Curly birch (*Betula pendula* var. *carelica*), wooden ´marble´ from Finland – soon easily available

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Abstract

Curly birch (Betula pendula var. carelica (Mercklin) Hämet-Ahti) is a special variety of silver birch, known for its hereditary and unique, highly decorative curly-grained and brown-figured wood. It is the most highly-priced variant of native tree species in the Nordic countries. Curly birch logs and veneer are used for furnishing and paneling e.g. banks, offices, luxury homes, ships and expensive cars. Wood with smaller dimensions is used in carpentry for highly valued products such as gifts, souvenirs, tools and furniture. Curly birch occurs naturally, but rare, in Northern Europe and parts of Eastern and Central Europe. Its cultivation has a long tradition in Finland. Interest in commercial cultivation of curly birch has, however, increased significantly since the 1980's. As a result some 6500 hectares of curly birch stands have been established. They will soon start reaching their rotation age (35-50 years). Small-sized wood from thinnings is already available in abundance. The significantly increasing availability of this exceptionally beautiful wood resource makes it possible to develop new wood products based on this, now cultivated, variant. The wood material is suitable also for premium products with high class design. Earlier the poor availability of curly birch wood has prohibited developing such products. Now wood will soon be available regularly in larger quantities than today, enough for both domestic use and export. Silvicultural management of curly birch has to be done with special care, from plantation establishment, through right-timed thinnings to branch pruning and final cutting. In this article the wood characteristics and utilization, silvicultural practices and the rapidly changing market issues of this wooden ´marble´ are reviewed.

1. Introduction

Curly birch is known for its hereditary and unique, highly decorative curly-grained and brown-figured wood. Due to its rarity and very special wood, it has for centuries been sought after in the forests for purposes where decorative or strong wood was needed and it is still the most highly-priced variant of native tree species in the Nordic countries.

According to the current taxonomy (Hämet-Ahti 1987, Hämet-Ahti et al. 1992) curly birch (*Betula pendula* var. *carelica* (Mercklin) Hämet-Ahti) is regarded as a special variety of silver birch, but several Latin names have been in use in course of time. A number of generic names have also been used, e.g. Masur or Mazer birch, Karelian birch and speckled birch (see Velling et al. 2000 and references therein).

Curly birch occurs naturally in southern Scandinavia and Finland, the Baltic countries and western Russia, Belorussia and Ukraine. Sporadic populations are to be found also in Poland, Germany and Slovakia (Pagan and Paganová 1994). Throughout its distribution area curly birch is rare, occurring as solitary trees or small groups of trees. Its distribution is often related to areas where shifting agriculture including burning of land was practiced until the early 1900's (Heikinheimo 1951).

Cultivation and research of curly birch have a long history in Finland, dating back to the first experiments by Aaltonen and Heikinheimo in the 1920's and 1930's (Heikinheimo 1951). Thanks to the active guidance and consulting by the Finnish Curly Birch Society (Huuri 1978), the enthusiasm and knowledge about curly birch increased, which led to a significant and long-lasting increase in its

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cultivation starting in the late 1980's. Thus, in the near future wood of this earlier rare variant will be available in larger quantities than before.

The aim of this article is to review and discuss the special features of this unique variant in terms of wood characteristics and utilization, silviculture and the rapidly changing market issues.

2. Curly wood formation and wood properties

Curly birch wood is the result of abnormality in the functioning of the cambium. Groups of cambium cells cease to divide, as the surrounding cells divide rapidly and wound callus and brown parenchyma cells are born and become incrusted in the wood (Hintikka 1941, Ruden 1954, Johnsson 1974). As a result, the annual rings become wavy, the tissue exceptionally oriented and the pith rays dilated. In the cross section of a curly-grained birch stem, V-shaped brown patterns are seen, which can form a pronounced and closed "curly-grain flower" configuration. When the bark is peeled off, the surface of the stem has a decorative granulated appearance with small oblong swellings and depressions. A longitudinal tangential cut shows a lens-like configuration (Hintikka 1941, Ruden 1954, Saarnio 1976). Scientific studies of the technical properties of curly birch in Finland are practically nonexistent, in spite of the fact that curly birch is such a regional specialty in our country and the neighbouring areas. In Russian literature more studies may probably be found (see the literature list by Etholén and Huuri 1982).

Wood density and hardness of curly birch are higher than those of ordinary silver birch. Wood density and strength properties of curly birch were studied by Hintikka (2004). Oven-dry density ρ_0 of wood samples consisting entirely of curly birch wood was 680 kg m^{-3} and air-dry density ρ_{12} (in 12% humidity) was 730 kg m^{-3}, while air-dry density ρ_{15} of silver birch was 640 kg m^{-3}. In wood samples which were mixtures of curly and normal wood the values were somewhat lower, i.e. oven-dry density ρ_0 was 650 kg m^{-3} and air-dry density ρ_{12} 700 kg m^{-3} (Hintikka 2004). The strength properties of curly birch reported by Hintikka (2004) were generally lower than those for silver birch. However, according to Sokolov (1937, cited in Hintikka 2004) the Janka-Brinell hardness of curly birch and normal silver birch was 471 kg cm^{-2} and 403 kg cm^{-2}, respectively.

3. Growth form and various stem types of curly birch

Curly birch trees differ in many ways from normal silver birches in terms of external morphology. The stem form of curly birch varies from crooked multi-stemmed bushes to straight single-stemmed trees (Ljubavskaja 1978). Due to their slower growth curly birches remain shorter than normal silver birches (Heikinheimo 1951, Kärkkäinen et al. 2017). The trunk of curly birch, which is typically forked and leaning, contains swellings, knots and protuberances and is covered by thick, cracked and partly black bark. The abundance and appearance of the curly formation also varies (Mikkola 2004).

Saarnio (1976) described four stem types which differ regarding their external morphology and the abundance and type of internal curly configuration with brown figures in the wood: *protuberance*, *neck*, *stripe* and *ring* curl. The trunk of *protuberance* curl contains small knobs, approximately an inch in diameter, located close to each other. Usually they are externally visible and can be felt by hand. Straight-stemmed treelike individuals, suitable for turning (veneering) with abundant protuberance formation and rich curly configuration with brown figures in the wood are the most valuable and in highest demand (Mikkola 2004). In the trunks of the *neck* type there are distinct thickenings "muffs", containing curly grain pattern in the wood, and thinner parts "necks", usually containing normal wood. The trunk of the *stripe* type contains vertical ridges with furrows in between, and that of the *ring* type transverse thickenings. The wood of these latter two types does not have brown configuration, but the *ring* type typically contains light-coloured patterns resembling wavy or flamy birch. *Stripe* and *ring* types are not planted or collected commercially for export (Mikkola 2004), since they are quite rare types. Most of the curly birch trees are, however, mixtures

of two curly types (Saarnio 1976). It should be noted that wavy and flamy wood forms are called "curly" e.g. in American classification of figured wood (Beals and Davis 1977). This differs from the classification used in our paper.

External signs of curliness on the stem do not always guarantee the existence of curly grained wood with brown figures within it, and on the other hand, sometimes a fine curly pattern can be found in the cross-section of a felled stem without any visible external signs on the stem. According to the external appearance of the stem, the formation of curly-grained wood can usually be detected at 5-6-year-old seedlings (Johnsson 1951, Ruden 1954, Saarnio 1976), but the age for appearance of external signs can vary as much as 2-30 years. Trees growing on fertile sites and in wider spacings, usually express the curly-grain formation at an earlier age (Heikinheimo 1951). So far, there is no method for reliable identification of the quantity or quality of curly pattern on living trees or even the entire felled logs. Salmi et al. (2007) presented an ultrasound method for differentiating curly birch from silver birch on wood samples in laboratory circumstances indicating 93% probability of correct type classification using computerized clusterization.

4. Curliness is a hereditary trait

Several hypotheses have been presented on the primary cause of curly wood formation (Velling et al. 2000). Site nutrition and climatic factors were regarded as reasons for this abnormal development 'Wisa disease' by Hintikka (1922). It has also been attributed to viruses and other pathogens by e.g. Atanasoff (1967). However, Heikinheimo (1933) was the first to show that curliness is a hereditary trait and passed from generation to another via seeds. This has later been confirmed in several studies using different types of breeding material (Heikinheimo 1951, Johnsson 1951, Velling et al. 2000, Paganová 2004, Kärkkäinen et al. 2017).

The proportion of individuals expressing curly-grained pattern within the progeny depends a lot on the mother tree and on the amount of pollen coming from the surrounding curly trees, when seed is collected from solitary trees in the forests. It can, thus, vary from 1 to 50 % (Heikinheimo 1951, Johnsson 1951). Seed from controlled crosses of curly trees produces 60-70% trees with curly-grained wood (Kärkkäinen et al. 2017).

Like the basic cause of curly-grained wood formation, also the pattern of inheritance of curly trait has been speculated (Johnsson 1951, 1974, Ruden 1954). Ruden (1954) was the first one to explain the genetical back-ground of curly-grain formation on the basis of a dominant 'masur gene' that is lethal in homozygotic conditions. The hypothesis of Ruden (1954) was supported by the observations of Paganová (2004) and recently by Kärkkäinen et al. (2017).

The molecular and physiological basis of curly wood formation is, so far, poorly known and only a few studies are available. Pätiälä et al. (1978) observed differences in carbohydrate composition of the sap of curly and normal silver birches, of which only the latter ones contained sorbitol. Novitskaya (1998) reported accumulation of sucrose in the phloem of curly birch. Ahokas (1985) found higher cytokinin content in the spring sap of curly birch compared to that of normal silver birch, which could be the reason for the poorer apical dominance of curly birch trees and possibly even for the curly-grained wood formation itself, as suggested by Ahokas (1985). Because curliness in birch entails drastic changes in the wood structure, growth form and external morphology as well as the vitality of the trees, it can be assumed, that the gene(s) behind are important, and thus studies on this aberrant form can provide knowledge and understanding of wood formation and growth processes in general (Kärkkäinen et al. 2017).

5. Cultivation and silviculture of curly birch

Cultivation and silvicultural management of curly birch has to be done with special care, from plantation establishment, through branch pruning and right-timed selective thinnings to final cutting.

Successful management demands special expertise, significant effort and economic contribution from the forest owner. However, if the silvicultural measures are well-timed and carried out in a correct way, it is possible to reach 10 times greater profit than that for normal birch (Raulo and Sirén 1978, Hagqvist 1996).

The history of curly birch cultivation in Finland dates back to the 1920's and 1930's, when the first large experiments were carried out mainly by professor Olli Heikinheimo (Heikinheimo 1951). Since then, the genetic quality of the seedlings cultivated has been improved by plus tree selection, crossings, progeny testing and production of genetically improved material in greenhouse seed orchards (Lepistö 1973). A tissue culture method for vegetative propagation of the valuable curly birch individuals was developed in 1986 (Ryynänen and Ryynänen 1986), and the micro-propagated plants are widely used (roughly 50% of all planting stock) for practical cultivation nowadays in spite of their higher price. Seed orchard seed produces 60-70% trees with curly-grained wood and vegetative micro-propagation 100%.

In Finland curly birch is mainly cultivated in the southern part of the country, where it grows best, but there are also a few encouraging examples from Northern Finland where cultivation of curly birch has succeeded well (Etholén 1978). For cultivation of curly birch a fertile upland site with light mineral soil and good aeration should be selected. Site preparation is needed before plantation establishment especially on former agricultural land (Hagqvist and Mikkola 2008). Usually 1600 seedlings are planted per hectare, but if there is a risk of damage by browsing animals, i.e. moose (*Alces alces*), hare (*Lepus* spp.) and voles (*Microtus* spp., *Myodes* spp.), it is recommended to plant up to 2500 seedlings per ha. When expensive micro-propagated plantlets are used, some 800-1000 plantlets (sometimes as low as 400) are used to reduce the costs. Seedlings can be protected against the moose by fencing and against voles and hares using plastic plant shields. Excess ground vegetation is removed from covering the seedlings during the first 2-3 years, and cleaning is needed to remove sprouts of other broadleaves.

Artificial branch pruning is practiced to maximize the amount of turnable wood in the stem (Heikinheimo 1951, Sarvas 1966). It should be started as early as after 2-3 years after plantation establishment and continued in stages until wanted height is reached, normally up to 2.5 – 5 meters. The best time to carry out pruning in Finland is from late June till late July (Hagqvist and Mikkola 2008).

Normal silver birches are removed from the stand at the age of about 10-13 years, when the dominant height is 7-9 m (Heikinheimo 1951, Sarvas 1966, Hagqvist and Mikkola 2008). Thereafter repeated thinnings from below are carried out to remove the curly trees with low quality to provide the best ones with sufficient space and light. As a general rule, the thinnings should be light and repeated at short intervals, because identification of curliness is unreliable especially in younger trees. The final cutting is usually conducted at the age of 35-50 years.

6. Processing of curly birch

Detailed instructions for processing curly birch were given by Kosonen (2004a), whose work is briefly cited below. Curly birch if preferably cut in the late winter, when the amount of water in the tree is smallest. In case the decorative outer surface of the curly birch beneath the inner bark is to be revealed, the best cutting time is in the sap season later in the spring, when the bark is easy to remove. If the trunk is to be dried as such, it is partly peeled from different sides along the length of the trunk, and then slowly dried for 2-3 years outdoors in a windy but sheltered location, in order to prevent splitting of the log. A dried round curly birch log is excellent material for making lathe-turned objects, and therefore such items of curly birch are very common. Grinding and finishing curly wood surface succeeds well (Kosonen 2004b). Curly birch wood suits well for turning, but as long massive items it bends and twists.

Curly birch logs are sawed immediately after cutting. The sawing adjustments depend on the use of the timber. If the use is not known it is recommended to saw the trunk into boards as thick as possible but with the log opened in the middle. The boards are then dried in the same way birch is usually dried. If light color of timber is desired, the drying should be carried out without high temperatures. The subsequent drying of curly birch after outdoor drying is carried out in normal indoor conditions (5-10 years). The dried board is worked and prepared just like ordinary silver birch (Kosonen 2004b).

Veneering of curly birch can be done either by rotary peeling transversely or by cutting longitudinally, the former being the most common method. Veneering is always begun with fresh time, even with the addition of humidity and temperature. The width of the veneer is usually 90-120 cm, which is due to the small number of straight curly birch logs. Cut curly birch logs provide long but narrow veneer. Making wide surfaces calls for composition, but it also permits more alternatives than rotary peeled veneer (Kosonen 2004b). From seed-borne curly birch trees every log is different, which means that in large works it is difficult to preserve the visual aspect unchanged. However, from clonal stands it is possible to get technically and visually uniform wood material in large quantities in the near future.

7. Traditional and modern uses of curly birch

Curly birch has been traditionally used in various vernacular tools and implements (Kosonen 2004c). Owing to the tough and non-splitting structure of the wood, curly birch has been suitable and sought after for purposes where durability and toughness is needed. Handles of knifes and chicels, stocks of veapons as well as cudgels were typically made of curly birch. In the kitchen, most of wooden vessels and containers were made of curly birch or burls before stave vessels were available. In addition, curly birch served people's everyday life in many other functional items, like salt cellars, scale weights, reelers, spool frames, sugar hammers, candlesticks etc. For traditional uses the durability of the wood, more than the decorativeness, was the starting point.

When industrial manufacturing of tools and vessels was started in the early 1900's, there was no more need to make things by hand. The skills and knowledge of the curly wood material among ordinary people and local carpenters was directed to making decorative objects. Curly birch began to be used by cabinet-making firms and furniture factories (Kosonen 2004c).

Curly birch has gained also symbolic meanings in addition to its value in vernacular use. Courts and members of the elite became interested in it owing to its rarity and decorativeness - particularly in Russia, where it was greatly valued at the Imperial court. Emperor Alexander I is known to have given Napoleon a set of curly birch furniture (Kosonen 2004c).

For the Finns, curly birch has been associated with the symbols of national existence. The Latin name of curly birch "var. *carelica*" refers to its important area of distribution in Karelia, where in turn Kalevala, the National Epic of Finland was generated. The Finland pavilion of the Paris World Fair of 1900 and its Iris Room with curly-birch furniture by Gallen-Kallela and other art objects manifested our national identity. In the 1930's the new Parliament House in Helsinki, the capital of the young republic of Finland, was fitted with curly and flamy birch furniture alongside items made from foreign types of timber. The simple forms of functionalist style in the 1930's utilized curly birch by enhancing the furniture with curly birch veneer. Famous Finnish architect, Alvar Aalto accepted curly birch veneer for the finish of some of his chair designs, but otherwise it was no more wanted in wooden products of the industrial era (Kosonen 2004c). However, during the 1990's designers and cabinet-makers collaborated in projects involving various types of wood, which reintroduced curly birch in the modernization of wooden materials.

Curly birch wood can be highly decorative containing curly-grained and brown-figured pattern. However, being a visually prominent pattern, curly birch has been and is still used only as a part of interiors, on small surfaces. The interiors of lifts, table tops, cupboard doors and the front part of

counters are often lined with curly birch. Wood with smaller dimensions is used in handicrafts and carpentry for highly valued products such as gifts, souvenirs, tools and furniture. Curly birch items are very popular as corporate gifts. Chairmen's gavels of organizations are one of the most common symbolic uses for curly birch at present.

After the Second World War curly birch was still rotary-cut into veneer in Finland, but at the limited use of veneer and the development of rotary cutting brought an end to its manufacture on a large scale in Finland. The Mahogany company in Lohja has continued making curly veneer in small amounts. The veneer is mostly cut in Germany (Kosonen 2004c).

8. Curly birch timber trade

Curly birch is by far the most valuable and highly-priced variant of native tree species in Finland – and the only one that is sold by fresh weight. The price of a kilo of curly birch wood has clearly exceeded the price of sugar, with which it used to be compared earlier. However, the price of curly birch can vary a lot depending on the quality and quantity of the batch for sale. The quality requirements vary according to the buyer, and every deal is a unique case which is agreed precisely between the seller and the buyer (Hagqvist and Mikkola 2008).

Curly birch timber is generally divided into two main quality grades according to the size and quality: (i) wood without knots, suitable for turning and (ii) curly grained branch wood (Visaseura 2017). In the former category, the minimum length and diameter above bark of the log is 75-100 cm and 20 cm, respectively. In the latter category, the minimum length is 50 cm and diameter 10 cm. Both grades are further divided into two according to the quantity of the curly-grained pattern. In addition to these grades, even smaller curly-grained branch wood (till 5 cm in diameter) is bought, if it contains rich curly configuration. The price for curly birch suitable for turning varies between 3–5 € kg^{-1} and the price for curly grained branch wood is around 0.5 € kg^{-1}.

Curly birch is mostly bought by dealers which market the timber further to users. The best time for curly birch commerce is in the winter season from October to April, when there is no risk of the logs to get spoiled. In summertime the demand is low and only minor batches are bought. Curly Birch Society disseminates information between the sellers and buyers of curly birch timber.

9. Changing markets

Since the first cultivation experiments in the 1920's, the annual cultivation area of curly birch remained very low – a few hectares at the most – till the 1980's, although seed material was available (Sarvas 1958) and the management methods were known sufficiently (Heikinheimo 1940, 1951, Sarvas 1966, Saarnio 1976). The Finnish Curly Birch Society (Visaseura ry) was established in 1956 to promote the cultivation and use of curly birch, and to co-ordinate the activities of curly birch growers, forest industry and research (Huuri 1978). Since then it has operated as a link between curly birch growers, enthusiasts and professionals and promoted cultivation, management, research, utilization and marketing of curly birch by information, guidance and consulting. Excursions, organized annually to interesting visiting points, have always been very popular among the members and the most important way of extension.

In 1980 the Finnish Dendrological Society nominated curly birch as the Tree of the Year, which raised new public interest in this variety and gradually led into launching of a new cultivation era. Genetically improved seedling material was soon available after establishment of the first curly birch seed orchard in 1981. Also the introduction of clonally micro-propagated plant material by the company Metsätyllilä Oy in the 1990's kept interest in curly birch high promising even higher monetary returns than growing of seedlings. These facts together with intensified extension especially by the Curly Birch Society and the Foundation for Forest Tree Breeding increased planting areas very rapidly between 1989 and 1998, from about 30 ha to 600 ha annually (Figure 1). After the

peak year 1998 annual planting areas have gradually been declining so that between 2011–2015 the average annual area was 100 ha. Planting statistics are available since 1984. From that year roughly 6 500 ha of curly birch have been planted in the period 1984-2017.

A vast part of this total area of plantations has suffered from damages by mammals and inadequate or careless management, which decrease the area of curly birch plantations able to produce commercial wood. Information of the silvicultural status of the plantations is not, however, available. In spite of the failures, greatly increasing amounts of curly birch from final cuttings will be available starting from the year 2025, since the rotation age of curly birch is 40-50 years for trees originating from seed (Hagqvist and Mikkola 2008) and 35-45 years for clonal plant material. This wood will contain a large proportion of log-sized dimensions suitable e.g. for making veneer and for sculpting or turning decorative items with big dimensions. The quality of the wood figures and patterns can be variable (from seedling origins) or uniform (from clonal plantations), depending on what is preferred by the customer. Smaller sized wood from thinnings is available already now in large quantities.

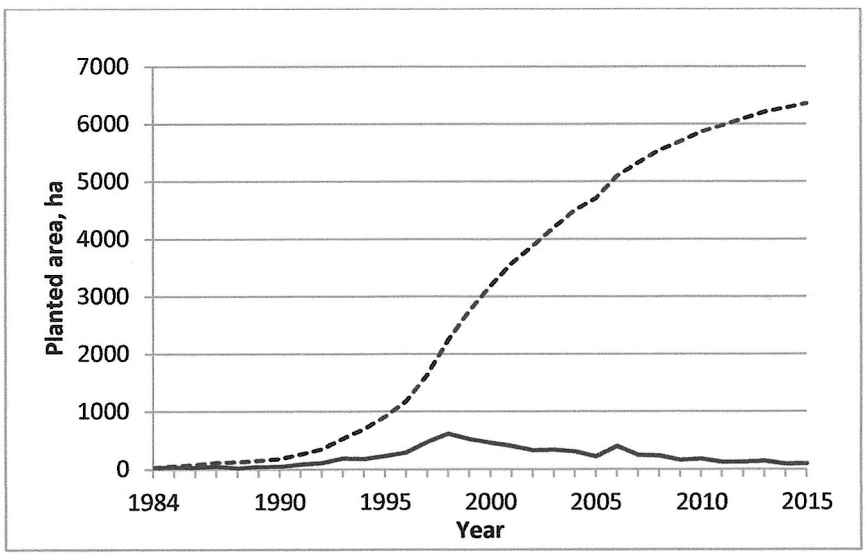


Figure 1. The annual (solid line) and cumulative (dashed line) area of curly birch planting in Finland from 1984 to 2015 according to the plant production statistics of Finnish Food Safety Authority (EVIRA). The areas were calculated using planting densities 1600 ha^{-1} and 900 ha^{-1} for seedlings and micro-propagated plantlets, respectively.

The significantly increasing availability of this exceptionally beautiful wood resource makes it possible to develop new wood products based on this, now cultivated, variant. The wood material is suitable also for premium products with high class design. Earlier the poor availability of curly birch wood has prohibited developing such products. The increase of the curly birch wood supply will be great and take place rapidly. This calls for need to extend the markets. Now wood will soon be available regularly in larger quantities than today, enough for both domestic use and export.

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