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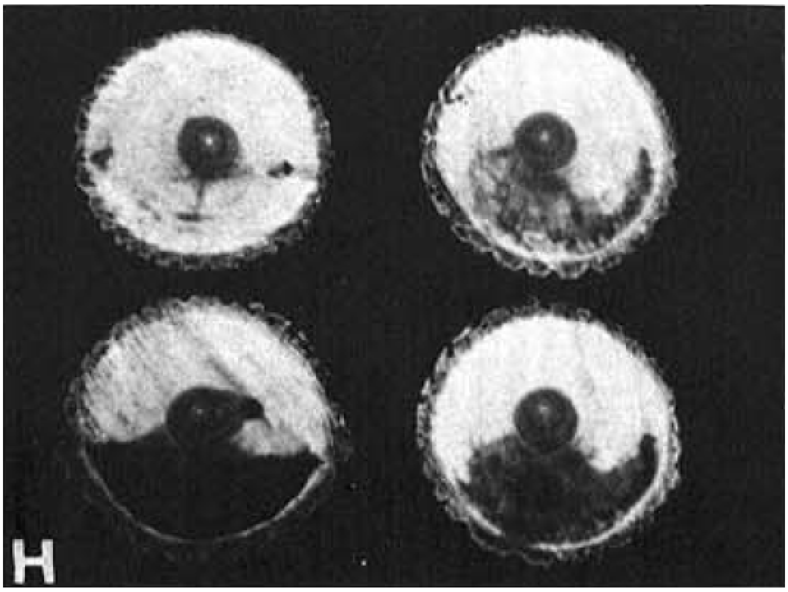

Discoloration in poplar tree and production of sprouts after harvest

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Abstract

Poplar is distributed widely throughout the world. There are about 30 natural species. Taxonomically poplars are divided into six groups. Poplar tree can be 200-300 years old. Normally two sets of 19 chromosomes are present in the nucleus of Poplar, while the size of genome is remarkably small.

Poplar is a fast growing species. Poplar species are deciduous and semi evergreen and are distributed widely on the northern hemisphere. Poplars have various ecological habitats. They can grow in pure stands or mixed with other hardwood and conifer species. Poplars are also used in short rotation forestry for production of biomass for bio energy, fiber and environmental services. The short rotation forestry in Sweden is based on Salix but in this study the focus is on poplar.

Discoloration occurs normally in the core wood for most poplar species. Present thesis is made in order to study the distribution of the discoloration for poplars. In the study 36 poplar trees from three provinces in Sweden (Lat. 56-60˚ N.) were measured. Discs were collected at different percentages of different stem height.

The objective of work was to observe the relationship of discoloration with diameter and height of poplar tree. Besides these 36 sample trees, a clear felled poplar stand at Valsätra in Uppsala Municipality was studied. Diameter and discoloration on 110 stumps were measured. In the third part the measurements of shootings of poplar species in Valsätra are shown.

The discoloration in stems was directly proportional with the height of the tree. The percentage of discoloration in a stem decreased with increasing tree height.

Key words: Discoloration, poplar, sprouting capacity,

Table of Contents

1 Introduction

1.1 Forest in Sweden

Total land area in Sweden is 40.8 million hectares, out of which 22.7 million hectares are productive forest land. Half of the forest area is owned by private owners. The growing stock is about 3400 million m^3. The main tree species in Sweden are Scots pine (*Pinus sylvestris L.)* and Norway spruce (*Picea abies (L.) Karst.)* They cover 42% and 42% respectively of the productive area in Sweden (Swedish Forest Agency, 2011). In a report by Swedish Energy Agency (2008), shows that renewable resources meet 43% of the total energy requirements in Sweden, out of which 23% is by wood fuels. Forest residues are renewable sources which can be used for bioenergy purposes. The demand of renewable energy have increased the recent years (Björheden, 2006).

1.2 Characteristics, botany and taxonomy of poplar tree

The genus *Populus* belongs to the family *Salicaceae*. Poplars are fast growing and easily adaptable to different climatic and soil conditions. Poplar wood is utilized as fuel wood, fiber and many other services. The species is used as a source of renewable energy and for soil remediation on contaminated sites (FAO, 2008).

Taxonomically poplars are divided into six groups. There are a number of factors, which make poplar as a species to be grown as a forest crop (Phelps et al.1987). Poplars due to its distinctive qualities are well known. Poplars mostly are deciduous, semi green trees and have a wide distribution on northern hemisphere. The trees are tall and straight, having many branches, warped and bent or some time shrub like in extreme environment. Poplars having triangular or egg shaped leaves. The tree can have deep root system which can absorb deep water or nearby water sources, such as streams or pounds. Poplars are susceptible to diseases and insect pest. Comparatively poplars are short leaved to other trees.

Some individuals of poplars can be 200-300 years old and the root system of European aspen (Populus tremula) clone can survive for thousand years and produces many successive generations of stems (Bärring,1988). The roots can reach large lengths because of rapid growth. Normally two sets of 19 chromosomes are present in the nucleus of poplar while physical size of poplar genomes is small.

Poplars have various ecological habitats. They can grow in pure stands and mixed with broadleaved and coniferous species. Mostly they are grown on alluvial, riparian and wetland habitats ranging from far northern latitudes to the tropics.

Discoloration in poplar stems is common. There are many names for the phenomenon: heartwood, wound heartwood, pathological heartwood, traumatic heartwood, discolored wood etc. Discoloration can be easily detected in the wood. It can be caused by aging or injury or both. Many factors are responsible for causing the formation. The main reason question is when color alone is the basis for distinguishing the type of tissue. A second question is when injured altered tissue is considered but the role of micro-organism is not considered, then the interpretation of accurate situation is impossible. A third question is when injury process occurs in tissues already altered by aging. The clarification in these processes is needed (Shigo, 1989).

1.3 Properties of Poplar tree

The poplar wood has a low basic density. The mean relative density of poplar ranges between 0.300-0.390 g cm^3. Strength of poplar wood is low compared with other species. Values of bending strength and stiffness are at the same level as spruce, pine and fir.

The moisture content in a poplar tree is high, 100%, with only minor differences between sapwood and heartwood. Because of the low density, poplar species have high volumetric shrinkage 11-12%. (Koubaa et al.1988 a,b).

1.4 Utilization of Poplar

Poplars wood is used in a large scale in a variety of primary and secondary forest products in North America. Main products are pulp and paper, lumber, veneer and plywood, composite panels, structural composite lumber, pallets, furniture components, fruit baskets, containers and chopsticks.

During the last 30 years wood using industries in USA and Canada have turned over to the utilization of poplar wood because of the broad availability and low production cost. Poplar has strength to become a major source of wood fiber in coming times. (Balatinecz and Kretschmann, 2011).

1.5 Biomass for energy

In many countries during the energy crisis in 1970,s hybrid poplar was the options for the power companies to come over on the crisis. Due to the shortage of petroleum and increased petroleum prices, the establishment of intense cultivated and managed short rotation plantation of hybrid poplar was needed. Poplar was used as cogeneration power plants. Poplar farming became popular as they could be harvested after 2-5 years, (Hansen et al.1983).

1.6 Poplar in the world

Poplars are widely spread all over the world, mostly in China, Canada and USA. In some areas poplar plantation is still new but concept of poplar as improved tree is not a new concept. In 1947 the International Poplar Commission (IPC) was created and 34 countries including Canada attended its 1996th session. IPC reported from the session that though poplar plantation increased it is not of high significance, except in China.

The genus *Populus* has about 30 natural species in northern hemisphere. According to a study made in US the best soil type for planting poplar in loamy with pH 5.5 to 7.8, < 8% slope, 3-8% organic matter and having a high capacity for water (www.fao.org/forstry/org/ipc.en). They are also planted in the southern hemisphere (Reach for unbleached foundation).

Figure1. World map showing distribution of poplar tree (communication Birger Hjelm 2012)

Poplar as domestic specie growing on forest land and on plantations is a dominant specie in Northern China. Since the foundation of the People's Republic of China, poplar is planted in various types of shelter belts to protect farmland and settlements. Today 1.34 million ha in China is covered by natural and planted poplars of which 350,000 ha is established between 1991 and 1995. The hybrid poplar can supply an increasing amount of pulp wood and also poplar trees have no negative environmental effects (www.cathayforest.com/product.asp). Recently the government in china has encouraged the development of commercial plantations as a solution of the wood supply shortage. Poplars plantation are the first priority of this effort. In China poplars have a wide field of application important raw material and they have many uses like veneer wood, plywood and building timber. In the northern part of China intensive logging have accelerated desertification. Poplars are the fast growing specie and to reforest the semi-desert areas they can play great role (www.cathayforest.com/product.asp).

1.7 Poplar in Sweden

European aspen (*Populus tremula* L.) is the only native *Populus* specie in Sweden. This specie occurs in the whole country except on the regions where alpines are grown (Hultén 1971).

Poplars are used in short rotation forestry for production of biomass for biofuel. Swedish short rotation forestry is based on *Salix* but poplar is also under consideration. The effect of poplar on the environment is focused (Karačić, 2005).

In Sweden renewable energy resources from forest and agriculture are considered to be valuable resources for energy supply. From forest land 20 % of energy is supplied. New ideas about producing wood for pulp and fuels (heat, ethanol, hydrogen gas, dimethyleter, electricity) in southern part of Sweden have been practiced. For example the farmers start farming the hybrid poplar on farmland areas at Sångletorp, Johannesholm, Kadesjö and Näsbyholm in southern Sweden in 1991. Some trees have been harvested and the wood was used for pulp and paper. Other poplar stands are still growing and they are analyzed for economic, ecological and energy point of view.

The attempts for planting hybrid poplar in Sweden were made in 1930,s and 1940,s but these attempts failed due to various kinds of diseases. The main problems were leaf rust, leaf beetles, hymenoptera, browsing by wild animals, summer frost. The major problem was stem canker. Now a day's growers are using different methods to minimize the risks by: utilization of good farmland, careful soil preparations, dense plantations, weeding during first two years, no thinning, fencing, clear felling after 15 years. The advantage of clear felling at the age of 15 years is to avoid stem canker as this disease starts at the age of 15-20 years (Christersson, 2007).

1.8 Discoloration in Poplar tree

Poplar trees are susceptible to discoloration and decay. The discoloration and decaying in poplar wood affect wood quality to be used in solid wood products like cabinetry or moldings. There are two main reasons for the appearance of discoloration.

(1) Fungal discoloration, the discoloration caused by fungi is fungal discoloration. Molds, yeast, wood decaying fungi and staining fungi are commonly causing discoloration in poplar wood. (www. Forientik, 2002)

(2) Non fungal discoloration, there are three processes which causes discoloration in poplar wood. Iron stain, dirt and weathering. Iron particles react with phenols in the wood leaving behind black iron tannates. Simple exposure of wood to sunlight and rain also causes wood discoloration. All these are non-biological discoloration in wood.

1.9 Aim of study

The main objectives of this study were:

- To find out the percentage of discoloration in the studied 36 poplar trees.
- To describe the distribution and proportion of discoloration on stumps in a single recently harvested poplar stand (Valsätra).
- Study the number of living stumps and sprouts on clear felled area at Valsätra the first season after clear felling.

2 Materials and Method

Sample of disks from poplar tree samples were collected. Most of the stands were planted on former farmland between 1988 and 1992. These stands were established for research and commercial use focusing on production.

Data used in were collected from 36 poplar trees growing on 14 different sites in central and southern Sweden between latitude 55 and 60^{o}. The management of stands varied. Some of the stands were thinned with thinning regimes from moderate to heavy. The mean number of stems per hectare was calculated from data measured on sample plots. The area of the studied plantations varied between 0.5 and 3 has. DBH was measured by cross callipering and the arithmetical mean diameter was calculated for each stand.

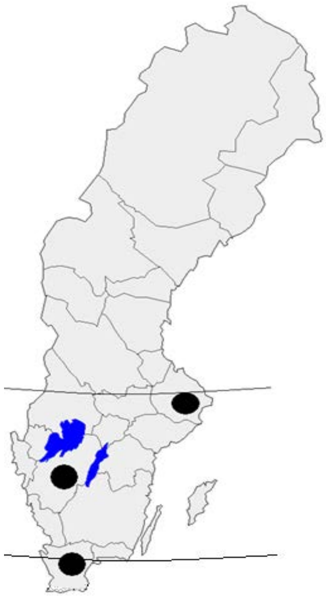

Figure 2. Three locations in Sweden from where samples were collected.

2.1 Study of the percentage distribution of discoloration

Discs from 36 poplar trees from14 sites in three provinces in Sweden were collected by destructive sampling and brought to laboratory for storage and later measurements, Table 1.

Table 1. The number of sites and sample trees in respective province

Location name	No. of sites	No of sample trees
Uppland	4	9
Västergötland	6	20
Skåne	4	7
Total	**14**	**36**

Mean and standard deviation of diameter at breast height (DBH) for the sampled 36 trees on the 14 sites are shown in Table 2.

Discs of poplar species were collected from 14 sites which are located in three areas in south and middle of the Sweden. Discs were taken at different heights. The study is based on an average of eight samples from the stem. The discs collected were at: 1%, 10%, 30%, 50%, 70% and 90 % of tree height and at 1.3 and 4.0 m, Figure 3.

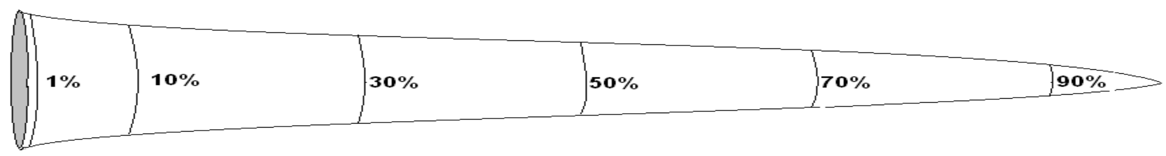

Figure 3. Relative tree heights where the disc was taken.

Table 2. Mean ± SD diameter at breast height (DBH) of sampled poplar trees.

Plot no.	DBH Mean ± *SD*, mm
1	175 ± 77
2	161 ± 70
3	129 ± 53
4	53 ± 19
5	110 ± 42
6	104 ± 42
7	97 ± 36
8	129 ± 53
9	328 ± 165
10	293 ± 135
11	343 ± 185
12	307 ± 160
13	237 ± 108
14	392 ± 20
15	267 ± 134
16	274 ± 122
17	291 ± 123
18	189 ± 75
19	242 ± 112
20	203 ± 86
21	243 ± 106
22	193 ± 84
23	294 ± 150
24	123 ± 49
25	111 ± 47
26	200 ± 88
27	153 ± 66
28	177 ± 76
29	139 ± 56
30	177 ± 74
31	145 ± 57
32	193 ± 83
33	290 ± 153
34	215 ± 95
35	137 ± 59
36	191 ± 83

In the laboratory the diameter of the disc and the diameter of discoloration were measured by a ruler in two directions. The total number of samples was 288.

2.2 Measurement of diameter and discoloration on Valsätra stand

The distribution and proportion of discoloration in a single recently harvested poplar stand (Valsätra), which was clear felled in 2010 was registered. The stump diameter and discoloration on the stump surface, 15-25 cm above the ground, was measured (Figure 4). The total no of stumps on Valsätra plot were 110.

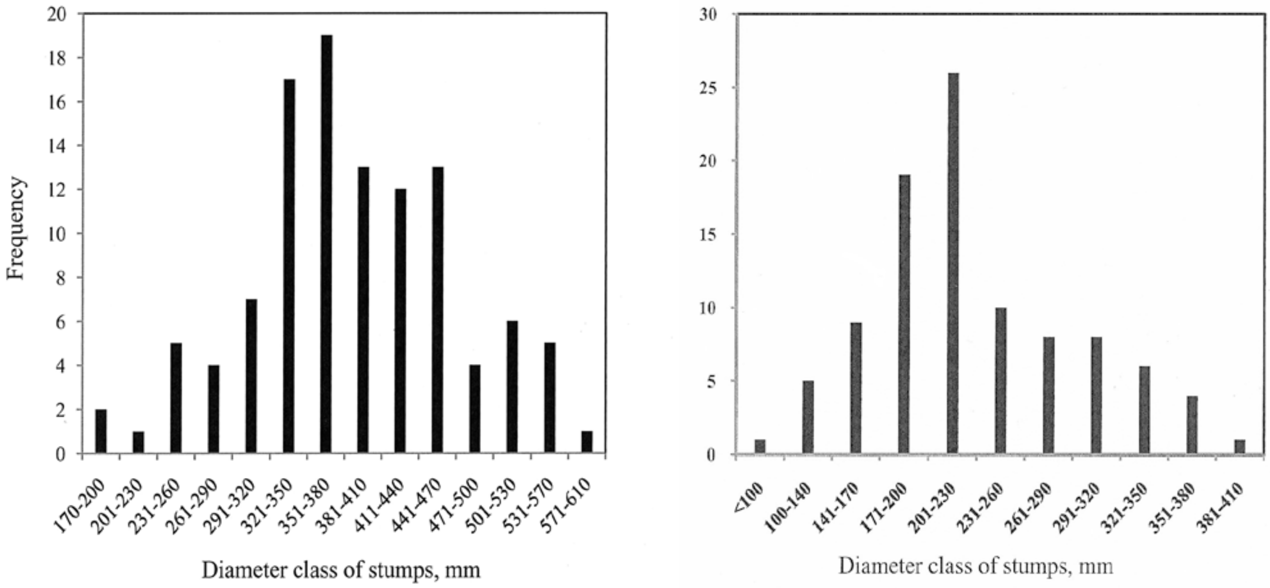

Figure 4. Frequency of stump diameter (left) and of discoloration (right) in different class interval, mm, of poplar stumps.

2.3 Production and distribution of sprouts in Valsätra plot

One season after clear felling of a poplar stand at Valsätra the number of sprouts was registered.

Then four plots were made in the stand which consisting 25 stumps each. Stump diameter and number of sprouts were measured on all stumps. On every fifth poplar stump diameter and height and diameter of the sprouts was measured. The mean diameter of the sprouts was insignificant ($p > 0.05$) between the four plots.

3 RESULTS

3.1 Discoloration in the sampled 36 stems

After measuring the discs in the laboratory the data was used for construction of curves describing the correlations between the relative diameters and the relative diameters of discoloration against the relative height. The percentage of discoloration and diameter of the tree in (mm) are shown in figures below.

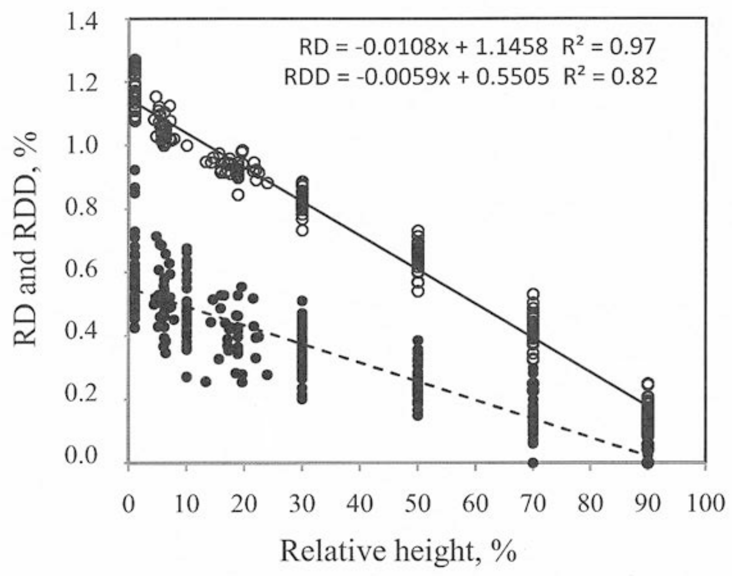

Figure 5. Relative diameter (RD) —— and relative diameter of discoloration (RDD) - - - - by relative height.

The diameter and discoloration of discs were measured at different height percentage (1, 10. 30, 50 ,70 and 90 %) of the stem. For the different height percentages stem diameter was divided by stem diameter at 10% (RD). The diameter of discolorattion at different height percentages was divided by stem diameter at 10% (RDD). Diameter at 10 % of stem height is a common factor acording to describing the taper of a stem.height. These two parameters were compared in Figure 5. The correlation between relative tree height and relative diameter (RD) is 0.97. The correlation between relative height and relative diameter of discoloration (RDD) shows a decreasing percentage discoloration by increasing tree height. The correlation between the discoloration and the height of the tree was 82 %. This implies that the discoloration have a natural larger variation in poplar trees, compare to the tree diameters along the stem.

3.2 Discoloration in stumps on a single site (Valsätra).

The quotient is the mean diameter of discoloration/mean stem diameter at the stump sections. The figure shows a weak correlation between the quotient and stump diameter in the Valsätra stand. The R^2 value was 0.01. The distribution of stump diameter by the quotient and the diameter of discoloration was clustered between 0.4 and 0.8 and a few abnormal values exceeding 0.9 and as low as between 0.2 and 0.3 (Figure 6).

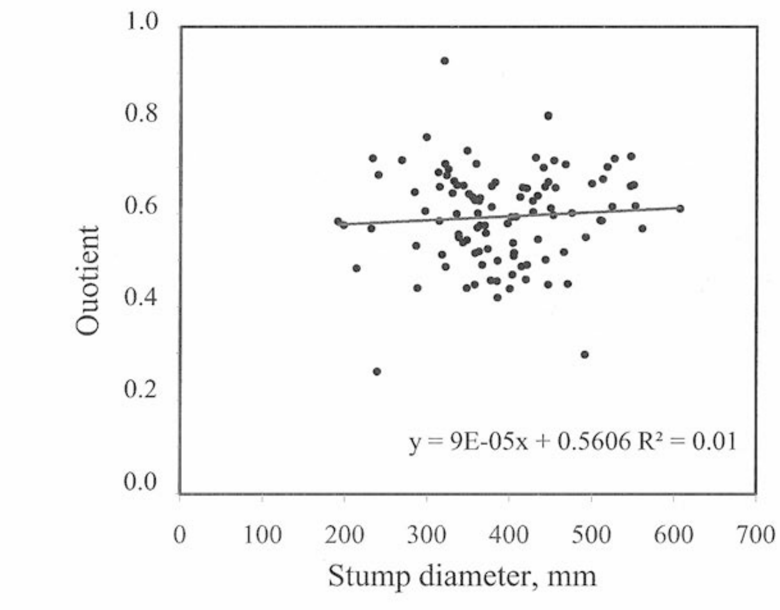

Figure 6. Quotient (the mean diameter of discoloration/mean stem diameter at the sections) at different stump diameter, mm, in a former poplar stand (Valsätra).

3.3 Production and distribution of one-year-old sprouts.

The number of sprouts increased with increasing stump diameter (Figure 7).

The figure shows the height of the sprouts on y-axis and the diameter of the stumps on x-axis.

The diameter of sprouts at 0.1 m increased with increasing sprout height (Figure 8).

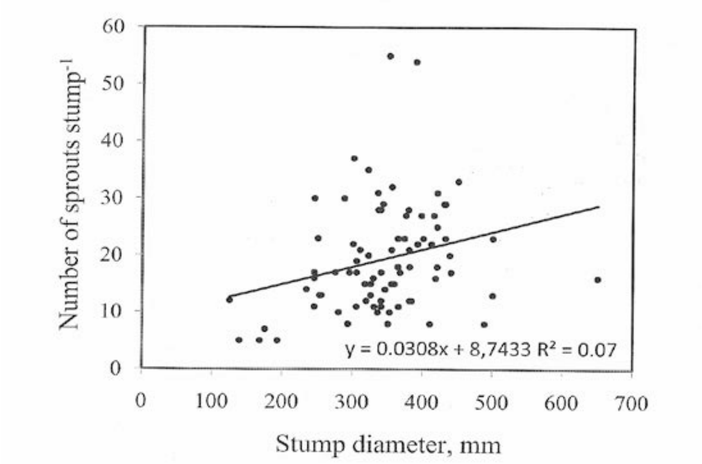

Figure 7. Number of sprouts by living stump by stump diameter, mm.

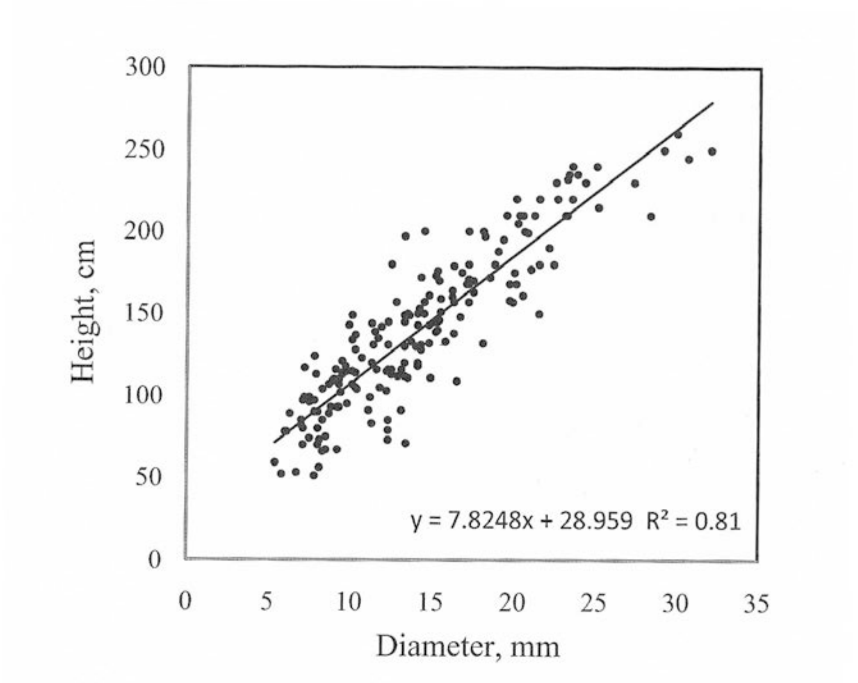

Figure 8. Sprout height, cm, and diameter (0.1 m), mm of sprouts.

In the study of the measured sprouts (figure 8) at the “Valsätra” stand there was strong correlation between the height and the diameter of the sprouts on the base (10 cm above the stump) , R^2 = 0.81 (with simple linear model).

4 DISCUSSION

The interest of growing poplar in short rotation forest plantation has increased the last 10 – 15 years. The sapwood of European aspen is white and normal heartwood is cream to grayish brown. This discoloration in heartwood of a tree might reduce the quality of matches and timber logs for furniture. There are three reasons for the dark color in aspen: a) decay b) wounds through the bark into the xylem and c) and branch intersections (Anderson, 1958). The results show that the diameter and discoloration is directly proportional to the height of the tree. There are many reasons causing discoloration in poplar trees (Shortle and Cowling, 1978). The wounding of xylem tissue leads to discoloration in poplar tree and later on to the decay of the discolored tissue. The present master thesis is only focused on the physical parameters of the poplar tree. In practice the diameter and the distribution of discoloration on stem discs were measured. The relation of stem diameter and diameter of discoloration is shown. Secondly the comparison between the discoloration and height of the tree can be shown. The comparison among three parameters: height of the tree, discoloration in poplar tree and diameter of poplar tree can also be shown.

In two poplar trees discs at 70% stem height and for 17 poplars discs at 90% no discoloration was indentified. The correlation of diameter and discoloration is directly proportional. The greater the diameter the more is discoloration in the disc. The stump diameter and discoloration of 110 poplar srumps were also measured in a stand at Valsätra in order to find out different reasons for discoloration. The distribution in poplar stumps at Valsätra is simultaneous as shown in Figure 7.

Timber has many end products, with different uses. Poplar could either be used as: biomass (biofuel), timber for furniture, logs for construction and pulpwood used in the pulp industry. A major constituent of wood is the heartwood and the sap wood. The proportion of heartwood to sap wood leads to logs of different desired end uses. For example, in some tree species timber used for furniture, the manufactories desire wood that constitutes more heartwood to sapwood ratios (Therrell et al., 2007). This is due to the fact that heartwood in furniture and construction wood is needed for its durability (Bamber, 1961).

Discoloration in poplar stems

When trees should be used for pulp production the log should have less heartwood to sap wood ratios. This is because it has been proven that heartwood contains more extractives that lead to low pulp yields (Isabel et al., 2007). Heartwood leads to a decrease in pulp quality, more chemical must be used in pulp process hence increasing the cost of making pulp (Pereira et al., 2003). Isabel et al. (2006) assessed the influence of irrigation and fertilization on the proportion of heartwood in *Eucalyptus globules* Labill. In their experiment they applied fertilizers and irrigated the plantation for six years. The control plots were not irrigated or fertilized. When the plantation was 18 years old they measured the amount of heartwood volumes in both the control and the treated plots. They found that the heartwood proportion decreased from the base upwards. They also found that the heartwood volumes on the treated plots represented 65.6% of the total tree volume, whereas in the control plot the heartwood content represented 55.6%. Their conclusion was that heartwood volumes in *Eucalyptus globules* Labill. might be influenced by irrigation and fertilization.

From our results, for the 36 samples when assessing the relationship between heartwood proportion and diameter with increasing height of the tree a trend is observed. The decrease in the tree diameter with an increasing tree height is compatible with the topping off effect phenomenon in forestry, whereby the diameter of the tree decreases from the base upwards to the tree top as the size and age of the tree increases. This supports the fact that the proportion of heartwood in trees varies with a number of factors for example tree age, tree growth rate, site quality and vitality of the tree, tree species concerned, quality of the soil and climatic conditions prevailing (Isabel et al., 2007).

In our results, the heartwood proportion was more prominent at the lower half of the tree up to 30% tree height and attained a height of up to 90% of tree height(Figure 4 and 5). Heart wood was absent in a few number of stumps. This is similar to works done by Morais and Pereira (2007) on *Eucalyptus globulus* Labill. Whereby they assessed the variation of heart wood proportion in the stump relative to the stump height .In their studies, they observed that the heart wood proportions reached levels as far as 82.1 to 87.2% of the overall tree height. In their studies they did not find heart wood at 90% tree height and at 65% tree height some trees showed no heartwood. Their results were different from ours; this may be because the study was performed on two different species and on different agro-ecological zones.

Discoloration in stumps on a single site (Valsätra)

The correlation between stump diameter and quotient (the mean diameter of discoloration/mean stem diameter at the sections) in this study was low, which shows that the discoloration quotient neither tends to increase nor decrease with the increasing diameter of the stumps in this particular study. The mean diameter of the stumps on the Valsätra site showed a significant difference with respect to the 36 different sites. This may be due to: site soil properties may vary, age of the trees in each site or landscape may be different, density of stocking and different management practices used. The number of stumps in the sampling population was relatively low, which makes it difficult to draw strict conclusions.

Production and distribution of one-year-old sprouts

The mean number of sprouting and density of sprouts per living stump on the four plots were compared and it was found to be statistically insignificant. The mean number of sprouts per stump ranged from 17 to 20. In our study with an increasing stump diameter the density of the sprouts increased (Figures. 7 and 8). Our results also showed that the mean height of sprouts between the plots was non-significant ($P>0.05$). This may be supported by the works of Crist et al. (1983), were they studied the effect of stump height after clear cut on sprout growth. In their research they used the *Populus* species “Tristis # 1”. The trees were growing on farmlands, which were fertilized and irrigated and treated under optimal conditions for 6 years. They harvested the trees in the dormant season (February), by the use of shearing or chain saw. Felling of the trees was done at three stump heights (8, 15 and 46 cm). They found that 8 and the 15 cm stumps produced taller sprouts and with larger diameter than 46 cm stumps. The larger stumps had a larger surface area needed for sprouting. Then taller stumps consume more carbohydrates stored in respiration compared to the shorter stumps and leaving lesser energy reserves for the sprouts, compared to the shorter stump. The sprouts on the shorter stumps receive more energy to sustain growth. In the 46 cm stump sprouts also decreased drastically during the growing season from 13 to 3, because of competition for nutrients thus giving no advantage to using the taller stumps for coppicing to attain high sprouting biomass.

In a study by Strong and Zavitkovski (1983) where they used the poplar hybrid, *P. nigra* var. *beatulifolia* x *P. trichocarpa*, on plots grown four years to assess the effect of different harvesting seasons on generation of sprouts. In their works, they harvested stumps at 10 cm and 30 cm heights. One year later the mean height of dominant sprouts was 2.3 m, where as the mean height of dominant sprout of stumps cut in the growing season was 0.9 m. The mean number of sprouts taller than 1.3 m measured in the dormant season was 7.5, whereas for those measured in the growing season the mean number was 3.4. Related works by Strong and Zavitkovski, (1982), followed a similar trend, thought they used different species of populous, the *P*. “Tristis # 1“.

5 CONCLUSION AND RECOMMENDATIONS

Heartwood occurrence in Poplar trees is due to natural process. It is concluded that the heartwood in poplar tree has relation with the diameter and height of the tree. The discoloration decreases along the diameter and height of the tree.

It is recommended to find out basic reasons for discoloration in poplar tree; many other variables are also needed to be studied. It is of interest to conduct further studies weather variables, such as for example: hybrid/species, soil-types, and forest management have impact in the occurrence of heartwood discoloration in poplar trees. Further future work could also be to study the wood chemical components and properties in poplars discolored heartwood and its impact on wood quality in potential use for bio fuel and pulp.

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