Forest Research

Short Rotation Forestry Trials in Scotland

Progress Report

2017

The Research Agency of the Forestry Commission

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Executive Summary

Six Energy Forestry trial sites have now been established across Scotland; four planted in 2010, one in 2011 and one in 2012. In addition, two trials were planted in Orkney in 2013. Further plantings of alternative species have also been added to the mainland sites during 2015 and again in 2016.

Having reached six years of age, the 2010 species and eucalyptus trials are not due a growth and survival assessments this year, the next planned measurement for these sites will be at year 10 (end of 2019). However, last year's age 6 height data has been used to compare against the performance of the newer species trial sites measured at the end of the 2017 growing season, see previous report for full details of earlier trials.

As per last season, hybrid aspen appear to have the most potential for use in SRF systems on these sites as it is tolerant of site conditions and able to grow fast. Hybrid larch also performed very well, but future planting may be limited due to *Phytophthora ramorum*. Common alder, silver birch and Sitka spruce may also have potential on certain site types, but do not appear to be universally suitable for SRF.

Although red alder has the greatest mean height after 6 years across all sites, it also had the lowest survival rate and appears to be largely unable to tolerate site conditions. A similar pattern is emerging with Italian alder and, on some sites, common alder. However, total biomass may still be comparable to species with higher survival rates but lower growth so these species should not be entirely written off until assessments of total biomass and density have been carried out.

In contrast, ash and sycamore (and sweet chestnut at some sites) had high survival rates and appear to be the most tolerant of site conditions, but growth rates were very low. Further monitoring will show whether growth rates of these species improve as the trees become fully established.

Further monitoring and assessment of the trials will confirm whether these early trends continue, and will allow volume to be calculated indicating which species are the most likely productive SRF candidates.

There has also been an increasing interest in growing more Native aspen in Scotland, a selection of clones were planted out at five of the existing SRF sites in March 2016 (not Sibster) and this report now contains the first two years of establishment figures for these.

The trials are continuing to make a significant contribution to improving our knowledge of SRF in Scotland. The demonstration value of the sites is increasing, with a greater visual impact to practitioners, researchers and policy makers throughout Scotland. As the rotation progresses, this value will continue to be built upon.

Background

Wood fuel has an important role in contributing to the Scottish Government's climate change and renewable energy targets, particularly the target for renewable heat. Currently the majority of the wood fuel used in Scotland comes from the conventional forest resource (waste wood is around one third of total wood fuel use) and there may be a role for Short Rotation Forestry (SRF) to produce wood fibre specifically for the wood fuel market with the benefit of obtaining the fibre on a reduced rotation.

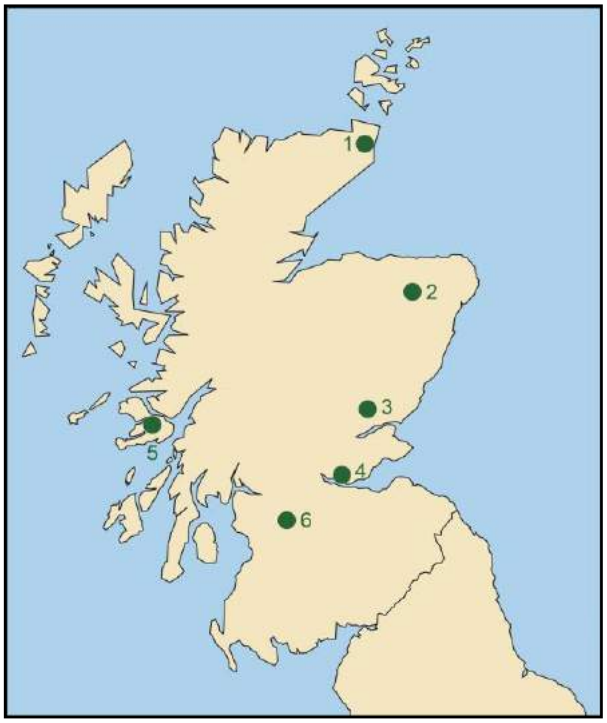
However, there was little current knowledge of SRF in the UK and so in 2007 Forestry Commission Scotland (FCS) and Forest Research (FR) began developing a network of Energy Forestry (EF) exemplar sites. The aim was to address the important information gaps on the growth of short rotation forestry in Scotland, as well as being a practical, operational demonstration of its potential. As these trials mature, information from the exemplar sites will highlight the opportunities for these new crops to foresters and farmers as well as providing useful new data on the growth of tree species in their early years.

Establishment of the trial sites

Six trial sites have now been established in Scotland. These are all ex-agricultural sites with the exception of Aros which is a restock site, previously a Sitka spruce crop (Table 1; Figure 1).

Table 1: Location and land use history of the six trial sites

Site	Altitude (m)	Aspect	NGR	History
Sibster	30-40	West	ND147597	Ex-arable
South Balnoon	180-210	North east	NJ645428	Livestock farming
Alyth	210-220	South	NO235493	Ex-agricultural
East Grange	45-60	South	NS993891	Ex-agricultural
Aros	30-90	South	NM541456	Sitka spruce restock
Auchlochan	225-245	West	NS829404	Ex-agricultural



1. Sibster, North Highland FD
2. South Balnoon, Moray & Aberdeenshire FD
3. Alyth (Westfield), Tay FD
4. East Grange, Scottish Lowlands FD
5. Aros (Mull), West Argyll FD
6. Auchlochan, Scottish Lowlands FD

Figure 1: Map showing the locations of the six full SRF trials.

At each of the six sites a fully replicated randomised block experiment was established trialling species likely to have fast early growth of high-density timber suitable for use in SRF. The following 10 species were originally planted:

Sycamore (Acps)	*Acer pseudoplatanus* L.
Italian alder (Alco)	*Alnus cordata* Desf.
Red alder (Alru)	*Alnus rubra* Bong.
Silver birch (Bepe)	*Betula pendula* Roth.
Sweet chestnut (Casa)	*Castanea sativa* Mill.
Ash (Frex)	*Fraxinus excelsior* L.
Hybrid larch (Lama)	*Larix x marschlinsii* Coaz
Common alder (Algl)	*Alnus glutinosa* (L.) Gaertn.
Hybrid aspen (Potr)	*Populus tremula* L. *x tremuloides* Michx.
Sitka spruce (Pisi)	*Picea sitchensis* (Bong.) Carr. (from vegetative propagation)

A second experiment at each of the sites planted in 2010 trialled a range of Eucalyptus species with potential for growth in SRF:

E. glaucescens
E. gunnii
E. nitens (NSW)
E. nitens (Vic)

The experiment sites were fenced and ground preparation and weed control were carried out prior to planting. Species plots were 20 m x 20 m, planted at 1 m spacing along the rows and 2 m spacing between rows, giving 200 trees per plot. Assessments were carried out in the central 12 m x 15 m area containing 96 trees.

After heavy losses during the first two winters, which were extremely severe, the plots were beaten up to 100% stocking with trees of the original species and batch (grown on in a nursery until required). Throughout this report the survival figures presented are post beating up, and mean height figures include those of beat up trees.

Surviving eucalyptus were not assessed this past year; the next planned assessment is due at the end of the 2019 growing season.

Orkney Trials

Two further short rotation forestry trials were established in Orkney by the Agronomy Institute, Orkney College, University of Highlands and Islands, also funded by Forestry Commission Scotland. These are located in Muddisdale (Orkney Mainland) and Newfield (on Shapinsay) and were planted in spring 2013.

The trials are based on a very similar design to the mainland trials, and contain some of the same species:

Sycamore	*Acer pseudoplatanus* L.
Italian alder	*Alnus cordata* Desf.
Common alder	*Alnus glutinosa* (L.) Gaertn.

As well as some additional species suited to Northerly climates:

Downy birch	*Betula pubescens* (Ehrh.)
Beech	*Fagus sylvatica* (L.)
Native aspen	*Populus tremula* (L.)
Goat willow	*Salix caprea* (L.)
Mountain ash	*Sorbus aucuparia* (L.)
Whitebeam	*Sorbus intermedia* (Ehrh.) Pers.

As the most Northerly mainland trial at Sibster was lost due to severe herbicide damage (and was only partially replanted as some species were not then available), the results of the Orkney trials may provide important additional information to supplement the mainland network. Summary results are presented here for comparison, and the full results for the end of the third growing season by Peter Martin and John Wishart, from the Orkney College, University of Highlands and Islands, is included in Appendix 1.

2016 Native Aspen trials

Native aspen trials have been planted at five of the original SRF sites Sibster was not included although two of the same clonal lines used there have been deliberately included within the latest trials for comparison. These consist of Randomised blocks of clonal material as follows:

C1 Orkney 'Rackwick' origin -CL9 (20-40cm) (used at Sibster and Orkney also)
C2 'Shropshire' -Zone 404 (40-60cm) (used at Sibster also)
C3 Arran origin -EECL024 micro-prop. (20-40cm)
C4 North Galloway origin -EEDG 008 micro-prop. (20-40cm)
C5 South Galloway origin -EEDG 030 micro-prop. (20-40cm)
C6 Standard mixed clones from -Zones 106 and 202 CT LKCM micro-prop. (20-40cm)

Trees were planted at the same 1m x 2m SRF spacing used in the original species trials, each of the four blocks consists of 6 rows of 20 trees, each row contains an individual clone, all plot trees are assessed (80 per clone on each site).

Plant quality testing was carried out on a sub-sample of trees from each clone just before the trees were planted. Root electrolyte leakage (REL) values indicated that all six clones were in good physiological condition with mean scores ranging from 16 to 24%, suggesting all material was fully dormant at planting (below 30%) and well within the acceptable max REL value for cell grown stock (40%).

Update on the past year

Aspen suckering continues to increase at East Grange with more sucker stems appearing out with the species plot lines. These are very fast growing with some already over two metres in height, these could block access tracks in time if not controlled, fortunately this growth is from the two outer rows of buffer trees, so removal should not affect biomass calculations within the assessment plots, but it can be expected that similar suckering will start to occur between rows within the treatment area, this could make it more difficult to mechanically harvest lines of stems at maturity. It is likely this problem will occur on other sites and should be monitored.

Three Roe deer were also spotted within the fenced enclosure at South Balnoon; they had already browsed on the aspen and sweet chestnut causing some shoot damage. Removal by the local keeper was rapid and damage should have been minimised.

As mentioned in the two previous reports, the loss of propyzamide use on FC land prevented pre-planting control on the new Aspen trials. However, the heavy growth of grass and broadleaf weed competition has now been successfully controlled on all sites by a post planting application of herbicide and some manual cutting.

SRF plots on the Mull site featured during two FR led knowledge transfer events in May 2017, one for FC Scotland West Argyll district staff and the other as part of an EFI Atlantic research group meeting in Scotland. Both visits were well received by participants and generated interesting discussion both on the day itself and afterwards.

Results

Fast-growing broadleaves

Height assessments are carried out annually until the trees have had six growing seasons in the ground. Sites at Balnoon, Alyth, East Grange and on Mull reached this point last year so no assessment was carried out this year. Trees at Auchlochan have now been in the ground for six seasons so these (along with other sites mentioned above) will not be assessed again until they have been in the ground for ten growing seasons. The site at Sibster was replanted in May 2015 and has therefore had a year 3 assessment this year.

Sibster (Caithness)

Eight species were replanted on the site in May 2015 and heights from planting to the end of year three, together with the latest survival rates are shown in Figure 2 below. All species have put on good growth over the past year, including the Rackwick Aspen clone which had previously performed extremely poorly. As the other native aspen clone (403) appeared to be growing much better, it was previously thought that poor quality stock may have been involved.

Of the other six species common alder is leading the field with a mean height of 93cm, followed by sycamore next at 89cm, and then Sitka spruce at 83cm. Survival rates are generally good; 7 of the 8 treatments are 80% or higher. Italian alder has fared less well and currently 54% of individuals have died.

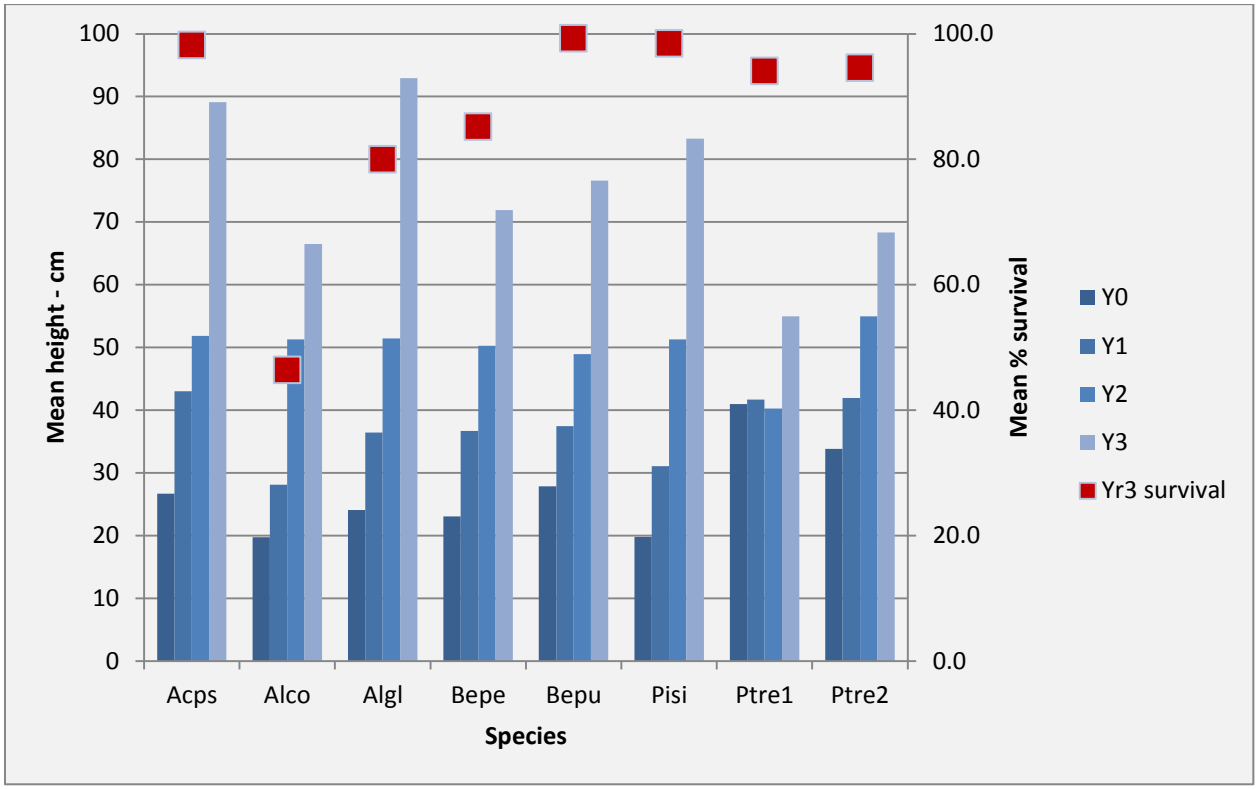


Figure 2: mean heights (cm) for the three years since planting, and % survival at the end of year three at Sibster (re-planted area).

Auchlochan (South Lanarkshire)

This site, near Lesmahagow in South Lanarkshire, was planted in the spring of 2012, two years after the initial four sites, and one year after Aros on Mull. Delays in site acquisition and determining the location of mains water pipes forced changes in the ground preparation and the ultimate layout of the site. Way-leaves for the pipes and also overhead cables reduced the usable area of the site by about a third. As a result, fewer trees could be planted here than at the other EF trial sites, although it still remains a substantial trial.

Survival of all species during the first year was very good (>90%) compared to the sites planted in 2010, probably because winter weather conditions after planting were much less severe than for the first four sites. Minor beating-up was carried out in April 2013.

Survival of most species remains good at the end of 2017, with seven of the ten species above 80%. Italian alder continues to decline and mean survival is now 28% (Figure 3). 2017 saw the majority of species producing significantly improved growth rates when compared with the two previous years. Hybrid aspen, Sitka spruce, ash, and red alder all put on around 1m or better, while common alder exceeded 2m during 2017. At the last assessment Red and common alder had been the tallest species. This year Red alder is still the tallest (mean height 4.9m, but hybrid larch (4.6m) and hybrid aspen (4.5m)

are close behind. Common alder is now the 4th tallest with a mean height of 4.2m. (Figure 3).

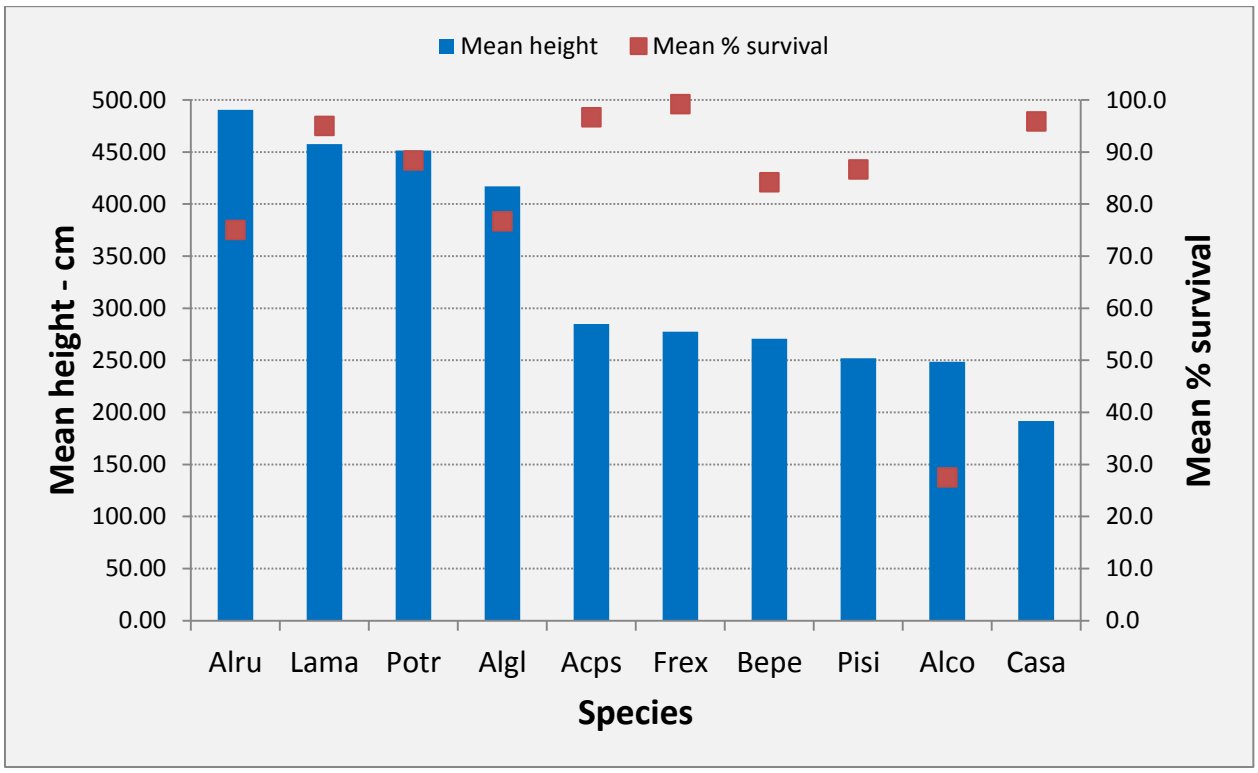


Figure 3: Mean height and survival after 6 growing seasons at Auchlochan

Orkney sites

In addition to the trials described above, Forestry Commission Scotland continues to fund two SRF trials in Orkney, established in 2013 and managed by the Agronomy Institute, Orkney College, University of Highlands and Islands (UHI). These trials are on ex-agricultural land, located at Muddisdale (Orkney Mainland, HY 435 110) and Newfield (Shapinsay, Balfour Mains Farm, HY 516 181). The windy, exposed conditions of these northerly sites make them a good comparison for the Sibster site, which was partially replanted following herbicide damage to many plots.

Measured across all species survival is still high at Muddisdale (98%) but continues to decline at Newfield; 96% in 2014, 76% in 2015, 63% in 2016, and now 55% at the end of 2017.Survival for six of the nine species in the trial was considerably lower at Newfield

than at Muddisdale, only common alder, aspen, and goat willow were comparable (Fig. 4).

Trees in the species trial were consistently taller at Muddisdale than Newfield. At Muddisdale, the tallest species were Italian alder and common alder (261 and 267 cm, respectively) and aspen and goat willow (192 and 201 cm, respectively). The 4 tallest species at Newfield were common alder (107 cm), goat willow (89 cm), aspen (83 cm) and downy birch (71 cm). At both sites, sycamore, mountain ash and beech were the shortest species (36-43 cm at Newfield and 80-109 cm at Muddisdale).

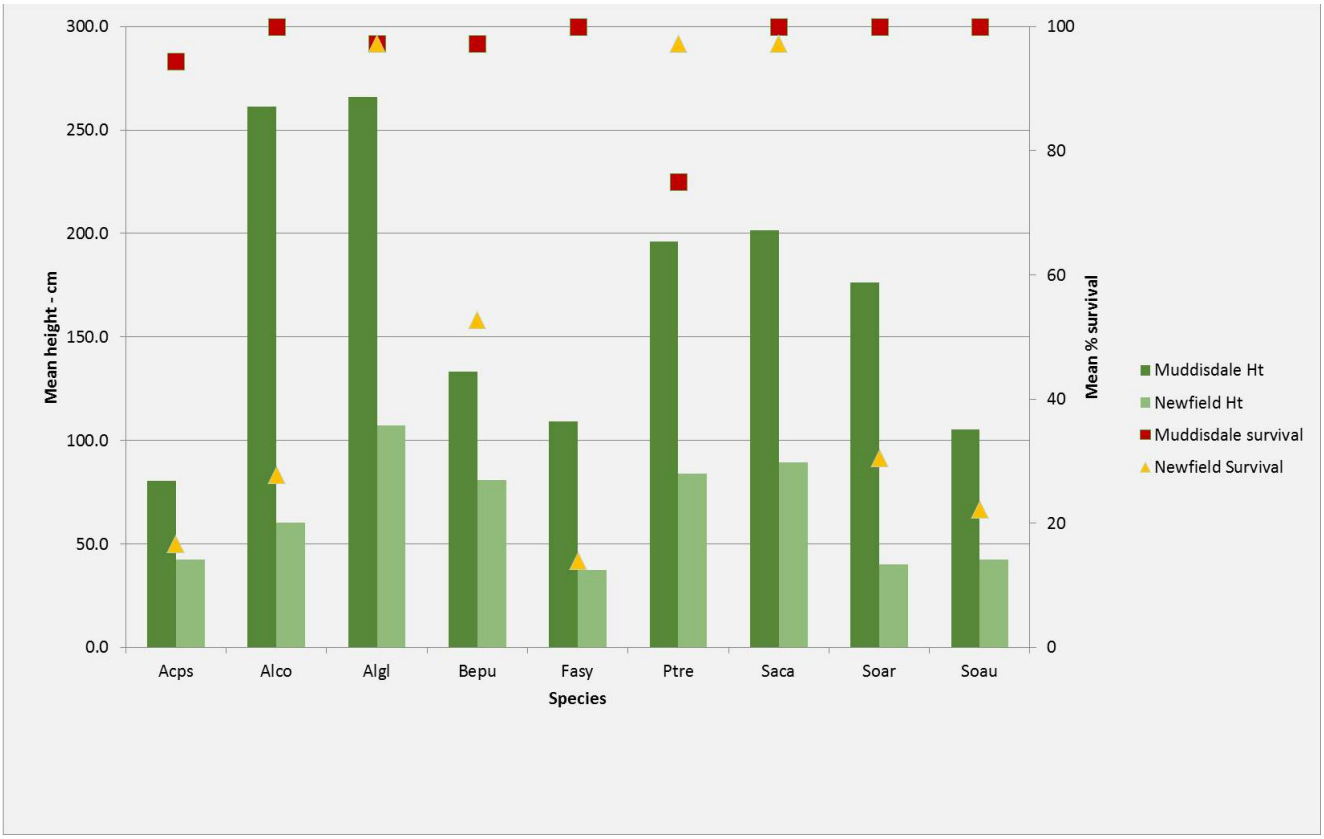


Figure 4: Mean heights and survival at Muddisdale and Newfield on the Orkney Islands.

At Newfield several species showed a reduction in height, either as a result of dieback or stems leaning because of the wind. The lower survival scores and reduced heights at Newfield clearly indicate that conditions there are very challenging and of all the species common alder seems to be much better suited to them..

The full 2016 UHI report appears as Appendix 1 of this report.

Native Aspen trials

These trials were assessed at planting in early 2016, after one growing season at the end of 2016 and most recently at the end of their second year in late 2017. With two complete growing seasons of data we can start to make comparisons of establishment and early growth of the different clonal material across five sites.

The main priority has been controlling vigorous grass and broad-leaved weed growth present on the majority of the sites, considerable amounts of natural regeneration also required attention at East Grange. Problems with Roe deer browsing was also noted this year and this may have caused a number of individual trees to display negative height increments within the Huntly 14 (Balnoon) data.

Height, root collar diameter and survival was measured immediately after planting, at the end of year one (March 2017), and the end of year two (January 2018). It is too early to draw any firm conclusions as to comparisons between the clones. However, the mean heights of all clones are lowest at the Mull site suggesting that the site is less suited to Aspen than the others (Figure 5). In addition, mean growth increments have been lower there over the past year than at all of the other sites (Figure 6).

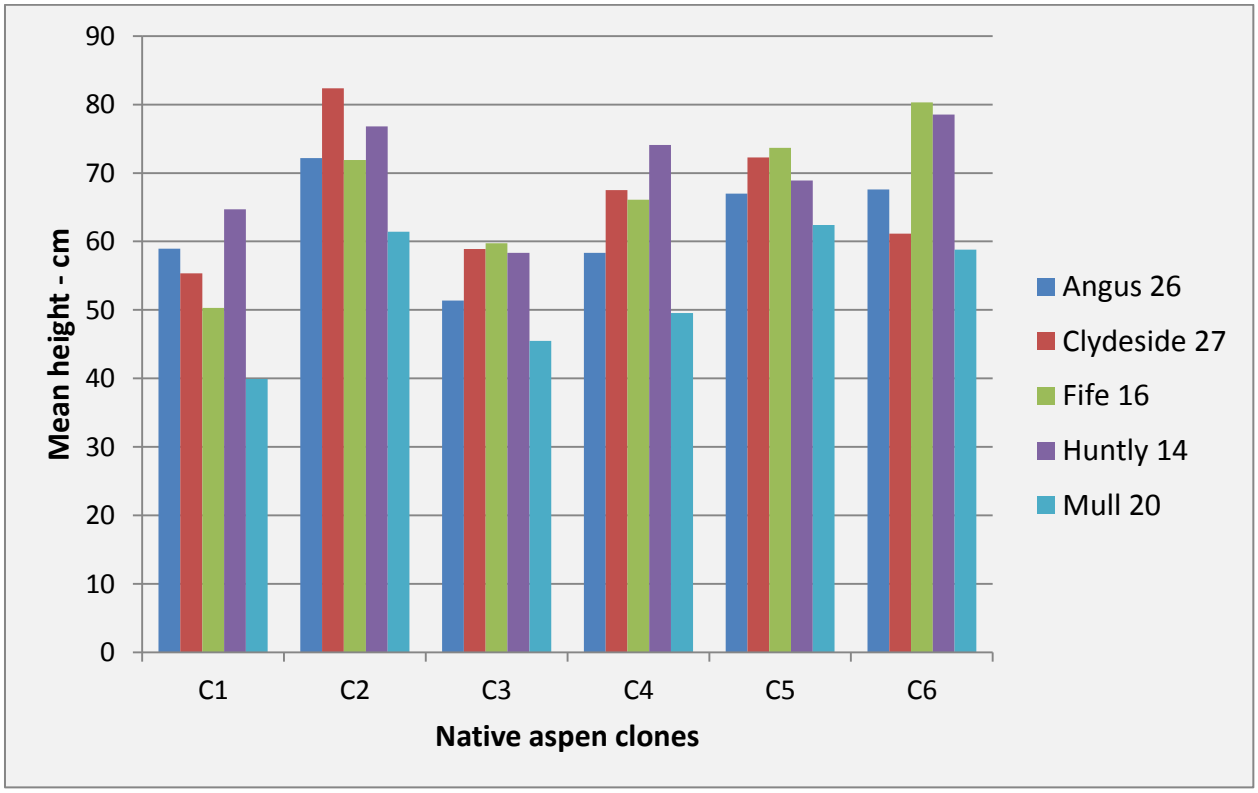


Figure 5: Mean heights at the end of year 2 (2017) of six native aspen clones across the five trial sites.

Initial establishment was very even across all five sites. For the majority of clones across all sites survival was in excess of 90% with one notable exception. At Fife 16 (East Grange) clone 6 (Standard mixed clones from Zones 106 and 202 CT LKCM micro-prop) had dropped to 73%. On other sites clone 6 has performed well, never below 90% mean survival, and the other clones at Fife are all above 90%. No clear reason for this drop has been observed.

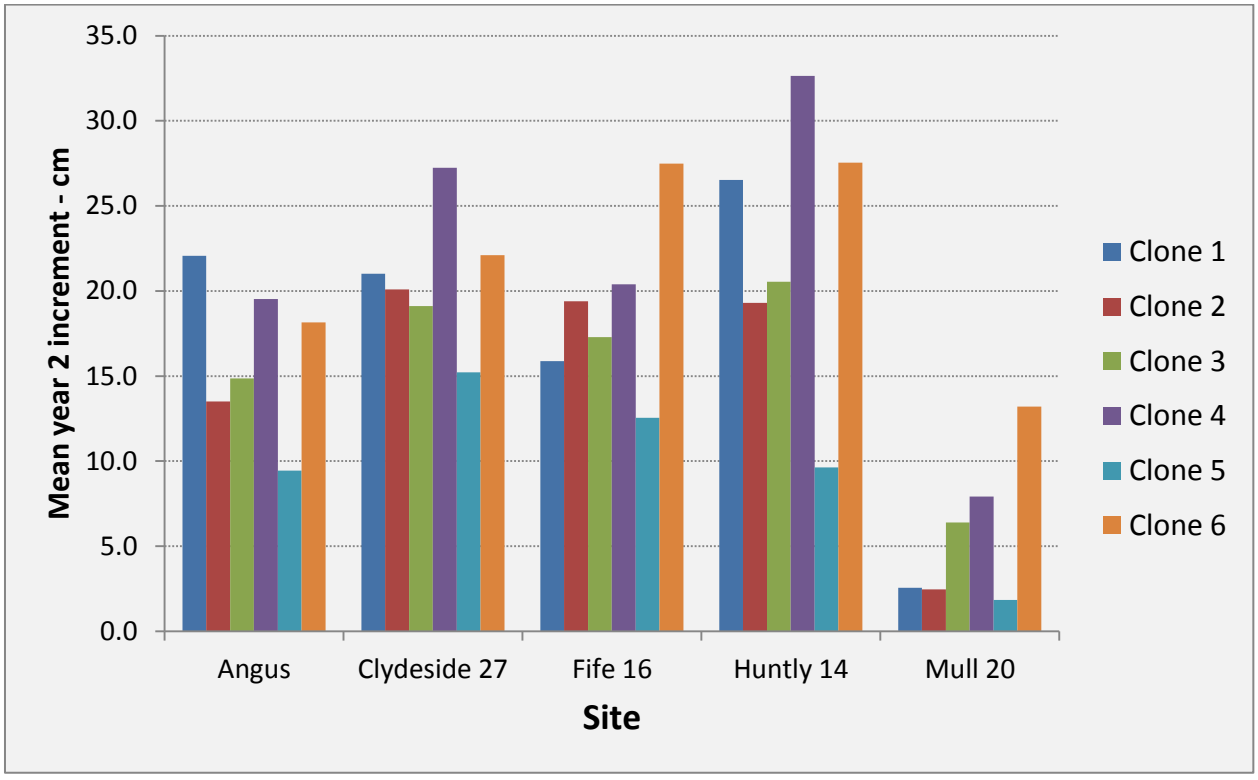


Figure 6: Mean year 2 growth increments (cm) of the six native aspen clones across all five sites.

Stem diameters are were measured and found to be very similar for all clones across the five trial locations with no discernible patterns and are therefore not graphed here. Over the next few seasons differences in this measurement are likely to become more apparent.

Early conclusions

Following the year 6 assessment of Auchlochan this year we now have year 6 data available for 5 of the 6 sites. It is intuitive that site would be a factor and this is borne out by the data collected to date. East Grange has the greatest mean heights for six of the ten species, followed by Auchlochan which has four of the ten. Neither Balnoon, Alyth, nor Mull produced greatest mean heights for any species (Figure 7).

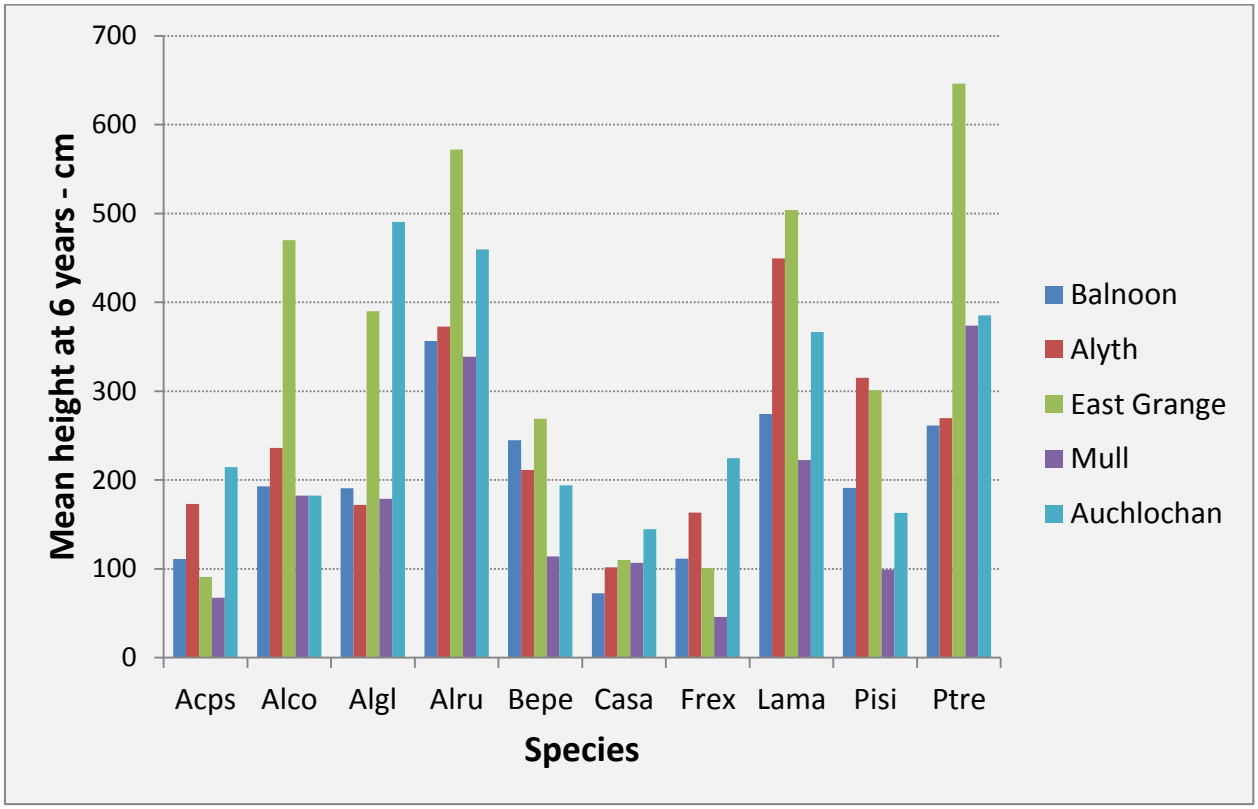


Figure 7: Mean heights across all sites measured at year 6. Note that for Balnoon, Alyth and East Grange this was at the end of 2015, for Mull at the end of 2016, and for East grange the end of 2017.

To summarise general performance after six years of growth across all sites the mean heights and the mean percentage survival of each species are presented in Figure 8. Red alder has the greatest mean height, but also has the worst survival (63.1%). Hybrid Aspen was the second best in terms of height with 387cm, but with a considerably higher mean survival of 92%. Hybrid larch was a close third in height (363cm) with the same mean survival (92%).

Height wise sweet chestnut is still the worst performer with a mean height of 107cm, and survival of 81%. Sycamore and ash are broadly similar at 131cm and 129cm, and survivals of 94% and 963%.

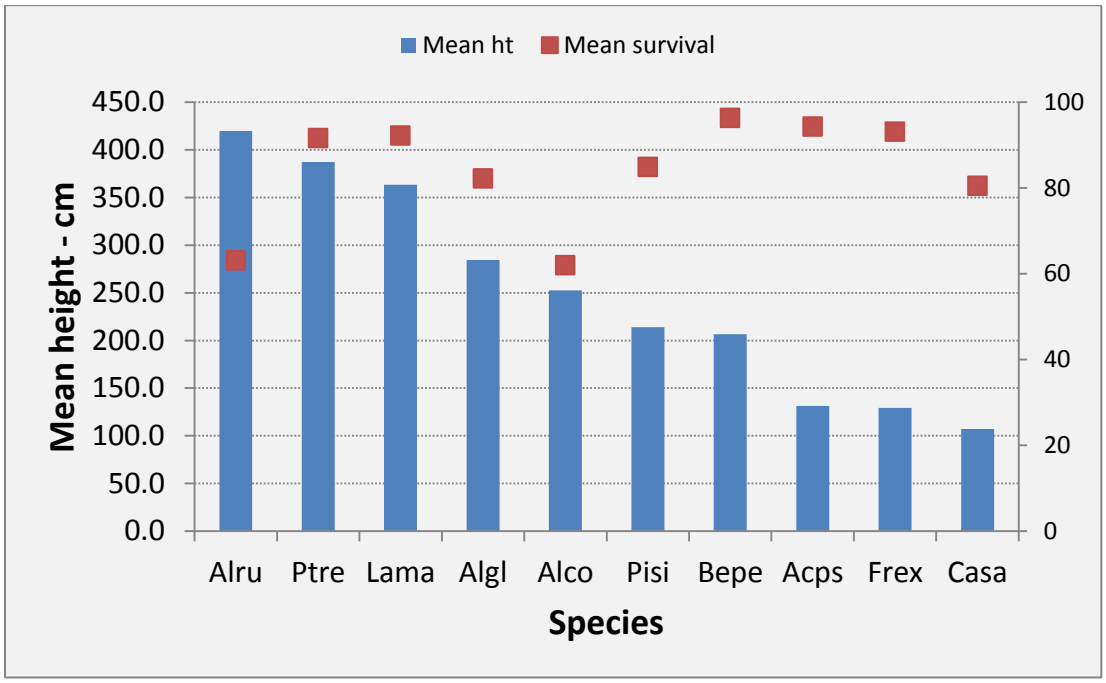


Figure 8: Mean heights and survival for each species across all sites after six growing seasons (note that Sibster is excluded from this analysis as it has yet to reach 6 years following re-planting).

The species that currently appear to have the most potential for use in SRF systems on these sites based on performance to date are hybrid aspen and hybrid larch (depending upon the development of *Phytophthora ramorum*). Common alder, silver birch and Sitka spruce may also have potential on certain site types, but do not appear to be universally suitable for SRF.

For a species to be a suitable choice for use in SRF systems in Scotland it must be able to tolerate the site conditions and achieve good growth rates. The results to date show that some of the species found to have high growth rates (red alder, Italian alder and on some sites common alder) are unable to tolerate the site conditions and have very low survival rates; these would be high risk choices for SRF. However, total biomass may still be comparable to species with higher survival rates but lower growth so these species should not be entirely written off until assessments of total biomass and density have been carried out.

Future plans for the sites and work due in 18/19

SRF trials

Annual assessments of the original species trials will continue to the end of year 6, this means only Sibster will be due a height assessment in the coming year 2018/19 (year four). Any weed control requirements on the slower growing species across all sites should be assessed at the same time as maintenance of new native aspen trials takes place.

A year three height assessment will also be required on the replanted Sibster plots. Establishment operations and maintenance will be provided by Scottish Woodlands until the end of the fifth year.

A general pest and disease inspection should take place to check if any further weevil damage has occurred or hybrid aspen canker has appeared on any other sites.

Given the issues with suckering at East Grange, an assessment of hybrid aspen stem growth within the species trial assessment plots should be undertaken, depending on the findings, plan removal of any problematic stems during control of any natural regeneration within plots.

New native aspen trials

Application of herbicide to control weed competition will again be required at all sites, as will end of year height and diameter measurements, projected assessment times for these are included in brackets within Table 3. These should be combined with any other work on the same sites whenever possible.

Data from the site weather station loggers should continue to be collected and sent to the Northern Research Station.

Future assessment schedules

Longer-term assessments at all sites are recommended at years 10, 15 and perhaps 20 for each site according to the schedule in Table 2. These later assessments would include measurement of diameter at breast height and calculation of volume.

Table 2: Recommended assessment schedule for all SRF experiments.

Calendar year	18/ 19	19/ 20	20/ 21	21/ 22	24/ 25	25/ 26	26/ 27	29/ 30	34/ 35
East Grange	(3)	10 (4)	(5)	(6)	15			(10)	(15)
Alyth	(3)	10 (4)	(5)	(6)	15			(10)	(15)
South Balnoon	(3)	10 (4)	(5)	(6)	15			(10)	(15)
Aros	(3)	(4)	10 (5)	(6)		15		(10)	(15)
Auchlochan	(3)	(4)	(5)	10 (6)			15	(10)	(15)
Sibster	4	5	6		10			15	

Values are age in years. (n) indicates Native aspen trials also scheduled.

Appendix 1: Report to Forestry Commission Scotland on the monitoring of short rotation forestry trials in Orkney during 2017

Aspen trees at the Muddisdale Short Rotation Forestry trial in Orkney in June 2017

By
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Orkney College UHI
November 2017

University of the Highlands and Islands
Oilthigh na Gàidhealtachd agus nan Eilean

AGRONOMY INSTITUTE

University of the Highlands and Islands
Orkney College

Contents

Executive Summary

- Monitoring of two short rotation forestry (SRF) trials, established in Orkney in 2013, was carried out in 2017 by the Agronomy Institute at Orkney College UHI. The trials are located at Muddisdale (Orkney mainland) and Newfield (on the island of Shapinsay),

- Both trials contain the same tree species: sycamore, *Acer pseudoplatanus*; Italian alder, *Alnus cordata*; common alder, *Alnus glutinosa*; downy birch, *Betula pubescens*; beech, *Fagus sylvatica*; aspen, *Populus tremula*; goat willow, *Salix caprea*; mountain ash, *Sorbus aucuparia*; whitebeam, *Sorbus intermedia*.

- At each trial there are 6 plots (each containing 25 plants) of each of the 9 tree species, arranged in a randomised block design with 6 replicates (54 plots in total). Four of the replicates comprise a species trial and the others are single replicate observation blocks, one planted at 1.0 x 1.0 m (instead of the 1.5 m spacing used in the rest of the trial) and the other using a polythene mulch square (0.6 x 0.6 m) around each tree at planting to reduce weed competition.

- Weed control has been carried out by the Agronomy Institute at Muddisdale since the start of the trials and at Newfield since winter 2015/16. For the 2017 growing season, weed control at both sites consisted of an application of the residual herbicide Kerb Flo over winter 2016/17 and topping and strimming of weeds in June 2017.

- Tree survival and height were recorded on the 9 innermost plants of each plot at the end of the 2017 growing season.

- Tree survival over the 6 replicates continued to be high (98%) at Muddisdale but has declined annually at Newfield (96% in 2014, 76% in 2015, 63% in 2016 and 55% at the end of 2017). Survival at Newfield was lowest in beech (20%), sycamore (22%), whitebeam (24%) and mountain ash (28%).

- Averaged over all species, trees in the species trial were much taller at Muddisdale than Newfield (170 cm compared with 63 cm). At Muddisdale, the tallest species were Italian alder and common alder (261 and 267 cm, respectively) and aspen and goat willow (192 and 201 cm, respectively). The 4 tallest species at Newfield were common alder (107 cm), goat willow (89 cm), aspen (83 cm) and downy birch (71 cm). At both sites, sycamore, mountain ash and beech were the shortest species (36-43 cm at Newfield and 80-109 cm at Muddisdale).

- While the average height of all species at Muddisdale increased from 2016 to 2017, at Newfield most species showed a reduction in height, either as a result of dieback or stems leaning because of the wind. While conditions at Newfield are clearly very challenging, common alder seems to be much better suited to them than any of the other species.

- At both sites, the mean heights of species in the replicates planted with a 1.0 x 1.0 m spacing and with polythene mulch were similar to those in the main species trials.
- There are differences and similarities in the performance of tree species starting to appear at the two Orkney sites:
    - There are common species at both sites amongst the tallest and shortest species (tallest: common alder, goat willow and aspen; shortest: sycamore, beech and mountain ash).
    - While survival is still good amongst the shortest species at Muddisdale, it is much lower amongst them at Newfield.
    - Compared with their performance relative to that of other species at Newfield, Italian alder and whitebeam have grown much better at Muddisdale.
- Even though weed control at Newfield has been considerably improved since 2016, this has not resulted in a marked improvement in tree growth or decline in tree deaths. It therefore seems likely that the poor growth and survival of most species at this site are the result of its exposure and possibly high soil water content.

Introduction

Between November 2011 and December 2013 Forestry Commission Scotland (FCS) provided funding to the Agronomy Institute (AI) at Orkney College UHI to work with local stakeholders to start investigations into the potential of short rotation forestry (SRF) in Orkney. Protocols for establishing trials, including the selection of species, were developed with the Orkney Woodland Group (OWG) and FCS and in 2013 two trials were established - one at Muddisdale (58° 58' 53.51" N, 2° 59' 9.27" W; near Kirkwall on Orkney mainland) and one at Newfield (59° 2' 48.34" N, 2° 50' 43.51" W; on the island of Shapinsay). Survival and growth of the trees has been monitored and reported at the end of each year since 2013. The current report provides information on the growth and survival of trees in 2017, their fifth field season.

Trial Sites, Management And Experimental Design

Trial Sites And Management

The trial sites were located at Muddisdale (HY 435 110) on land owned by Orkney Islands Council and Newfield (HY 516 181) on land belonging to Balfour Mains farm. The sites are at 25 and 35 m asl, respectively, and are approximately 10.5 km from each other in a straight line. The same weed control practices were employed at both sites over the year: the residual herbicide Kerb Flo was applied over the winter 2016/17 at 3.75 l ha^{-1} and grass and weeds were further controlled by topping and strimming in June 2017.

Experimental Design

This was described fully in previous reports and only a brief summary is provided here. Both trials (see Appendices 1 and 2) had the same layout and consisted of plots of 25 trees (5 x 5) of 9 different species (sycamore, *Acer pseudoplatanus*; Italian alder, *Alnus cordata*; common alder, *Alnus glutinosa*; downy birch, *Betula pubescens*; beech, *Fagus sylvatica*; aspen, *Populus tremula*; goat willow, *Salix caprea*; mountain ash, *Sorbus aucuparia*; whitebeam, *Sorbus intermedia*). The trials used a randomised block design in which plots were arranged in 6 replicates (each containing one plot of each species) as follows:

- A species trial consisting of 4 replicates.
- An observation block (1 replicate) with trees planted at a closer spacing (1.0 x 1.0 m, instead of the 1.5 x 1.5 m used in the remainder of the trial).
- An observation block (1 replicate) with each tree planted in the middle of a polythene mulch square (0.6 x 0.6 m) to reduce weed competition.

Methods Of Measurement

As in previous years, tree height was measured from ground level to the tip of the top leaf or shoot. In each plot of all replicates, tree height and survival were recorded on the 9 plants in

the centre of each plot. Data were collected on 22 September at Muddisdale and 26 September at Newfield. For presenting data, the mean height of surviving trees was calculated for the measured trees in i) the species trial (reps 1 to 4); ii) the replicate planted at 1.0 x 1.0 m spacing; and iii) the polythene mulch replicate. In Figures, the names of species have been abbreviated as follows: sycamore, SYC; Italian alder, IAR; common alder, CAR; downy birch, DBI; beech, BEE; aspen, ASP; goat willow, GWI; mountain ash, MAS; whitebeam, WHI.

Results

Observations On Trials

Frequent visits were made to the Muddisdale site and Newfield was visited in January, June and September 2017.
Both trials were visited in early June (Muddisdale on 14 June and Newfield on 15 June) and this allowed a visual comparison to be made of the differences in the stage of tree development. As noted in the 2016 report, trees at Newfield were later at coming into leaf than those at Muddisdale (Photos 1 to 4, pp. 13-14). This probably reflects the greater exposure at the Newfield site as the trials are at a similar altitude and only 10.5 km apart. Weed control at Newfield has been better since this has been managed by the AI from winter 2015/16 but it will be clear from this report that this has not prevented a serious decline in tree numbers, indicating very challenging conditions at this site which seems to be the result of exposure and possibly also high soil water content. As a result, a number of the species in the trial appear to be dying out (e.g. sycamore, mountain ash, beech, whitebeam and Italian alder). Wind rock has resulted in socketing of several species at Newfield, (see, for example Italian alder in Photos 13 and 14, p. 19) which has probably contributed to some of the tree deaths; common alder seems to have been less affected by this.
At Muddisdale, common and Italian alder have developed the largest canopies and, as mentioned in the 2016 report, the prevailing wind is causing some trees to lean. In some cases, stem breakage has occurred. Leaning of common alder has also occurred at Newfield. At Muddisdale, a few trees of mountain ash flowered for the first time in 2017.
The perimeter windbreak of 3 rows of biomass willows at Newfield has continued to survive well, with some trees in excess of 2.7 m (Photo 10, p. 17).

Tree Survival And Growth At Muddisdale

Averaged over all plots in the species trial, the average height and survival at Muddisdale was 170 cm and 99%, respectively. Fig. 1 shows the survival of trees at Muddisdale in September 2017 and their average height at the end of each season since planting. The trends established in previous growing seasons continued and common alder (Photo 4, p.14) and Italian alder (Photo 8, p.16) were the tallest species followed by goat willow, aspen and whitebeam; these were followed by downy birch, beech and mountain ash which were all taller than sycamore. Photos 4 to 8 (pp. 14-16) show most of the species at Muddisdale in June 2017. Averaged over all species, the increase in height over the growing season (34 cm) was greater than in any of the previous growing seasons. Survival of all species continues to be very good, but was lowest in sycamore (94%).

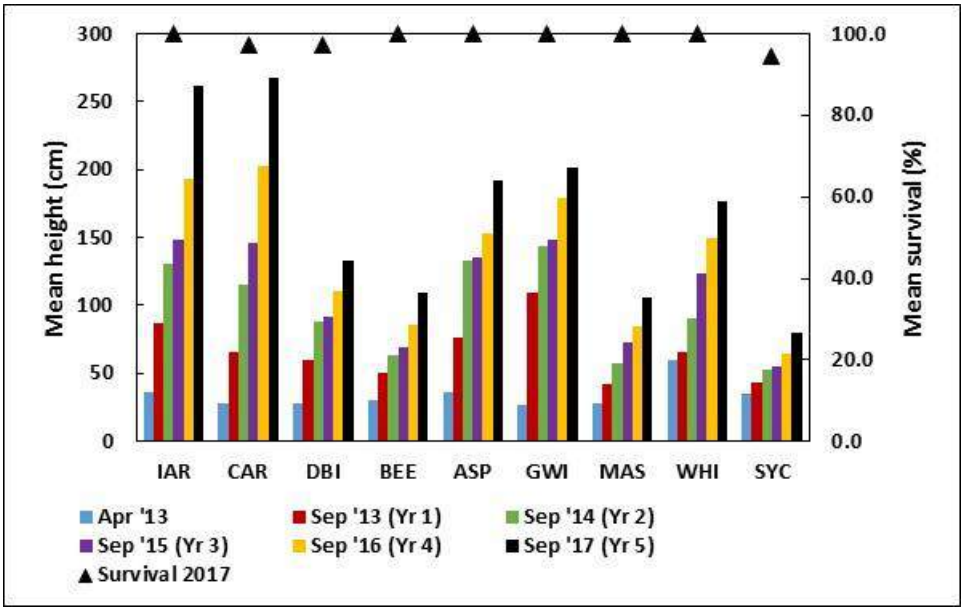


Fig. 1. Mean tree height in the species trial at Muddisdale at the end of each season since planting and survival in September 2017.

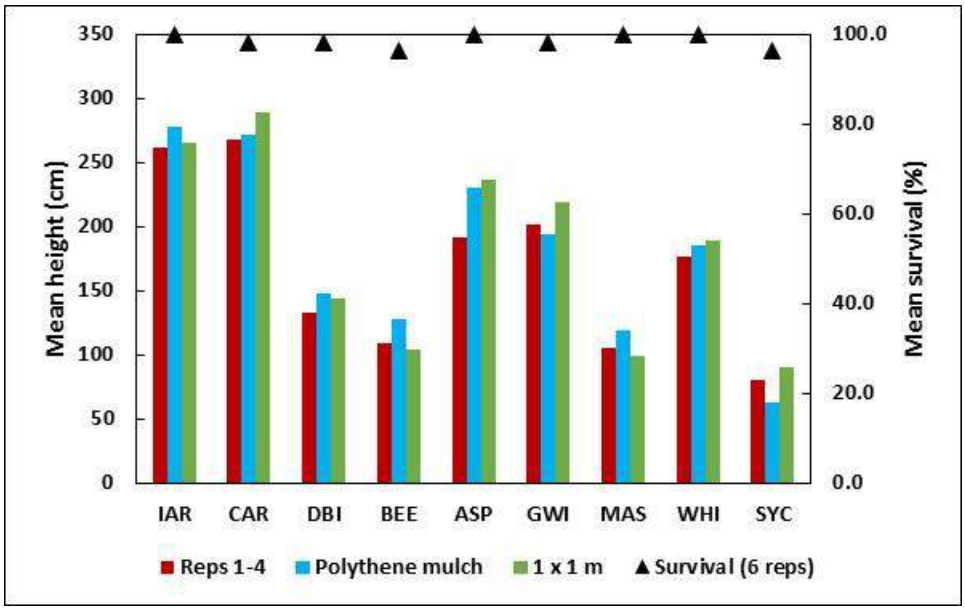


Fig. 2. Mean tree height in the species trial (Reps 1-4), polythene mulch and 1.0 x 1.0 m spacing replicates at Muddisdale in September 2017 and survival over the 6 replicates.

Fig. 2 compares mean tree height for each species in September 2017 in the species trial (Reps 1-4) with that for the polythene mulch and 1.0 x 1.0 m spacing replicates. For each species, mean tree heights were similar in the three treatments. Survival in Fig. 2 was calculated for the 54 core trees of each species across the 6 replicates and was lowest for beech and sycamore (96% in both).

In the 1 x 1 m spacing replicate, especially, but also in replicates 1-4 (1.5 x 1.5 m spacing), there is already considerable canopy overlap in plots of the two alder species (Photo 8, p. 16), suggesting that these species require a wider spacing in sheltered sites like Muddisdale.

Tree Survival And Growth At Newfield

Averaged over all core trees in the species trial, the average height and survival at Newfield was 63 cm and 51%, respectively. Fig. 3 shows the survival of trees at Newfield in September 2017 and their average height at the end of each season since planting. The tallest species were common alder, goat willow, aspen and downy birch; Italian alder was of intermediate height while whitebeam, beech, mountain ash and sycamore were the shortest species. Most species showed no, or negative, increase in height over 2017. The loss of height resulted mainly from dieback of the lead shoots caused by wind pruning, and also from the wind causing trees to lean away from the vertical, often accompanied by socketing (Photos 13 and 14). Sycamore, whitebeam and mountain ash have hardly increased in height since they were planted. Tree survival was highest for goat willow, aspen and common alder (all 97%), intermediate for downy birch (53%), low for whitebeam and Italian alder (28-31%) and very low for beech, mountain ash and sycamore (14-22%). Over the year there has been a particularly marked decrease in survival of Italian alder (from 67% to 28%) and whitebeam (from 56% to 31%). Common alder appears to be the species which is most tolerant of the site.

In some species (especially, Italian alder, common alder and goat willow) there is a tendency for trees to lose their leading shoots each season as a result of wind damage and this is often accompanied by the growth of basal shoots, giving trees a shrubby appearance.

Fig. 4 compares mean tree height for each species in September 2017 for the species trial (Reps 1-4) with that for the Polythene mulch and 1.0 x 1.0 m spacing replicates. For each species, mean tree heights were approximately similar in the three treatments, although the low survival of some species means that some of the averages in the mulch and 1 x 1 m replicates are based on few observations. Survival in Fig. 4 was calculated for the 54 core trees of each species across the 6 replicates and, averaged over all species, has decreased considerably in the last four years: from 96% in 2014, to 76% in 2015, 63% in 2016, and 54% in 2017. It is lowest (Fig. 4) for sycamore, beech, whitebeam and mountain ash (22-31%). Survival over the last year has declined markedly in both Italian alder (from 72% to 41%) and whitebeam (from 43% to 24%).

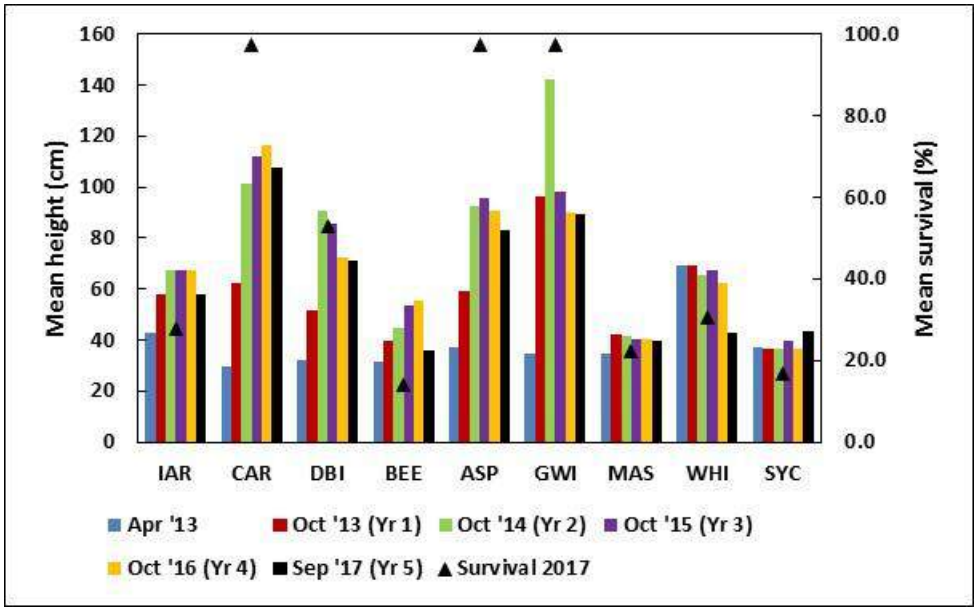


Fig. 3. Mean height of trees in the species trial at Newfield at the end of each season since planting and survival in September 2017.

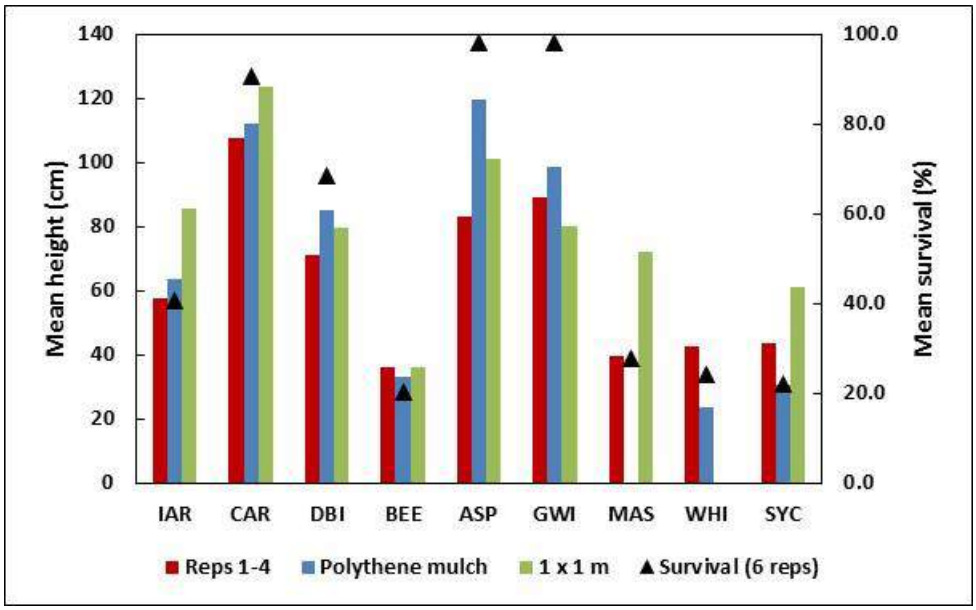


Fig. 4. Mean height of trees in the species trial (Reps 1-4), polythene mulch and 1.0 x 1.0 m spacing replicates at Newfield in September 2017 and survival over the 6 replicates.

Comparison of Survival and Growth at Muddisdale and Newfield

Tree survival and growth in each of the species trials (replicates 1 to 4) at Muddisdale and Newfield are shown in Fig. 5. It is clear that all species have grown much better at Muddisdale and most have survived much better at this site. At both trials, the highest

survival and best growth occurred with common alder, aspen and goat willow while sycamore, mountain ash and beech had the poorest growth. These last species also had the lowest rates of survival at Newfield. While Italian alder and whitebeam have grown well at Muddisdale, they have not grown well at Newfield and appear to be dying out at this site. Although downy birch has survived better than Italian alder, beech, mountain ash, whitebeam and sycamore at Newfield, there has also been a gradual loss of trees of this species each year at this site.

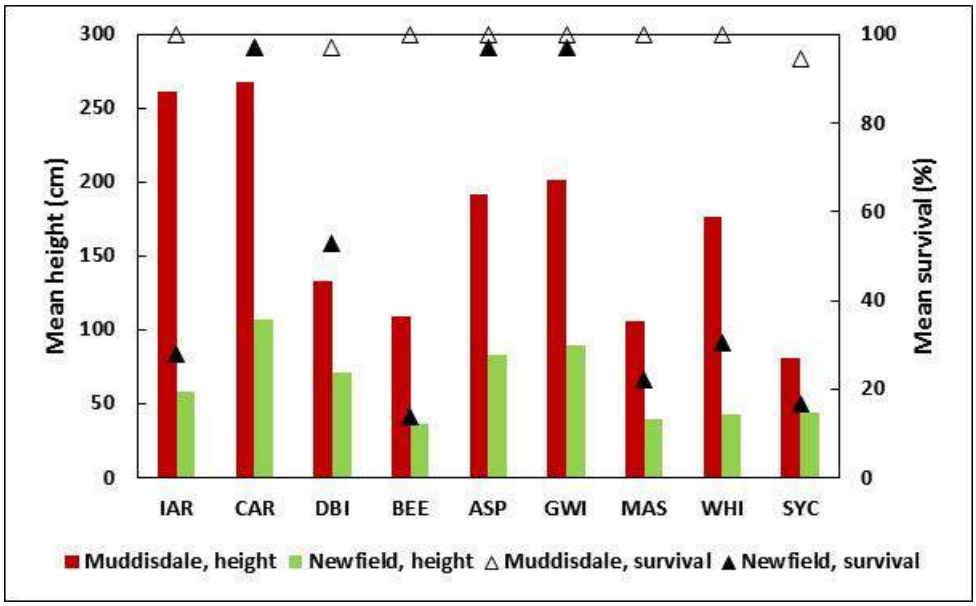


Fig. 5. Comparison of mean tree height and survival in the species trial (Reps 1 to 4) at Muddisdale and Newfield at the end of 2017.

Discussion

The good growth of most species at Muddisdale in 2017 reflect the favourable growing conditions over the year. Although the May to September temperature[1] (12.1 °C) was only slightly higher than the average for 2000-2016 (12.0 °C), June was warmer than average (12.2 °C compared with 11.6 °C) and July had considerably more sunshine hours[2] than average (179 h compared with 138 h). In contrast to Muddisdale, there was no marked increase in height of trees at Newfield and most species decreased in height, even common alder, which is the best performing species at this site. A major cause of this was shoot dieback, apparently caused by wind burn damage to shoots. Several species have responded to this by the production of basal shoots so that their growth habit is tending to resemble that of a shrub. In contrast to the poor growth of several of the tree species at Newfield, the 3 rows of biomass willows have survived and grown reasonably well, suggesting that some of these clones might have potential within a high planting density SRF system.

In spite of the large differences in tree survival and growth at the two sites, the species which have grown and survived best at Newfield (common alder, aspen and goat willow) are also

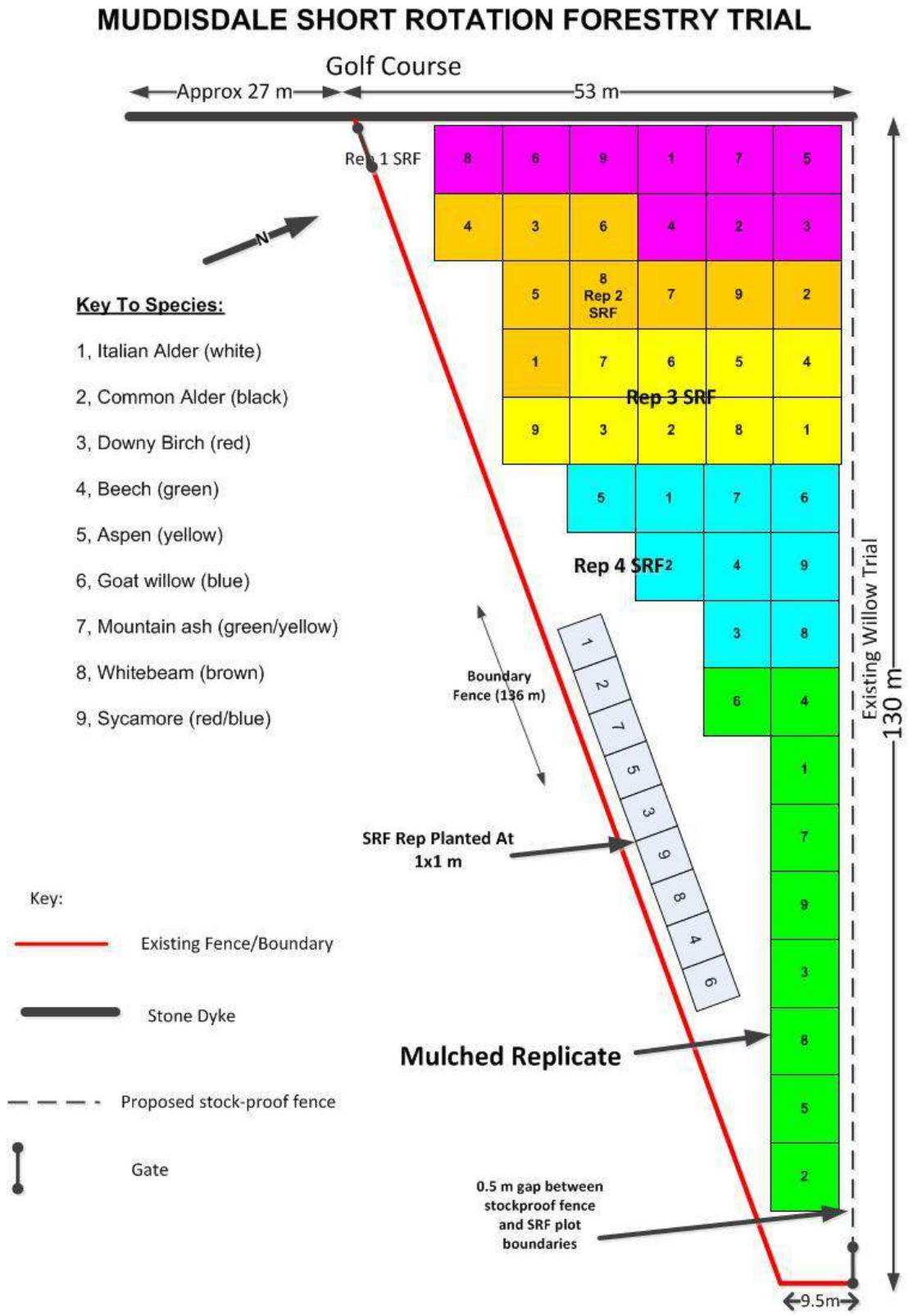
[1] Temperature data from Kirkwall airport (https://en.tutiempo.net/climate/ws-30170.html).
[2] Sunshine data from Loch of Hundlanad climate station.

amongst the best at Muddisdale, while the poorest for growth and survival at Newfield (sycamore, mountain ash and beech) have also grown slowest at Muddisdale. Relative to their performance at Newfield, Italian Alder and Whitebeam have grown much better at Muddisdale. At both sites, the performance of downy birch has been intermediate between the best and the poorest species.

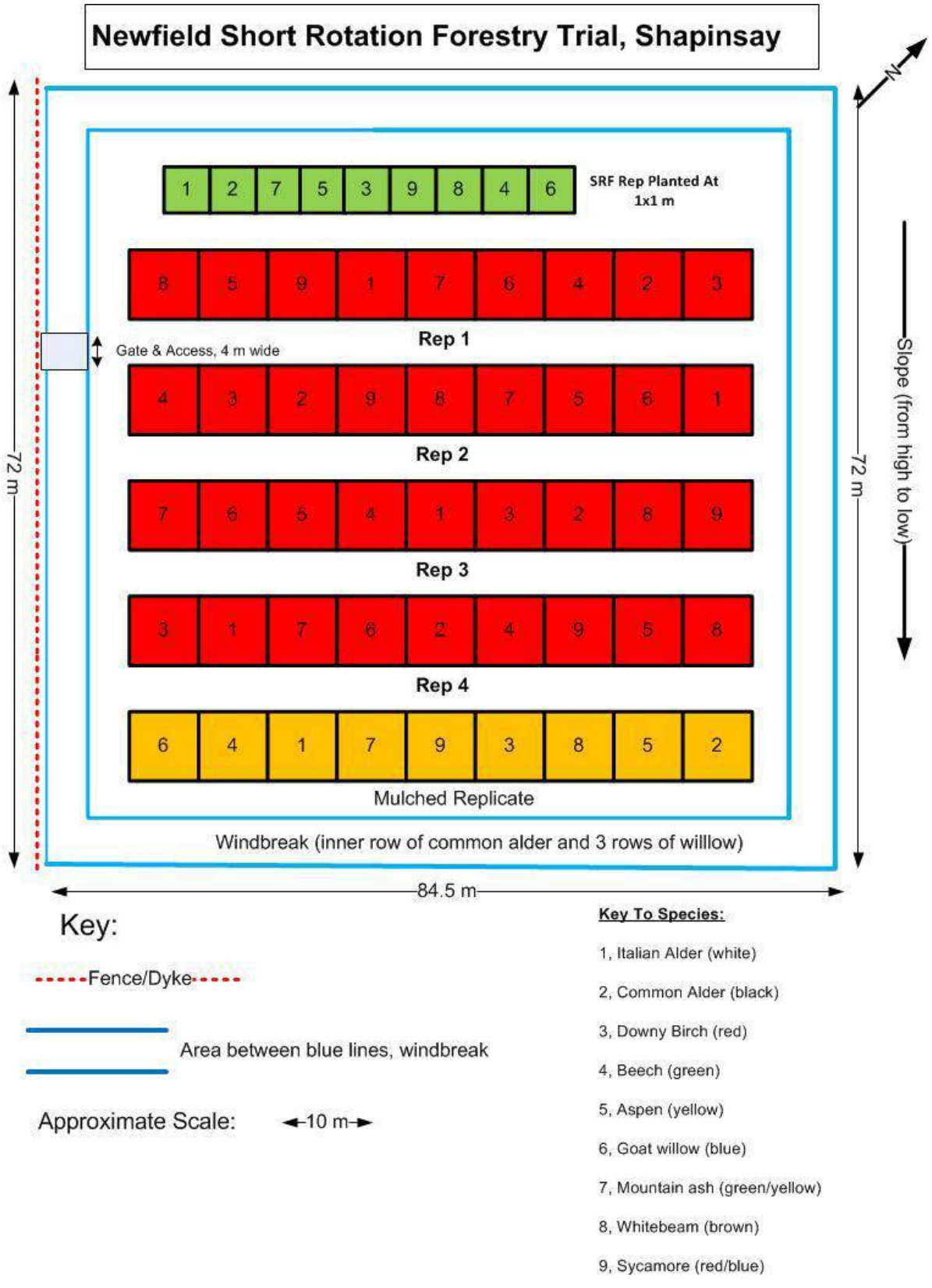
Acknowledgements

The authors are very grateful to Forestry Commission Scotland and, in particular, John Risby for his enthusiastic support and interest in these trials. They would also like to thank Jean-Baptiste Bady at Balfour Castle for his help during visits to the Newfield trial and Keith Johnson for providing data for sunshine hours from the Loch of Hundland climate station.

Appendix 1. Plan Of The SRF Trial at Muddisdale



Appendix 2. Plan Of The SRF Trial at



Newfield

Appendix 3. Photographs

Photos 1 (top) and 2 (bottom). The difference in leaf emergence of trees on 15 June 2017 at Newfield (top) and on 14 June at Muddisdale (bottom). At Muddisdale, all tree species showed advanced leaf development while at Newfield trees were only just coming into leaf (see also photos 3 and 4). The dense clump of leaves around the base of some trees at Newfield is ragwort (*Senecio jacobaea*).

Photos 3 (top) and 4 (bottom). Common alder in the Newfield trial (top) on 15 June 2017 and at Muddisdale on 14 June 2017 (bottom). Leaf emergence of most species occurred later at Newfield than at Muddisdale.

Photos 5 (top) and 6 (bottom). Tree growth on 14 June 2017 at Muddisdale in the block planted at 1 x 1 m: Photo 5, beech (left) and goat willow (right); Photo 6, sycamore (left) and whitebeam (right).

Photos 7 (top) and 8 (bottom). Tree growth on 14 June 2017 at Muddisdale in the block

planted at 1 x 1 m: Photo 7, aspen (left) and mountain ash (right); Photo 8, Italian alder (left) and common alder (right).

Photo 9 (top) and 10 (bottom). Tree growth at Newfield on 26 September 2017: Photo 9, effect of wind pruning on goat willow; Photo 10, goat willow (foreground) with the windbreak of SRC willow in the background.

Photo 11 (top) and 12 (bottom). Effect of wind pruning on tree growth at Newfield on 26 September 2017: Photo 11, Italian alder; Photo 12, common alder.

Photo 13 (top) and 14 (bottom). Socketing of Italian alder at Newfield on 26 September 2017: Photo 13, Italian alder showing socketing; Photo 14, detail of socketing.