

Short Rotation Forestry Trials in Scotland

Progress Report
2018

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 had their last assessment when they reached six years of age, the trials planted in 2010 were not due a growth and survival assessment at the end of the 2018 growing season, the next planned measurement for these sites will be at the end of 2019. Year 4 results are presented for the Sibster trial which was re-planted in 2015. At that site common alder currently has the highest mean height; sycamore, Italian alder, silver birch, downy birch and Sitka spruce are comparable, and the two aspen clones trail behind.

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 three years of establishment figures for these. Although it is too early to determine true trends there are differences between the sites, and between the six clones used. The lowest values for height, annual height increment, and root collar diameter for each clone were recorded on Mull, suggesting it as the least favourable site for aspen. All clones except clone 5 (South Galloway origin - EEDG 030 micro-prop) recorded their greatest heights at Balnoon, and their greatest annual height increment except for clone 1 (Orkney 'Rackwick' origin -CL9).

Survival of all six clones has been good, with all but two of them greater than 85% survival on all sites. Clones 1 (Orkney 'Rackwick' origin -CL9) and 3 (Arran origin - EECL024 micro-prop.) were considerably lower than others at Auchlochan. Interestingly the same two clones frequently had lower survival scores than others on the same site. Survival is likely to stabilise over the next few years but patterns in height and root collar diameter variation are likely to become more pronounced.

The sites on Orkney continue to provide useful information about the potential of SRF systems further north on more exposed sites. Survival and growth at the two sites is quite different; average survival at Muddisdale is 98%, compared with 55% at Newfield. Mean heights for many species at Newfield were less than half that of the same species growing at Muddisdale. In both cases common alder seems best suited to these conditions, along with Italian alder at Muddisdale.

The demonstration value of the sites is increasing, with a visit to East Grange planned by the RSFS for May 2020. The majority of the sites will be ten years old this summer and their importance as an educational resource for practitioners, researchers and policy makers throughout Scotland continues to grow.

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.

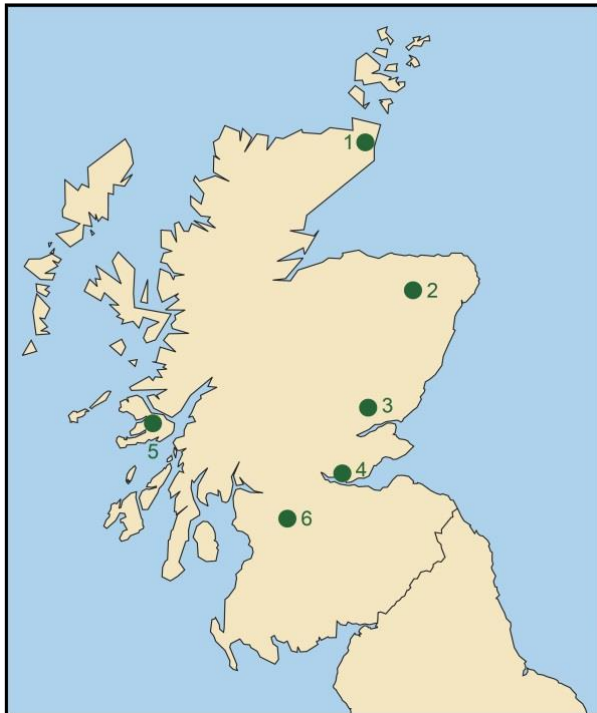
However, there was little current knowledge of SRF in the UK and so in 2007 Forestry Commission Scotland (FCS) and Forest Research (FR) began developing a network of Energy Forestry (EF) exemplar sites. The aim was to address the important information gaps on the growth of short rotation forestry in 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
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. 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)	<i>Acer pseudoplatanus</i>
Italian alder (Alco)	<i>Alnus cordata</i>
Red alder (Alru)	<i>Alnus rubra</i>
Silver birch (Bepe)	<i>Betula pendula</i>
Sweet chestnut (Casa)	<i>Castanea sativa</i>
Ash (Frex)	<i>Fraxinus excelsior</i>
Hybrid larch (Lama)	<i>Larix x marschlinsii</i>
Common alder (Algl)	<i>Alnus glutinosa</i>
Hybrid aspen (Potr)	<i>Populus tremula x tremuloides</i>
Sitka spruce (Pisi)	<i>Picea sitchensis</i> (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	<i>Acer pseudoplatanus</i>
Italian alder	<i>Alnus cordata</i>
Common alder	<i>Alnus glutinosa</i>

As well as some additional species suited to Northerly climates:

Downy birch	<i>Betula pubescens</i>
Beech	<i>Fagus sylvatica</i>
Native aspen	<i>Populus tremula</i>
Goat willow	<i>Salix caprea</i>
Mountain ash	<i>Sorbus aucuparia</i>
Whitebeam	<i>Sorbus intermedia</i>

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%).

Results

Fast-growing broadleaves

Height assessments were planned for the first six growing seasons on all sites and were therefore were only assessed at Sibster for the 2018 growing season.

Sibster (Caithness)

Eight species were replanted on the site in May 2015 and heights from planting to the end of year four, together with the latest survival rates are shown in Figure 2 below. Most species have put on reasonable growth over the past year, the exceptions being

the two aspen clones. Growth of the Rackwick Aspen clone was lower than last year, and that of the Shropshire clone was significantly less than in previous years.

Of the other six species common alder is leading the field with a mean height of 133cm, followed by Sitka spruce (109 cm), downy birch (104 cm), sycamore (100 cm), silver birch (97 cm, and Italian alder (93 cm). The two aspen clones now have the lowest mean heights on the site at 71cm for the Shropshire clone, and 62 cm for the Rackwick.

Survival rates have declined slightly on last year. Sitka spruce, sycamore, and downy birch are in excess of 90%; the two aspen clones are at 84%; common alder and silver birch at 75% and 73% respectively; and red alder at 35%. This is more or less the same pattern as on other sites at year 4, Italian alder having the lowest survival score.

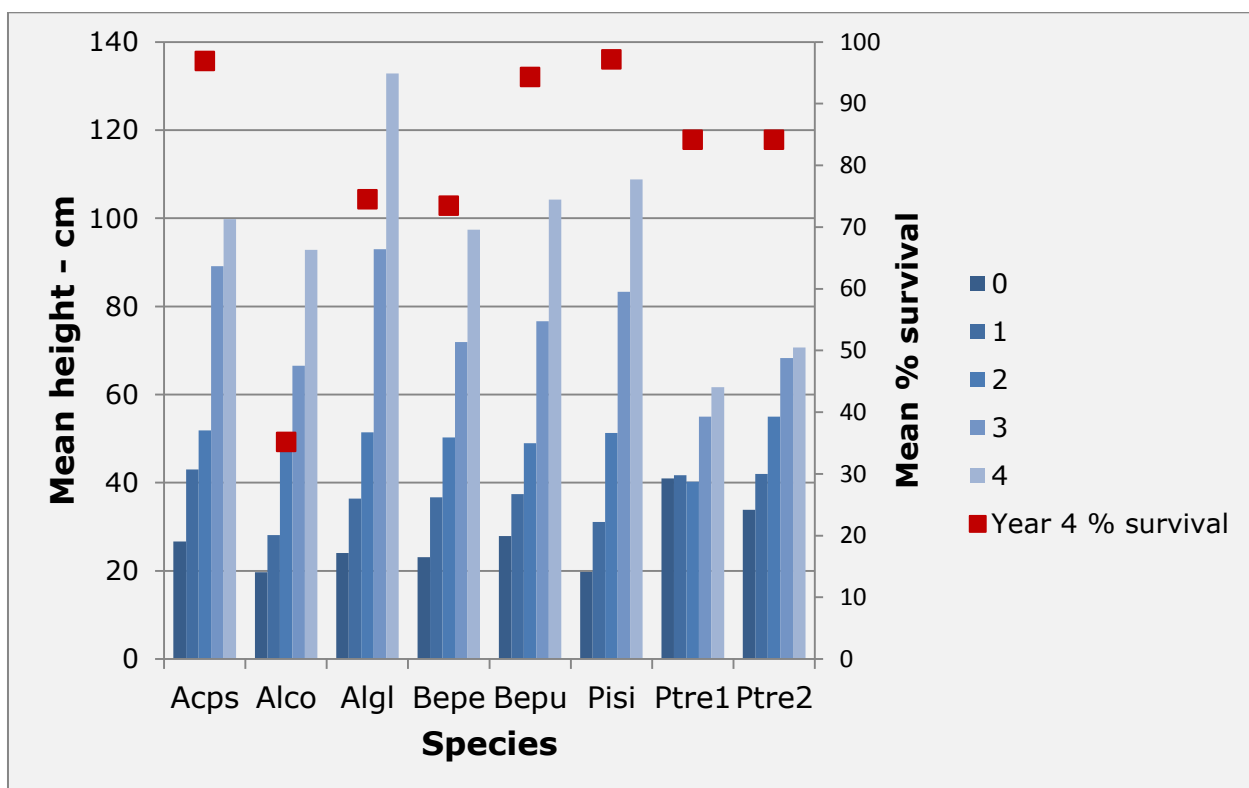


Figure 2: End of season mean heights (cm) and mean % survival at the end of year four at Sibster (re-planted area).

For comparison, the mean heights of species which were included on the other five trials sites are presented in figure 3. Italian alder, common alder, and silver birch recorded their lowest mean heights at Sibster. No species recorded its lowest mean height at Sibster.

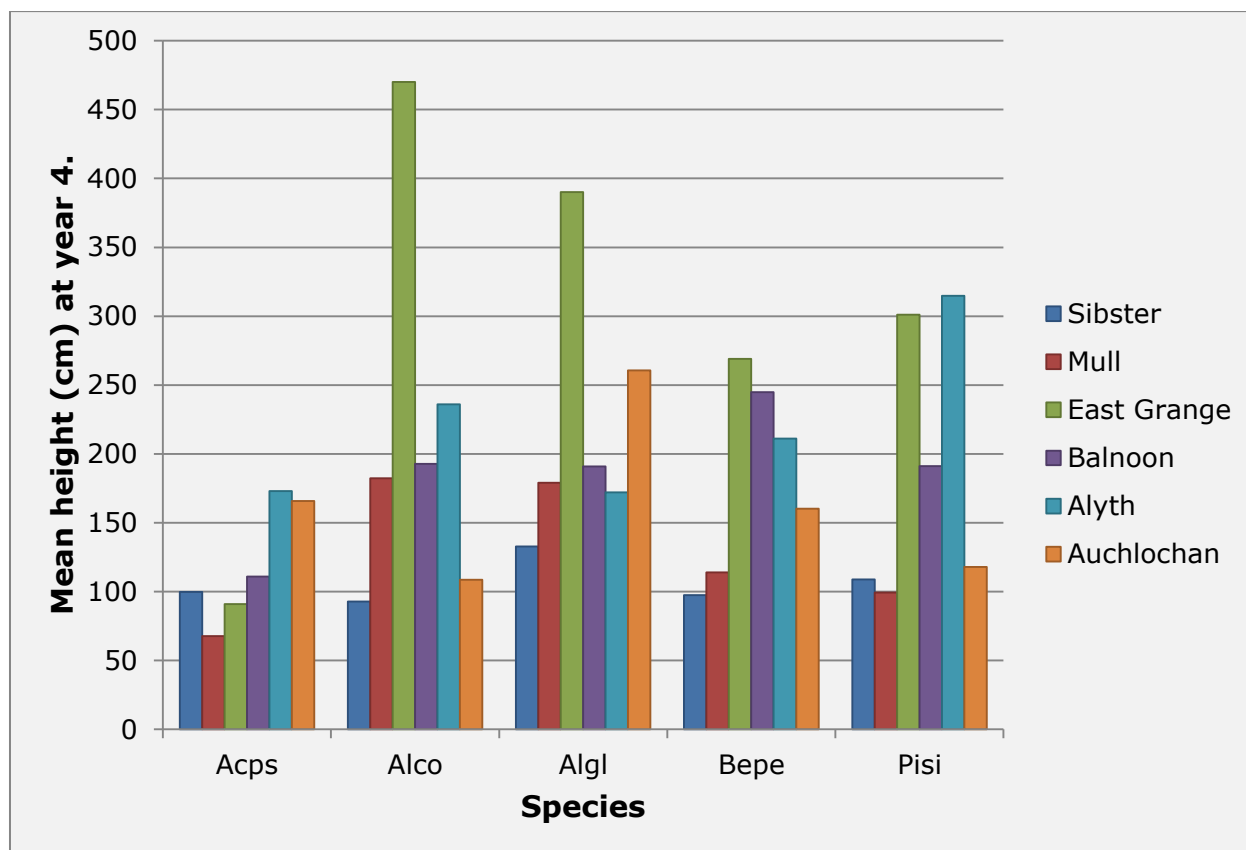


Figure 3: Comparison of mean heights after four growing seasons of species present at all six trial sites.

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%) with no single species falling below 90%. After several years of constant decline overall survival at Newfield has now stabilised at 55%. However, only three species (common alder, aspen, and goat willow) were above 90%, downy birch was 56% and the remainder all below 31%. As per last season, only survival of common alder, aspen, and goat willow were comparable at both sites whereas for all other species survival is much lower at Newfield (Fig. 4).

Trees in the species trial were consistently taller at Muddisdale than Newfield. At Muddisdale, the five tallest species were common and Italian alder (305 and 298 cm, respectively), aspen (238 cm), goat willow (215 cm), and whitebeam (209 cm). The five tallest species at Newfield were common alder (108 cm), aspen and goat willow (87 cm), downy birch (80 cm) and Italian alder (65 cm). Beech and sycamore are among the shortest three species on both sites along with rowan at Muddisdale and whitebeam at Newfield.

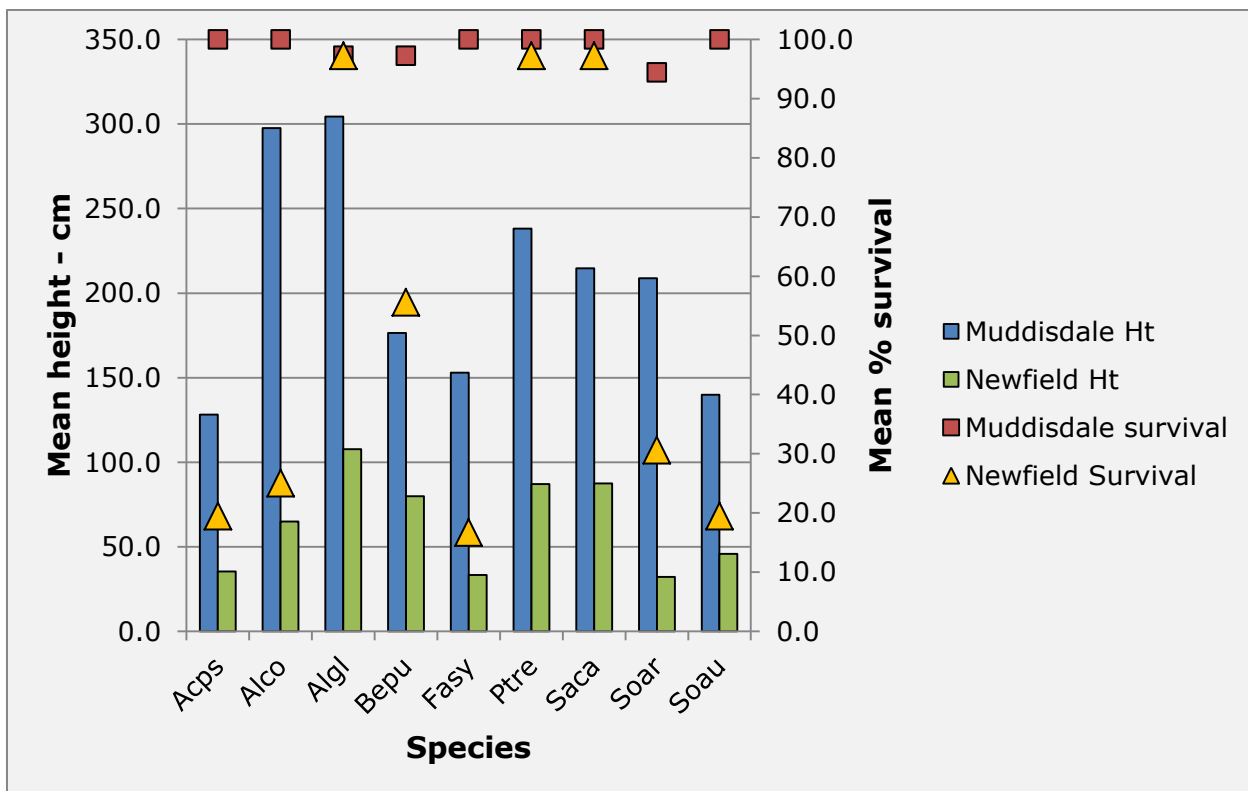


Figure 4: Mean heights and survival at Muddisdale and Newfield on the Orkney Islands.

As in previous seasons, 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 better suited to them..

The full 2018 UHI report appears as Appendix 1 of this report.

Native aspen trials

These trials were assessed at planting in early 2016, after one and two growing seasons at the end of 2016 and 2017 respectively, and most recently at the end of their third year in early 2018. With three complete growing seasons of data we can start to make comparisons of establishment and early growth of the different clonal material across five sites.

Vegetation management continues to be a key operation on the majority of the sites, considerable amounts of natural regeneration also required attention at East Grange. There has been no further evidence of the roe-deer damage seen at Huntly 14 last year.

At Mull Clone 6 has the highest mean growth increment for the past year, 20.4 cm which is comparable to increment for that clone at Alyth (21.2 cm) and at East Grange (21.8 cm). Increment of this clone at Auchlochan and Balnoon was considerably greater; 32.6 cm and 42.1 cm respectively.

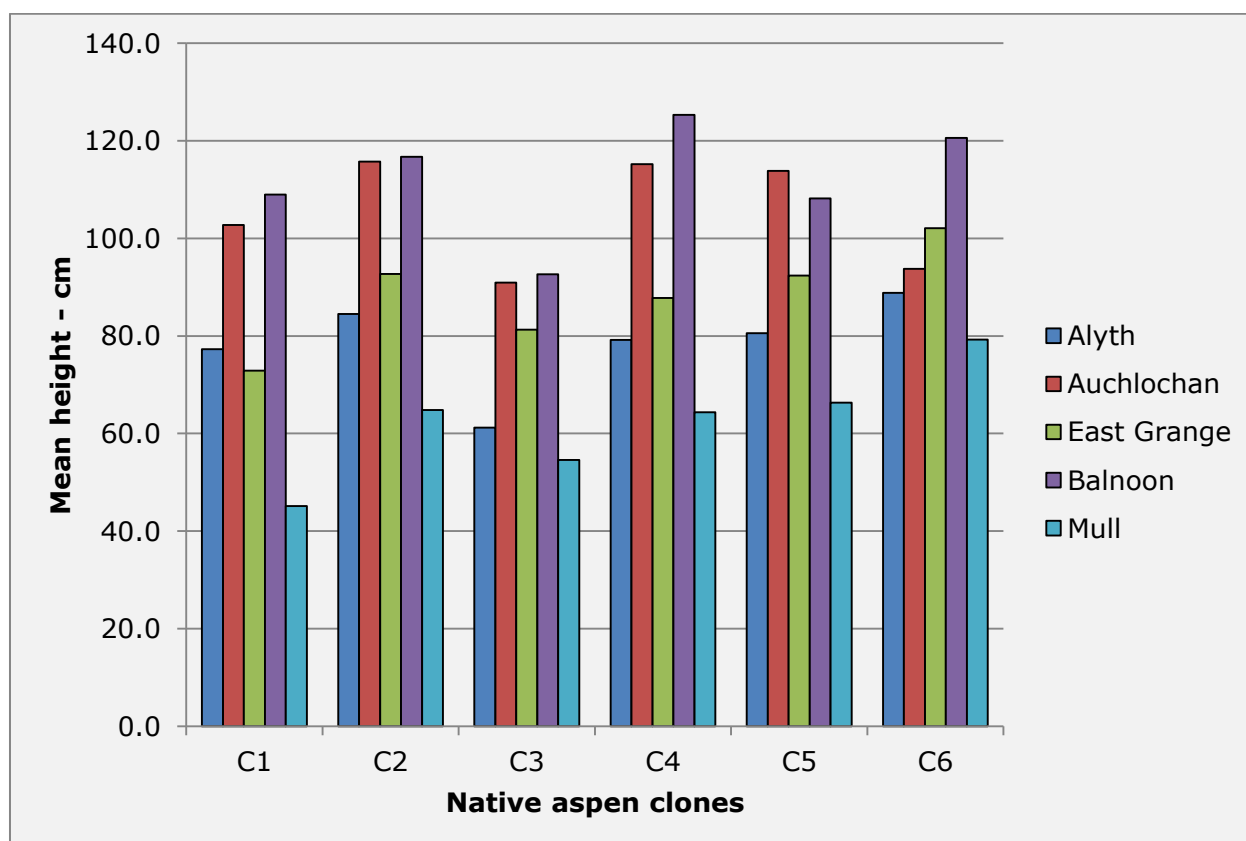


Figure 5: Mean heights at the end of year 3 (2018) of six native aspen clones across the five trial sites.

Initial establishment was very even across all five sites. For the majority of clones across all sites survival is currently in excess of 90% with a couple of notable exceptions. Clones 1 (Orkney 'Rackwick' origin -CL9) and 3 (Arran origin -EECL024 micro-prop) both have lower survivals at Alyth and Auchlochan than on any other site.

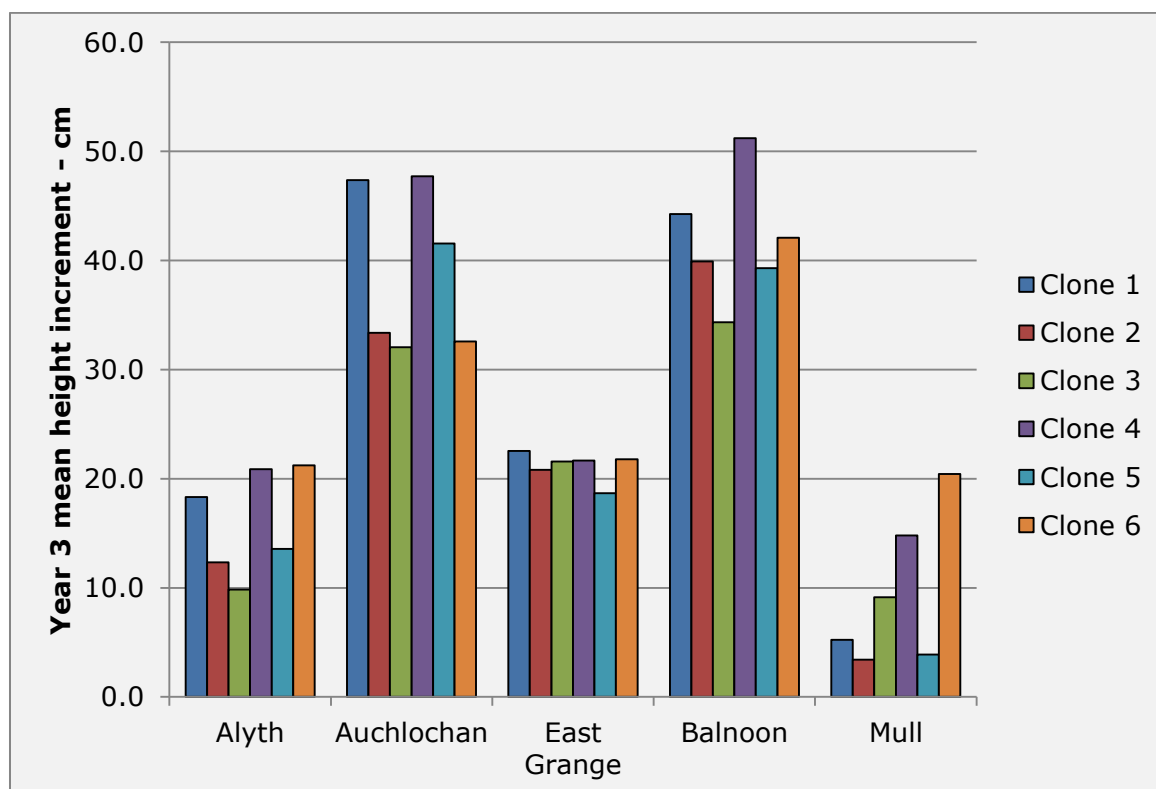


Figure 6: Year 3 mean growth increments (cm) of the six native aspen clones across all five sites.

For the past two years of measurements the root collar diameters (RCDs) have been broadly similar for all clones across all sites and no data has been presented in previous reports. However, small differences in RCD between sites and clones can now be seen. As with height, mean RCD's for all clones were lowest on Mull. Clone 3 had the lowest mean RCD across all sites, and no single clone consistently had the highest mean RCD. However, these differences are still small; maximum RCD was 13.12 mm (clone 4, Balnoon) and minimum was 6.03 mm (clone 3, Mull).

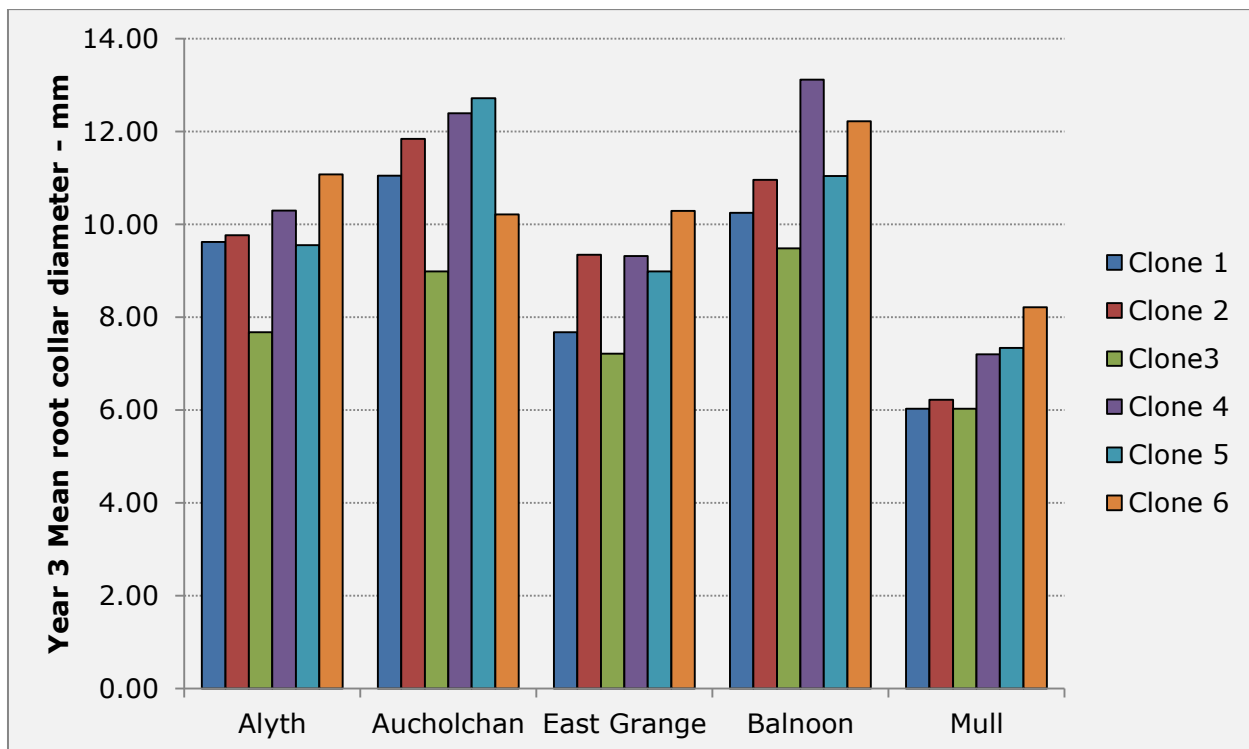


Figure 7: Mean year 3 root collar diameter measurements (mm) of the six native aspen clones across all five sites.

Early conclusions

SRF trials

As most sites were not assessed this year there is no change in the general conclusions from the last report which are summarised here. Year 3 results from Sibster are broadly in line with this although red alder was not among the species re-planted there.

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.

Native aspen trials

It is still 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 (Figure 5) and mean growth increments over the past year have generally been lower than at the other sites (Figure 6). This tentatively suggests that the Mull site is generally less suited to Aspen than the others.

Of the six clones in the trial there are no clones which stand out as being uniformly good or uniformly poor across all five sites. However, clone 6 is currently out-performing the others in terms of height at Alyth, East Grange, and Mull, and is the second tallest at Balnoon. At Auchlochan however it is the second worst performer.

Future plans for the sites and work due in 19/20

SRF trials

Year 10 assessments are due at East Grange, Alyth, and Balnoon, and a year five height assessment on the replanted Sibster plots. This will be the final year that establishment operations and management at Sibster will be provided by Scottish Woodlands, after which responsibility will revert back to Forest Research.

Vegetation management will very likely be required at some or all sites and will be carried out as required at the beginning and the end of the growing season.

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.

Native aspen trials

Application of herbicide to control weed competition will again be required at all sites, as will year four height and diameter measurements. Given the appearance of suckering stems at some of the sites it would be prudent to carry out an informal inspection to determine if they constitute a problem and if remedial action is required.

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. An assessment of the surviving Eucalyptus is also scheduled.

Table 2: Recommended assessment schedule for all SRF experiments.

Calendar year	19/ 20	20/ 21	21/ 22	24/ 25	25/ 26	26/ 27	29/ 30	34/ 35
East Grange	10 (4)	(5)	(6)	15			(10)	(15)
Alyth	10 (4)	(5)	(6)	15			(10)	(15)
Balnoon	10 (4)	(5)	(6)	15			(10)	(15)
Aros	(4)	10 (5)	(6)		15		(10)	(15)
Auchlochan	(4)	(5)	10 (6)			15	(10)	(15)
Sibster	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 2018



Italian alder (left) and common alder (right) at the Muddisdale short rotation forestry trial in Orkney in June 2018

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December 2018



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Executive Summary

1. Monitoring of two short rotation forestry (SRF) trials, established in Orkney in 2013, was carried out in 2018 by the Agronomy Institute at Orkney College UHI. The trials are located at Muddisdale (Orkney mainland) and Newfield (on the island of Shapinsay),
2. 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*.
3. 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.
4. 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 2018 growing season, weed control at both sites consisted of an application of the residual herbicide Kerb Flo over winter 2017/18 and topping and strimming of weeds in June 2018.
5. Tree survival and height were recorded on the 9 innermost plants of each plot at the end of the 2018 growing season.
6. Tree survival over the 6 replicates was high (98%) at Muddisdale but much lower at Newfield (55%). The survival at Newfield was the same as at the end of 2017, suggesting that annual decline in survival which has previously occurred at this site (96% in 2014, 76% in 2015, 63% in 2016 and 55% in 2017) has stabilised for now. Survival at Newfield was lowest in beech (22%), sycamore (24%), whitebeam (24%) and mountain ash (26%).
7. Averaged over all species, trees in the species trial were much taller at Muddisdale than Newfield (206 cm compared with 62 cm). At Muddisdale, the tallest species were Italian alder and common alder (337 and 334 cm, respectively) and aspen and goat willow (230 and 228 cm, respectively). The 4 tallest species at Newfield were common alder (108 cm), goat willow (87 cm), aspen (87 cm) and downy birch (70 cm). At both sites, sycamore, mountain ash and beech were the shortest species (17-19 cm at Newfield and 104-132 cm at Muddisdale).
8. While the average height of all species at Muddisdale increased from 2017 to 2018 (37 cm across all species), at Newfield most species showed a small increase or decrease (average change, a decrease of 1.1 cm across all species). Decreased

height at Newfield resulted either from shoot 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.

9. 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.
10. There are differences and similarities in the performance of tree species at the two Orkney sites:
 1. 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).
 2. While survival is still good amongst the shortest species at Muddisdale, it is much lower amongst them at Newfield.
 3. Comparing their growth and survival relative to the other species at Muddisdale, Italian alder and whitebeam have performed poorly at Newfield.
11. Even though weed control at Newfield has been considerably improved since 2016, this has not resulted in a marked improvement in tree growth. Although tree deaths stabilised from 2017 to 2018, there are several which are in very poor condition and can be expected to die over the next couple of years. It 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 2018, their sixth 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 in early January 2018 at 3.75 l ha⁻¹ and grass and weeds were further controlled by topping and strimming in June 2018.

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:

1. A species trial consisting of 4 replicates.
2. 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).
3. 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, if leaves were not present. In each plot, tree height and survival were recorded on the 9 plants in the centre of each plot. Data were collected on 28 September at Muddisdale and 8 October at Newfield. For presenting data, the mean height of surviving trees was calculated for the measured trees in i) the species trial (replicates 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 October 2018.

Both trials were visited in early June (Muddisdale on 5 June and Newfield on 6 June), allowing a visual comparison to be made of the differences in the stage of tree development at the two trials. As noted in previous reports, trees at Newfield were later at coming into leaf than those at Muddisdale. 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 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 are dying out (e.g. sycamore, mountain ash, beech, whitebeam and Italian alder). Wind rock has resulted in socketing of several species at Newfield, which has probably contributed to some of the tree deaths; common alder seems to have been less affected by this. Very often at Newfield it seems that the current season's extension shoot growth is cut back by strong winds at the end of the growing season (from September) or over the winter and this has resulted in very little change in height, and often a decrease, over the last four growing seasons.

At Muddisdale, common and Italian alder have developed the largest canopies and, as mentioned in previous reports, the prevailing wind is causing some trees to lean (Photo 1, p. 14). In some cases, stem breakage has also occurred. Leaning of common alder has also occurred at Newfield. At Muddisdale, several trees of mountain ash flowered for the first time in 2017 and 2018.

The perimeter windbreak of 3 rows of biomass willows at Newfield has continued to survive well, with an average height of 2.0-2.5 m, which is more than that of any of the species in the trial (Photo 2, p. 14).

Tree Survival And Growth At Muddisdale

Averaged over all plots in the species trial, the average height and survival at Muddisdale was 206 cm and 99%, respectively. Fig. 1 shows the survival of trees at Muddisdale in September 2018 and their average height at the end of each season since planting. The trends established in previous growing seasons continued and common alder and Italian alder (Photo 3, p. 15) 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 3 to 6 (pp. 15-16) show most of the species at Muddisdale in June 2018. Averaged over all species, the increase in height over the growing season (37 cm) was slightly more than that of 2017 (34 cm), and greater than in any of the previous growing seasons. Survival of all species continues to be very good, but was lowest in sycamore (94%).

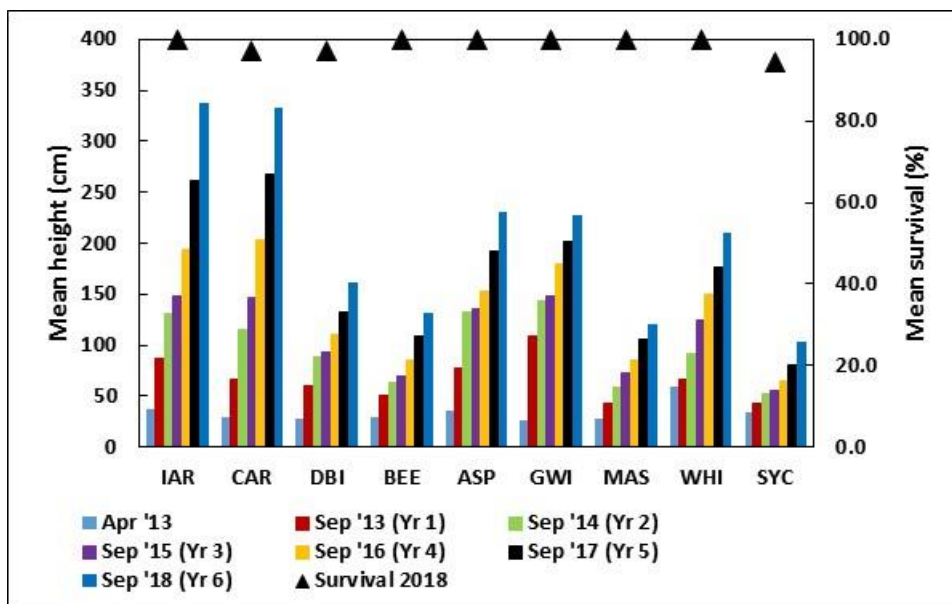


Fig. 1. Mean tree height in the species trial at Muddisdale at the end of each season since planting and survival in September 2018.

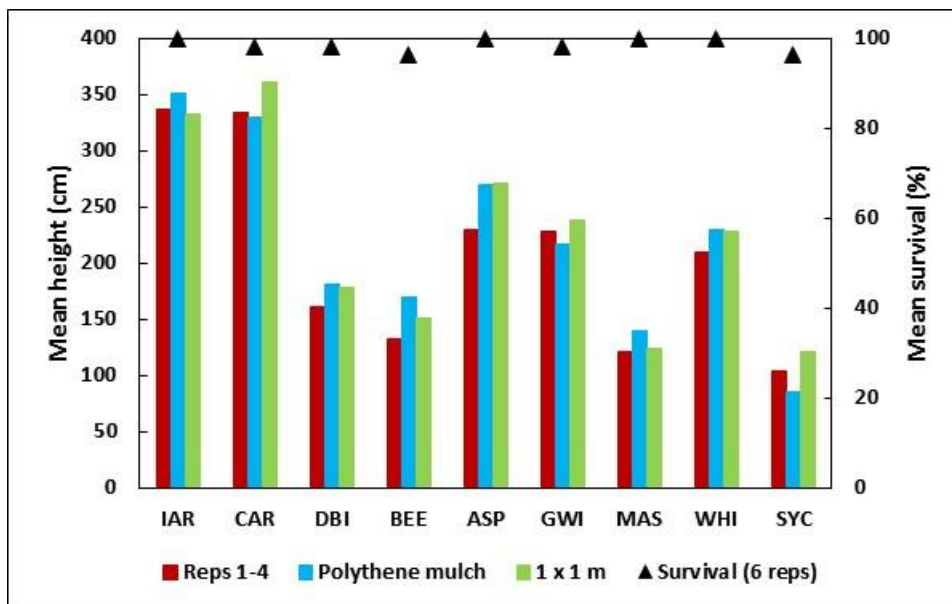


Fig. 2. Mean tree height in the species trial (Replicates 1-4), polythene mulch and 1.0 x 1.0 m spacing replicates at Muddisdale in September 2018 and survival over the 6 replicates.

Fig. 2 compares mean tree height for each species in September 2018 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 3, p. 15), 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 62 cm and 51%, respectively. Fig. 3 shows the survival of trees at Newfield in September 2018 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 little change in height over 2018, and in some cases this was negative. 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. Sycamore and mountain ash have hardly increased in height since they were planted while whitebeam has lost height. Tree survival was highest for goat willow, aspen and common alder (all 97%), intermediate for downy birch (56%), low for whitebeam and Italian alder (26-31%) and very low for beech, mountain ash and sycamore

(17-19%). Common alder appears to be the species which is most tolerant of the site, and the plots of this species are the most conspicuous in the trial (Photos 7 and 8, p. 17).

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 (replicates 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, was 55 % in 2018. This suggests that the decline in survival which occurred between 2014 and 2017 (96% in 2014, 76% in 2015, 63% in 2016, and 54% in 2017) has stabilised. Nevertheless, several trees are in poor health and can be expected to die over the next few years. Survival is lowest (Fig. 4) for sycamore, beech, whitebeam and mountain ash (22-26%).

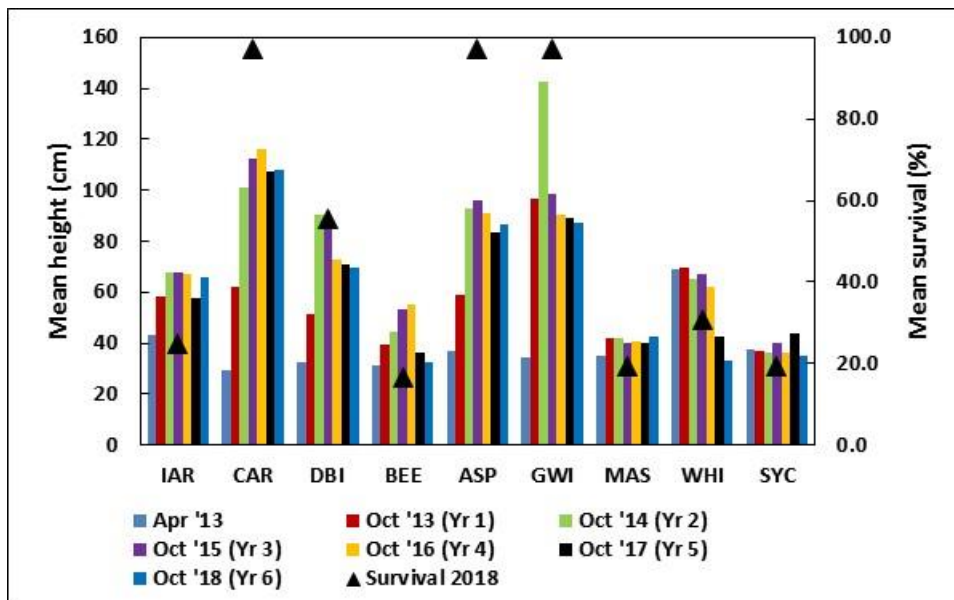


Fig. 3. Mean height of trees in the species trial at Newfield at the end of each season since planting and survival in October 2018.

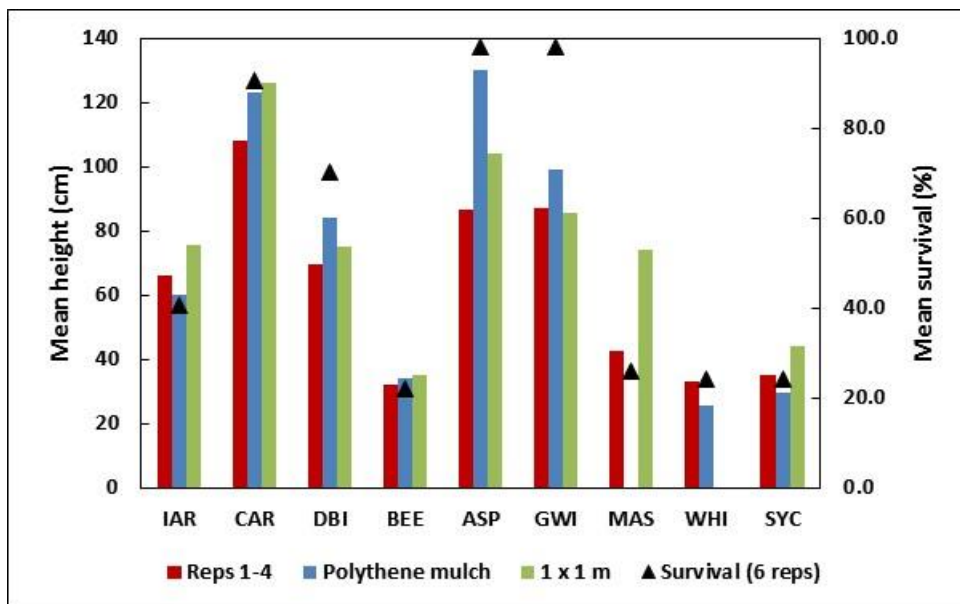


Fig. 4. Mean height of trees in the species trial (Replicates 1-4), polythene mulch and 1.0 x 1.0 m spacing replicates at Newfield in October 2018 and survival over the 6 replicates.

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 or survived 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 until 2018.

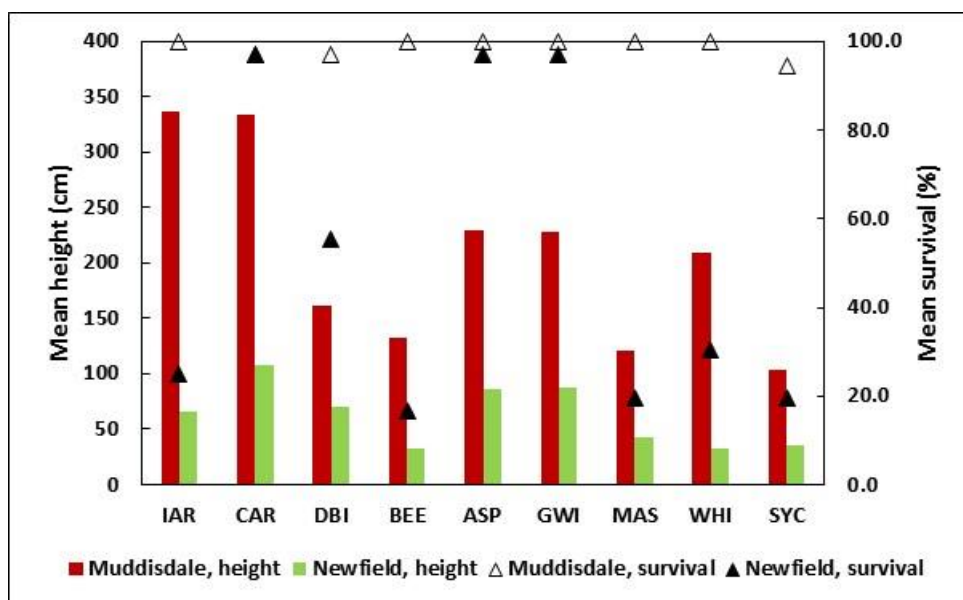


Fig. 5. Comparison of mean tree height and survival in the species trial (Replicates 1 to 4) at Muddisdale and Newfield at the end of 2018.

Discussion

The good growth of most species at Muddisdale in 2018 reflects the favourable growing conditions over the year. The May to September temperature¹ (12.2 °C) was higher than the average for 2000-2017 (12.0 °C), and July, in particular, was warmer than average (14.7 °C compared with 13.3 °C). In contrast to Muddisdale, there was no marked increase in height of trees at Newfield. A major cause of this was shoot dieback, apparently caused by wind 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 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

¹ Temperature data from Kirkwall airport (<https://en.tutiempo.net/climate/ws-30170.html>).

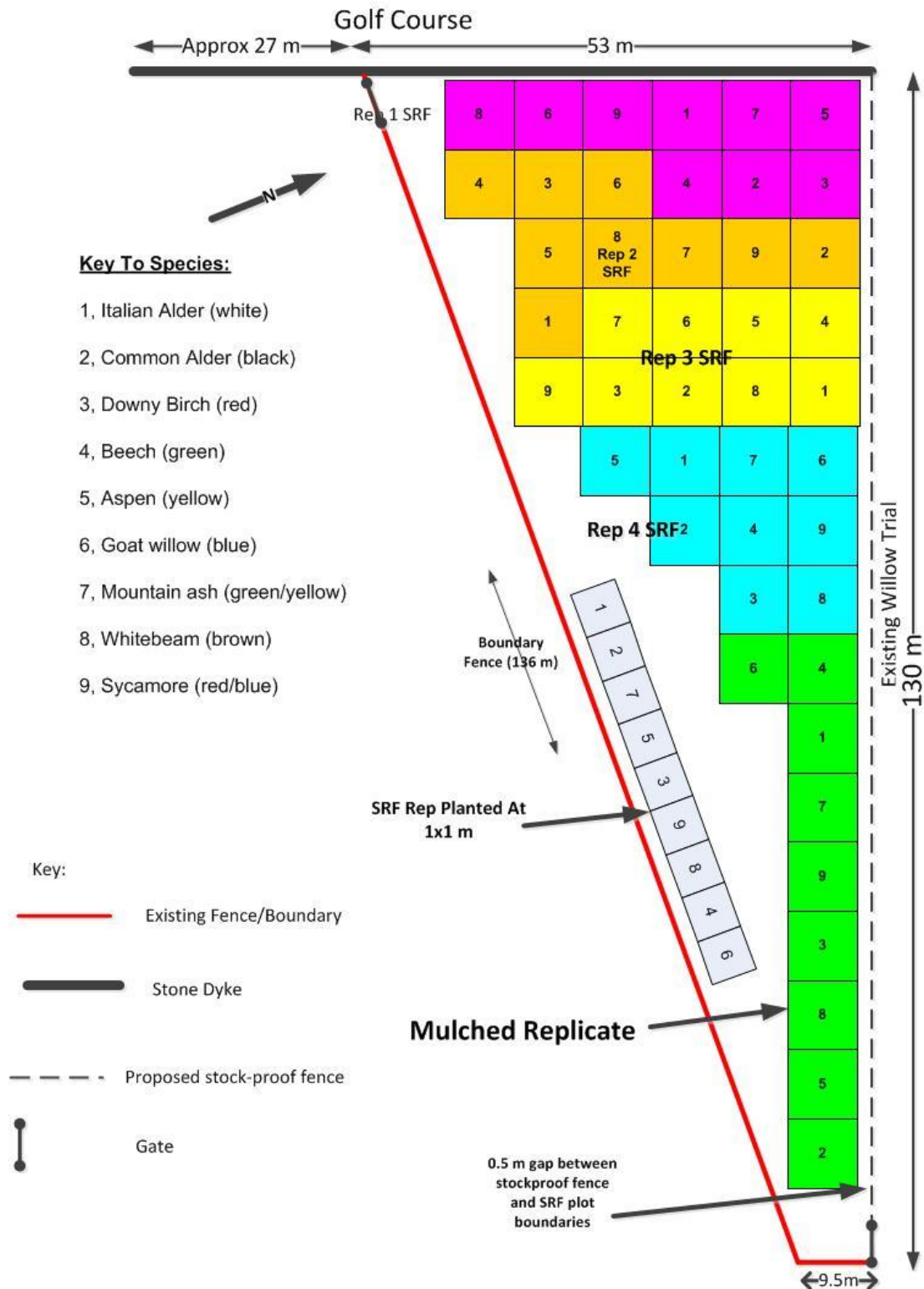
Muddisdale. At both sites, the performance of downy birch has been intermediate between the best and the poorest species.

Acknowledgements

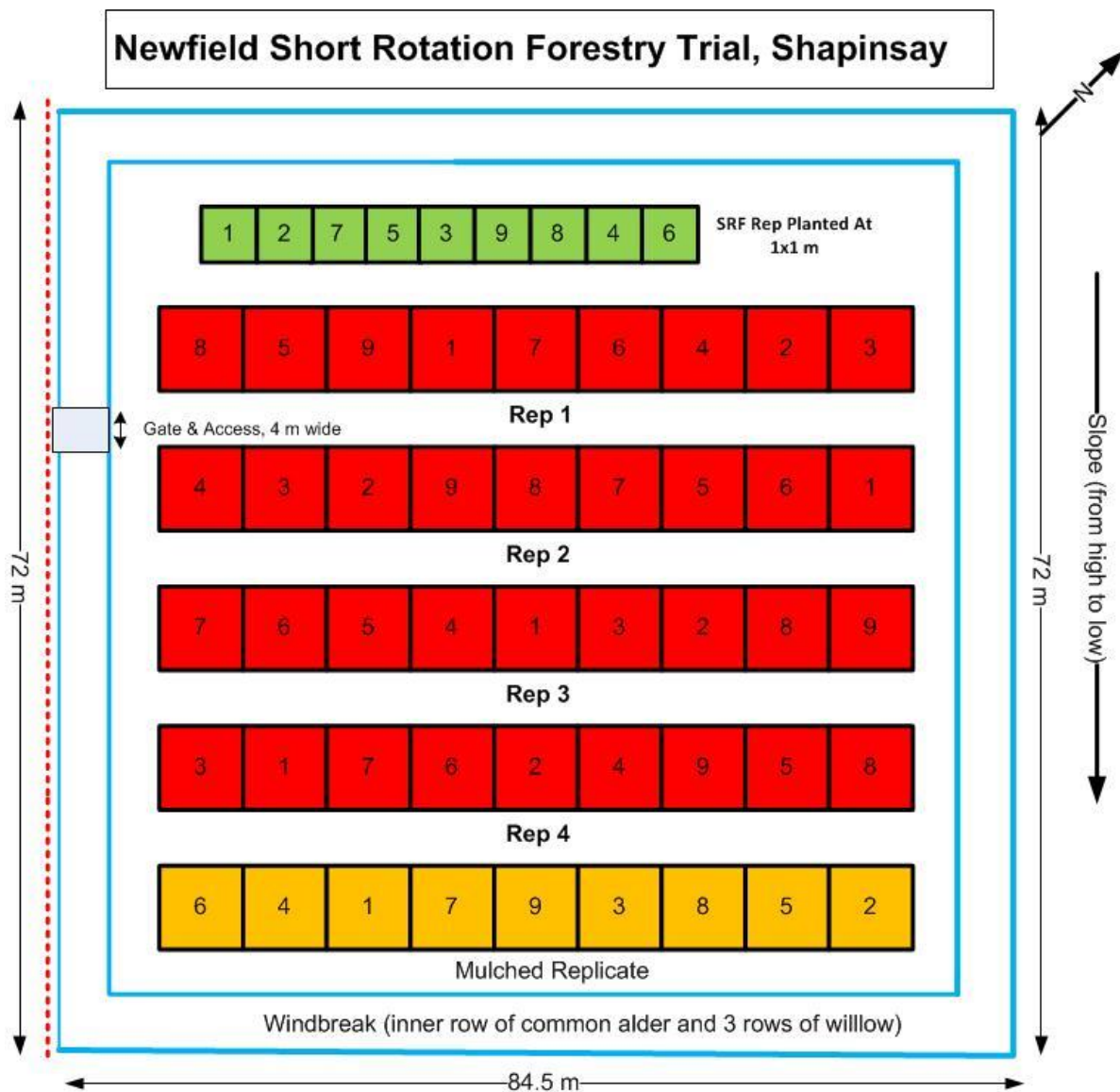
The authors are very grateful to Forestry Commission Scotland and, in particular, John Risby for his enthusiastic support and interest in these trials. They would also like to thank Jean-Baptiste Bady at Balfour Castle for his help during visits to the Newfield trial.

Appendix 1. Plan Of The SRF Trial at Muddisdale

MUDDISDALE SHORT ROTATION FORESTRY TRIAL



Appendix 2. Plan Of The SRF Trial at Newfield



Key:

--- Fence/Dyke ---

==== Area between blue lines, windbreak

Approximate Scale: ←10 m→

Key To Species:

- 1, Italian Alder (white)
- 2, Common Alder (black)
- 3, Downy Birch (red)
- 4, Beech (green)
- 5, Aspen (yellow)
- 6, Goat willow (blue)
- 7, Mountain ash (green/yellow)
- 8, Whitebeam (brown)
- 9, Sycamore (red/blue)

Appendix 3. Photographs



Top: Trees of Italian alder at Muddisdale in April 2018 showing leaning in response to the prevailing wind.
Bottom: Trees of goat willow (foreground) compared with those of SRC willow.



Top: Trees of Italian alder (left) and common alder (right) at Muddisdale in June 2018. **Bottom:** Trees of aspen (left) and downy birch (right) at Muddisdale in June 2018.



Top: Trees of sycamore (left) and whitebeam (right) at Muddisdale in June 2018. **Bottom:** Trees of beech (left) and goat willow (right) at Muddisdale in June 2018.



Top: Trees of goat willow (left) and common alder (right) at Newfield in October 2018. **Bottom:** Trees of downy birch (left) and common alder (right) at Newfield in October 2018.