due to their structure e.g. twin stem and unfeathered trees have yet to develop lateral branches. The statistically significant differences in these results and for tree volume are unsurprising.

The objectives have been achieved via following the programme of work and specifically:

A. To select five different tree types with potential for use in the Fruit Wall System;
Achieved during 2012/2013 when trees were planted and having established during 2013;

B. To measure the performance of each tree type under the same Fruit Wall management technique over 5 cropping years by recording yield and grade out;
Partially achieved through assessments and records during 2014 and continuing;

C. To measure tree volume by recording height and spread each year;
Partially achieved through assessments and records during 2014 and continuing;

D. To provide growers with guidance on the attributes including cost of establishment and of the different tree types, so that they can make informed decisions with establishing new orchards;

Partially achieved through assessments and records during 2014 and reports for 2013 and 2014 and continuing;

E. To communicate the results of the trial via grower meetings, AHDB Grower articles and open day(s) at the trial site;
   Partially achieved via AHDB Grower articles 2014 and 2015 and at the FAST Members Conference 2015 and continuing.

Conclusions

- The speed at which newly planted trees can fill their space and achieve good yields in the early years after planting are crucial to the success of new orchards. Already the trial is showing significant differences in both these measures.
- Despite the differences determined in 2014 it is not yet conclusive which tree type is most suited to growing in a Fruit Wall system.

Knowledge and Technology Transfer

Results from 2014 were presented at the:

- FAST LLP growers' conference in February 2015.
- An article for the AHDB Grower was submitted in March 2015 for publication in May.

References

Abbot, (1974); cited in 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.

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.

AHDB Horticulture, (May 2005). Concept Orchard TF 151. AHDB Grower (May 2005).

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.

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

Appendices

Appendix 1

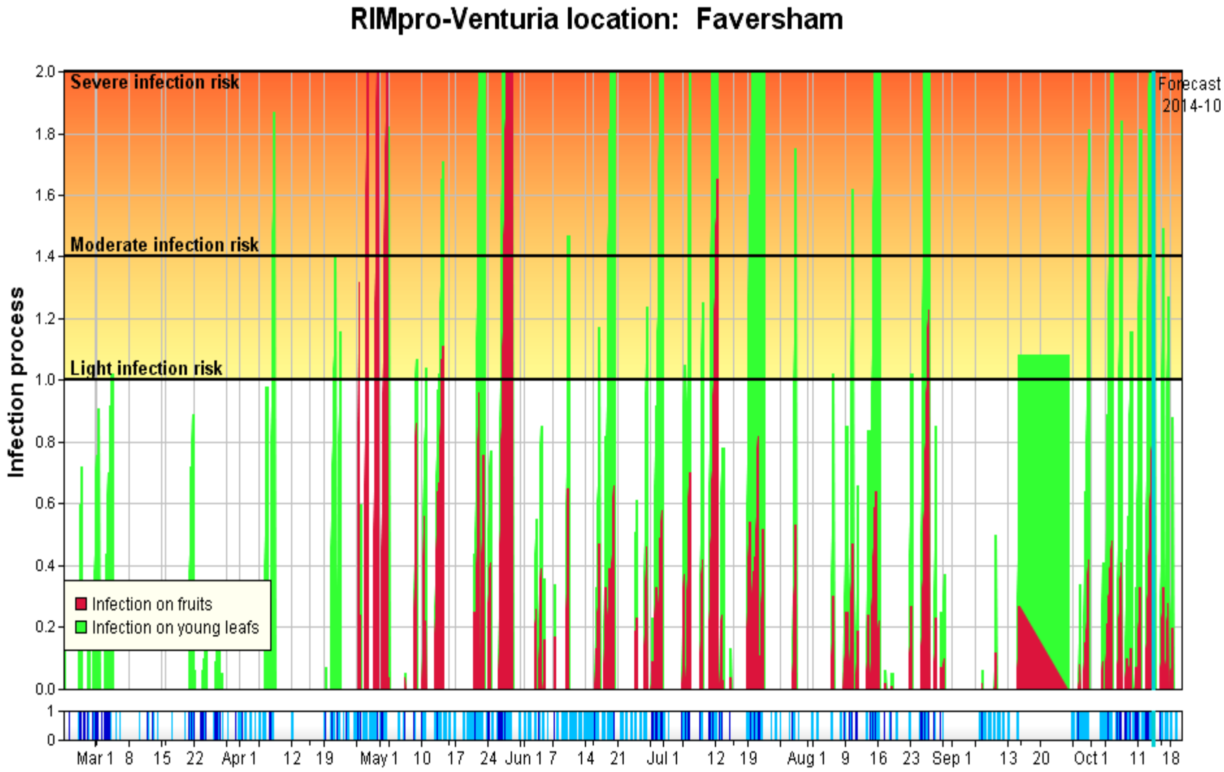

Diagram 1. Scab infection events for 2014.

Appendix 2



Photograph series 1. Standard knip - plots before 9 leaf cut, after 9 leaf cut and after thinning.



Photograph series 2. 1 year unfeathered - plots before 9 leaf cut, after 9 leaf cut and after thinning.



Photograph series 3. 1 year 5 + branches - plots before 9 leaf cut, after 9 leaf cut and after thinning.



Photograph series 4. 2 year old grow through - plots before 9 leaf cut, after 9 leaf cut and after thinning.



Photograph series 5. Twin stem - rows before 9 leaf cut, after 9 leaf cut and after thinning.

