International Commission on Poplars and Other Fast-Growing Trees Sustaining People and Environment

26th Session, Rome, Italy, October 2021

COUNTRY REPORT 2016-2019 from National Commission of Fast-Growing Trees in Sweden

Activities Related to the Cultivation and Utilization of Poplars, Willows and Other Broad-leaved Fast-growing Trees 2016-2019

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I POLICY AND LEGAL FRAMEWORK

A number of recent investigations from Swedish government suggest that cropping systems with fast-growing woody species have a high potential to produce woody raw materials for renewable products, liquid biofuels and bioenergy (Börjesson 2016, Regeringskansliet 2020, Svebio 2020). Several scientific investigations point out that plantations with fast-growing deciduous woody species on agricultural land have threefold biomass production potential compared to forestland (Rytter, Ingerslev et al. 2016, Mola-Yudego, Arevalo et al. 2017). In spite of the high potential, the total area planted with *Salix*, poplar or hybrid aspen has decreased from 11081 ha to 8401 ha between the years 2015 and 2019 (Jordbruksverket 2020). This decrease is mainly due to reduction of *Salix* area from 9016 ha to 5971 ha between 2015 and 2019, co-occurring with low market prices of wood chips - 180 SEK m^{-3}.

On the other hand, the relatively high prices (360 SEK m^{-3}) of pulpwood of *Populus* species have motivated, however, few land-owners to invest into poplar or hybrid aspen plantations.

This is reflected in marginal increase of the areas planted with poplars and hybrid aspens from 1609 ha to 1703 ha and from 456ha to 727 ha, respectively, between 2015-2019 (Jordbruksverket 2020).

Salix, hybrid poplar and hybrid aspen are eligible for the Basic Payment Scheme, which provides financial support per each cultivated hectare of agricultural land in the framework of the European Common Agricultural Policy. The National Board of Agriculture supports cultivation of poplar and willow by areal support if the rotation period does not exceed 20 years. In addition, landowners can also apply for investment support from the Rural Development Program for seedlings and planting on agricultural land, as well as for fencing. However, current experience of several landowners is that investment support for establishment of poplar and hybrid aspen plantations have often been rejected (personal communication with landowners). Local authorities have preferred approval of investment support for installation of solar panels in farms or they decide that these plantations do not fit into the landscape.

Perennial woody crops grown on agricultural land are often considered as negative in terms of land use change in EU countries, also in Sweden. Farmers, policy makers and authorities in Sweden and other EU countries, are not aware of multiple benefits that production systems with fast-growing trees would provide for society and climate (Parra-Lopez, Holley et al. 2017). Strategic establishment of perennial cropping systems in agricultural landscapes can mitigate negative environmental impacts of traditional production of annual crops, while providing biomass for materials, liquid biofuels and bioenergy. For example, a recent study quantified soil loss by wind and water erosion, nitrogen emissions to watercourses and losses of soil organic carbon, and concluded that 10-46% of agricultural landscapes in EU28 would benefit from such land use change (Englund, Borjesson et al. 2020). Another study has shown, that biomethane production from willows has higher climate mitigation effect compared to maize cultivation as a result of lower primary energy inputs (Moghaddam, Ericsson et al. 2019). The authors showed also that willow as feedstock in biomethane production, had lower methane loss in the pyrolysis process compared to maize. Climate mitigation potential of willow system increases, when the byproduct in biomethane production – biochar – is used as a soil amendment or as additional source for energy (Moghaddam, Ericsson et al. 2019).

Agricultural land, which <u>does not</u> receives annual areal payments from Swedish Agricultural Board, reach 88 000 ha – so called set aside agricultural land (Börjesson 2016). No crops at all are cultivated on these areas and are considered thus as set aside agricultural land. The potential to increase biomass production on Swedish agricultural land without competing with cropland for food production is larger than the abovementioned area. Decreasing consumption of meat should lead to decrease in area needed for feed production. This area is estimated to be as large as 200 000 ha (Börjesson 2016). Assuming that productivity and efficiency in Swedish agriculture will increase by 2050, additional 900 000 ha of cropland may become available for alternative crops such as cropping systems of fast growing species (Jordbruksverket 2012)+-

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Perhaps, the incentive for increased cultivation of fast-growing woody species on agricultural land would be the availability of multiple markets for this raw material. Swedish forest industry needs to double supply of woody raw materials, to significantly contribute to the replacement of fossil based materials by renewable materials (Skogsindustrierna 2018).

II TECHNICAL INFORMATION

1. Taxonomy, Nomenclature and Registration

Indigenous species, **silver birch** (*Betula pendula* Roth) and **downy birch** (*Betula pubescens* Ehrh.), are valuable raw materials for pulp and for mechanical wood manufacturing in Sweden. These species account for 12.5% of total growing stock in Sweden (Skogsdata 2019). Silver birch is preferred for planting owing to its higher yield. Silver birch regenerates spontaneously by seeds at clear cuts or is planted by seedlings from commercial nurseries. Large variation in morphological characteristics between these two species makes it difficult to distinguish between seed trees of silver birch and downy birch as they form mixed stands of variable proportions. Therefore, a methodology using visible and infrared spectra of single seeds was developed (Tigabu, Farhadi et al. 2018).

Several clonal trials, established between 2003 and 2014 with **hybrid poplars** from *Tacamahaca* section, have been evaluated during 2016-2019 to identify site suitable clones for different climates and latitudes in Sweden (Adler, Karacic et al. 2020, Karacic, Adler et al. 2020, Richards, Karacic et al. 2020). An application for registration of new *P. trichocarpa* provenances in Central Sweden will be sent to the Swedish Forestry Agency. The growth of these new clones is compared to the common clone planted in Southern Sweden – OP42. The information on the two registered clone mixes of **hybrid aspen** and hybrid poplar is available in the previous Country Report for Sweden (Rytter, Dimitriou et al. 2016).

Lantmännen AB has registered a new ***Salix*** cultivar Julia in 2019.

2. Domestication and Conservation of Genetic Resources

Betula ssp, *Salix* ssp and *Populus tremula* among other species, such as *Hippophae rhamnoides* and *Pinus sylvestris*, formed a semi-open steppe environment in south-west Sweden 13500 years ago (Hannon, Halsall et al. 2018). Frequent fires and succession of the vegetation developed these landscapes into forests with *Pinus*, *Betula*, *Corylus*, *Alnus*, *Ulmus* and *Populus* (Hannon, Halsall et al. 2018). These indigenous species have today minor importance in Swedish forest industry. As much as 96% of all planted seedlings in Swedish forests are *Picea abies* since this species is a major raw material in the forest industry. During 1950-1960 Norway spruce (*Picea abies*) was planted on surplus agricultural land. These production forests are today in harvestable age. Insect pests because of mild winters during last years, damaged large areas of these plantations. Large portion of these damaged spruce plantations are established in temperate (boreo-nemoral and nemoral) part of Sweden (Southern Sweden) where Norway spruce is not a native species. Landowners consider now other species than spuce for these areas. *Betula* and *Populus* are economically important hardwoods as raw material in present pulp mills and most likely in future biorefineries and deserve increased attention as raw material in forest industry.

Poplars:

(a) Aigeiros section

Current poplar research in Sweden does not focus on poplars from Aigeiros section.

(b) Leuce section

Induced flowering is an important application in forest tree breeding. Molecular mechanism of short day induced growth cessation was investigated in a model hybrid aspen clone T89 (Ding, Bohlenius et al. 2018). An invention that relates to the identification and characterization of poplar genes involved in induced flowering and repression of short-day induced growth cessation, was registered (Nilsson and Bohlenius 2016). A molecular mechanism describing accumulation of a storage lipid - triacylglycerol - in cambial meristem and pith rays of hybrid aspen as a response to photoperiodic signal, was described (Grimberg, Lager et al. 2018). A gene that controls the induction of growth cessation, mediated also the accumulation of triacylglycerol.

Several studies dealed with evolutionary genetics in *Populus*. Using whole-genome re-sequencing data of 24 *P. tremula* and 22 *P. tremuloides* individuals, the time of phylogenetic divergence of these two species was demonstrated in 2.2-3.1 million years ago, coinciding with the severing of the Bering land bridge and the onset of dramatic climatic oscillations during the Pleistocene (Wang, Street et al. 2016). The rate of meiotic recombination that determines the speed of natural selection was investigated in *P. tremula*, *P. tremuloides* and *P. trichocarpa* from Tacamahaca section (Wang, Street et al. 2016, Apuli, Bernhardsson et al. 2020, Wang, Street et al. 2020). Molecular background in adaptation to local climate in *Populus tremula* was in focus in several investigations (Mahler, Wang et al. 2017, Cole and Ingvarsson 2018, Michelson, Ingvarsson et al. 2018, Wang, Ding et al. 2018, Ingvarsson and Bernhardsson 2020). Genome assemblies of *P. tremula* and *P. tremuloides* were produced (Lin, Wang et al. 2018).

(c) Tacamahaca section

An ongoing project "**Cl**imate-**A**dapted **P**oplar through more efficient breeding and better tools for matching genotype and site – developing the poplar bio-economy market in Sweden and the Baltic" aims at identification of genes behind bud flushing, growth cessation and bud set. This knowledge will be necessary in developing molecular markers for selection of clones with proper adaptation to different climates (http://www.slu.se/clap). Sustained public investments are crucial to facilitate genetic improvement of fast-growing ligno-cellulosic crops for different end-uses (Clifton-Brown, Harfouche et al. 2019).

Willows

Willows are interesting source for bioenergy and recently also for liquid biofuels, now investigated within the project "Optimized Utilization of *Salix*" (https://www.slu.se/centrumbildningar-och-projekt/optus/). To facilitate breeding and selection of high-yielding clones, genotype-phenotype associations were studied in key biomass and phenology traits in a hybrid *Salix viminalis* x *(S. viminalis* x *S. schwerinii*) population (Berlin, Hallingback et al. 2017). As a next step, molecular markers for growth and phenology traits were developed (Hallingback, Fogelqvist et al. 2016, Hallingback, Berlin et al. 2019, Hallingback, Berlin et al. 2019).

Investigation of genetic background of different chemical traits of willow stems revealed that many genes with small effects influence lignin, cellulose, hemicellulose and the water content of the wood samples in the above-mentioned hybrid *Salix viminalis* x (*S. viminalis* x *Salix schwerinii*) population (Pawar, Schnurer et al. 2018). In the same study, the correlation analysis between chemical traits and biogas production revealed that higher content of cellulose and hemicellulose resulted in a faster methane production. In addition to high yield, sugar release for ethanol production was positively correlated with lignin S/G ratio (Ohlsson, Hallingback et al. 2019). This was studied in a large population of unrelated *S. viminalis* individuals and the authors suggested that these highly heritable traits are relatively easy to use in breeding programs to develop low-recalcitrance varieties. Biomass recalcitrance to anaerobic digestion was also studied in a selected part of the above-mentioned population (Ohlsson, Harman-Ware et al. 2020).

Other fast-growing tree species
Grey alder (*Alnus incana*) is an indigenous fast-growing species adapted to grow in wet and harsh habitats in Northern Europe. Gray alder would be able to produce 6-7 t ha yr of aboveground woody biomass during a rotation up to 25 years (Rytter and Rytter 2016).

3. Plant Health, Resilience to Threats and Climate Change

(a) Biotic factors (*Melampsora* on poplars and willows)
Specific regions in the genome and a resistance gene that suppresses infestation by leaf rust fungus *Melampsora larici-epitea* were identified in a *Salix viminalis* x (*S. viminalis* x *S. schwerinii*) breeding population (Martin, Ronnberg-Wastljung et al. 2016). While *Melampsora* leaf-rust on willows has received lot of attention during last two decades, few studies have focused on fungal pests in other fast-growing trees. Occurrence of *Melampsora larici-populina* leaf rust varied greatly on *hybrid poplars* with different spring and autumn phenology planted in clonal trials in Sweden, Northern Poland, Lithuania and Latvia (Karacic and Samils 2017). In addition, a virulence test in lab based on eight poplar clones, specifically selected for their resistance to *Melampsora* leaf rust, showed that this fungal rust from the abovementioned study regions contained all the virulences present in Central Europe.

Invasive *Phytophthora* pathogens are known to cause stem lesions in industrially important broadleaved tree species, *Fagus sylvatica* and *Quercus robur*, in Southern Sweden (Blomquist 2016). A recent study has identified that a number of *Betula pendula* genotypes and one *P. trichocarpa* genotype, were susceptible to three different taxa of invasive soil borne pathogens that cause widespread decline of *Fagus sylvatica* in Europe (Cleary, Blomquist et al. 2017).

These results emphasize that emerging breeding program of commercial poplar clones for Sweden and Baltic Sea Region (www.slu.se/clap) needs to take into account tolearance/ resistance against fungal pests of commercially deployed genotypes.

(b) Abiotic factors (drought)

Selection of genotypes with high biomass yield needs to be conducted specifically in the environments where the clones will be deployed at commercial scale. A great variability of water use patterns in closely related *Salix* genotypes allows selection of suitable genotypes for different drought conditions (Beyer, Jack et al. 2018).

4. Sustainable Livelihoods, Land-use, Products and Bioenergy

Production, protection, conservation

(a) Nursery

Production and storage of **willow** cuttings and effect of these steps on willow establishment have been in focus during the years 2016 – 2019. Willows from freshly harvested cuttings, which were planted early in the growing season, had better ability to suppress weeds compared to willows established from dormant cold-stored cuttings (Welc, Lundkvist et al. 2017). Interestingly, the aboveground biomass of willows from these two different types of cuttings did not differ. This implies that storage costs for willow cuttings can be avoided, which also should decrease the market price of willow cuttings.

Effective micropropagation protocols were developed for provenance hybrids of P.trichocarpa to facilitate mass propagation of these new poplar cultivars for commercial deployment (Adler 2016). Two critical steps in the micropropagation of these poplars were identified: 1) establishment of the contamination-free stock plants; 2) large clonal differences in propagation rate.

(b) Planted forests

Re-measurements of experimental plots with **hybrid aspens** in the age of 23-30 years in Southern Sweden revealed that mean annual volume growth was 20-22 m^3 ha^{-1} yr^{-1} (Fahlvik, Rytter et al. 2019). Clonal rankings at the age of 7-9 years in the same trials were similar to clonal rankings 20 years later. This indicates that selection for superior growth in young trials with hybrid aspens is sufficient predictor of their growth in mature age.

An experiment comparing six tree species was established at five sites in Sweden (56–64°N) (Rytter and Lutter 2020). Willow, poplar, hybrid aspen, birch, larch and Norway spruce were planted in a randomize block experiment and remeasured after 8-9 years. Poplar and hybrid aspen grew well on all sites and had the greatest production at the northern sites so far. A yield simulation study that compared different forest management scenarios in warming climate in Southern Sweden, concluded that cultivation of rapidly growing species, such as hybrid larch (*Larix* x *marschlinsii* Coaz.) and hybrid aspen (*Populus tremula* L. x *P. tremuloides* Michx.), could be as profitable as Norway spruce cultivation, or even more profitable (Subramanian, Bergh et al. 2016).

Hybrid aspen regenerates after harvest from root suckers. Clones vary in their ability to regenerate from root suckers. This variation results in reduced clonal diversity in second generation of hybrid aspen stands (Rytter and Jacobson 2018, Stener, Rungis et al. 2018). Such stands with few clones have a greater risk for infestation by clone-specific pathogens compared to stands with multiple genotypes. Authors suggest that seedlings from different unrelated families should be planted in new hybrid aspen plantations instead of few clones to prevent future-clone specific damages. Economic aspects of medium rotation forestry with hybrid aspens and **poplars** should receive more attention during coming years (Stener, Rytter et al. 2019).

The sustainability of hybrid aspen root sucker stands managed in rotations of 4, 8 and 16 years was studied in an experiment in southern Sweden (Rytter and Rytter 2017). The 4 years rotation was left unmanaged between harvests whereas thinning actions were performed in plots managed with 8 and 16 years rotation. The first 8 years of measurements has not revealed any decrease in number of root sucker at short rotations. The production has been equal for all management alternatives but thinning has stimulated diameter growth.

Establishment of hybrid poplar plantations have been tested on set aside agricultural lands since the beginning of 1990ties. Increased demand for hardwoods for manufacturing of textile pulp in Southern Sweden has led landowners to consider poplar as a new cash crop. However, knowledge about the establishment of these perennial woody crops has been missing. Hence, several studies compared the establishment of poplars with different plant material on different types of land (Bohlenius and Overgaard 2016, Bohlenius, Fransson et al. 2017, Mc Carthy, Rytter et al. 2017, Bohlenius, Asp et al. 2018, Hjelm, Mc Carthy et al. 2018). An important finding was that hybrid poplars are sensitive to low pH, which often characterizes forest soils (Bohlenius, Overgaard et al. 2016, Hjelm and Rytter 2016). Low pH implies high levels of Aluminium (Al) in forest soils, which limits root growth of hybrid poplars (Bohlenius, Asp et al. 2018). Growth of hybrid aspens was not affected by low soil pH (Hjelm and Rytter 2016). Comparison of 3-4 years growth, survival and phenology of hybrid aspens and poplars in 13 Scandinavian field trials confirmed better performance of hybrid aspens, compared to hybrid poplars, on soils with low pH (Stener and Westin 2017). General conclusion to be drawn is that hybrid aspens are better adapted to growth on forest soils with low pH (Hjelm and Rytter 2018).

Other site properties might also be important to consider when selecting plant material. Mc Carthy et al. (Mc Carthy, Lof et al. 2018) studied root development of poplar clones at different soil water content. They found a clonal variation in root growth response to water content and stressed the importance of selecting genotypes well suited for the site.

Fertilization of poplar trees with NO_3 in moderate doses of 75 and 150 kg N ha^{-1}, increased significantly stem diameter increment in a young (7 years) plantation on clay in Central Sweden (Dimitriou and Mola-Yudego 2017). In the same study, fertilization did not have any effect on diameter increment in a 10-years-old plantation on sandy soil in Southern Sweden nor in 22-years-old plantation on clay in Central Sweden.

Biomass yield in willow plantations is significantly affected by fertilization. Several studies have assessed nutrient use efficiency among other crops also in willows (Weih, Westerbergh et al. 2017, Weih, Hamner et al. 2018, Agren and Weih 2020).

Fertilization with N did not affect annual net energy yields in a LCA study, where energy balance of mature (18-24 years) fertilized and unfertilized poplar plantations in Southern and Central Sweden were compared (Nordborg, Berndes et al. 2018).

Weed removal in *Salix* plantations during establishment is crucial for their biomass production. Weeds have strong effect on early growth of willows during the first weeks after planting (Edelfeldt, Lundkvist et al. 2016). Willows in weeded plots produced 15,29 t DW ha^{-1} compared to willows in unweeded plots, which produced 2,55 t DW ha^{-1} during one cutting cycle of 3 years (Welc, Lundkvist et al. 2018).

Standard procedure for **establishment of short rotation willow plantations** is herbicide treatment prior to planting and mechanical weed control between the rows after planting. A recent study compared yields in two mechanical and two cultural treatments (with cover crops) with the standard procedure of willow establishment in an experimental willow plantation (Albertsson, Verwijst et al. 2016). The authors found that standard establishment procedure resulted in highest yield after the first harvest cycle (17,3 t/ha dry matter-DM), compared to

13,9 t/ha and 11,0 t/ha in the mechanical treatments with two different types of row crop cultivators. However, all treatments resulted in positive financial annual returns when the whole life span of the plantations was considered. In contrast, modelling harvesting records from 1790 commercial willow plantations in Sweden revealed that commercial willow plantations in Sweden produced 4-5 t DM ha^{-1} yr^{-1}on average (Mola-Yudego, Rahlf et al. 2016).

Establishment of willow plantations by cuttings of variable size or by clone mixtures, led to size hierarchy between individual stools, which, in turn, promoted to high stool mortality and gaps in the stand (Edelfeldt, Lundkvist et al. 2018). The authors suggest to use large, even-sized cuttings for establishment of willow plantations (Edelfeldt, Lundkvist et al. 2018).

Willow cultivation did not result in long-lasting infestation by weeds in the succeeding cereal crop (Welc, Lundkvist et al. 2017).

(c) Naturally regenerating forest

Populus tremula and *Salix caprea* are keystone species in boreal biome of Sweden. Increased abundance of these native species contributes to restoration of biodiversity of managed forests. To increase the abundance of fast-growing deciduous keystone species, they need suitable conditions for recruitment. In a gradient between the boreal and temperate forest biome in Sweden, the recruitment of these keystone species is limited by increased abundance of large herbivores (Angelstam, Pedersen et al. 2017).

(d) Agroforestry and trees outside forests

Agroforestry systems in Sweden do not deploy fast-growing deciduous trees.

<u>New knowledge, technologies and techniques in</u>

(a) Harvesting of poplars, willows

One or two early and relatively heavy thinnings promoted the development of remaining **hybrid aspens** in studied stands in Southern Sweden and did not decrease total volume production during a rotation of 25-30 trees (Fahlvik, Rytter et al. 2019).

Harvesting **willows** during winter is a common practice in Sweden. However, most biomass processing plants require continuous year-round delivery of raw material. Whole-stem harvesting and handling system was designed for cost-effective year-round deliveries of *Salix* biomass (Nilsson, Larsolle et al. 2017).

(b) Utilization of poplars, willows and other fast-growing trees for various wood products

Pruning of trees is a management practice that improves wood quality during growth in field. Pruning of two silver birch stands at age 9/10 years, confirmed earlier findings that pruned birch trees produced more defect-free wood 10 years later resulting in logs with higher value for forest industry (Stener, Rytter et al. 2017).

Fast-growing hardwood species are suitable raw materials in an innovative process for future biorefineries. This process - catalytic fractionation – uses poplar and birch wood in an innovative organosolv pulping process, which results in viscose fiber for textile industry and lignin-oil for production of liquid biofuels (Galkin and Samec 2016, Galkin, Smit et al. 2016).

(c) Utilization of poplars, willows and other fast-growing trees as a renewable source of energy

Increased area of fast-growing woody biomass crops is considered as one of the methods to reduce fossil CO_2 emissions to the atmosphere. Several life cycle assessments of willow coppice systems in Swedish conditions have been carried out earlier. Less is known about cropping systems with hybrid poplars. Poplars are grown as single-stem medium rotation systems (ca 20 years) on agricultural lands. Compared to *Salix*, poplar-based systems are more energy efficient, due to higher energy output:input ratio (Nordborg, Berndes et al. 2018). The authors conclude that higher energy efficiency in poplar-based systems is due to 1) high yields are received without fertilization and 2) single-stem poplar systems are harvested only once (the end) during a 20 years rotation. The total primary energy inputs correspond only to 3% of the gross energy yield in production systems with poplars when biomass production from cradle to gate, i.e. combustion unit, is considered (Nordborg, Berndes et al. 2018).

The ethanol production in Sweden is currently based on wheat. However, utilization of fast-growing woody species from intensive cropping systems follows with less CO_2 emissions from land use change compared to cultivation of wheat for ethanol production (Borjesson, Ahlgren et al. 2016).

Plantations of fast-growing trees have a significant effect on biogenic C fluxes on landscape scale. Climate policy should be developed based on LCA of different bioenergy systems (long-rotation vs short rotation) on landscape scale (Hammar, Sundberg et al. 2017). When use of willow biomass for energy from agricultural land was compared to use of forest residues from conventional long-rotation forestry for Uppsala county, positive effect of willow system on biogenic C was evident (Hammar, Stendahl et al. 2019). This study revealed that use of forest residues decreased the forest C stocks over the landscape, while willow system on previous fallow land increased the total C stocks at landscape scale (Hammar, Stendahl et al. 2019).

Climate impact and energy efficiency of conversion of willow feedstock into bio-oil and bio-char before generating electricity and heat, was compared to direct combustion of this feedstock. The pyrolysis system with soil application of the biochar removed the largest amount of CO_2 from the atmosphere (Ericsson, Sundberg et al. 2017). Production and application of mineral fertilizers contribute by 40% to the energy use during one willow rotation compared to harvest (35%) and transport (20%) (Hammar, Hansson et al. 2017).

5. Environmental and Ecosystem Services

(a) Site and landscape improvement

Mixtures of genotypes with different functional traits in plantations with fast-growing woody species are likely to increase species richness at various trophic levels, which contributes, for instance, to pest resistance in tree plantations (Weih and Polle 2016, Verheyen, Vanhellemont et al. 2016, Djukic, Kepfer-Rojas et al. 2018, Grossman, Vanhellemont et al. 2018, Paquette, Hector et al. 2018). Mixtures of different *Salix* clones compared to monocultures increased richness of taxa of endophytic fungi on *Salix* roots and increased the activities of hydrolytic soil enzymes involved in P mineralization (Baum, Hrynkiewicz et al. 2018). Increased species richness may contribute, for example, to increased plant resistance to pests and diseases and promote sustainable biomass production in cropping systems with fast-growing woody species (Weih, Glynn et al. 2019). Yet, the increased diversity of *Salix* genotypes in experimental willow plantations did not increase yield of harvestable biomass (Dillen, Vanhellemont et al. 2016, Hoeber, Arranz et al. 2018). Choosing clones for mixtures requires knowledge of their ecophysiological traits. Mixing a clone with low N uptake efficiency with a clone, which has high N uptake efficiency, did not contribute to higher aboveground biomass production of a experimental willow plantation (Hoeber, Fransson et al. 2017, Hoeber, Arranz et al. 2018).

The effect of afforestation with hybrid aspens, hybrid poplars and willows on soil properties of agricultural land has gained attention. After 5 years growth, soil carbon (C) pool had not changed compared to the C pools in soil before planting in 4 trials in Southern Sweden (Rytter 2016). The same study revealed that, total N pools in soil had increased in willow plantations, while total P pools had decreased in soils planted with poplars or hybrid aspens. Redistribution of NH_4-N, K and Mg from deeper soil layers to upper soil through root uptake and release via decomposition of leaf litter was observed for willow as well as for hybrid aspen and poplar plantations. Unchanged C and nutrient pools and redistribution of NH_4-N, K and Mg were observed also after 8 years growth in a hybrid aspen plantation, which was initiated from root suckers after the harvest of first generation of hybrid aspen (Rytter and Rytter 2018). When C concentrations in top soil of poplar plantations and adjacent arable fields in Central and Southern Sweden were compared, no differences were found (Dimitriou and Mola-Yudego 2017). For subsoil, the average C concentrations in poplar plantations were equal to those in adjacent arable fields, but were higher when compared to grassland. Increased soil organic carbon (SOC) in subsoil was found in willow plantations in a study that compared SOC in poplar and willow plantations in Southern and Central Sweden (Dimitriou and Mola-Yudego 2017).

(b) Phyto-remediation of polluted soil and water

NO_3-N leaching from poplar plantations in Central and Southern Sweden was compared to NO_3-N leaching from adjacent agricultural fields. NO_3-N leaching from poplar plantations was significantly lower than leaching from adjacent cereal fields, but did not differ when compared to neighboring grasslands (Dimitriou and Mola-Yudego 2017). Specifically, spring NO_3-N leaching was significantly lower compared to reference fields, while NO_3-N leaching in autumn did not differ. Establishment of buffer zones with fast-growing willows along Southern coast of Sweden would avoid leaching of 626 Mg $PO_{(4)}$e to watercourses each year (Styles, Borjesson et al. 2016).

III GENERAL INFORMATION

1. Administration and Operation of the National Poplar Commission or equivalent Organization

(a) Indicate here any changes in the composition of the Commission, amendments to its statutes, changes of address, etc.

The board of National Commission of Sweden has decided in April 2020 to change focus according to the reform in IPC during the previous year. Our vision and name are reformed and goals are revisited. Earlier, when Salix and Poplar were new crops in Sweden, major focus has been on discussions with land-owners how to cultivate these crops. Now, our aim is to include market representatives and general public in our discussion forum – annual meetings - to gain more acceptance to these crops and demonstrate the opportunities with fast-growing trees.

New name: National Commission for Fast-Growing Deciduous Species

New vision: National Commission for Fast-Growing Deciduous Species is a discussion forum for different stakeholder groups from forestry and agricultural sector, academia and governmental agencies.

New goals:

1. Exchange ideas and knowledge between enterprises from forestry and agricultural sector, academia and consumers about the social benefits of native and introduced fast-growing deciduous trees;

2. Exchange knowledge of climate benefits with fast-growing deciduous trees;

3. Promote increased cultivation of native fast-growing deciduous trees;

4. Arrange conferences and study visits;

5. Produce reports and recommendations on fast-growing deciduous trees for FAO etc.

(b) Report briefly on meetings, congresses and study tours, and on other activities of a general nature organized by the Commission at the national level.

Annual meeting, which have been organized each year, have included visits to land-owners who cultivate fast-growing deciduous trees at commercial scale. Establishment, suitable clones and management have been the major focus during 2016-2019.

(c) Indicate also the difficulties encountered by the Commission in the course of its work and any lessons learned.

There has been confusion around who is the official body for National Commission for Fast-Growing Deciduous Species in Sweden. The declaration from Swedish Government in January 20, 2012, states that Swedish University of Agricultural Science is responsible for Swedish delegates active at IPC. Financial support to National Commission for Fast-Growing Deciduous Species in Sweden has never been emphasized. There is no budget for activities at the Commission. The dues from our members cover only the costs to sustain homepage and bank account. Our focus now is to find where to apply for financial support for the Commission.

2. Literature

Publications on poplars, willows and other fast-growing trees issued in the period under review, (2016-2019) including technical papers presented at meetings, congresses, etc. are listed below as a reference list. Some publications, which were accepted for publication during 2019, but will appear in press during early 2020, are also included.

3. Relations with other countries

New provenance hybrids of *P.trichocarpa* adapted to Northern European climate are in commercialization phase at SweTree Technologies AB. These clones are shared with stakeholders from forestry or agricultural sector in all three Baltic States – Lithuania, Latvia and Estonia. A clonal trial, established in Northern Poland during 2018, include these new clones.

Innovative machinery, which contributes to significantly reduced cost of establishment of Salix plantations, is developed in Sweden (pers. Comm. Henriksson Salix AB). This technology is currently exported to Lithuania, United Kingdom and Canada. The technology is also helpful during establishment of plantations with hybrid poplars.

4. Innovations not included in other sections

An invention that relates to the identification and characterization of poplar genes involved in induced flowering and repression of short-day induced growth cessation (Nilsson and Bohlenius 2016), was mentioned above. This invention is relevant in breeding process to facilitate early flowering of genotypes of trees that otherwise have long generation times.

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