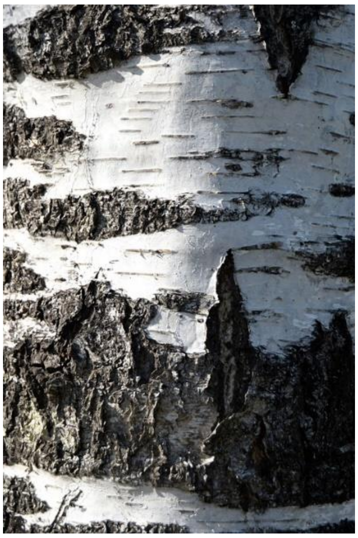
European Innovation Partnership (EIP) Wales

Small scale birch tapping in Wales:

A manual for artisanal tappers



March 2023

A manual for artisanal tappers based on the findings of EIP Wales project 38 – 'Comparing on-site preservation techniques for fresh Welsh birch sap for use in artisan products by local businesses.' (Jan 2021 – Jun 2022)

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The purpose of EIP Wales was to fund agricultural projects across Wales that encouraged the collaboration between farmers and others that work within the sector. Bringing people from both practical and scientific backgrounds creates a great opportunity to draw from different experiences, benefit from the latest knowledge and introduce new ideas whilst tackling problems. Since 2017, EIP Wales has funded 46 projects across Wales, working with over 200 farmers, and a multitude of individuals, businesses and academics working across the agricultural sector.

Acknowledgements: The experience and data on which this manual is based would not have happened without the enthusiasm and hard work of the EIP Operational Group members. This manual is a testament to the hard work of Wild Spirit; Llais y Goedwig; Llyn Parc Mawr; Abergavenny Community Woodland Group, Cwmffrwd and Lower Pen y Graig farms and we hope it does it justice. Thanks are also due to Lafan, the EIP Wales team and Farming Connect who actively supported and promoted the project at every stage including navigating the strictures of covid restrictions.

LLAIS Y GOEDWIG The voice of community woodlands in Wales

LLYN PARC MAWR Grŵp Coedwig Cymunedol Community Woodland Group

Abergavenny Woodland Group

Wild Spirit Bushcraft

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Introduction

There is a long and active tradition of tapping birch trees for sap in northern Europe, and it has recently become popular in Alaska and Canada as a means of extending the season for Maple syrup businesses. Birch sap is tapped for just a few weeks during early spring just before leaf burst. The sap is consumed fresh as a drink (popular in northern Europe) and concentrated into a sugar-rich syrup (more common in North America). Birch sap is a niche product within the tree waters market and is imported into the UK from Europe so has an established market presence. However, preserving sap requires significant investment in high tech processing equipment and large-scale production. Birch syrup is made by concentrating the sugars in sap and is a unique product with only a handful of suppliers in North America and Europe. It commands high prices from niche markets and small-scale production using artisanal methods is feasible.

Between 2019 and 2022 two projects: the Dewis Gwyllt project (Llais y Goedwig & WRL) and the EIP birch project, undertook complementary work to explore birch syrup production for woodland income diversification in Wales. The intention was that tapping, and production of syrup could be a viable commercial proposition for woodland owners and small businesses. The sap run is highly seasonal so could never provide a full-time income. Whether tapping birch makes sense depends a lot on what else you need to do in March and whether birch tapping is compatible with this.

The development of a well thought-out birch tapping venture is laid out in a costed business plan. This doesn't have to be a complex written document with spreadsheets, but you do need to know how much the venture will cost to set up, how you will market the syrup, and whether it will be profitable. Profit is what make from selling a product once you have deducted the costs of making it – even a high sales price does not guarantee a profit if costs are also high. So, you need to know what you can sell your product for and how much it will cost to make, including your time, before you can be certain the venture will be profitable. Finishing birch syrup is costly for small quantities and marketing small quantities of a novel product can be challenging. It may therefore be worth considering working together with other producers on finishing and marketing.

A lot of questions you won't be able to answer at the outset, so it is a good idea to start small and build up as you gain experience.

This manual is based on the findings of the EIP trials and research which are contained in the report "**Small scale birch tapping in Wales: Final project report**" which can be downloaded from the EIP project webpage alongside a "**Birch sap start up support**" document which outlines the elements of what a basic business plan for your venture might contain.

https://businesswales.gov.wales/farmingconnect/business/european-innovation-partnership-eip-wales/approved-eip-wales-projects/comparing-site

The Dewis Gwyllt webpage also has instructional videos and information leaflets on birch tapping for syrup. https://www.dewisgwyllt.co.uk/product-research/birch-syrup/

Part 1: Birch sap, trees and woodland

According to the National Forest Inventory in 2011, there are 11,400 ha of Wales classified as birch woodland which are estimated to contain some 129.3 million trees[1]. This makes birch the fourth commonest broadleaf species in Wales and 90% of this resource is on private land, with much of this being small farm woodlands. Despite birch being a prime timber species in northern Europe, in the UK it is considered of little value as a commercial species, considered a 'weed' and birch woodlands somewhat disparaged as 'scrub'. However, birch is an ecologically significant species as it is the principal pioneer tree which establishes woodland cover on disturbed, degraded, and abandoned land and paves the way for other species and the establishment of woodland through natural regeneration. Birch is also one of the hardiest of species and forms woodlands in the uplands where few other species grow. Birch itself provides food and habitat for more than 300 insect species (only surpassed by oak and willow), it is associated with many fungi such as fly agaric, birch milkcap, and birch polypore, while the plentiful seed is a useful late autumn and winter food for birds such as siskins, greenfinches, and redpolls. Birch woodlands have a light open canopy which provides sheltered conditions for woodland ground flora such as wood anemone, bluebell, wood sorrel and bilberry. The leaf and twig litter that accumulates under the trees rots down quickly and has long been thought to ameliorate acidic soils and improve soil fertility and earthworm activity. The roots can break up ironpans and rot quickly which improves soil porosity and water holding capacity. Birches' tolerance of occasional water-logging and rapid establishment means it can find a place in riparian management: leaves falling into water are a food source for aquatic insects, the light canopy provides dappled shade, and roots can stabilise banks.

There are many reasons to value birch and the woodlands it creates but it has little economic value. It is hoped that promoting sap as a product will help to add value to birch, provide an incentive for pro-active management of the resource, and provide some income so it can "pay its way" in the farm economy. Sap production is entirely compatible with carbon capture and storage so could potentially add income to woodlands within the carbon market.

Ecological profile of birches

Each species of tree has its own unique role in the ecological processes which shape wooded landscapes. There are several approaches which seek to describe and understand interactions between a species and the environment (autecology), which determine where in the landscape it occurs (its niche), how it lives its life to take advantage of opportunities (life history strategies), and its role in the development of the communities of plants which make up current vegetation cover.

The size, growth potential, seed dispersal etc. of Birch is strongly related to its life history strategy as a **pioneer** tree. Birches are the first trees to colonise areas of bare soil and may successfully establish and dominate on many sites unsuitable for other native species, such as acidic peat bogs and fens, upland sites, in tree-fall gaps, clear-fell sites and burnt areas. Birches produce prolific wind-borne seed and once seed lands on a suitable site it germinates the following spring, and if in full sun grows rapidly to produce dense stands of young trees. Associations with mycorrhizal fungi are common and help the tree scavenge nutrients and water from disturbed soil. As the canopy develops the conditions become too shady for further establishment of birch, and the species gives way to what are usually more robust shade-tolerant species such as oak. As a typical pioneer, birches' strategy is to move around the landscape from one area of disturbance to another on a generational timescale. The consequence of this opportunistic life history which favours translocation over endurance

[1] https://cdn.forestresearch.gov.uk/2022/02/nfi_prelim_bl_ash_estimates.pdf

results in a tree with a short life span, weak defensive reactions to wounding, and inability to respond positively to a changing environment - even if this is favourable for birch growth.

Does it matter which birch?

There are two species of birch native to Wales: silver birch / bedwen arian / *Betula pendula* and downy birch / bedwen llwyd / *Betula pubescens*. Of these, downy birch is generally considered to be more common in Wales as it is better able to tolerate wetter, colder, and more exposed sites than silver birch. If your birch trees are 'wild' in that they weren't planted, then they should be trees best suited to your site and it hardly matters which species they are. This is especially true as there is little evidence that there is any difference between the species in terms of sap flow and quality. However, silver birch is regarded as growing up to 20% faster and has occasionally been reported in Eastern Europe as having higher sap yield than downy birch, so you may be interested to know which, if any, of your trees are silver birches.

The two birches are similar and are slender trees with pale bark, triangular leaves, and catkins. It is notoriously difficult to separate the two species and many of the characters often said to be distinctive to each species are often inconsistent i.e., leaf shape may indicate downy, while bark texture may indicate silver. There is some genetic basis to this mixing as silver birch is diploid (has one set of chromosomes from each parent) to give 2n=28, while downy birch is tetraploid (two sets of chromosomes from each parent) to give 2n=56. Being tetraploid, downy birch can readily hybridise and exhibit intorsion (inclusion of genes from other species) and the trees can exhibit a wide range of characters including those which overlap with other species. Some of these hybrids are consistent enough to be recognised as distinct sub-species or varieties, and there are several of these present in Wales. It is not known if there are any differences between downy birch subspecies in terms of growth rate or sap production. For practical purposes, if a tree exhibits the classic suite of distinguishing characters for silver birch (white bark, triangular leaves, and warty young twigs) then you have silver birch. Any trees which don't have any of these i.e. bark is grey or twigs are covered with fine hairs, then they can be considered to be downy birch. However, if you wish to examine your trees in more detail then Appendix 1 gives a description of silver birch and the main UK sub-species of downy birch.

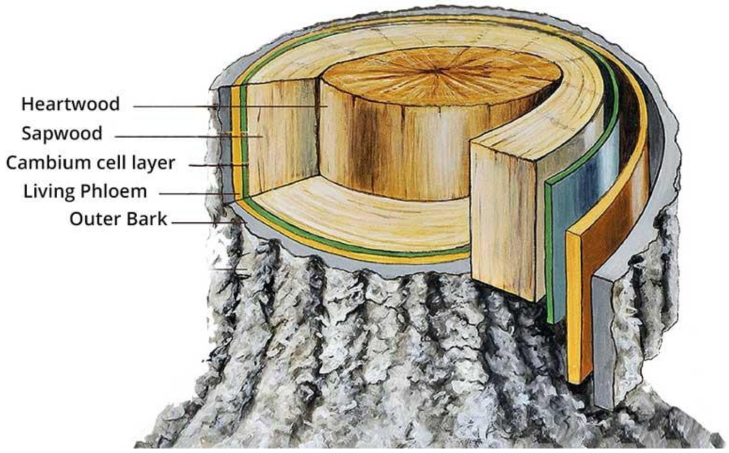
Birch trees within a woodland will also vary – it is unlikely you will encounter a woodland of pure silver birch, but this is possible with downy birch. Planted trees are perhaps more likely to be silver birch as this is considered more attractive and faster growing, and therefore favoured by seed collectors and nurseries.

What is birch sap?

Sap is the life blood of a tree. It flows from the roots up the trunk to the leaves through the outer ring xylem vessels that make up wood known as sapwood (Figure 1).

Birch trees prepare for spring by drawing water into the roots and releasing stored sugars and nutrients into the sap. Tapping into the pressurised sapwood causes the sap to flow out of the tree. Once the buds burst and leaves open the pressure is released and sap flow ceases. The season for tapping – when the sap runs - is about three weeks in March when sap pressure is at a maximum and rich in sugars and minerals. Predicting the start of sap flow is problematic, as it depends on a complex interaction of weather conditions over the winter - especially the depth and duration of freezing temperature, and how quickly and when temperatures start to rise. Sap flow is usually higher in cool, late springs – sometimes dramatically so. In Finland, warmer years were found to have two to three times less sap than cooler years.

Figure 1 Internal structure of a tree trunk



From: https://www.gotreequotes.com/anatomy-of-a-tree/

What is in sap?

Sap is mostly water with a small amount of sugar, some acids and trace minerals. Fresh from the tree the sap is around 0.7 °Brix sugar and half glucose, half fructose. Birch sap also contains malic acid and succinic (fruit) acids which give it a pH of around pH 5.5 to 6. Sap also contains a range of trace components including free amino acids (citrulline, glutamine, asparagine) and proteins. Of the mineral in sap, levels of zinc, copper and manganese are comparable to that in a mineral water.

Birch sap is very different from maple sap, which is only sucrose, does not contain acids, and has lower levels of salt (i.e. potassium, calcium and manganese). The process of heating sap in the production of syrup creates complex Maillard reactions and caramelises the two sugars, which with the acid and salt, creates a thin dark syrup with complex flavours likened to treacle with umami overtones.

What is Brix?

A measure of the dissolved solids in a liquid commonly used as a measure of dissolved sugar in an aqueous solution. It is the units given by most refractometers and hydrometers.

One Brix degree (°Brix) represents 1 gm of sucrose in 100 g of solution. However, for other dissolved solids Brix is only an approximation.

Birch sap contains glucose, fructose and minerals which means Brix overestimates sugar content with multiplication by 0.9 taken as a correction to give a measure of actual sugar density.

Part 2: Tapping birch trees

Finding a suitable woodland and site

There are several contexts in which you might find birch:

- Plantation of birch
- Natural regeneration in "failed" forestry plantations
- Alongside railway lines and roads and on brown field sites
- On farms on land with low numbers of grazing animals
- On upland moorland and fringes of bogs with low grazing intensity

Not all of these might be equally suitable for tapping. Since trees accumulate nutrients from the environment those growing on contaminated sites e.g. alongside very busy roads, on mine spoil etc. may contain harmful compounds.

Access arrangements may also vary. If you own land then you are free to tap birch. If you don't own suitable trees, then you may be able to make an agreement with someone who does to tap their trees. This could be a neighbouring farmer or with the managers of a commercial forest. A simple written agreement between owner and tapper is recommended so that all parties understand what is involved. One of the EIP project operational group (OG) members (the farmers in the project) in the EIP project obtained a permit from Natural Resources Wales (NRW) to collect sap from a NRW forest. Discussions with the managers of private woodlands suggest they would also be willing to consider permitting birch tapping. For birch that has arisen within a commercial plantation the manager may be willing to allow access to birch trees as they have little value to them, and allowing tapping will help meet their social obligations under a sustainable forest management certification.

The Dewis Gwyllt project raised the possibility of extending sustainable forest certification to birch sap products. Following on from this, sap has been included as a named product in the draft UK Woodland Assurance Standard: UKWAS 5.0 with the reports and manual prepared by the EIP project contributing to good practice standards. Once approved, UKWAS 5.0 will form the basis for FSC and PEFC certification for responsibly harvested birch syrup from UK woodlands.

Applications for a Permit to tap birch in a Welsh Government forest should be addressed to the Permissions team in the relevant NRW area. Expect to have to indicate the exact location, number of trees, and provide a method statement detailing procedures to be used. Prior to operations you will also need to provide a Risk assessment and a Safety plan. Operations should conform to Biosecurity measures including use of an alcohol-based disinfectant on drill bits and to minimise risk of transfer of pathogens between sites.

Choosing a site to tap

Ideally, the tapping site should be level or gently sloping. Heavy buckets of sap will need to be carried out, and steep slopes can make this both dangerous and difficult. Nearby road access for extracting the sap collected each day is needed. A dense understorey, particularly of bramble, can make access to trees difficult, and is worth controlling especially if the site is intended to be tapped long-term. Ideally, tapping sites should be in areas away from general public access as there is a risk the equipment might be disturbed.

When to tap and what to expect

Sap flow in birch starts in late winter as the trees 'prime' themselves for bud burst and in Wales this is in March. However, there is wide variability between sites and between trees, and small volumes of sap may be produced over a wide time period. Observations over three years (2019-2022) suggests that the sap run can start as early as the last few days of February on the south coast and is progressively delayed, starting some ten days later on the north coast (see Figure 2 for data for 2021). Sugar content is as important as the volume of sap and it seems that sugar content is highest at the beginning to middle of the run. If you wish to get a better understanding of the performance of trees on your site, you could invest in some scales and a Brix meter to track total sap volumes and average sugar through the season.

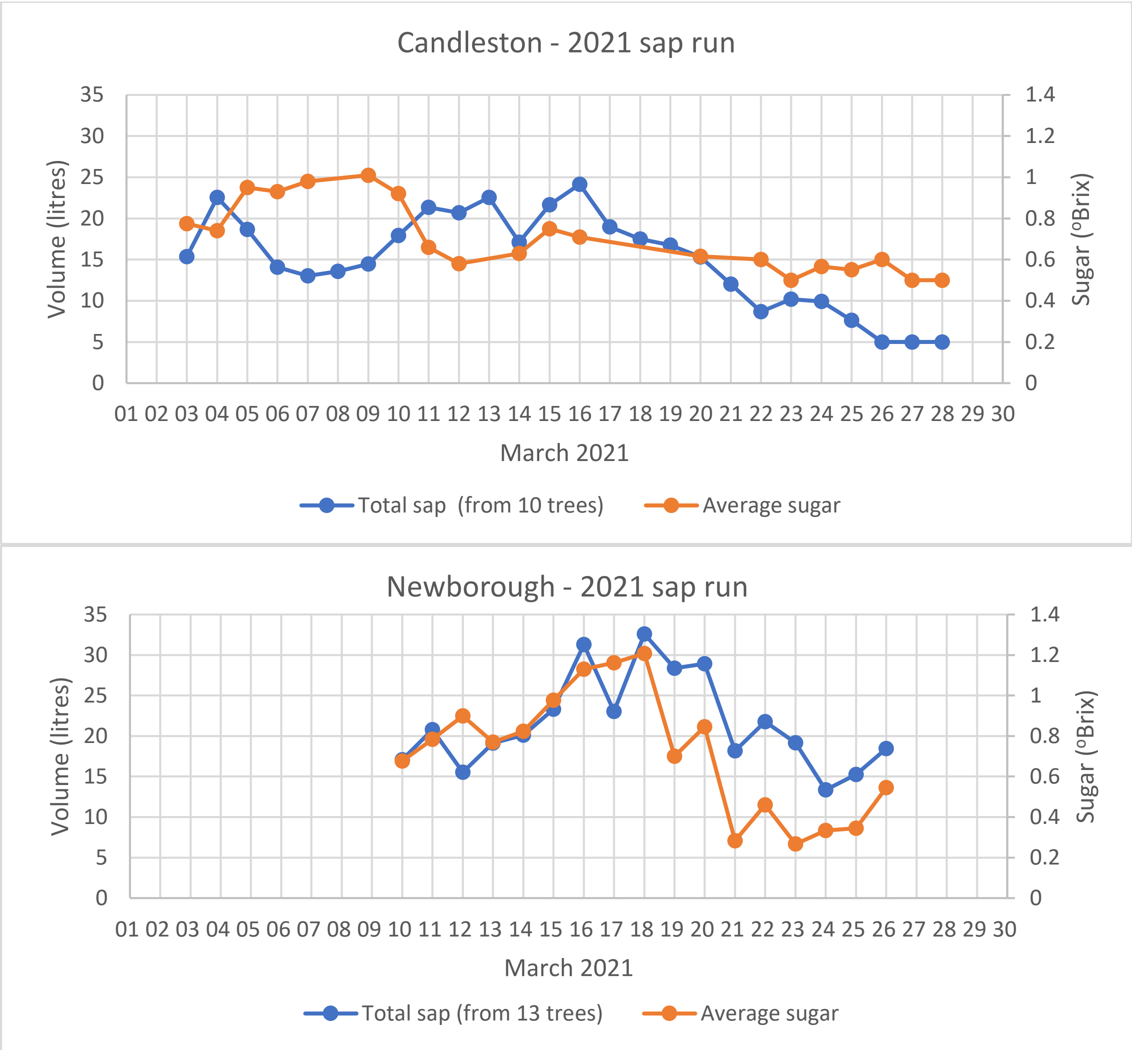


Figure 2: Sap flow season in 2021 for Candleston (south coast) and Newborough (north coast)

Putting a hole in a tree stimulates a wound response and allows in air and microorganisms. Expect the first trees to start producing milky, contaminated sap from about 12 days later. You need these 12 days of clear sap to coincide with the peak in sap production and highest sugar content. There is nothing more frustrating that having to throw away litres of milky sap from a tree that has only just started producing good volumes. In the EIP trials we started tapping too late and all trees dried up before they went milky or too early so sap was milky and still producing good quantities of sap. Judging the timing of tapping is further complicated by each tree doing its' own thing with no outward sign of whether it is yet to start, in the middle or before its own sap run. As you gain experience of tapping and get to know your woodland and site it should become easier to capture the most sap from your trees. In the early years this may require tagging trees and making notes of how each behaves.

In North America it is suggested that three test taps should be installed – in Wales in late February/early March – once two are producing steady flow of sap (to give ~ 1 litre a day) it is time to start tapping. Foraging advice is to use clues such as daffodils opening, hawthorn buds swelling to "the size of a squirrel's toe", etc..

Alternatively, if staff planning is important then trials in 2019-2022 suggest that installing taps in the first week of March in South Wales, and second week of March in North Wales should catch the sap run in most years.

Sap yield can vary greatly from tree to tree. Although there is general synchronicity across the season, each tapped tree can take its own trajectory and may start sooner or finish later and have maximum flow at different times, as shown for Newborough in Figure 3. Here we see that some trees (e.g. in #359 and #410 in 2021 and #409 in 2022) consistently give low sap yields across the whole run. In 2021 (the cooler year) the sap run is longer and ends with the sap going off after tapping for 14 days - represented in Figure 3(a) by the ‘stutter’ with yield of clear sap varying from one day to the next while sap was still flowing. In 2022, tapping based on timings in 2021, tapping started five days later but this year was warmer and before the sap could start going off the trees dried up as shown in Figure 3(b). Note also that the cooler year had maximum daily yield some 30% higher than in 2022.

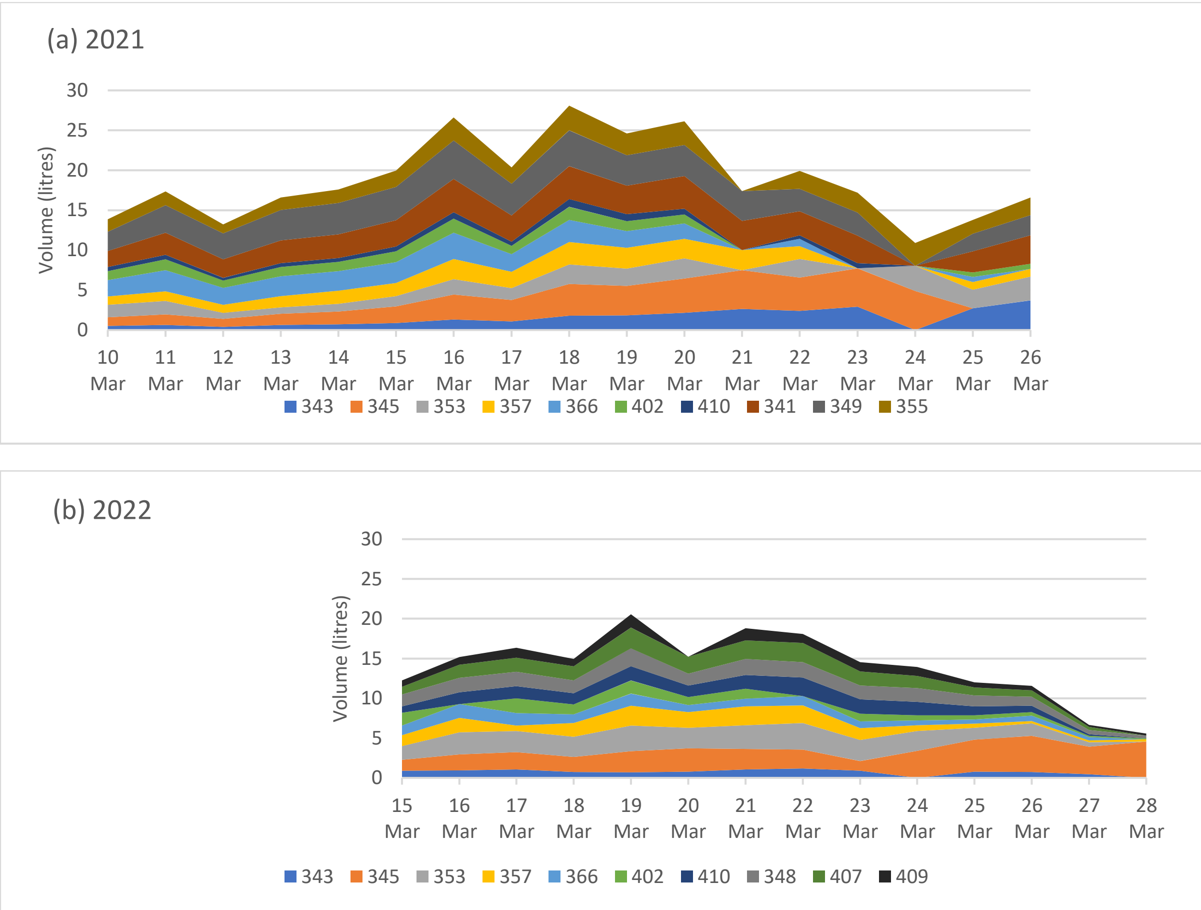


Figure 3: Daily sap yield for individual trees at Newborough

Examination of yields from individual trees at all sites revealed that very few trees which give very low yields (less than 0.5 litres) on the first two days go on to give any useful quantity of sap. It is therefore worth considering removing taps from these trees and placing them on alternative trees. Just over half of the trees have similar yields i.e. a high yielding tree in one year also gives high yields then next – so it is worth making a note of high yielding trees for tapping in subsequent years – but not to be too disappointed if they fail to live up to expectations.

The average sap yield across the EIP trials was ~2 litres per tree per day and this can be used as a general guide. However, generally larger trees give higher yields than smaller ones so if your trees are on the small side then you might expect lower yields – for trees between 20-24 cm estimate 1.5 litres per tree per day and for sites with larger trees maybe quite a bit higher. Yields also vary from site to site but not in way which makes it possible to estimate yield.

The key observations regarding the timing of the sap run from the combined experience of the Dewis Gwyllt, EIP projects and WRL tapping trials (2019-2023) are:

- Test taps can be used to detect the start of the sap run – but intuition, especially if based on previous tapping at the site can be just as reliable.
- It takes around 7-10 days for the peak in sap flow to progress from the south to north coasts of Wales (approximately 1 day later for every 20 km further north).
- If you need to fix dates for tapping then starting in first week of March in south and second week in March in north will probably catch the main part of the season.
- The sap run will start earlier in warmer years compared to cooler years.
- The sap run is likely to be shorter and end with sap going off in warm years.
- The sap run may be longer, with trees running dry in cooler years.
- Expect overall yields to be higher in cooler than warmer years.

In terms of the performance of individual trees expect:

- Each tree to have its own trajectory through the season – some will have peak flow early, others late and some will continuously produce large amounts - or only a trickle.
- Sap in collection bottles will start being milky, a sign it is going off, from around 12 days – while others can remain clear for 20+ days. To keep sap clear, be scrupulous in sterilising all equipment, use a sharp drill bit and rinse out the hole before inserting spile. Shading the bottles in sunny weather may also help keep sap cool.
- Consider moving taps to new trees based on their behaviour – i.e. abandoning a tree after several days of very low flows, perhaps putting taps in new trees mid-way through the season if flows are good but sap is starting to go milky.

Predicting yields with any accuracy is not yet possible as there are insufficient data for any form of modelling and the extreme variability means predictive models may never be useful. In order to get a better feel for your trees and how they react to local weather and microsite conditions – consider the following:

- Tag your trees and keep notes of individual tree performance – this does not need to be every day but maybe twice in the season.
- Keep a record of total daily sap yield and sugar content.
- Make a note of any significant weather events e.g. heavy rain, temperature, presence of snow on the ground, periods of warm sunshine etc.

See Chapter 4 in the EIP *Final project report* – for results of the EIP tapping trials for further details.

Choosing trees

Both native species of birch; Silver birch (*Betula pendula*) and Downy birch (*Betula pubescens*), will produce sap and there is little indication that there is much practical difference between the species in terms of sap production or quality. Most birch arise from natural regeneration and are those best suited to your site, so you need to work with what you've got.

The sustainability of birch tapping depends on the extent of damage caused by the tap hole and the speed at which the tree recovers. So, the lower size limit (20 cm) is determined by the proportion of the wood in the 'tap zone' while the upper limit (45 cm) is determined by the slowing of growth as the tree ages and the onset of senescence. Unhealthy trees (i.e. ones showing signs of disease, rot, or broken leaders) should be avoided as it may be difficult to find clean (unstained) wood to tap into, yields are likely to be low, and tap wounds are likely to heal slowly and may hasten death of the tree. Old trees, especially those with veteran tree characters, should not be tapped even if they appear healthy.

The best trees for tapping will be well spaced, between 20 and 45 cm diameter at 1.3 m (63 cm – 141 cm girth), with no visible damage to trunk or branches, with deep, full crowns, and well-developed root systems.

How many trees?

The number of trees you intend to tap can be determined by either the number of suitable trees in your woodland, available staff time, or the number needed to produce a specified volume of sap or product (such as concentrate or syrup). As an illustration: over a typical season of 14 days say you will get around 20 litres of fresh sap per tree. So, if you have a pre-order for 10 litres of sap concentrate at 30% sugar content you would need ~330 litres of fresh sap from ~12 trees. If you have trees and time to tap 100 trees then you could produce around 22 litres of finished syrup.

Sufficient trees will be needed within easy walking distance to produce the volume of sap required that season. Additional trees are useful in case some taps do not produce worthwhile quantities.

Tapping equipment

Make a list of what you will need and order well in advance of tapping, as some items may need to be imported and this can be delayed around Christmas. You may also wish to look out for second-hand items, shop around for good deals, and/or join with other tappers to do a bulk purchase. You also need time to prepare equipment before tapping.

To install taps you will need:

- Battery hand drill + 8 mm auger bit. This should be sharp and kept sterile. An alcohol-based disinfectant (such as industrial methylated spirit or isopropyl) or Milton's in screw top glass jar works well. Mark 40 mm from the tip of the drill to indicate the depth of the tap hole.
- Pump water spray filled with clean tap water.
- Scrubbing brush to clean off moss and dirt on trunk.
- Optional - tree marker paint (from forestry suppliers) to mark position of tap hole (make this a standard position e.g. 10 cm left of hole).

For every tree you will need:

- An 8 mm spile. These can be nylon or metal and there are as yet no manufacturers of spiles in Europe. Reliable spiles (spouts) are:

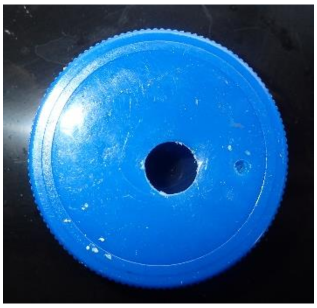
  D&G 5/16" nylon spouts. Dominion & Grimm Inc., Canada

  Sap Meister 5/16" tubing spouts, Marathon Machine Technologies LLC, USA

  For larger quantities it is probably best to import directly from Canada or USA.

  Before use, sterilise spiles by soaking in Milton's, rinse, dry and store in sealed bags.

- Food grade tubing sized to fit the spiles: so, 8 mm internal and 9 mm external diameter. If clear tubing is used any build-up of detritus can be seen. You should buy sufficient to give 50 cm of tubing per tree. There are many manufacturers and suppliers in UK so shop around. You can prepare tubing by cutting to length or by taking the roll in a bucket and cutting off required length in the woods. Ideally sterilise tubing before first use.



- A food-grade plastic bottle – this should be large enough to accommodate daily yield - 5 litres is generally enough for most trees and days. Clear plastic is best as then you can see if the sap is looking milky. It is cheaper to buy water in a suitable bottle than to buy empty bottles. Before tapping prepare bottles by drilling 9 mm hole to take the tubing and a small < 1 mm breather hole to prevent any build-up of pressure that could reduce sap flow. Wash out bottles with dilute Milton's, rinse and dry. Seal the holes in the bottle cap with tape until ready to attach to a tree.

- Optional - Tags to identify tapped trees. Forestry suppliers sell consecutively numbered aluminium tags – these can be fixed to trees using long-shanked aluminium nails with the tag on loose to give space for the tree to grow. Alternatively, thread tags onto strong cord (dyneema cord is ideal) and tie loosely to branch or around trunk of tree. If your wood has a lot of visitors, tags can be stolen so you may wish to use other means of identifying individual trees.

For collecting sap:

- Food grade barrels or lidded buckets, of number and size to accommodate maximum daily yield – estimate this as 3x number of tapped trees in litres.
- Bottle of clean water to rinse out collection bottle.
- Transport - you will need to haul large volumes of sap from the trees and out of the woodland. Smaller volumes can be carried, or better still, use a wheelbarrow or perhaps for large quantities or distances a quadbike fitted with a large tank or bowser.

- Refractometer – either a digital one (expensive) or an optical wine/beer model (cheap) – this will be useful to check sugar content of fresh sap but also to check progress through the concentration process.
- Optional - Hanging scales, as used by fishermen, to weigh bottles on a couple of days to have a record of high yielding trees if you intend to tap over several years.

Installing taps

The recommendations listed here are based on the experience gained tapping birch at different sites in Wales over several seasons. Additional advice material, including links to videos showing the methodology used, are listed in the references below. Watching a practical demonstration of tapping is a useful way to understand what is involved. Additional information on best practice for birch tapping is provided on the EIP and Dewis Gwyllt webpages which include a series of demonstration videos.

At every stage of tapping hygiene is extremely important to prevent sap contamination, so good quality sap can be collected for as long as possible and minimise introduction of pathogens into tree.

Follow these steps to install taps in each tree:

Step 1: Select tree
Choose a healthy tree, ideally with a deep crown between 20-45 cm diameter (63 cm – 141 cm girth) at 1.3 m from the ground.

Choose a suitable tapping spot between 40 cm and 80 cm from the base of the tree. It is easiest to tap where the bark is smooth although for some trees this might not be possible.

If the trees have previously been tapped then – **only place a new tap if the previous hole is closed over.** Place the new hole 10 cm to the right and 10 cm above the previous hole.

If necessary, clear a path to the tree of obvious trip hazards such as brambles.

Step 2: Clean and sterilise the tapping area
Clean the bark approximately 10 cm around the area to be tapped. A small scrubbing brush can be used to remove excessive moss, lichen and algal growth and clean the bark. Rinse the area with clean water before drilling.

Step 3: Make 8 mm diameter 4 cm deep drill hole in tree Use a sterile and sharp 8 mm drill bit to make a 40 mm deep hole into the tree. On older trees, especially of silver birch, you may need to make a deeper hole to accommodate the thickness of the bark. Use a battery-powered hand drill or auger and ensure that the hole is circular (not oval) and angled slightly upwards to assist drainage of sap, and later to prevent rain water entering the hole while it heals. Each tree should only be tapped once each season.	
Step 4: Clean hole Check the sawdust coming from the drill-hole. If the wood (ignore bark) is dry or discoloured at the tip of the drill then the hole is not suitable and the tap should be relocated further around the trunk (at least 5-10 cm away), or (better) don't use this tree. Use a small hand-held pressure spray to remove any debris from within the drill hole using clean water NOT any sterilizing solution as this will damage the wood. This is to remove any sawdust that could contaminate the sap later on.	
Step 5: Insert spile Insert a sterile 8 mm spile carefully into the hole and seat it firmly using light 'taps'(!) from a small hammer. Do this gently so as not to split the bark, but firmly enough so that they won't fall out or sap leak from around them.	
Step 6: Fit collection bottle Attach clear food-grade tubing to the end of the spile. This can be fitted beforehand if you standardise the height at which you will place taps. Attach a 5 litre collection bottle to the tube, keeping the tube length within the bottle as short as possible. If the site is windy, tie the collection bottles to the tree, and keep them shaded (e.g. with bracken fronds) especially if they face the sun.	

Daily collection of sap

Each tree is visited every day and the sap decanted into a large container to be taken out of the woods.

The sap bottles on the tree should be rinsed out regularly (daily is best) using clean water so as to reduce microbial build up.

Good quality sap is very clear. The first collection maybe tinged orange-brown or greenish, but sap collected by the second day should be clear.

If on the second day you see that the volume of sap produced by a tree is less than say 0.5 litres then consider removing the tap and placing it in a new tree.

If you intend to tap in subsequent years, it might be a good idea to record which trees give the best yield. You can do this for tagged trees by weighing the bottles with hanging scales or by counting the rings on the collection bottle. You only need to do this on one or two days.

End of sap run

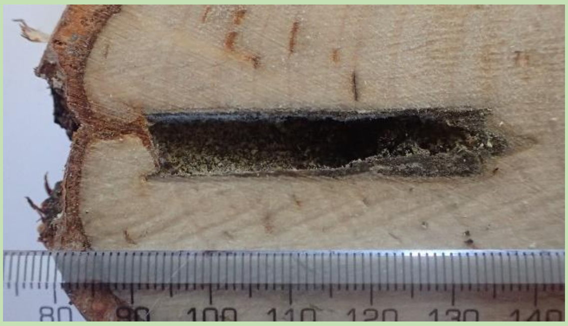
The end of the sap run comes with either flow reducing to a dribble or the sap going milky as the sap goes off. Sap that is a little cloudy can be processed for syrup but anything which is 'cloudy' with obvious strings of white yeast should be thrown away and there should be no further collection from that tree.

This cloudy sap should be thrown away

The decline in sap production varies between trees, so the decision on whether to continue visiting the site will depend on how many trees are still producing useful quantities of clear sap.

When it is time to stop tapping, the spile should be carefully removed from the tree (do not use excessive force, e.g. prising it out, as this can damage the cambium under the bark (Figure 1) and cause slow healing). The drill hole should be left open – **DO NOT plug tap holes** with anything. Sap flow will stop naturally as soon as the leaves open and the tree will naturally heal the small wound within one to two years.

If you intend to tap in following years mark the position of the tap hole with tree paint. This is because a healed hole can be difficult to find.



Healed tap hole after one year. Inserting a bung will keep the hole open and introduce rot into the tree.

At the end of the season all equipment should be removed from the site and thoroughly washed, sterilised, dried, bottle caps taped, and stored ready for the following year.

Part 3: Processing of sap to syrup

The sap flowing from the tree is sterile but the low levels of sugar in sap means it is an ideal growth medium for micro-organisms, especially yeasts. When handling sap think of it as having the shelf life of milk – a day at room temperature, a few days refrigerated, and pasteurised maybe a couple of weeks in the fridge. This means sap should be processed immediately or frozen. Turning sap into syrup involves removing 99% of the water to raise sugar concentration from 0.7 °Brix to 66 °Brix as shown in Figure 4.

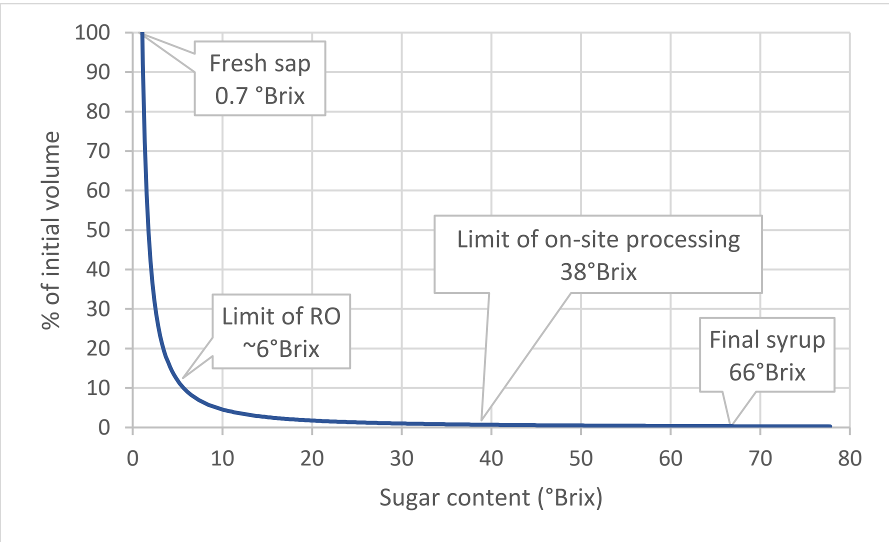


Figure 4: Relationship between sugar content and concentrate volume

The temperature at which sap is processed is critical to syrup quality. The sugars in birch sap are a 50:50 mix of fructose and glucose. Heating the sugars induces the Maillard reaction which darkens the concentrate and gives the syrup its distinctive flavour. However, fructose in particular will start to caramelize to give bitter, burnt flavours if exposed to temperatures much above 85°C. However, this doesn't mean you can't boil the sap. At low sugar concentrations the large amount of water buffers the sugars, so they don't get hot enough to burn, but as the sugar concentration rises so does the risk of burning and lower temperatures are required. This, together with the need for increased hygiene standards as the product is finished, means that generally concentration using direct heat to boil the sap is stopped at around 38°Brix. This change in process effectively forms the limit to what can be done with on-site processing.

Maple syrup production is a highly industrialised process in North America and there is increasing experimentation with different technologies for removing water to better control syrup consistency and composition. Technological development is in the direction of either removing water at low temperatures, or using controlled heat to speed up evaporation so the sugars are only briefly exposed to high temperatures. The following technologies are in use or development:

- Evaporation (direct heat from wood, gas or electricity)
- Reverse osmosis
- Vacuum evaporation
- Steam injection
- Microwave evaporation
- Cryoconcentration

Many of these require significant investment which will only be viable for large scale, industrialised production and are therefore not appropriate for small-scale artisanal production. However, this does not mean that scaling down is not feasible and experimentation is encouraged!

Artisanal methods for initial processing of sap

Three methods which are suitable for small scale processing were trialled by the EIP project:

- small-scale reverse osmosis (RO),
- evaporation in open pans on a wood stove, and
- evaporation in an electric urn.

Each of these was found to have its own benefits and drawbacks as shown in Table 1.

Table 1: Comparison of three sap processing systems

Aspect of processing	Reverse Osmosis	Catering Urn	Wood-fired stove
Initial purchase cost of kit	£388 - £500	£119 - £161	£380 including new bricks, flue and evaporating pans
Ongoing running costs	Replacement membranes: £114 x 2 (Pentair) £45 x1 (RB5) + £1.20 each for pre-filters x 3 per season	Low? No recurring costs to maintain, and should last 5-10 years?	Periodic replacement of heat-damaged components (blocks and grills)
Reduction in volume over average session	To 29% of start (average)	To 75% of start	To 89% of start
Approx. time to reduce volume by 1 litre	7 minutes	23 minutes	6.5 minutes
Approx. time to reduce 30 litre sap volume by 50%	95 – 100 minutes depending on RO system	~600 minutes depending on temperature setting. Plus 15-30 mins if sap processed from frozen	~180 minutes once fire running well
Average energy cost per hour	£0.01 - £0.03 Negligible	£0.45 (at £0.17 per kWh) To £1.02 (at £0.34 per kWh)	0 (if free fuelwood available) - £3.08 (2022 prices ~2x this)

Aspect of processing	Reverse Osmosis	Catering Urn	Wood-fired stove
Maximum sugar concentration achieved in one session from fresh sap	6°Brix	28°Brix	30°Brix
Supervision required during processing	Some, mainly towards end	Some at beginning & towards end	Regular checks every 30 mins throughout. DO NOT leave fire untended.
Most efficient sap volumes for processing	50 to 100 litres	~30 litres per urn	150 to 200 litres

Reverse osmosis is very cheap and quick but can only take sugar concentration to around 6 °Brix. Starting with 80 litres of sap, taking concentrate from RO (now 10 litres) up to the limit for on-site processing would take ~2.5 hours on a wood stove and 4.5 hours in a catering urn. The wood stove can be very cheap to run if free fuelwood is available and is efficient for large volumes of sap but requires constant supervision. A catering urn is relatively expensive and slow, but being thermostat controlled can be left untended for long periods of time and at lower temperatures.

You could also transfer the RO concentrate directly to a commercial kitchen and use a Bratt pan, stove top Gastronorm pans or steam jacket kettle for evaporation. Trials have been conducted of stove-top pans at the Llais y Goedwig commercial kitchen in Machynlleth and a Bratt pan (Cucimax Firex 130 litre capacity) at the Food Tech Centre at Llangefni. Both worked well, though the stove top pans needed constant tending and while the Bratt pan has an agitator and efficient thermostatic controls, the hire of the kitchen is quite costly and time for full processing is limited to around five hours per day (after allowing for set up and cleaning).

The choice between systems is highly dependent on fuel costs, labour costs, and how much time operators have available. For processing 100 to 150 litres of sap the fuel costs for running an electric urn were comparable to using bought-in fuelwood. However, if wood fuel is available at no- or low-cost then using the wood stove may be more economical. Although using a single urn for boiling down large volumes of sap takes a long time, it can be left to run with little supervision – perhaps just five minutes every hour, whilst the stove requires much more frequent checking. One possibility is to use several urns at the same time which would allow greater volumes to be processed at once, but electricity costs will always be an important consideration. Other factors might also play a part, for example: having an outdoor 'boil-down' using a wood-fired stove might be preferred if it is run as a social event where volunteers can help to share the work.

Trials indicated that the optimal use of available technologies was to pass the fresh sap collected each day through an RO and to freeze the concentrate (now at ~4°Brix sugar content and 12-20% of sap volume). At the end of the season the RO concentrate was defrosted, pooled, and concentrated to 38°Brix sugar content on a wood-fired stove or urn and again frozen for storage and transfer to a commercial kitchen as shown in Table 2.

Table 2: Stages in processing of birch syrup

Stage	Sugar content °Brix	Water removed (%)	Max temp °C	Description	Process / Storage
Fresh sap	0.7	0.0	Ambient	Clear	Freeze if not processed immediately
Reverse osmosis	0.7 - >6	87.5	Ambient	Pale yellow	RO / Store frozen
Evaporation	~6 - 28	97.5	100	Darkening to amber	Wood-stove or catering urn / Store frozen
	28 - 38	98.2	< 93	Some sugar sand forming - will start to darken quickly	
Finishing in commercial kitchen	38 – 60	98.2	< 93	Full colour and flavour developed	Bain-marie / Shelf stable in sealed bottles
	60	98.8	<85	Thin syrup for finishing	
	67	99.0	<85	Minimum to be called 'syrup'	
	74	99.1	<85	Thick syrup	

An indication of the time taken to pass through these stages is given in Table 4.

Table 3: Comparison of methods for post-harvesting processing of sap

	Sugar °Brix	Trial equipment		
		RO	Wood stove	Urn
Time taken to process 80 litres of fresh sap at 0.7°Brix to:-	4-6	3-4 hrs	4-5 hrs	27 hrs
	28	-	+1-2 hrs	+4 hrs
	38	-	+20 mins	+30 mins
Indicative cost per run (2021 prices)		£0.05	£0 - £20.00	£14.76
Reduction rate (litres per hour)		20-30	10	2.5

If you wish to estimate how much sap you will need to fulfil an order for syrup, or to estimate the amount of syrup you can make from frozen concentrate, then there are ready reckoners for doing this. Be a bit conservative with these estimates as you also need to account for losses e.g. film left inside pans etc. especially if the sap is repeatedly moved between containers.

During processing you need to be able to keep track of sugar content using either a digital or optical honey refractometer. Optical refractometers are considerably cheaper than digital versions but are slightly more awkward to use.

Estimating syrup production

(1) This rule is valid up to starting sugar content of 5° Brix and assuming finished syrup is to be 66 Brix. Then the following applies:

$$\frac{87.5}{\%\ sap\ sugar} = ratio\ of\ sap\ to\ syrup$$

Example:
Sugar content: 0.7° Brix
87.1 divided by 0.7 = 124.43

Ratio of syrup to sap = 1:124 so 124 litres of sap will be needed to make 1 litre of syrup

(2) For higher sugar content use:

$$\frac{1}{target\ sugar / initial\ sugar} x\ initial\ volume$$

So, for 10 litres coming out of the RO at 5.6°Brix intended for syrup at 67°Brix

$$= \frac{1}{67/5.6} x10 = 0.83\ litres\ syrup$$

Freezing sap and concentrate

At its simplest the *fresh* sap can be placed into lidded buckets and frozen. For this to be effective you need access to freezer capacity scaled to the volumes of sap you intend to collect. The ideal would be a walk-in freezer such as those located at the Food Tech Centres who also have defrosting rooms for when you wish to process the sap. It may also be possible to hire a mobile freezer and there are some plans to provide community walk-in freezers. Freezing from the tree would facilitate the supply of fresh sap throughout the year and might provide some interesting product opportunities. However, it is unlikely direct freezing is a practical or cost-effective solution for most syrup producers.

Freezing *concentrated sap* to separate the progression of sap to syrup is used to good effect to break down the process into manageable stages. A large chest freezer is ideal and there is good availability of second-hand freezers. Concentrate should be stored in food grade sealed containers. Square, 5 or 10 litre capacity tubs are best as the ice cubes can easily be removed for defrosting. Care must be taken not to overfill the buckets and allow some space for expansion as the sap freezes. Labelling the tubs with the date, weight/volume and sugar content will make it easier to keep track of what stage the contents have reached. Due to the shape of storage buckets and that they are rarely never filled to capacity, a 300 litre freezer was only able to hold 220 litres of sap in buckets.

If processing sap from frozen then it should be removed from the freezer the night before it is required so that it begins to defrost and can be tipped from the buckets easily. Do not completely defrost at room temperature as the first defrosted sap will likely go off before all the ice melts. Either defrost in a fridge or by careful heating in urn, wood stove etc.. The time taken to defrost the concentrate needs to be considered in processing time.

Reverse osmosis

Reverse osmosis (RO) involves forcing a solution under pressure through multiple semi-permeable membranes which hold back larger molecules (e.g. sugars and minerals) while pure water passes through. The permeate which passes through the membranes is pure water while the fraction which doesn't pass through contains a higher concentration of sugar and minerals. RO systems are used in a variety of applications, including drinking water purification, aquarium systems, window-cleaning and in the brewing and fruit juice industries. RO has been used for many years in maple syrup production and proprietary ready-made kits designed for tree sap processing are produced and sold in the USA with models made especially for use with birch sap. A simple home-made RO system can be adapted from standard water purification kits sold in UK or bespoke RO for sap imported from North America.

RO systems use a low power electric pump to collect pure sap via a tube and force it through a semi-permeable membrane inside a plastic housing. This membrane separates the sap into 'concentrate' and 'permeate' fluids. Permeate is purified water with large particles and almost all of the sugars and minerals removed, this is always collected in a separate container. The 'concentrate' fluid contains the sugar and minerals with a reduced amount of water which is cycled back through the RO until it reaches around 5^{O}Brix (so intake and concentrate outflow feed into the sap bucket). Although higher sugar contents can be generated from RO, the higher the sugar concentration, the slower it will pass through the system at higher pressure which clogs up the semi-permeable membranes and shortens the lifespan of the filters.

Home-made RO kit

A design for a home-made RO kit obtained from the North American Maple syrup Council Research (https://mapleresearch.org/pub/rochildsvideo3/) was put together based on a 'Pentair' (previously known as 'Merlin') domestic water purification unit (**Error! Reference source not found.**). The 'Pentair' system has three 5 litre canisters (horizontal white tubes shown in photo), two of which contain semi-permeable membranes and the third is either empty or holds a coarse (5µm) pre-filter with higher porosity. For birch sap the coarsest filter is not required so this canister can be left empty. Pentair systems can be obtained second hand though it should be carefully cleaned and fitted with new filters. The filters are readily available and with care should last for a few seasons.

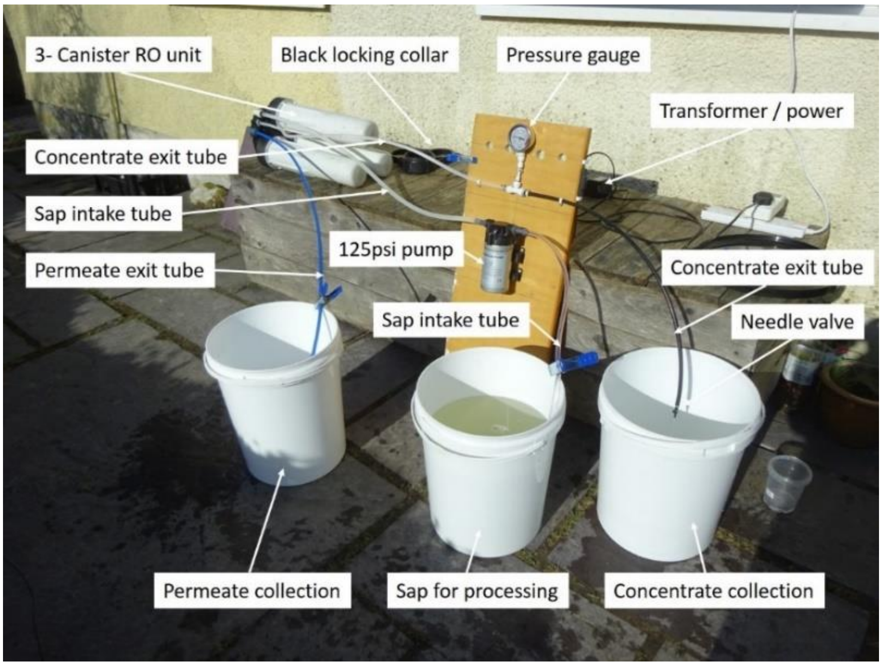


Figure 5: Home made RO system based on 'Pentair' domestic water filtration unit

ROBucket kit

The ROBucket company specialises in small kits RO kits for hobby maple tappers (https://www.therobucket.com/). They supply either a complete system in a bucket or kits for DIY installations scaled to support tapping of up to 35, 75, 150 and 200+ trees. The smallest kit in a bucket – the RB5 (Figure 6) for up to 35 trees was trialled by the EIP project and found to be simple to use. Delivery from USA was prompt and the company is responsive and has an active Facebook group for updates and answering questions (https://www.facebook.com/TheROBucket/).

Figure 6: RB5 unit from ROBucket

The RB5 unit has just a single semi-permeable membrane and a single coarse pre-filter, but upgrades of this system are available, with additional semi-permeable membranes and more powerful pump units. The units are graded depending on the typical processing time expected to reduce the volume by 50% for a 4% sugar solution. The RB5 has a stated flow rate of 36 litres per hour whilst larger models can process up to 180 litres per hour.

Of the two RO systems trialled the RB5 was found to be quicker and wasted less sap as it was more appropriately sized and is self-priming so can be dry to minimise the retention of sugar rich concentrate in the filters.

Set up and use of RO

Given spillages are very likely you should site your RO somewhere water on the floor won't do any damage. A shed or lean-to would be ideal. As you will be using electricity in close proximity to liquids all appropriate safety precautions should be taken regarding power supply, cables and plugs. Power demands are low (the RB5 unit is rated at 125W) so it is feasible to run an RO from a solar-charged battery pack with an inverter or off mains electricity supply.

Before using any of the RO equipment for the first time it should be cleaned thoroughly by flushing the entire system with pure, unchlorinated water to remove any impurities (and preservative chemicals if it has been in storage using these). Chlorinated water can damage the RO membranes, so tap water should not be used unless the chlorine has been removed first – by standing for 2-5 days or boiling. Permeate is ideal for cleaning all the equipment, so it is useful to retain a couple of big buckets produced during processing.

For ease of use, the different hoses for raw sap intake, permeate outlet and concentrate outlet should be colour coded. To ensure the tubes stay in place they can be clipped to the sides of the containers (Figure 7). The intake tube can be fitted with a one-way valve and filter to prevent large particles entering and to keep the pump fully primed with fluid.

Permeate (blue tube), concentrate (black tube), fresh sap (clear tube)

Figure 7: Separating sap into concentrate and permeate using RO

Once all the tubes are in place and the system is ready to run, the pump can be switched on and raw sap forced through. After a short time, permeate will begin to be produced followed by concentrate. A control valve on the exit of the concentrate tube enables the flow to be adjusted. When the production of concentrate is equal to that of permeate this means that 50% of the water is being removed from the sap and the sugar concentration should be doubling. The balance between concentrate and permeable production can be estimated by eye or using a pressure gauge on the concentrate line. Never allow the concentrate production to be less than that of the permeate as this can cause rapid deterioration of the semi-permeable membranes. The set up in Figure 7 is for a single pass through the RO – however this will only raise the sugars to ~ 1.4 °Brix. It is more efficient to place the concentrate line into the sap bucket so it continuously cycles through the RO. The RO should then be stopped when the contents of the sap bucket are not more than 6 °Brix (you can go higher but this reduces the life of the filter). Using a Brix meter, you could mark a line on the bucket which represents your target sugar content or volume of your storage tub. Time how long it takes to reduce a full bucket to the line and set a timer to alert you when the RO needs attention.

For small-scale birch tapping the sap collected can be processed daily through the RO, then stored in a freezer in labelled, food-grade buckets. If 40 trees are tapped, an *average* of 12.5 litres (possibly up to 25 litres at peak flow) of RO concentrate will be produced and need freezer storage each day, and this will require either one or more large domestic chest freezers or access to a larger commercial facility.

Table 4 gives estimates of timing of RB5 based on a number of trial runs - though note that ambient temperature and pumping pressure can also affect the rate of processing.

Table 4: Processing time for re-cycling fresh sap at 0.7 °Brix through RB5 unit to 4.0 °Brix

Initial sap volume (litres)	Estimated processing time (hours)	Final volume (litres)
100	6.0	17.5
80	4.8	14.0
70	4.3	12.2
60	3.8	10.5
50	3.3	8.7
40	2.7	7.0
30	2.3	5.2

Care of the RO kit

To prevent microbial build up, once processing of the days sap is complete the RO system should be flushed through: To do this the intake tubes should be removed and the unit allowed to run dry (if safe to do so – see manufacturer's instructions), then the intake should be placed into a bucket containing at least 25 litres of fresh permeate water with the permeate and concentrate tubes sent into a waste bucket and the system run for at least 10 minutes. The first slug that comes through the concentrate line once you start passing permeate through will contain sugar and you may wish to save this. You can work out how much liquid is worth saving by tracking sugar content and recording the volume when it drops below a useful amount (say ~ 0.5 °Brix).

After flushing is complete retain permeate in the tubes and semi-permeable membrane canister (don't run dry). Ideally the coarse 5µm pre-filter should be removed and stored in fridge overnight to prevent bacterial build up and the canister left open to dry. Pre-filters are not expensive (approx. £2 each) and can be re-used for up to 7 days if stored correctly but will then need to be replaced.

At the end of the season the RO unit needs to be cleaned more thoroughly for storage until the following year. This is done by flushing the unit with permeate as before, followed by a warm preservative solution for at least 30 minutes then left for 24 hours. Proprietary RO membrane cleaner (sometimes called 'RO soap') is normally a solution of Sodium Hydroxide (~20g in 23 litres) and can be purchased from the RO distributors. Always follow the safety instructions for use as the chemicals are caustic (pH 11). The unit is then flushed with permeate, and the 5µm filter removed and discarded. The semi-permeable membrane should be stored wet and should continue to work well for several years or over 10,000 litres of sap processing, after which it should be replaced. Some RO users also recommend storing the semi-permeable membrane in a sealed bag in a fridge between seasons. RO membranes are relatively expensive (approximately £80 each depending on the size and RO model), so it is worth storing them carefully to extend their life.

Evaporation in a catering urn

A catering urn is a large vessel with a heating element controlled by a thermostat designed to boil water – usually for making tea. The heating element and thermostat are good features for boiling down sap but the tall shape gives a rather small surface area which restricts evaporation. Nevertheless, trials suggest that a large (40 litre capacity) urn can be a useful means of processing small quantities of concentrate. Both gas and electric urns are available, but if electric, the heating element must be separate from the liquid. Examples of suitable urns include 'Buffalo' and 'Adexa' brands, though other models are available (Figure 8).

	
Buffalo 40 litre urn	Adexa 40 litre urn with level gauge

Figure 8: A selection of 40 litre electric catering urns

Evaporation produces vast quantities of slightly sticky steam so it is best to run an urn outdoors under cover. A clean working space is needed, and all the equipment must be protected from rain and wind. Getting the urn up to boiling in cold conditions can take some time and it was useful to fit a makeshift (heat resistant) insulating jacket (made from an old camping mat) around the sides to help retain heat, a rechargeable automatic pot stirrer was also used to agitate the contents and increase evaporation (Figure 9).

	
Buffalo urn with insulating jacket and battery-operated stirrer	Urn in use outdoors

Figure 9: Urn in use

The side-by-side comparison of the two urns gave the Adexa urn a distinct advantage with an average evaporation rate over a five hour run that was at least 50% faster than that for the Buffalo. This is because the Adexa had both a higher power rating (3 kW) and a higher maximum temperature (110°C) than the Buffalo (2.6 kW and maximum of 100°C) so could more easily keep the full urn at a rapid boil.

The automatic pot stirrer was considered beneficial, by reducing processing times, possibly by 10%. Unfortunately, the only model available was battery-operated and could only run for about 150 minutes before it needed re-charging. If a fully mains-operated model was available this would be more useful.

Using a catering urn

For small batches, it should be feasible to use a catering urn for the whole process from fresh sap to final syrup (converting it into a bain-marie for final stages). However, the urn comes into its own at the end of the season to process the accumulated RO concentrate. Frozen concentrate can be defrosted using the urn, though large blocks of ice need to be placed into the urn with care so as not to damage the base and the lid kept closed. Once the sap is fully defrosted, remove the lid so as to encourage maximum evaporation.

A 40 litre urn can initially be filled with up to 35 litres of concentrate but more can be added as the level goes down. It is useful to check progress by taking sugar readings and noting liquid levels in the urn. Once you have a sense for how the urn performs you should be able to manage it with minimal supervision. It is best to reduce the temperature once you reach 28 °Brix and stop at 38 °Brix or when you are within 5 cm of the bottom of the urn. You can store and pool concentrate from several urn runs if needed. Until concentrate reaches more than 28°Brix it remains highly perishable and ideally it should be processed in a single run to higher sugar contents or frozen between sessions. For storage, concentrate should be filtered through clean muslin (or other food-grade filter material) placed in a sieve over a suitably sized container, and allowed to cool before freezing. At the end of each day, the urn should be rinsed with clean water. At the end of the sap collection season, the urn should be given a thorough clean to remove any burnt sugars on the inside surfaces, especially near the heating element.

Average evaporation rate from an urn was quite slow - approximately 2.8 litres per hour, though this varies depending on initial sugar concentration, thermostat settings and ambient temperatures. Processing large volumes takes a long time for example: 30 litres may take 9-10 hours to be reduced so use of the urn for reducing fresh sap is impractical. However, starting with RO concentrate it should be possible to take sugar up to around 30°Brix in one session.

Energy consumption is directly related to the length of time that the urn is operated – typically this is in the region of 16 kW for an eight hour run, cost will depend on the unit price paid for electricity at the time. Although energy cost is significant, labour cost is potentially lower than other methods as processing does not need to be supervised continuously.

A catering urn may be most useful in very small operations to evaporate RO output.

Evaporation on a wood stove

Wood-fuelled evaporators are a popular means of processing sap in small-scale maple and birch tapping operations in North America. Numerous designs are commercially available, usually consisting of a series of long, shallow, interconnected trays over a firebox or steam heat exchange system, scalable for different volumes of production. However, many producers use simpler self-build systems they run in seasonal 'sugar shacks'.

Figure 10 shows a simple design for a low-cost stove adapted for use in the EIP trials from North American examples. The stove consists of a firebox made of standard concrete 'breeze' blocks with a heat-proof flue inserted at the rear and topped with two 45 litre stainless steel 'Gastronorm 2/1' catering pans. Full design and instructions for this stove are given in Appendix 2. This design functions as a rocket stove and can reach high temperatures and is fuel efficient.

Wood stove system showing firebox

Wood stove in operation with two 45 litre Gastronorm pans

Figure 10: Wood stove evaporation in progress

Using the wood stove

The wood stove has a fast enough evaporation rate to manage direct boil down of fresh sap within reasonable period of time. This could be efficient if the stove is run on tapping days to reduce handling the sap. Putting sap through RO and directly onto a wood stove would also save freezing and defrosting of concentrate. However, it is most likely that a wood stove would be used at the end of the season to process frozen batches of RO concentrate.

The sap (with approximately 5% sugar content after passing through the RO) can be boiled until it reaches 28^{O}Brix and then simmered to 38^{o}Brix. Temperature readings should be taken frequently using an infra-red thermometer or similar to help keep temperatures within range as sugar concentration rises. Some degree of caramelization is acceptable and will contribute to the final taste of the syrup.

The greater surface area of the pans on a wood stove and higher temperatures of the fire mean that evaporation rates on a stove are much higher than for an urn. Using a wood stove over 120 litres of raw sap at 0.5°Bx sugar content was processed to 23°Bx in one nine-hour session. Note that as the stove is used for longer and heats up the evaporation rate and fuel efficiency increases so a wood stove is best used to process large volumes. Figure 11 is based on trials runs of the wood stove illustrated in Figure 10 provided as a guide to expected time to reduce a range of starting volumes to 4 litres of concentrate which is about the minimum quantity it is safe to process in a 45 litre Gastronorm pan – though for the higher volumes stop before 4 litres as this would exceed 38°Brix.

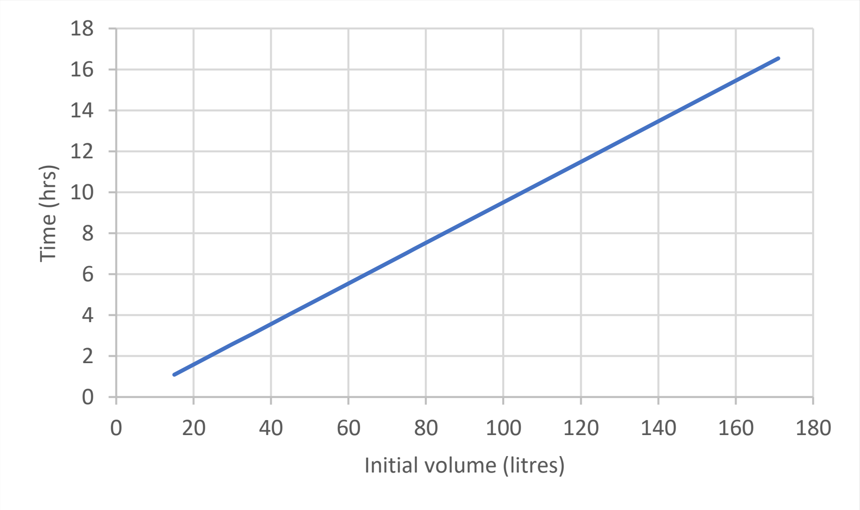


Figure 11: Time to reduce initial volume to four litres on wood stove

Fuel consumption for a wood stove is difficult to predict, as much depends on the type of fuel used (hard/soft-wood, log size, and water content). In trials using good quality split logs of kiln-dried birch approximately 12 kg of wood was burnt each hour, or 70 kg for a typical processing session. The cost of fuel for a six-hour session was £18-£20 (2021 prices) using purchased kiln-dried firewood. However, if you have access to firewood on-site fuel costs could potentially be much lower. Other waste wood could be used for fuel, but it is important that whatever is used it is dry and clean (i.e. without paint or other contaminants that could be potentially be transferred to the sap).

Finishing syrup

Finishing of the syrup is usually done in a commercial kitchen to meet food standards and in a bain-marie at temperatures not exceeding 85°C. Chemical reactions caused by heating precipitate out nitre or sugar sand in the form of gritty black specks in the syrup. This needs to be filtered out before bottling. Passing a thick syrup through a filter to remove small specks is best done with the assistance of a vacuum. The vacuum can be provided by a cheap diaphragm pump or using a water jet vacuum pump attached to a tap.

Part 4: Managing a birch woodland for sap

This section of the manual is intended for woodland owners who wish to develop a long-term sustainable birch sap enterprise on their resource or who wish to develop or create birch woodland which could support a tapping venture in the future. Management of woodland is the nudging of natural ecological processes, so this section starts with a brief summary of the ecology of birch and the value of birch woodland. From this appropriate management interventions can be decided and a management plan prepared.

Understanding how birch grows

The sustainability of tapping is related to the growth rate of the trees, as faster growing trees will heal over the tap hole quickly and replace the wood damaged by tapping with new wood (see EIP *Final project report* Section 5.2). There is as yet insufficient evidence to suggest that sap or sugar yield is related to growth in any simple way, but it is axiomatic that it is best to tap vigorous healthy trees. Silviculture is the theory and practice of controlling forest establishment, composition, and growth, usually to achieve specific objectives such as maximising biomass accumulation rates (for carbon sequestration) or timber quality (which means straight, unbranched trunks), habitat quality for red squirrels, or indeed to enhance the yield of sap. At its most fundamental, silvicultural prescriptions (what will be done) are interventions intended to modify but work with the natural growth patterns and ecological characteristics of trees and stands (groups of trees e.g. a plantation block). For sap production we are mainly concerned with enhancing growth rates of individual trees which is well understood in conventional forestry. However, birches are generally disregarded as a timber species in the UK and there are very few studies which examine growth and yield of birch in the UK and Ireland and no studies specific to Wales.

Birch trees are generally noted as both fast growing *and* low yielding. This apparent contradiction is related to both the small size of birch and its preference to grow in open stands. So, for an individual tree, height growth can achieve rates of 1 m per year but this slows after about 10-20 years. Diameter growth is likewise rapid and can exceed 1 cm per year and is also fastest between 5-20 years (Figure 12). Growth is vigorous until 40-50 years when the trees is 'mature' at around 40 cm diameter and ~20 m tall. Vigour then declines and the tree becomes susceptible to damage and rot with few trees living beyond 80 years. There are ancient trees[2] with diameters in excess of 1 m and heights up to 30 m but these are exceptional and should not be tapped.

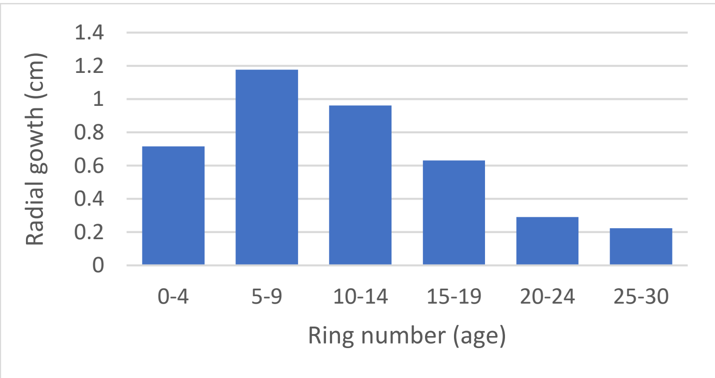


Figure 12: Radial growth by age for eight sectioned trees

[2] You can search for ancient birch in your locality on the Ancient Tree Inventory https://ati.woodlandtrust.org.uk/

Each tree has its own growth curve as evidenced in the cumulative widths of the annual growth rings for a number of felled and sectioned birch trees from different locations in Wales (Figure 13). Being shade-intolerant it is only dominant (biggest) trees within a stand which will maintain fast growth. This means there can be considerable variation between trees within a stand as shown by the two trees in Figure 13 in Merthyr Mawr. However, there is also a degree of consistency within woodlands (Amman Valley) which is related to site conditions.

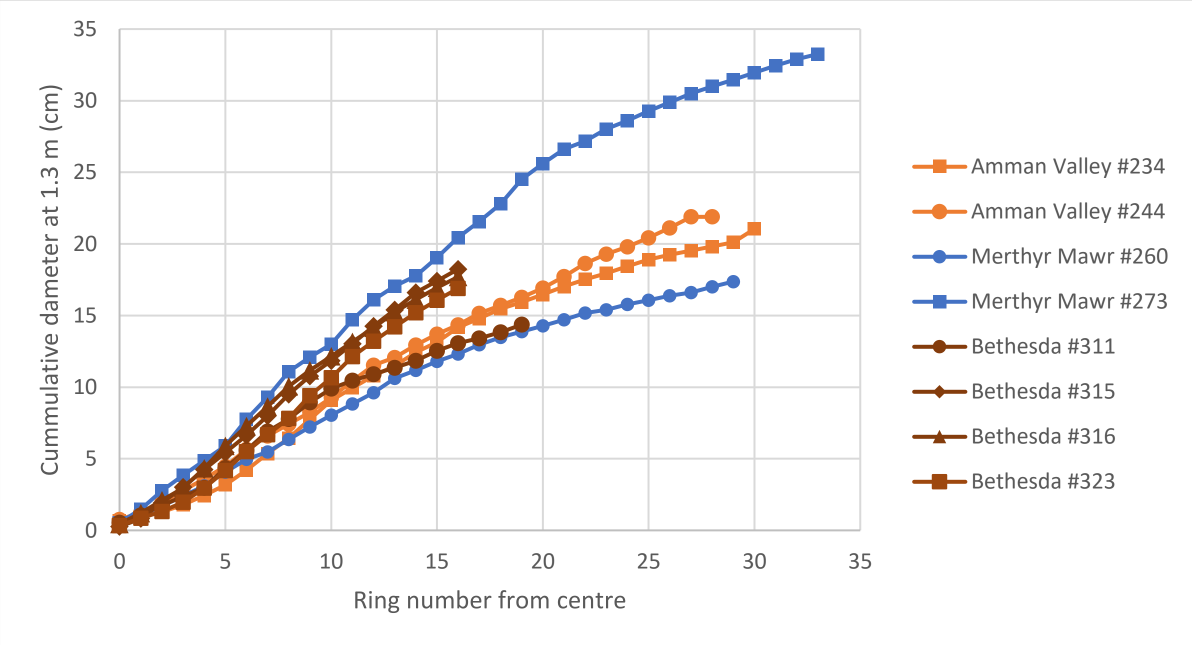


Figure 13: Diameter growth rates for individual trees

To keep trees growing well they need to have good access to light. Birch crowns are not very dense so a tree needs a deep crown to have sufficient leaves to maintain high growth rates and this means they need to be widely spaced – at low density of trees per hectare. For vigorous growth the living crown (branches with green leaves) should extend over 40-50% (or more) of the tree height. Birch is fast growing in high light conditions and crown depth is set early. Once lower branches have self-pruned (died off) and canopy is less than 40% of tree height the tree is unable to replenish its crown and unable to respond to thinning.

Yield class

In the UK, site yield class (YC) models are used to estimate the potential yield of a stand in m^3 /ha for each species on poorer and better quality sites – so a poor site might give an accumulation rate of 4 m^3 /ha at maximum growth rate while a good site with the same species could give 12 m^3 /ha. These site-based models work on the 'top height' of the stand – the average height of the 100 largest diameter trees). Unfortunately, the lack of interest in birch as a timber species means that birch is grouped in with ash and sycamore and the YC model is generally considered rather crude. Nevertheless, given this model is widely used in forestry it is useful to have some idea of how birch stands in Wales perform in terms of yield class. The average heights of the trees measured in the EIP tapping trials are very similar at 15.8 to 16.9 for stands estimated as around 30 years old. This gives yield class of 8-10 which is corroborated in Figure 14 which plots the ring count at 1 m intervals up the tree for the felled trees. Yield class 8-10 for birch is also reported for young natural downy birch stands in Ireland so this seems reasonable.

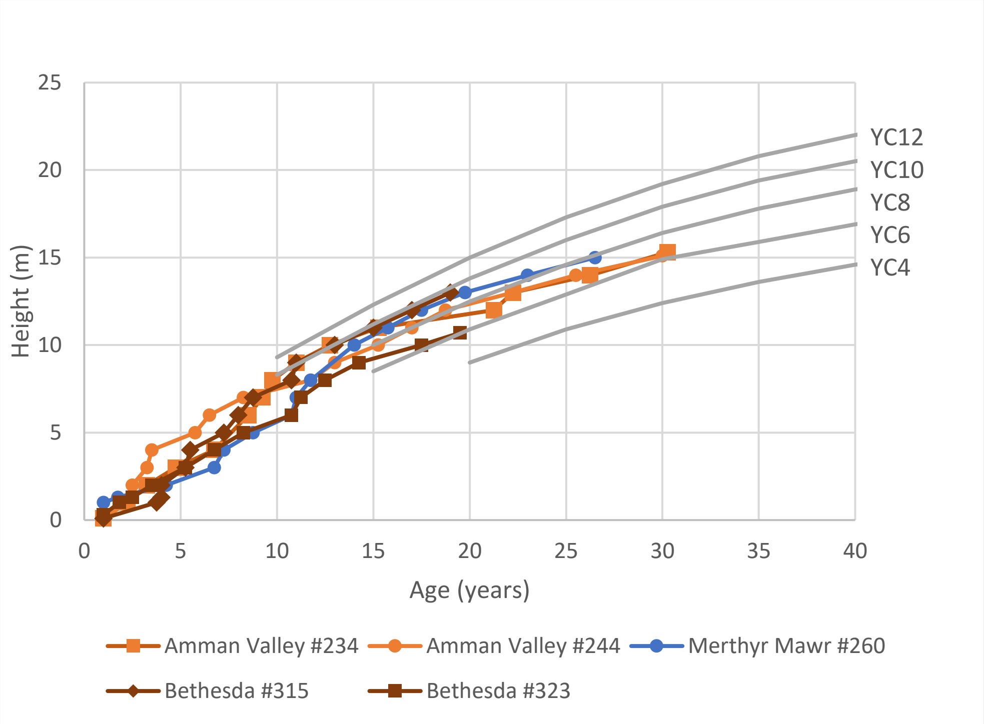


Figure 14: Estimated yield class for three stands in Wales

Understanding something of how trees and stands grow helps us plan thinning regimes and other interventions to help realise the potential of your woodland, at least in terms of health and vigour of the trees.

Thinning regimes

Thinning is the main tool for nudging a woodland to produce what you want and is often, erroneously, equated with 'management' (there would be no thinning in minimum intervention silviculture).

At its simplest "thinning" may take the form of clearing some space around your best yielding trees to provide light to the crown (remembering that crowns should be half the height of the tree). In larger woodlands or for a stand managed for sap a little more formality is required to design an appropriate thinning regime for your woodland.

Natural regeneration of birch can be extremely dense which means many of the trees will die, losing out in competition with their neighbours for light, water or nutrients in a process called self-thinning. Self-thinning models are curves showing the density of trees per ha for trees of increasing size that will maximise growth rates of the stand. Self-thinning models for silver birch in northern Europe[3] indicate stand density of 600 stems per ha (spaced 4 m apart) for trees of 25 cm diameter. This is very low compared to other species e.g. for Norway spruce the tree density can be around 1400 trees per ha for the same sized trees. Such self-thin models form the basis for deciding the target density for a stand and so how many trees should be thinned.

A further consideration is the restricted ability of the crown to respond to thinning once it has been reduced to less than 50% of tree height which can affect trees as young as 10 years. This means

[3] Hynynen J., Niemistö P., Viherä-Aarnio A., Brunner A., Hein S., Velling P. (2010) Silviculture of birch (*Betula pendula* Roth and *Betula pubescens* Ehrh.) in northern Europe. Forestry, 83(1): 103-119. https://doi.org/10.1093/forestry/cpp035

thinning must start early, especially in the very dense stands which arise from natural regeneration. Given the differences in site conditions advice from northern Europe does not agree on exactly when a stand should be thinned. We therefore follow the Forestry Commission[4] recommendations for Scotland (Table 8).

The timing of thinning is dictated by growth rates and it is usually height which is used as the indicator for when thinning is needed. In the UK “top height” is used as the measure of height. Top height in a large commercial stand is given as the average height of the 100 largest diameter trees. For small sites the number of trees to be measured is much lower as shown in Table 5.

Table 5: Number of top height trees required

Area of stand (ha)	Uniform stand	Variable stand
0.5 – 2	6	8
2-10	8	12
Over 10	10	16

To derive top height – select the required number of random points in the stand. Measure the height of the largest diameter tree within 5.6 m of the point (if there are no trees select another point). Take the average of the measured trees as the top height of the stand.

There are many (expensive) instruments for measuring the height of trees but just as many simple ways such as estimating height from a distance with reference to a stick of known length propped against the trunk. The lesson plan on the following link gives 10 methods to choose from. https://outdoorclassroomday.org.uk/wp-content/uploads/sites/2/2019/05/lesson-activity_ways-to-measure-a-tree-1.pdf

If you wish to thin your stands then what follows is a summary of current advice on how to thin birch to maximise growth rates.

Thinning should start at around 15 years with stocking of 2,000 to 3,000 trees /ha derived from either planting at 2 m spacing or after re-spacing natural regeneration. Thinning should remove trees to give a final density at 40 years of around 400 trees/ha (4 m spacing between trees). The reduction can be done in a small number (2-3) heavy thins which take out a large proportion of the trees at once or as light thinning to take out a small number of trees every 5-7 years extending to 8-10 years as the larger trees grow more slowly. Heavy thinning should be guided by top height rather than age to account for differences in yield class. The aim of thinning is to reduce competition around the best trees though these should also be spaced so each has sufficient room to maintain a full crown.

Example thinning schedules based on a 45-50 year rotation with a target diameter of 25-35 cm are given for Scotland for timber production and are reproduced in Table 6. Of course, for sap production we wish to establish and maintain a stand with trees between 20 and 45 cm diameter so would not be looking to fell at 45 years but to maintain stocking by allowing younger trees to replace the ones retired from tapping in a selection system.

[4] Price A., MacDonald E. (2012) Growing Birch in Scotland for Higher Quality Timber. The Research Agency of the Forestry Commission/Forest Research, Roslin. https://forestry.gov.scot/images/corporate/pdf/growing-birch-for-high-quality-timber.pdf

Table 6: Example thinning schedules for birch

2 x Heavy thin	Top height	Age	Stocking after thinning	Spacing
First thin	11-14 m	16-28 years	800 – 1000 /ha	3 - 3.2 m
Second thin	18-20 m	29-48 years	400 - 500/ha silver 500 - 700/ha downy	4.5 - 5 m 3.6 - 4 m

3 x Heavy thin	**Top height**	**Age**	**Stocking after thinning**	**Spacing**
First thin	10-12 m	15-25 years	1200 – 1300/ha	2.8 - 2.9 m
Second thin	15-16 m	25-40 years	800/ha	3.5 m
Third thin	20-21 m	34-60 years	400 - 500/ha	4.5 – 5 m

Light/frequent	**Top height**	**Age**	**Stocking after thinning**	**Spacing**
First thin	10 m	15 years	1400-1600/ha	2.5 - 2.7 m
Thin every 5-7 years			Reduce by ~ 200/ha at each thin	Increase by ~0.5 m at each thin
Thin every 8-10 years				
Final density	20 m	50 years	400/ha	5 m

Modified from Price & MacDonald (2012)

For more information on how to design a thinning regime refer to: Forestry Commission (2015) Thinning control. Field Guide. https://cdn.forestresearch.gov.uk/2015/09/fcfg004.pdf

Managing existing woodland for sap

There will be constraints on whether you can pro-actively manage a woodland. Some are legal – as if you only have a tapping agreement then you may need to negotiate for additional rights to manage the woodland. Some maybe regulatory - if you are working in a woodland designated for nature conservation such as SSSI/SAC or nature reserve then it Is unlikely thinning the stand is going to be permitted or indeed desirable. Where management is likely to be feasible and beneficial is in young dense stands of natural regeneration and plantations. The ideal time to start thinning is between 10-20 years old when there may be a few trees large enough to tap but where thinning will encourage rapid growth to tappable sizes. With careful thinning it should be possible to create a very attractive birch sap "orchard" with widely spaced well developed trees. Younger stands would also benefit from thinning or weeding though it would be longer before you would see the benefits.

In older stands - individual mature trees may not be able to respond to thinning but it may be worth cutting back competition around your best sap trees and thinking about the future of the stand – are you happy to let the woodland naturally drift away from birch? Would you like to maintain birch as a dominant species? For upland birchwoods it maybe that the stocking density is already low and thinning is neither needed or useful.

The very first thing you need to do in woodland you are considering for sap production is to undertake a survey of the site and trees. If you wish to commence tapping straight away then you need to locate sufficient number of accessible trees with stems with diameter over 20 cm at 1.3 m as your potential sap trees. You should also consider the spacing of these trees, how much competition they have - are they overshadowed by larger trees, choked with young trees and shrubs? Are the crowns well developed? Try and measure the top height of the stand. Look out for any logs from which you could take a section to count the rings to estimate age and size.

There is no reason to delay tapping as this will provide useful insights into the tapping potential of the site. A visit to the woodland to inspect tap wounds the autumn after tapping should give you useful information on growth rates. Select trees for tapping the following year from those which gave a high yield and the tap hole had healed over. The second year add new trees to maintain sap production. Over a few years you should be able to have a set of reliable trees and a good understanding of the sap potential of the woodland.

If you wish to develop the woodland to enhance growth rates in the larger trees and hence sustain sap production you should develop a management plan for the woodland. It may be possible to obtain assistance developing a plan from Farming Connect or from Natural Resources Wales – do check the relevant websites for any grants or assistance that maybe available. If your plan requires any felling then you should register your plan with Natural Resources Wales as this stands in for Felling Licenses for the first five years and gives outline approval for a further five years.

https://naturalresources.wales/permits-and-permissions/tree-felling-and-other-regulations/forest-management-plan-scheme/?lang=en

Table 6 gives an indication of thinning regimes you could employ but you also need to consider the end point of your thinning and this leads to your choice of a suitable silvicultural system. A silvicultural system covers the:

- The method of regeneration of the trees in the woodland (this can be natural regeneration, seed sowing or planting)
- The form of the trees (straight clear boles for timber, curved boughs, coppice stems or left to nature); and
- The arrangement of the trees and stands to facilitate management (layout of tracks, working areas etc.)

The basic classes of silvicultural systems are given in Table 7 after the descriptions given in the NRW Good practice guide along with a few thoughts on how they may relate to management of birch for tapping.

Birch stands are often fairly even-aged and are not well suited to the more sophisticated selection based continuous cover systems. Deciding what to do in your woodland depends the age of the trees and the dynamics of the stand. For example, if the stand is young (15-20 years old) and is well stocked (at least 2000-3000 trees/ha) there may not be many trees which are large enough to tap - but it should be possible to start thinning to encourage the growth, and especially crown development, of a framework of sap trees. Stands of more than 20 years old are unlikely to respond well to thinning but if there is a good number of trees giving a decent sap yield you may decide to do a heavy thin, not for the sake of the existing trees, but to work towards a shelterwood system to create a cohort of young trees you can develop as replacement sap trees. Of course, you may also decide that the sap yield from the existing trees is sufficient and there is no need to do any thinning and you adopt a minimal intervention system.

For farm woodlands, grazing is a particular issue. Birch is not particularly favoured by sheep, and it is feasible to allow them into the woodland in February to take advantage of the shelter and forage. This will benefit the woodland by controlling brambles and manuring the trees. But regular inspection is needed, and sheep should be removed as soon as you see signs of any damage to the trees. You may also wish to close the woodland to animals and the public during the sap season (only feasible to close footpaths if these are permissive) or perhaps put up signs.

Table 7: Basic silvicultural systems in use in Wales

System	Description	Relevance to birch
Minimum intervention	This does not involve felling trees or modifying the wood in any significant way and is appropriate for conservation woodlands. Minimum intervention may give low sap production on good sites as it is likely that by the time the trees are large enough to tap, the stand will be dense with trees, young trees of other species, and choked with brambles. Clearing around sap trees rather than formal thinning would perhaps be an acceptable compromise in minimal intervention woodlands. However, minimum intervention will probably be entirely acceptable in upland sites which naturally form low density birch stands.	Used on any site which has a high priority for conservation. Sap collection is very low impact and should be compatible with conservation management, but you may wish to restrict tapping to trees on the edges and in glades which have well developed crown. Remember older trees are more susceptible to wounding and no tree exhibiting veteran characteristics should be tapped.
Continuous cover forestry (CCF)	Continuous cover forestry is also termed ‘close to nature’ and is an attempt to mimic natural processes in a more formal silvicultural regime. The critical feature of these systems is that the canopy of mature trees is maintained at all times with felling causing only small gaps in the canopy.	This is the preferred system for use in native woodland.
CCF – Shelterwoods	These are relatively simple systems where regeneration is encouraged under an overstorey of maturing trees that are progressively thinned until just seed trees remain. Once regeneration is established the seed trees are removed. These simple shelterwoods create even-aged crops where successive generations periodically replace each other.	Suitable for use in dense monoculture or plantation where the intention is to maintain site under birch. For second generation of birch mature trees should be thinned to 20-40 per hectare, the site scarified.
CCF – Selection systems	These are more complex and are based around managing individual trees – once thee are mature they are felled to create gaps within which regeneration occurs – the end result being an intimate mix of ages and often species of trees in the woodland.	Less suitable for birch as gaps are often too small to allow in sufficient light to support many pioneer trees. In many situations birch stands will naturally become more species diverse as shade-bearing species come in. If natural succession is the objective for the stand then selection systems can be used to encourage these changes. In such a system sap production would likely diminish as the woodland matures.

System	Description	Relevance to birch
Small coupe felling	This is similar to shelterwood in that the crop is felled at once but in this case nothing is done to specifically encourage regeneration and the felled area is replanted.	This could be used for birch but given birch produces prolific seed and will readily establish in clear-fell sites it would more likely be cheaper and indeed easier to use a shelterwood system.
Coppice	This is the cutting of trees just above ground level and managing the shoots which spout from the stump. The sprouts are sometimes thinned and cut once they reach a useful sizes. Coppice of hazel and willow is well known but can also be done for oak, chestnut and other species. The cutting period is longer for slower growing species and for larger dimensions e.g. for poles or firewood. The short life span of birch means it is not routinely managed as coppice.	Birch does coppice even from trees cut at 25-30 years of age. Coppice stems can be tapped below 20 cm and will give good yield as they are connected to a large, well developed root system. Work in Finland[5] suggests that coppice derived shoots will grow significantly faster than seedlings for at least the first 15-20 years. More robust early dense growth of coppice shoots may mitigate browsing damage with some stems being protected. Use of coppice gives a means of increasing light within a stand of birch by maintaining a proportion of the trees at different coppice stages.
Standard clearfell	This is the 'standard' system used for commercial conifers in Wales. It is based on growing trees as a planted crop. The stands which develop from planting are regularly thinned to promote growth of final crop trees. Pruning is also employed to keep stems straight and reduce side-branching to give a clear length of bole suitable for use as timber. All trees are felled when growth rates start to diminish and the site is replanted with a second crop.	Plantation birch could be managed in this manner if intended for use as timber. Where this is the case tapping maybe restricted to the few years before final felling so the tap wounds do not stain the heartwood used as timber. If it doesn't matter if wood is stained then sap and wood could be co-produced. Planting of birch is usually less successful than natural regeneration so a shelterwood would be preferable for a second crop of birch.

For more information:

NRW (2017) Forest resilience Guide 1: Improving the structural diversity of Welsh woodlands. Good Practice Guide 6. Natural Resources Wales. https://cdn.cyfoethnaturiol.cymru/media/681945/gpg6_forest-resilience-1_structural-diversity.pdf

[5] Hytönen J. (2020) Development of downy birch (*Betula pubescens* Ehrh.) coppice stands during nine years. Forests 11: 958. https://doi.org/10.3390/f11090958

If you do plan to do any thinning then you may wish to consider what you will do with the wood and brash (branches). Birch is a decent hardwood and can be used in furniture, it also makes a good firewood, the bark and wood can be heated to extract oils and tar, fine twigs are made into brooms and horse jumps. Or you can leave it in the woodland to add to the soil carbon store.

Devising thinning regies and silvicultural aspects of a management plans will likely require specialist forestry advice.

Funding for improvements to your woodland is available, as is support for training in the development of a management plan:

The National Forest for Wales – TWIG (The Woodland Investment Grant)

https://www.gov.wales/national-forest-for-wales-the-woodland-investment-grant

https://businesswales.gov.wales/farmingconnect/skills-and-training/training-course/woodland-management-conservation

https://www.focusonforestryfirst.co.uk/

Creating a new birch woodland

You may wish to extend your woodland or are already planning on creating a woodland and wondering about whether this could be used for sap to add an income stream in the future. Birch might be a good option if your intention is to create a native woodland for biodiversity as it is the natural woodland pioneer tree in Wales. There are several options for creating a new birch woodland depending on context and the level of investment. These are briefly outlined here.

Natural regeneration

There are distinct advantages to the use of natural regeneration to establish a new birch woodland or a second rotation in a shelterwood system. Briefly these are:

- the trees will be best adapted to local conditions
- trees with undisturbed root systems will grow quickly and strongly

Grazing animals will need to be excluded by fencing at least until the trees are taller than the reach of the animals. Birch establishes best in bare soil or in moss and is not able to compete with grass and rank vegetation. You therefore need to remove vegetation to expose mineral soil - a process termed scarification. Ideally you should scarify in the summer to provide a seed bed into which the seed shed in the autumn can fall. The site can be scarified mechanically by harrowing, rotavating or ploughing - though take care to anticipate and control runoff. Burning works well if it is hot enough to burn off the organic material on the surface. You can also take advantage of the new fence to put in animals to over-graze the site e.g. pigs are particularly good at turning over soil, though take care the animals are given supplementary feed and removed before their diet becomes too restricted.

For a heavy seed rain you need to have mature birch trees close to the site – best within 50 m but certainly within 400 m.

Pest and diseases will affect trees arising from natural regeneration, but the density of young trees is usually very high and more than enough survive to ensure that the site will be fully stocked. After two years the site should be dense with young trees that will need to be re-spaced (Table 8). This is the process of reducing stocking in anticipation of self-thinning and to encourage the fastest possible development of strong fast-growing trees. Re-spacing is done once the trees are established and done alongside weeding. Re-spacing can be done with a clearing saw, hand tools or simply by breaking off the top of the tree. The brash is left on site as it is both too fine and bulky to be much use and on-site the nutrients will quickly return to the soil. While re-spacing do control bramble as this can damage young trees if left to scramble through the crowns.

Table 8: Re-spacing of natural regeneration

Age	Stand height	Tree density	Distance between trees
0	0	11,000+ /ha	-
2-3 years	1.5 – 2 m	Re-spacing to ~ 5,000/ha	1.4 m
5-10 years	~ 6 m	2,500 – 3,000/ha	1.8 – 0.6 m

Natural regeneration using a shelterwood system is the preferred option for restocking of an existing birch woodland, though in this case you may wish to consider scarifying small patches (strips of 20-60 m have been suggested but seem rather large for a small woodland) rather than lose the established woodland ground vegetation from the whole site at once.

Direct seeding

In situations where there are insufficient seed trees available – or perhaps where you wish to use seed of a different species or provenance, you can use direct seeding. The site is prepared as for natural regeneration but collected or purchased seed is broadcast over the site in the late autumn.

Seed may be sourced from an existing birch woodland you have permission to access or from a commercial seed merchant. Seed may be collected during August and September from trees over ten to fifteen years old. Seed quality is higher in years with warm springs and abundant flowering so watch for the catkins in the spring. As fruits ripen their colour will develop from light green to brown and dangle or stick out of the catkins. Ideally seed should be harvested at peak of ripeness, but strobiles should be harvested when they are still sufficiently green to hold together to prevent shattering. Seed is collected from the tree so you will need some means of reaching the branches – a ladder or telescopic secateurs may help. Seed is best preserved in plastic bags in the fridge (at 6^{o}C) and should be sown as soon as possible as viability declines rapidly. For this reason, when ordering seeds from a reputable merchant, you should expect to need to order a year in advance.

The minimum recommended sowing density is 200,000 viable seed /ha to aim for establishment of ~ 10,000 trees/ha. This sounds like a lot of seed but will only weight 100 grams.

Planting

Site preparation for planting is much the same as for natural regeneration except that planting the trees into screefs rather than site level scarification is feasible. Screefing is the removal of vegetation and humus to expose mineral soil (or peat) in a small area (roughly 50x50 cm) with the tree planted into the centre of the cleared area.

Birch seedlings do not recover well from root damage and need to be handled carefully and should be ordered as container-grown rather than bare rooted. Matching of planting stock to the site is important in terms of altitude – so try and specify the altitude range for the seed source. This information should be available from the nursery as the Forest Reproductive Materials require this and other source information to be recorded for each seed collection and this should accompany your young plants. Plant birch at 2 x 2 m spacing to give 2,500 trees/ha.

Weeding of planted birch is important – screefing will help reduce root competition for at least a few years but tall vegetation between the screefs can flop over the trees and push them over so the trunks will have a permanent sweep. This would not affect tapping or sap production so there is no need to worry overmuch with small deformities as long as the trees survive and grow well. Weeding will be required for several years – at least as long as re-spacing is required for natural regeneration and direct sowing so these costs are probably comparable between these methods. If your site has lots of bramble you should try and cut it back to prevent damage to the trees. The looping stems of bramble will scramble over trees up to 5 m tall and in the wind can saw through bark causing deep wounds and deformities in the young trees. Dense bramble is also difficult to move through collecting sap.

Voles can be an issue with planted stock – in bad years a large proportion of the plants can be lost or badly damaged. A number of methods including poisoning and traps have been employed in the past but less lethal methods are preferable. The smaller variety of plastic tree guard (an increasing variety of non-plastic alternatives are also available) can be used to reduce vole damage. However, these are expensive, need to be collected up once the trees are too big to be gnawed by voles (about 5 cm diameter after say 4 years) and even if biodegradable will introduce chemicals into the environment. Vole populations tend to go through boom-and-bust cycles. So, if you have had a bad year, you might anticipate the next year will have far fewer voles so it maybe more useful to invest what you would spend in tree guards in purchasing additional seedlings for "beating up" (plant up spaces with no tree) in the second year. If you are successful in the first year then you've made a real saving. Avoiding the use of tree guards unless strictly necessary is increasingly standard advice.

Guidance on use of tree guards
https://www.gov.uk/government/publications/tree-protection-the-use-of-tree-shelters-and-guards

Funding for woodland creation

There is funding and assistance available for woodland creation available from several sources – the most obvious being direct grants, sale of carbon credits and schemes run by third sector organisations. Most of these grants can be used for natural regeneration as well as tree planting though rates may vary. Grants and assistance available in early 2023 are:

The National Forest for Wales – TWIG (The Woodland Investment Grant)
https://www.gov.wales/national-forest-for-wales-the-woodland-investment-grant

Welsh Government – Woodland Creation Grant
https://www.gov.wales/woodland-creation-grant

Coed Cymru (advice, access to small grants, access to woodland carbon credits)
https://coed.cymru/index.html

Farming Connect
https://businesswales.gov.wales/farmingconnect/land/woodland

Stump up for trees (small woodland creation grants in Abergavenny area)
https://stumpupfortrees.org/

Sources of further information

Tapping/processing equipment

Spiles: "Maple Sap Tap Spile, 5/16" Ecolo Spout" River Ridge Products LLC (USA)
https://www.amazon.com/s?i=merchant-items&me=A19FKLHR7968GW

Food grade buckets & lids of various sizes: Oipps Packaging https://oipps.co.uk/

Digital Refractometer: https://www.creamsupplies.co.uk

Reverse Osmosis kits: https://www.therobucket.com/

Information on tapping & processing

EIP Wales: 'EIP' Welsh birch sap – published on Farming Connect YouTube channel May 2022
https://www.youtube.com/watch?v=J4AvSftJxy8

Dewis Gwyllt website pages on birch tapping:
https://www.dewisgwyllt.co.uk/product-research/birch-syrup/

USDA (2014) National Agroforestry extension service video "Small scale reverse osmosis"
https://www.youtube.com/watch?v=_BOO2L1RD2s&list=PL8uVHUIycx2MpOIgulSiPLxnA5pQYNFhY&index=6

Further reading:

Farrell M. (2013) The Sugar maker's companion. An integrated approach to producing syrup from Maple, Birch and Walnut trees. Chelsea Green Publish, Vermont. ISBN 978-1-60358-397-8

Dixon-Warren H. (2010) The birch syrup production manual. Tapping into syrup boreal forest style. Moose Meadows Farm. ISBN 978-0-9783466-0-7

Cameron A.D. (1996) Managing birch woodlands for the production of quality timber. Forestry 69(4): 357-371.
https://doi.org/10.1093/forestry/69.4.357

Forestry Commission (2015) Thinning control. Field Guide.
https://cdn.forestresearch.gov.uk/2015/09/fcfg004.pdf

Forestry Commission (2020) Tree protection: The use of tree shelters and guards. Guidance and sustainability best practice.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/896121/Tree_shelters_guide.pdf

Hynynen J., Niemistö P., Viherä-Aarnio A., Brunner A., Hein S., Velling P. (2010) Silviculture of birch (*Betula pendula* Roth and *Betula pubescens* Ehrh.) in northern Europe. Forestry, 83(1): 103-119.
https://doi.org/10.1093/forestry/cpp035

NRW (2017) Forest resilience Guide 1: Improving the structural diversity of Welsh woodlands. Good Practice Guide 6. Natural Resources Wales.
https://cdn.cyfoethnaturiol.cymru/media/681945/gpg6_forest-resilience-1_structural-diversity.pdf

Price A., MacDonald E. (2012) Growing Birch in Scotland for Higher Quality Timber. The Research Agency of the Forestry Commission/Forest Research, Roslin. https://forestry.gov.scot/images/corporate/pdf/growing-birch-for-high-quality-timber.pdf

Appendix 1: Identification of birch species

These identification characters have been collated from a wide range of sources. However, they are not constant and an individual tree may not exhibit all characters and still be a good representative of the species. The characters in **bold** are those which are considered the most definitive by:

Amphlett A (2021) Identification and taxonomy of Betula (Betulaceae) in Great Britain and Ireland. British & Irish Botany 3(2), pp.99-135.

Ashburner K. & McAllister H.A. (2016) The genus Betula: A taxonomic revision of birches. Botanical Magazine Monograph. Kew Publishing, Royal Botanical Gardens, Kew.

Chater A.O. *Betula celtiberica* in Wales. BSBI Welsh Bulletin 85: January 2010 pages 17-19.

Silver birch / Bedwen arian / *Betula pendula*

Circumpolar species which grades from *B. pendula* in west to *B. japonica* in east. Tree supposedly with elegant drooping branches but this is not always obvious from the ground in a woodland and is not a constant feature (i.e. can also be seen in downy birch). There is a weeping cultivar ("Youngii") with hanging curtains of fine branches.

Diploid 2n=28

Leaf: Triangular – straight at base tapering to sharp tip; Double toothed leaf margin; underside with no hairs

Shoots and young twigs:

- **no hairs**,
- **translucent, resinous (sticky), wart-like glands**

Bark:

- Silver-white
- V-shaped over branches where they spring from main trunk
- In older trees lower bark thickens and fissures first as distinctive diamond-shaped scars into deep corky black fissures
- Older trees nearly always buttressed

Downy birch / Bedwen llwyd / Betula pubescens

Range extends from Newfoundland, across Europe to Lake Baikal and from northernmost limit of tree growth to northern Greece. Very variable and includes many named subsp. and varieties.

Tetraploid 2n=56

Leaf:

- triangular but rounded or angled at base rather than straight, less obviously pointed
- single or irregular toothed

- hairs on underside of leaf

Shoots and young twigs:

- **covered in dense, velvet-like fine hairs**; (most easily seen at x10 magnification with hand lens)
- no wart-like glands

Bark and trunk:

- matt white/pale grey;
- may have outer bark peeling into curls
- usually has notable stripped appearance arising from horizontal alignment of long lenticels;
- trunk maybe fluted or sinewy

Downy birch / Bedwen llwyd / *Betula pubescens* subsp. *celtiberica*

Described in Cantabrian Mountains of Spain. Also recorded in mid-Wales. Considered to be stable hybrid with a mix of characters from both parents.

Tetraploid 2n=56

Leaf:

- diamond shaped
- tufts of hairs in junctions of veins on underside – otherwise smooth
- single toothed

Shoots and young twigs:

- **fine hairs**
- **wart-like glands**

Bark and trunk:

- white to the base not broken unto fissures
- no buttressing

Downy birch / Bedwen llwyd / Betula pubescens subsp. fragans

Found on mountains in Scotland – but possible in Wales? There are trees around Llanidloes which have particularly small leaves

Tetraploid 2n=56

Leaf:

- oval
- small
- single toothed
- fragrant - scented

Appendix 2: Design for an outdoor wood stove for sap evaporation

Site
A sheltered, flat site is needed, with good access around it for supplying fuel and handling the sap and hot evaporating trays. Setting up the stove on an established bonfire site within the woodland is ideal.

Be careful with regard to the fire-risk. Ideally there will be a water supply (hose-pipe connection) nearby in case of fires and to wash out tray at the end of the day. Buckets of water should be kept in easy reach to douse any out of control fire and ensure fires are out / fire is out before leaving site.

It is useful to have somewhere comfortable to sit as the stove should not be left unsupervised! A table is also useful and keeps equipment and finished concentrate off the ground.

A canopy over the stove is useful in case of rain or strong winds but be aware that any roofing needs to be fire-proof. Nevertheless, it is probably best to restrict use of stove to days with a good weather forecast. If concentrate is frozen, use of the wood stove can be delayed until the summer and (hopefully) better weather.

A more permanent structure could easily be set up within a north American-style sugar shack for which there are many designs available online.

Materials needed to build a basic 2-course stove:
18 to 30 standard 4" hollow breeze blocks (440mm x 215mm x 100mm). 18 blocks are used to form the stove but additional blocks are useful to help support the walls and insulate the firebox.

Welded metal mesh to support evaporating trays and a grate to lift fuel off ground to provide air flow from beneath. Concrete reinforcement steel mesh is fairly cheap and works well as a support for the trays but under the fuel tends to deform and may need to be replaced every time the with use.

Flue / chimney – approximately 2.5 m of 5" / 6" flue (second-hand pipe or chimney liner) and some means of supporting it. The flue needs to be freestanding and can be supported with fencing pins, rebar or suspended by wires from overhead rope. The flue will get very hot so wooden posts are not recommended.

Useful, but not essential:
6 x 1m 8mm steel fencing pins/ reinforcing rods (to provide extra support to the blocks)
A few firebricks or similar to lift the grate off the ground to improve air-flow
Fire cement / stove tape / rockwool or similar, to wad around flue entry at the back of the stove.

Video on Dewis Gwyllt site gives instructions for a 3 course stove – the lower 2 course stove is more efficient.

Evaporation trays:
2 large 43 litre stainless steel catering grade trays (2/1 Gastronorm, dimensions: 650mm x 530mm x 150mm)

2 pairs Heat resistant gloves / oven gloves (for handling the hot trays)
Skimmer to remove any debris from the sap (also sieve and muslin to filter finished concentrate)
Lidded stainless steel pans to cool concentrate before storing in lidded plastic containers.
Brix meter to measure sugar concentration throughout the process – either digital or Honey refractometer

A plentiful supply of clean (tap or permeate) water for cleaning is essential along with brushes and cloths to clean everything when finished.

Note that stainless steel pans must be used as birch sap is acidic (~ pH 5.5-6.5) and can eventually corrode more susceptible materials and this can contaminate the syrup.

Fuel:
The stove is in effect a rocket stove and is quite efficient in terms of the amount of fuel required and the heat generated. The amount of fuel needed varies with the nature of the fuelwood being used and ambient temperatures. Experience with ten EIP wood stove trials at three different sites gave an average of ~ 11.5 kg of fuelwood per hour of burn.

Longer lengths of small sized wood makes the fire easier to control and to pass fuel to the back of the stove. Sawmill offcuts, branch wood, untreated pallet wood, as well as spit logs are all suitable fuel for the stove. A variety of sizes of fuel is useful so that the temperature of the fire can be controlled. If scrap wood is used, make sure it is clean and does not contain any contaminating materials such as paints or preservatives. Slightly damp~~ish~~ wood can be used once the fire is well established with well-seasoned fuel.

Using the stove:
A fire should be set along the length of the stove and given some time to settle down to embers before placing the pans on top and adding the sap.

Ensuring everything that is needed is ready to hand, place the first pan at the rear of the stove and add one or two frozen blocks of sap in a few centimetres of liquid. This is needed as the melting concentrate will boil off a hot pan and the sugars will burn. The second pan can then be added and filled in the same way. Although the pans have a nominal capacity of 45 litres, they should not be filled too high in case they boil over, and processing no more than 30-35 litres in each pan is recommended. As the levels reduce additional sap or concentrate can be added. Check the evaporation rate for your set up by recording volume present in the pans throughout the process. The simplest way to do this is to measure the depth of sap at regular intervals using a clean stainless steel ruler. Sugar content should also be measured and recorded regularly using a refractometer. Samples can be taken using a long syringe (e.g. turkey baster). As the sap is boiled, foam may be produced on the surface as proteins in the sap float to the surface - this should be skimmed off to prevent scorching at the edges, and to permit maximum evaporation.

Fuelwood needs to be added to the firebox in small quantities to maintain a continuous, even, and clean flame along its full length heating both pans evenly. This can be difficult~~,~~ but is easier with experience and some control of the fire can be achieved using blocks to control air flow. Try to manage the fire so it burns clean to minimise smoke / smuts that could land in the evaporating pans.

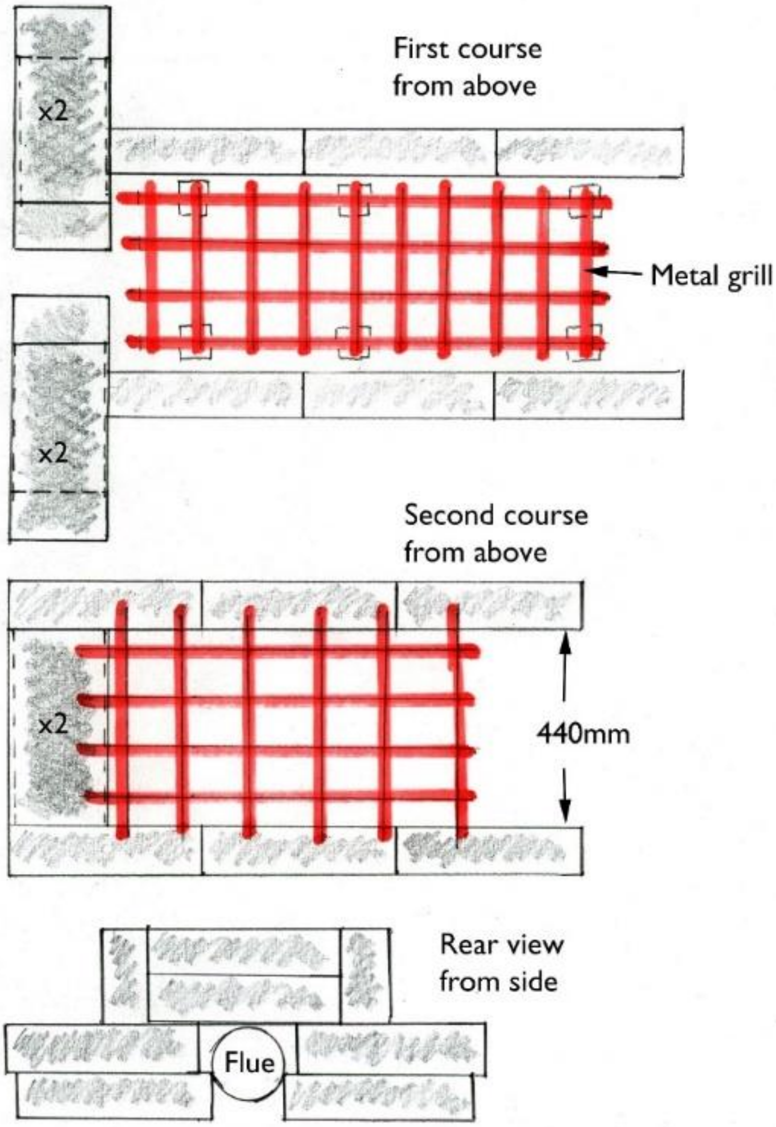
It is important not to boil the liquid too hard, especially when the sugar concentration begins to increase. A 'rolling boil' is ideal. It is also possible to manage the pans and fire to simmer rather than boil the contents of the pans which is especially important as the sugar content goes above 28^{o}Brix.

Take care not to let the pans become less than ¼ full with a high heat to prevent sap burning. You can add fresh sap to the pans as the levels fall.

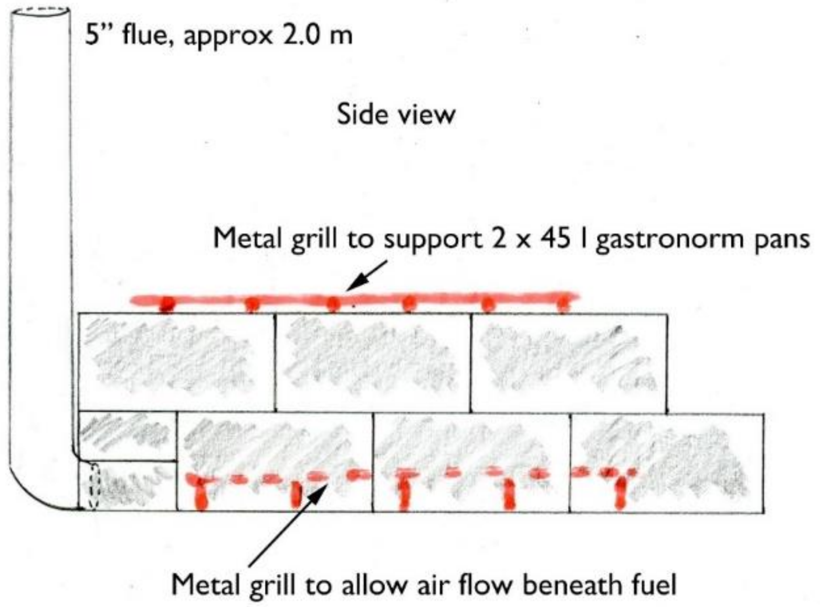
The boil-down should be stopped when the target sugar content is reached; perhaps best at 28°Brix, not more than 38°Brix and certainly before there is any risk of burning the sap as the levels go down. As volumes are reduced, the two pans can be combined to ensure what remains does not burn. To complete the process, the concentrate should be filtered through clean muslin (or other food-grade filter material) placed in a sieve over a suitably sized container. Due to the risk of scalding, care must be taken at all times when transferring hot sap. Two people may be required to do this and heat-proof gloves should be used whenever handling hot items. Once filtered the concentrate should be allowed to cool, then stored frozen in labelled buckets until required for finishing.

The evaporating pans should be thoroughly cleaned after use. The black gritty precipitate nitre or sugar sand should be scrubbed off the inside of the trays as leaving this can scorch the next batch.

Make sure that the fire is fully extinguished before leaving the site.



18 standard hollow breeze blocks
L = 440mm, W = 100mm, H = 215



Under a temporary corrugated iron roof

Erected on established woodland fire circle

Sealing flue to back of stove

Sawmill slabwood – approximate quantity required for a seven hour burn.