INTERNATIONAL POPLAR COMMISSION
COUNTRY NATIONAL REPORTS

Republic of Korea

ACTIVITIES RELATED TO POPLAR, WILLOW AND OTHER FAST GROWING TREE CULTIVATION AND UTILIZATION

Period: 2016 through 2019

Korea National Commission on Poplar and other fast growing trees
Suwon, 2020.

I. POLICY AND LEGAL FRAMEWORK

The National Reforestation Programme conducted during the period 1962-1987 was primarily concerned with restoration of forests that were severely degraded due to overexploitation. Although many more tree species have been used to restore the degraded land, both poplars and pitch pine were the predominant species since they were most accessible and adaptable. Whereas poplars were extensively planted on flood plains and river banks, pitch pine was introduced to cover the denuded slopes to re-establish vegetation since it is very endurant to infertile soil. The reforestation program was quite successful in rehabilitation of the country. The total planted area of poplar reached a peak of about 700,000 hectares by the end of 1980. However, during the early 80's, the newly legislated "River Act" strictly prohibited tree planting on flood plain because it might cause flooding during rainy season. Since then, poplar planting has steadily decreased to practically zero these days. Pitch pine was extensively planted on slopes to stop erosion during the period 1960-1998. The total planted area during the period was estimated 670,000 hectares. Now, most of them reached harvest age. However, besides its low quality and poor productivity, pitch pine proven to be very inadequate since it is very resinous and thus vulnerable to wildfires during dry season. It needs to be replaced with other economically more valuable and environmentally sounder species.

Yellow poplar (*Liriodendron tulipifera*) introduced from the US was one of the reforestation choices and has been tested various regions in Korea. It outperformed all other species tested including native red pine, Korean white pine and oaks in the central to southern parts of the country.

In November 28, 2017, "framework act on forestry" was revised to include "the act on the management and improvement of carbon sink". The purpose of the Act was to respond to climate change by managing and improving the role of forests as carbon sinks pursuant to Article 55 of the Framework Act on Low Carbon, Green Growth and to contribute to the realization of a low carbon society. Together with larch, oaks, and cypress, yellow poplar is a core species for sustaining carbon absorption as well as timber production in the country. Every year, Korea Forest Service sets a goal of planting yellow poplar as one of several bio-energy species. The reforestation campaign is government driven and thus partially subsidized by the government. In the case of yellow poplar, massive plantings have been conducted since 2000. During the period 2016 to 2019 alone, more than 3.5 million seedlings of yellow poplar were planted in around 1,200 hectares each year. A similar level of planting is expected in the future until most of the old pitch pine stands are replaced. In addition, more than 60,000 mature yellow poplar trees were planted as roadside trees in 2016 and 2017 throughout the country. No planting data were collected on roadside trees for the years 2017 and 2018.

II. TECHNICAL INFORMATION

1. Taxonomy, Nomenclature and Registration

No new cultivars of poplars and willows were reported during the period.

2. Domestication and Conservation of Genetic Resources)

Poplar sections:

(a) Aigeiros section

(b) Leuce section

Korean aspen (*Populus tremula* var. *davidiana* or *P. davidiana*) is distributed in the Far East of Russia, China, Mongolia, and Korea. Although it is growing at their geographic range margin, it contains high level of genetic variation (Lee et al. 2011) and thus has high value in conserving biodiversity. However, population decline has already started possibly by climate change. Their number dwindles and will eventually disappear. In 2016, fine-scale spatial genetic structure was determined for small natural stands of *Populus davidiana* using AFLP markers. The species mainly regenerates from root suckers when forest is disrupted by fire or other damages. To conserve the remnant populations, National Institute of Forest Science, Korea selected 204 trees from wild populations. The selected trees were further screened in the nursery and 60 clones were chosen to establish *ex situ* conservation stands at 6 different locations in 1991 and 1992. As the stands aged, further 50 selections were made from the overlapping populations for establishment of new *ex situ* conservation in 2018 and 2019. Their performance at ages 6, 12, and 27 in the conservation sites were evaluated and the clones were ranked according to their growth performance including survival rate, height and diameter growth. The clones could be utilized in the future when the demand arises.

Although poplars are not being intensively cultivated in Korea, genetics research is actively carried out with the species. The complete chloroplast genomes of *Populus alba* x *P. tremula* var. *glandulosa* and *Populus davidiana* were determined in 2019. The complete mitochondrial genome of *Populus alba* x *P. tremula* var. *glandulosa* was also fully revealed. Interestingly, a Lab at the University Arizona in the US published the full genome sequence of *Populus alba* x *Populus tremula* var. *glandulosa* clone 84K (Qiu et al. 2019). According to the report, *Populus alba* x *P. tremula* var. *glandulosa* genome is composed of two subgenomes, representing 356 Mb from *P. alba* (subgenome A) and 354 Mb from *P. tremula* var. *glandulosa* (subgenome G).

During the period 2016-2019, many nuclear genes have been isolated from *Populus alba* x *Populus tremula* var. *glandulosa* and their functions were determined through gene expression analysis mostly using transgenic plants. These include MYC2 gene in relation to leaf senescence response, Dormancy-associated protein 1 gene involved in abiotic stress tolerance, R2R3-MYB transcription factor that promotes anthocyanin production.

Several transgenic poplar clones were also developed. Most of the traits they transferred are related to either biomass growth or stress tolerance in *Populus alba* x *Populus tremula* var. *glandulosa*. The transgenic poplar expressing a gibberellin 20-oxidase 1 gene from *Pinus densiflora* improved biomass production. A remarkable development of gene expression technology was made by bicistronically expressing both wood forming tissue-specific *Pd*GA20ox1 and *Ptr*MYB221 genes in poplar. The

transgenic poplars showed improvement in both the quality and quantity of woody biomass. A novel xylem tissue specific promoter from *Populus trichocarpa* was screened and evaluated in transgenic *Populus alba* x *Populus tremula* var. *glandulosa*. Since the promoter activity is exclusively in mature xylem tissue, it may offer an effective means to improve the chemical and physical properties of the wood. Transgenic *Populus alba* x *Populus tremula* var. *glandulosa* expressing the constitutively active small G protein showed increased stem growth and produced 3–4 times greater dry biomass than hybrid control poplars. Fiber length and diameter were also increased by 15–26% and 28–38%, respectively. As for stress tolerance, the down-regulated GIGANTEA-like gene in transgenic poplar increased plant growth and salt stress tolerance.

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(c) Tacamahaca section

Both *P. koreana* and *P. maximowiczii* are growing in a few small patches in mountain valleys along the eastern part of the Korean peninsula. The populations of both species in Korea are at their geographical range margins and thus prone to extinction. In 2017, National Institute of Forest Science, Korea selected 105 trees of *P. koreana* and 57 trees of *P. maximowiczii* to secure genetic resources. Controlled crosses between the two species in the greenhouse also produced viable seeds that germinated normally. They are being grown in the nursery for further test.

(d) Other poplar sections

Willows

Other fast-growing tree species

The complete mitochondrial genome of yellow poplar was determined in 2019. It has 156,387 base pairs of DNA with 66 genes.

3. Plant Health, Resilience to Threats and Climate Change

Report on the incidence, scale and impacts of damage in poplars, willows and other fast growing trees by biotic and abiotic agents:

(a) Biotic factors including insects, diseases and other animal pests and outline economic aspects and success of control measures undertaken and damage prevention in the future.

(b) Abiotic factors including winds, floods, droughts, pollution and others, and outline economic aspects and success of control measures undertaken and

damage prevention in the future.

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

Report separately information on the application of new knowledge, technology and techniques in application of the culture of poplars, willows and other fast-growing trees different purposes, including production, protection or conservation:

(a) Nursery practices and propagation techniques including applications of biotechnology - particularly plant propagation, reproductive materials, use of GMOs etc.

It is very routine practice to produce seedlings (emblings) from somatic embryogenesis through tissue culture technique. Thousands of emblings are being produced to transfer to nursery at National Institute of Forest Science, Korea. However, unless it is absolutely superior clone, it is still more expensive to produce seedlings than conventional seed sowing techniques.

(b) Planted Forests with emphasis on the choice of cultivars, type of plants, spacing and layout of plantations; planting and tending (fertilization, irrigation, weeding, pruning, thinning etc.); management (growth, rotation in relation to yields and industrial requirements).

For yellow poplar, Korea Forest Service recommends a spacing of plants with a spacing between lines of 3 meters and a spacing of plants within a line of 3 meters, a planting density of 1100 trees per hectare for timber production. KFS also recommends the use of 2.5m x 2m spacing, a planting density of 2000 trees per hectare for biomass production purpose.

Heading (or topping) cut just above stem nodes is strongly recommended right after planting.

(c) Naturally regenerating forest, with emphasis on experiences and experiments concerning silvicultural treatments, harvesting, management, protection and regeneration.

(d) Agroforestry and Trees Outside Forests with emphasis on their effects on forest and agricultural crops or livestock and diversification of the landscape.

Report on the application of new knowledge, technologies and techniques in:

(a) Harvesting of poplars, willows and other fast-growing trees .

Allometric equations and biomass expansion were determined to survey biomass resources of yellow

poplar growing in Korea. To build statistical data, stem density, biomass expansion factor, and root-to shoot ratio were determined. Growth equation was developed using the diameter at breast height (D) and height. The stem density, biomass expansion factor, and root-to shoot ratio of yellow poplar growing in Korea were 0.43 $g \cdot cm^{-3}$, 1.2, and 0.2, respectively. The equations for the above-ground and the underground relative growth were $W=0.060D^{2.524}$ and $W=0.010D^{2.591}$, respectively.

(b) Utilization of poplars, willows and other fast-growing trees for various wood 3 products

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

Forest biomass can function as an alternative fuel and carbon sink. Therefore, it is considered as a key source for addressing climate change. Considering this, the Korea Forest Service has a plan to supply wood-pellet boilers by 2020 to 143,000 rural households which make up 16% of 900,000 rural households using oil boilers and to facilitate domestic wood-pellet production over 1 million tons by 2020. A wood-pellet processing plant was already built in Yeoju in 2008 to promote the use and production of wood pellets. Yellow poplar is being planted as timber species. However, when thinning starts, it generates wood that could be used as fuel, wood-pellet and chips by local communities.

5. Environmental and Ecosystem Services

Report on the application of new knowledge, technologies and techniques for cultivation of poplars and willows; and brief reports on other fast-growing species for:

(a) Site and landscape improvement (bank stabilisation, combating desertification and salinization, shelterbelts and windbreaks, soil rehabilitation, urban and periurban forestry for climate modification etc).

During the period 2013-2018, a total of 156.5 hectares of poplar plantation was established in the Saemangeum reclaimed tideland for rehabilitation as well as wood production. *Populus euramericana, P. deltoides* and *Populus alba* x *Populus tremula* var. *glandulosa* were planted. In the test plot of the plantation, A *P. deltoides* clone performed best and produced the above ground dry weight of around 6 tons per hectare in the first year. In the second and the third year, the production reached 9.33 and 13.73 tons per hectare per year, respectively.

The physiological characteristics of poplars on salty reclaimed soil with poor drainage were determined with *P. euramericana* and *P. deltoides* clones. Overall, *P. euramericana* clones were better than *P. deltoides* hybrid clones especially in the net photosynthetic rate. In contrast, the total chlorophyll and carotenoid contents were higher in *P. deltoides* hybrid clones than *P. euramericana* clones in July. The physiological activities such as net photosynthetic rate and stomatal conductance of *P. deltoides* hybrid clones were much lower in August than in July. The results suggested that *P.*

euramericana Venziano clone was better adapted to the soil with poor drainage than were the other clones tested in Saemanguem area.

Yellow poplar is being planted as roadside tree. Many local governments have planted yellow poplar to combat pollution. In 2016 and 2017, 33,534 and 36,828 mature yellow poplar trees were planted as roadside trees, respectively. Korea Forest Service does not give statistics regarding roadside trees on its own site since 2018. However, yellow poplar is apparently getting more attention as roadside trees in many local governments.

(b) Phyto-remediation of polluted soil and water (buffer zones, contaminated sites, waste water management/treatment etc).

A short rotation coppice plantation consisting of 2-year old poplar clones was established in a riparian area to select the most suitable clones for biomass. Biomass production, nitrogen and carbon absorption were determined in *Populus deltoides* hybrid clone 97-18, *P. euramericana* clone Eco28 and *P. alba* x *P. tremula* var. *glandulosa* clone 72-30. The average number of stems per stump was five and *P. euramericana* clone Eco28 had the greatest average number of live stems per stump with 5.9. The average stem diameter of all clones was 23.2 mm, and *P. deltoides* hybrid clone 97-18 showed the largest average diameter with 25.4 mm. The average annual above-ground biomass was 16.1 tons per hectare per year for *P. deltoides* hybrid clone 97-18, followed by 12.3 tons for *P. alba* x *P. tremula* var. *glandulosa* clone 72-30 and 5.4 tons for *P. euramericana* clone Eco28. The average annual nitrogen uptake of the clones was 46.5 kg per hectare per year. *P. alba* x *P. tremula* var. *glandulosa* clone 72-30 absorbed as much as 63.1 kg nitrogen per hectare per year. As for carbon absorption, *P. deltoides* hybrid clone 97-18 showed the best results with 7.7 tons of carbon per hectare per year.

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.

No changes have been made during 2016 and 2019 years.

(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.

During 2016 and 2019, Korea Poplar Commission carried out poplar related-projects received as an outside operation from National Institute of Forest Science.
The projects were as follows:

- Study on selection of superior individuals *in Populus nigra* var. italic and *Populus simonii* (2017),
- Growth characteristics and selection of superior trees of Korean aspen (2018), and

- Selection of superior clones of Korean aspen (2019)

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

2. Literature

1. Bae EK, YI Choi, H Lee, JW Choi (2019). Isolation and characterization of Auxin/indole-3-acetic acid 1 (Aux/IAA1) gene from poplar (*Populus alba* × *P. glandulosa*). J Plant Biotechnol. 46:180-188

2. Chandra R, H Kang (2018) Phytoremediation and physiological effects of mixed heavy metals on poplar hybrids. DOI: 10.5772/intechopen 76348

3. Chandra R, W Cho, H Kang (2016). Phytoextraction potential of four poplar hybrids under greenhouse conditions. Forest Science and Technol. 12: 1-8. 10.1080/21580103.2016. 1180325

4. Cho JS, HW Jeon, MH Kim, K. Vo, J Kim, EJ Park, YI Choi, H Lee, K-H Han, J-H Ko (2018) Wood forming tissue-specific bicistronic expression of *Pd*GA20ox1 and PtrMYB221 improves both the quality and quantity of woody biomass production in a hybrid poplar. Plant Biotechnol. J. 17: 1048~1057

5. Cho JS , SA Noh, YI Choi (2016) Characterization of a non-specific Lipid Transfer Protein (ns-LTP) promoter from poplar (*Populus alba* x *P. glandulosa*). J. Plant Biotechnol. 42: 356-363.

6. Cho JS, VP Nguyen, HW Jeon, MH Kim, SH Eom, YJ Lim, WC Kim, EJ Park, YI Choi, JH Ko (2016). Overexpression of *Ptr*MYB119, a R2R3-MYB transcription factor from *Populus trichocarpa*, promotes anthocyanin production in hybrid poplar. Tree Physiol. 36:1162-76.

7. Choi, H, EK Bae, J Cho, H Lee, YI Choi (2017) Identification and characterization of the MYC2 gene in relation to leaf senescence response in hybrid poplar (*Populus alba* × *P. glandulosa*). J. Plant Biotechnol. 44: 409-415. 10.5010/JPB.2017.44.4.409.

8. Choi H, EK Bae, YI Choi, SK Yoon, H Lee (2017) Characterization of Gibberellic Acid-Stimulated *Arabidopsis* (GASA) gene to drought stress response in Poplar (*Populus alba* × *P. glandulosa*). J Plant Biotechnol. 44:61–68

9. Choi MN, M Han, HS Park, MY Kim, JS Kim, YJNa, SW Sim, EJ Park (2016) The complete chloroplast genome sequence of *Populus davidiana* Dode. Mitochondrial DNA Part B 1: 674-675

10. Ganchudur T, A Khaulenbek, W Cho, S Lee, R Chandra, J Cho, W Chia, Rogers & H Kang, (2018). Effects of Oxidized Brown Coal Humic Acid Fertilizer on the Relative Height Growth Rate of Three Tree Species. Forests 9: 360. 10.3390/f9060360.

11. Jang JH, SH Kim, I Khaine, MJ Kwak, HK Lee, TY Lee, WY Lee, SY Woo (2018) Physiological changes and growth promotion induced in poplar seedlings by the plant growth-promoting rhizobacteria *Bacillus subtilis* JS. Photosynthetica 56: 1188–1203

12. Jeon HW, JS Cho, EJ Park, KH Han, YI Choi, JH Ko (2016) Developing-xylem preferential expression of *Pd*GA20ox1, a gibberellin 20-oxidase1 from *Pinus densiflora*, improves woody biomass production in a hybrid poplar. Plant Biotechnol. J. 14: 1161-1170.

13. Jin, X, Y Kim (2019) Taxonomic Study of *Populus maximowiczii* Henry and *Populus koreana* Rehder based on Morphological Characters. J. Agriculture & Life Sci. 53:77-85

14. Kang MS, KS Jang, YM Son, RH Kim, IH Park, KH Lee (2016). Allometric Equations and Biomass Expansion of Yellow Poplar (*Liriodendron tulipifera*) in Southern Korea. J. Kor. For. Soc.105: 463-471

15. Ke Q, HS Kim, Z Wang, CY Ji, JC Jeong, H-S Lee, Y-I Choi, B Xu, X Deng, D-J Yun, S-S Kwak (2016). Down-regulation of GIGANTEA-like genes increases plant growth and salt stress tolerance in poplar. Plant Biotech J. https://doi.org/10.1111/pbi.12628

16. Kim, HC, SJ Lee, WY Lee, JW Kang (2016) Selection of Poplar Clones for Short Rotation Coppice in a Riparian Area. Journal of Korean Society of Forest Sci. 105:103-107

17. Kim MH, JS Cho, HW Jeon, K Sangsawang, D Shim, YI Choi, EJ Park, H Lee, JH Ko (2019) Wood Transcriptome Profiling Identifies Critical Pathway Genes of Secondary Wall Biosynthesis and Novel Regulators for Vascular Cambium Development in *Populus*. Genes 10: 690

18. Kim MH, JS Cho, JH Lee, SY Bae, YI Choi, EJ Park, H Lee, JH Ko (2018) Poplar MYB transcription factor *Ptr*MYB012 and its *Arabidopsis At*GAMYB orthologs are differentially repressed by the *Arabidopsis* miR159 family. Tree Physiol. 38: 801–812

19. Kim NY, HS Jeon, MH Lee, A Cha, DS Lee, HJ Lee, HG Kim, H Lee, YI Choi, O Kim (2018). Field evaluation of transgenic poplars expressing the constitutively active small G protein for improved biomass traits. Biomass and Bioenergy 10: 16-22

20. Kim YW, JW Kang, HK Moon (2016) Somatic embryogenesis and plant regeneration of yellow poplar (*Liriodendron tulipifera* L.) at National Institute of Forest Science. 10.13140/RG.2.1.2325.4803.

21. Lee H, HC Kim, JW Kang, WY Lee, H Lim, K Jang (2018). Selection of Poplar Clones for Short Rotation Coppice in a Reclaimed Land. J Agriculture & Life Sci. 52: 21-32

22. Lee JK, JH Jang, L Yang, HN Kim, MJ Kwak, Ik Khaine, TY Lee, HK Lee, IR Kim, GH Jang, WY Lee (2017), Physiological Characteristics of Poplar Clones in the Saemanguem Reclaimed Land. J. Korean For. Soc. 106: 186-195

23. Lee KM, YY Kim, JO Hyun (2011) Genetic variation in populations of *Populus davidiana* Dode based on microsatellite marker analysis. Genes and Genomics 33: 163-171

24. Lee MW, KN Hong, YJ Park, J W Lee, HI Lim (2016). Fine-scale Spatial Genetic Structure of

a Small Natural Stand of *Populus davidiana* in South Korea using AFLP markers. J. Korean For. Soc. 105: 309-314

25. Nguyen VP, JS Cho, YI Choi, SW Lee, KH Han, JH Ko (2016). Evaluation of a novel promoter from Populus trichocarpa for mature xylem tissue specific gene delivery. Plant Physiol Biochem. 104: 226-233.

26. Park J, Y Kim, H Xi, W Kwon, M Kwon (2019). The complete chloroplast and mitochondrial genomes of Hyunsasi tree, *Populus alba* x *Populus glandulosa* (Salicaceae). Mitochondrial DNA Part B 4:

27. Park J, Y Kim, H Xi, W Kwon, M Kwon (2019). The complete mitochondrial genome of tulip tree, *Liriodendron tulipifera* L. (Magnoliaceae): intra-species variations on mitochondrial genome. Mitochondrial DNA Part B

28. Qiu D, S Bai, J Ma, L Zhang, F Shao, K Zhang, Y Yang, T Sun, J Huang, Y Zhou, DW Galbraith, Z Wang, G Sun (2019) The genome of *Populus alba* x *Populus tremula* var. *glandulosa* clone 84K. *DNA Research* 26: 423–431,

29. Yoon SK, EK Bae, H Choi, YI Choi, H Lee (2017) Isolation and Expression of Dormancy-associated protein 1 (DRM1) in Poplar (*Populus alba* × *P. glandulosa*). J Plant Biotechnol. 44: 9969–75

3. Relations with other countries

Include here information also on the international exchange of cuttings and plants of poplars, willows and other fast-growing trees, training etc.

In the past 11 years (2008~2018), Korea Forest Service planted 4,400,000 poplar trees in Kubuqi desert, China to combat desert expansion. The project will be continued over the years to come.

4. Innovations not included in other sections

List here any new developments not included elsewhere.

IV. SUMMARY STATISTICS (Questionnaire)

Please see attached.