Proceedings Seed orchards and the link to long-term tree breeding in response to climate change

KOREA FOREST RESEARCH INSTITUTE

IUFRO

Proceedings

IUFRO Working Party 2.09.01

Seed orchards and the link to long-term tree breeding in response to climate change

8-11 September, 2009
International Convention Center, Jeju, Korea

Organized by:
Korea Forest Research Institute

Sponsored by:
Korea Forest Seed & Variety Center

국립산림과학원
KOREA FOREST RESEARCH INSTITUTE

IUFRO Working Party 2.09.01

Proceedings of 2009 Jeju International Conference

Seed orchards and the link to long-term tree breeding in response to climate change

8-11 September, 2009

Edited by K.S. Kang and J. Hwang

IUFRO Working Party 2.09.01
Seed orchards

IUFRO WP 2.09.01 Seed Orchards was held the conference from September 8 to 11, 2009 in Jeju Island, Republic of Korea.

♠ Conference main theme

Seed orchards and the link to long-term tree breeding in response to climate change

♠ Scope of the conference

The aim of the conference is to present recent advances and to review the state-of-the-art concerning, techniques and methods related to genetics of seeds and seed orchards; in particular the link between long-term breeding and seed orchards, management of seed production; flowering; injuries and protection; economics; seed management, physiology and technology, seed dormancy; testing and storage; gene conservation. Aspects could impact on forests and ecosystems at the stand, the landscape, the national and the global level. Of special interest is the seed orchard in the perspective of changing environment and global warming.

♠ Host organizations

Korea Forest Research Institute (KFRI, main host)

The Korean Forest Society

Korea Forest Seed and Variety Center (KFSVC)

♠ Official organizing committee (IUFRO 2.09.01)

Dr. Kyu-Suk Kang (Korea Forest Research Institute, Korea)

Prof. Dag Lindgren (Swedish University of Agricultural Sciences, Sweden)

Dr. David Reid (Ministry of Forests and Range, Canada)

Dr. Nebi Bilir (Suleyman Demirel University, Turkey)

♠ Local organizing committee

Dr. Eul-Sun Baik (vice-Director General of KFRI)

Prof. Kyung-Jun Lee (president of Korean Forest Society)

Dr. Tae-Soo Kim (Director General of KFSVC)

Dr. Young-Bon Koo (Chief of Tree Breeding Division, KFRI)

Dr. Kyu-Suk Kang, Dr. Sang-Urk Han, Dr. Kwan-Soo Woo

♠ Contact: conference secretary

Dr. Kyu-Suk Kang

44-3 Omokcheon, Kwonsun, Suwon 441-847

Department of Forest Genetic Resources

Korea Forest Research Institute

phone: +82 31 290 1155, mobile: +82 10 2924 9614

(Permanent address)

Prof. Kyu-Suk Kang

1 Gwanak-ro Gwanak-gu, Seoul 151-921

Department of Forest Sciences

Seoul National University

phone: +82 2 880 4753, mobile: +82 10 2924 9614, email: kangks84@snu.ac.kr

Time Schedule

Sep. 8(Tue) : Registration at HANA hotel

Time	Events	Remarks
13:00-18:00	Registration open (HANA hotel)	
20:00-	Accommodation	HANA hotel

Sep. 9(Wed) : Indoor session at Jeje International Convention Center

Time	Events	Speakers	Remarks (moderator)
08:30-09:09	Registration & poster glue		
09:09-09:50	Opening ceremony/IUFRO 2010/Group photo	W.Y. Choi / D. Lindgren / H.-J. Yang	DG of KFRI / Chair 2.09.01 / Vice-governor
09:50-10:20	*Coffee break*	*provided*	
10:20-10:50	Oral presentations	Yousry El-Kassaby	(Dr. Zheng)
10:50-11:20	– Session 1	Dag Lindgren	
11:20-11:50		Tomas Funda	
11:50-13:00	Lunch (ICC)		
13:00-13:30	Oral presentations	Eun-Woon Noh	(Prof. Yi)
13:30-14:00	– Session 2	Anders Fries	
14:00-14:30		Kyu-Suk Kang	
14:30-15:00		Nebi Bilir	
15:00-15:30	*Coffee break*	*provided*	
15:30-16:00	Oral presentations	Wilfried Steiner	(Prof. El-Kassaby)
16:00-16:30	– Session 3	Steven Mckeand	
16:30-17:00		Ole K. Hansen	
17:00-18:00	Poster session	All participants	
18:00-20:00	Welcome reception (ICC)		

20:00-	Accommodation	−	HANA hotel

Sep. 10(Thur) : Indoor session and excursions to WTFRC, seed orchards & FSC forests

Time	Events	Speakers	Remarks (moderator)
09:00-09:30	Oral presentations	Jung Oh Hyun	(Prof. Lindgren)
09:30-10:00	− Session 4	Youngqi Zheng	
10:00-10:30		Yong-Pyo Hong	
10:30-10:45	*Coffee break*	*provided*	
10:45-11:15	Oral presentations	Mohamad Naiem	(Dr. Kang)
11:15-11:35	− Session 5	Nelly Siababa-Aggangan	(20')
11:35-12:55		Shen Xihuan	(20')
11:55-12:15		Kwan-Soo Woo	(20')
12:15-13:00	Lunch (ICC)		
13:00-13:30	Transfer (30')	JICC	Research Center
13:30-14:10	Forest research center		(40 min)
14:10-14:30	Transfer (20')	Research Center	Seed orchards
14:30-15:00	Visit seed orchards and field discussion		(30 min)
15:00-15:30	Transfer (30')	Seed orchards	FSC forests
15:30-17:30	Visit FSC forests and field discussion		(120 min)
17:30-18:00	Transfer (30')	FSC forests	Dinner place
18:00-20:00	Dinner (local restaurant)		Fish, vegetables, hot soup
20:00-	Accommodation	IUFRO business meeting	HANA hotel

Sep. 11(Fri) : Indoor session and field excursions to eco-sites

Time	Events	Speakers	Remarks (moderator)
09:00-09:30	Oral presentations	Yill-Sung Park	(30') (Prof. Hyun)
09:30-09:50	– Session 6	Heung Kyu Moon	(20')
09:50-10:10		So-Young Park	(20')
10:10-10:20	*Coffee break*	*provided*	
10:20-10:40	Oral presentations	Curt Almqvist	(20') (Prof. Mckeand)
10:40-11:00	– Session 7	Seog-Gu Son	(20')
11:00-11:30		Jae-Seon Yi	(30')
11:30-11:50		Dag Lindgren	(20')
11:50-12:20		Finnvid Prescher	(30')
12:20-13:30	Lunch (sandwich) while moving to Sangumburi (crater)		
13:30-14:10	Visit Sangumburi crater		(40 min)
14:10-14:30	Transfer (20')	Sangumburi (crater)	Bijarim Forest
14:30-15:20	Visit Bijarim (*Torreya*) Forest		(50 min)
15:20-15:40	Transfer (20')	Bijarim Forest	Seongsanpo
15:40-16:30	Visit Seongsanpo		(50 min)
16:30-17:00	Transfer (30')	Seongsanpo	Pyosun (Folk village)
17:00-18:00	Visit folk village		(60 min)
18:00-18:30	Transfer (30')	Folk village	Hotel
18:30-19:00	Relax		
19:00-21:00	Conference dinner at HANA hotel		
21:00-	Accommodation	-	HANA hotel

Table of contents

Oral Presentations

IUFRO Working Party 2.09.01 Seed orchards meeting

September 8-11, 2009.Jeju, Korea

List of Participant Country and Registered Number in Jeju, Korea

Countries : 12

Participants : 85

Country	No.	Remark
Sweden	5	oral
China	4	"
Canada	3	"
India	2	"
USA	1	"
Germany	1	"
Denmark	1	"
Indonesia	1	"
Turkey	1	"
Mongolia	1	"
Philipins	1	"
Korea	9	"
"	12	committee & administration
"	39	Poster
etc(Korea)	4	local province officers
Sum	85	

Opening Address

Distinguished Guests,/ Ladies and Gentlemen, / Good Morning!

First of all,/ on behalf of the Korea Forest Research Institute,/ I would like to express my sincere gratitude/ and warm welcome/ to all participants, speakers and guests./ My special thanks go to/ Dr. Dag Lindgren and Dr. Nebi Bilir/ for their support to the arrangement of the Conference. My sincere appreciation is extended to/ Mr. Jo-Hoon Yang, the Vice-governor of Jeju Special Self-governing Province/ for his welcoming.

It is a great honor and pleasure/ to host "International Conference/ on Seed Orchards and Link to Long-term Tree Breeding/ in Response to Climate Change"/ in this beautiful place,/ Jeju Island. I expect that/ the Conference will/ not only be the largest event of the year/ but also/ provide all of you/ with the best of science and technologies/ in the field of seed orchard management.

As you are aware,/ seed orchards play a critical role/ in the implementation of sustainable forest management/ because they provide genetically improved seeds for plantation. Recently/ more interests have been focused on/ continuous improvement of genetic quality/ of seeds produced from the seed orchards. In this regard,/ it is very timely/ that the IUFRO organized/ the Seed Orchard Working Party/ in October, 2008.

In Korea,/ seed orchard programs were initiated/ with the selection of plus trees in 1968. To date,/ a total of 702 seed orchards have been established. Various breeding and genetic techniques have been applied/ to enhance the quantity and quality of the seeds.

Meanwhile,/ now we are facing a challenge of global climate change. Definitely,/ it has an impact on the growth pattern/ and the distribution range of tree species. In Korea,/ the northernmost limit of the species' range/ is gradually moving northward. Thus,/ in order to meet this environmental change,/ we need to develop a new strategy/ and/or model for seed orchard management.

The objective of the Conference/ is to exchange the latest information on/ science and technologies related to seed orchard management/ and long-term tree breeding/ in response to climate change. I hope that/ the Conference will provide the opportunity for the participants/ to present and learn about/ different problems, issues and various approaches/ to management of the seed orchards.

I would like to/ close my speech by expressing my sincere wishes/ for the success of the Conference. I hope that/ your stay here is memorable/ and your deliberations are fruitful. Then,/ enjoy beautiful weather of autumn in Korea.

Thank you very much for your kind attention.

Wan-Yong CHOI

Director General, Korea Forest Research Institute

Welcome Address

General Director, Ladies and Gentlemen; It is indeed a great pleasure for me - on behalf of the IUFRO WP “seed orchards” - to welcome you all to this international symposium on “Seed Orchards”.

For me seed orchard research is one of the most important things in the World. Seed orchards are the main link between forest tree breeding, forest genetic research and the actual forest. A large share of the green interface between land and air on Planet Earth is forest. Seed orchards are the most cost-efficient way to influence many of these forests. Many trees forming the forests of tomorrow got their lives started in seed orchards, and the most important and easiest part of the management is usually just at the start. Seed orchards can help us repair deforestation and land degradation, which often followed in Man’s footsteps, Seed orchards are of outmost importance to tackle many key problems of the World, such as raw materials, energy, carbon dioxide, climate change, gene conservation and sustainability. Research resulting in better seed orchards is of outmost importance.

Knowledge and experiences of seed orchards and their role and management have accumulated during the last decades, but most has mainly been communicated on national or regional levels, there is a need for an international forum also. There is a need to see how similar problems are tackled in other environments and there is a need for direct communications with international specialists as well as managers. A conference may attract specialists in adjacent disciplines applicable to seed orchards. This conference offers openings in viewing seed orchards from fresh angles.

Two years ago a Seed Orchard conference took place in Umeå, Sweden. It was not a big conference, but it was the biggest in the last decades to focus only on seed orchards. The coordinator of IUFRO Division 2, Bailian Li asked if we wanted IUFRO blessing, but there was no IUFRO unit focusing on seed orchard suitable for such blessing. But if there was no unit in IUFRO working with seed orchards, one could be created! It took some lengthy procedures for IUFRO, but now we are here. I feel very happy that the WP Seed orchards has been created under IUFRO Division 2 Research Group 09 Tree seed, physiology and biotechnology and now can start its first meeting! The main purpose of the Working Party (2.09.01) on "Seed Orchards" is to facilitate exchange of information on the research and progress of seed orchards and their crops.

I am sure that all the presentations will be highly valuable to all of us by offering new insights to challenging issues and by initiating constructive discussions and from sharing each other’s expertise.

I would like to thank the Korea Forest Research Institute and its General Director, Dr. Wan-Yong Choi, for hosting and greatly supporting this Conference; and to members of the Korea Organizing Committee, who have worked hard to ensure the success of the Conference. Finally I would like to express our thanks to Dr. Kyu-Suk Kang, Coordinator of IUFRO Seed Orchards Working Party, who is the main organizer and driving force of this meeting and has worked very hard and dedicated to make it a fine and fruitful experience for us participants.

I welcome you to this Conference and I hope you enjoy your stay.

Dag Lindgren
Deputy Coordinator of the IUFRO WP Seed Orchards (2.09.01)

Oral Presentation

Breeding without breeding

Yousry A. El-Kassaby

Faculty of Forestry, University of British Columbia, Vancouver, BC, Canada

Abstract: Traditional tree improvement programs start with deliberate phenotypic selection of candidate trees followed by rounds of recurrent selection characterized by cumulative incremental gain advancements. While effective, the process is elaborate, quantitatively oriented, and follows sophisticated breeding theories. Breeding and testing start with the selection of pre-determined mating designs, requiring years to complete and often is not error free, followed by experimentally elaborate, large scale, multiple sites field testing. This process is costly, takes long time to complete, and most of all, requires sustained organizational commitments for its continuation. Here I present an innovative approach that allows the capture of the genetic gain attained through conventional tree improvement programs without conducting any crosses and with simplified or possibly without the establishment of progeny test trials. The method is called "Breeding Without Breeding" and is based on combining the use of phenotypic pre-selection of better individuals, spatial statistics, informative DNA markers for pedigree reconstruction to assemble full- and half-sib families after wind pollination, and quantitative genetics analyses to identify elite genotypes for seed orchards establishment. BWB's potential and applicability is illustrated through a retrospective study of a "conventional" Douglas-fir breeding program as well as an experimental trial of western larch. Results demonstrated the method's effectiveness in capturing substantial amount of the genetic gain with relatively minimal efforts and allowed the development of a framework for its utility as an alternative to conventional breeding programs.

Advanced generations "breeding without breeding" with only forests and combined seed orchards/breeding populations.

Dag Lindgren[1,3] and Xiao-Ru Wang[2]

[1]Department of Forest Genetics and Plant Physiology, The Swedish University of Agricultural Sciences, SE 90 183 Umeå, Sweden

[2]Department of Ecology and Environmental Science, UPSC, Umeå University, SE-901 87 Umeå, Sweden

[3]Correspondence to Dag.Lindgren@genfys.slu.se

Abstract: Genetic marker-based parentage analysis is now sufficiently powerful for reliable sibship reconstruction from open pollinated offspring of a clonal seed orchard. This opens up the option for a simple breeding strategy with only two groups of trees, which are managed by forestry and not breeders:

1. combined breeding population/seed orchard;
2. commercial plantations derived from this seed orchard.

No crosses or field-trials or clonal archives are needed and the strategy is not sensitive to turbulences in a breeding organization. Phenotypic pre-selection is made in the forests. Their inclusion in the next generation of combined breeding population/seed orchards is based on marker analysis of the parentage of the pre-selections. The strategy is a variant of "breeding without breeding" as suggested and coined by Yousry El-Kassaby. The system seems applicable only to clonal seed orchards today, seedling seed orchards would require more powerful marker systems for pedigree reconstruction of the many parental genotypes. One important reason for controlled crosses is to isolate the breeding population from unimproved and unknown parents. With marker-based pedigree reconstruction that motive for crosses vanishes.

In advanced generations where estimates of breeding values exist, there is a conflict between the seed orchard function and the long term breeding population function. For seed orchards more gain is desired, but for breeding populations more diversity. The desire of gain and diversity in the seed orchard crop can be compromised by "linear deployment", but sustainable long term breeding requires

more clones. However the disadvantage for the seed orchard function can be reduced if the low ranking clones needed in the breeding population are represented on by a few ramets. A special gene conservation forest can when be done by selective harvest of those ramets, and selections in that will carry on these genotypes. Additional aspects on how to construct advanced generation BWB populations will be given. Conversion from high input breeding in the first generation to low input breeding in later generations may be possible.

Breeding without breeding, but without markers, remains a useful tool for many low input situations. Phenotypic truncation selection can be as powerful as combined index selection in family plantations when gene diversity loss is considered, thus half sib family plantations from open pollination of selected trees can be useful for short and long term breeding. Although the use of markers in itself is not remarkable expensive, it requires high competence and considerable development for the species, and use of markers can be a doubtful general solution for low-input breeding in marginal species.

Optimization of combined genetic gain and diversity for collection and deployment of seed orchard crops

Tomas Funda[1,2,3], Milan Lstibůek[2], Jaroslav Klápště[2], Yousry A. El-Kassaby[1]

[1] Department of Forest Sciences, Faculty of Forestry, University of British Columbia, 2424 Main Mall, V6T 1Z4 Vancouver, B.C., Canada

[2] Department of Dendrology and Forest Tree Breeding, Faculty of Forestry and Wood Sciences, Czech University of Life Sciences Prague, Kamýcká 129, 165 21 Praha 6, Czech Republic

[3] Correspondence to tfunda@interchange.ubc.ca

Abstract: Genetic gain and diversity of seed orchard crops are determined by the number of parents, their breeding values and kinship, within-orchard pollination efficiency, and pollen contamination. These parameters can be manipulated at establishment by varying clonal representation (e.g., linear deployment), during orchard development by genetic thinning, or by selective harvesting. Since clonal fecundities are known to vary both within and among years, then each seed crop is likely to have a unique genetic composition and, therefore, crops should be treated on a yearly basis. Here we present an optimization protocol that maximizes crops' genetic gain at any desired genetic diversity through the selection of a subset of the crop that meets both parameters. The genetic gain is maximized within the biological limit set by each clone's seed-cone production, and effective population size is used as a proxy to genetic diversity whereby any relationship among clones is considered. The optimization was illustrated using three years' reproductive output data from a first-generation western larch seed orchard and was tested under the following scenarios: (1) male reproductive output is assumed to be equal to that of female, (2) male reproductive output is assumed to be a function of clonal representation, and (3) actual male and female reproductive output is used as estimated from the visual assessment of clonal pollen- and seed-cone production. Furthermore, various levels of kinship were assigned to the orchard's parents to simulate seed production from advanced-generations' seed orchards. Following the optimization, all solutions were effective in creating custom seedlots with different gain and diversity levels, and provided the means to estimate the genetic properties of composite seedlots encompassing the remaining "unused" seed from a number of years.

Key words: effective number, co-ancestry, seed orchard, tree breeding

Controlling of larch flower induction in seed orchards

Wi Young Lee[1], Jae Soon Lee[1], Hyo Shin Lee[1], Sang Urk Han[1], Byung Sil Lee[2], Jong Han Kim[2], Hyun Goo Hur[1] and Eun-Woon Noh[1,3]

[1]Dept. Forest Genetic Resources, Korea Forest Research Institute, Suwon, 441-847

[2]Korea Forest Seed & Variety Center, Chungju 380-940, Republic of Korea

[3]Correspondence to ewnoh@forest.go.kr

Abstract: In Korea, an exotic Japanese larch, *Larix leptolepis,* has been extensively planted throughout the country as a reforestation species. However, in spite of its high demand, planting has not been greatly expanded due to lack of seeds. This species has a reputation as a poor seed setter in Korea. Since it is fast growing trees with a straight and lofty stem, its improvement program is primarily concerned with seed production. In the early 80's, attempts were made to stimulate flowering in the seed orchards established in 1971, 1977 and 1978 without much success possibly due to their young ages. Since then, spontaneous abundant flowerings have occurred twice in the years 2001 and 2008. However, flowering was still very sporadic and thus it was almost impossible to predict the yield. In the present study, we reattempted to stimulate flowering in the now-more-matured seed orchards. We managed to induce flowers from the clones of *L. leptolepis* in the seed orchards at three different locations after treating them with GA4/7 (gibberellin 4 and gibberellin 7) in combination with stem girdling. The most effective treatment was a girdling though the stem injection of GA4/7 was also effective. However, the girdled trees became so weak that new shoot development was significantly suppressed. We also examined soluble polyamines, amino acids and total phenolics in needles after girdling treatment. Among 3 polyamines analyzed, putrescine increased significantly in the needles of the girdled trees. The total amino acid contents also increased significantly to 24 nmol/g fw in the girdled trees when compared to 13 nmol/g fw of control trees. In contrast, there was no significance difference in the total phenolics between the girdled and control trees. One exception was that girdling increased rutin content comparing with the control. Although both girdling and GA treatment stimulated flowering, the abundance of flowering varied significantly among the 3 orchards suggesting that the flowering is heavily dependent of the site conditions as well as prior flowering history of the orchard. Nevertheless, girdling and/or GA injection significantly improved the flowering of larch in the seed orchards.

Key words: Larix, flowering, girdling, GA4/7, seed orchard

Pollination patterns in Scots pine seed orchards

Anders Fries[1], Takeshi Torimaru[2], Xiao-Ru Wang[3], Bengt Andersson[4] and Dag Lindgren[1]

[1]Department of Forest Genetics and Plant Physiology, The Swedish University of Agricultural Sciences, SE-901 83 Umeå, Sweden. Anders.Fries@genfys.slu.se & Dag.Lindgren@genfys.slu.se

[2]Faculty of Agriculture and Life Science, Hirosaki University 3, Bunkyo-cho, hirosaki, Aomori, 036-8561, JAPAN. torimaru@cc.hirosaki-u.ac.jp

[3]Department of Ecology and Environmental Science, UPSC, Umeå University, SE-901 87 Umeå, Sweden. Xiao-Ru.Wang@emg.umu.se

[4]Forestry Research Institute of Sweden (Skogforsk), SE-918 21 Sävar, Sweden. bengt.andersson@skogforsk.se

Abstract: In Sweden most of the plants of Scots pine (*Pinus sylvestris*) originate from seed orchards. The percentage today is at least 85 % and this figure will increase. The full rotation genetic gains in production from the 2nd round of Swedish Scots pine seed orchards, established during the 1980s, are expected to be 10-15%, and plants from those now under establishment are expected to be around 25% . This percentage is however reduced by pollen contamination with pollen from outside the orchard. The contamination is difficult to avoid: Scots pine is a wide-spread species in Sweden, and even in areas where Norway spruce (*Picea abies*), the other major conifer in Sweden, dominate, non-bred natural Scots pines grow scattered among the spruces or in pure pine stands. The flight distance of pine pollen can also be quite long. As the seed orchards give more gain, the gain loss by pollen contamination becomes larger, and as the pine stands become genetically more disparate, the contaminating pollen cloud becomes more unpredictable. Although the contamination promotes the genetic diversity of the seed harvest, a general aim is thus to reduce it.

The first studies of pollen contamination in Scots pine seed orchards during the 1980s, used isozymes with limited precision. Today's molecular marker techniques

have higher precision and gives thus better estimates of the contamination, and can also be used for analyzing the pollination pattern within the seed orchard.

A study of the most advanced Scots pine seed orchard in production in Sweden, Västerhus, was performed the seed maturation year 2007 (Torimaru et al. 2009). All 28 clones in the seed orchard were genotyped based on nine microsatellite (SSR) loci. The nine SSR loci produced almost unique multilocus genotypes for each of the 28 clones, and paternal assignment of the studied seed was made with very high paternity exclusion probability. It was estimated that around 50% of the seeds produced in the seed orchard this year was seeds that had been contaminated with paternal genes from outside the orchard. Selfing frequency was very low. This contamination figure is compatible with similar old studies.

A clone-wise analyzes of the pollen contamination showed that the contamination varied considerably among clones. Furthermore, some clones contributed genetically around twice as much to the seed harvest, as compared to the number of grafts of the clone in the orchard, while other contributed genetically with only ca $1/10^{th}$ of what their number of grafts indicated.

Further development of molecular markers will make it possible to evaluate the functions of seed orchards. Possible aspects are: i) appropriate maturity of the seed orchard for seed harvest, ii) the annual variation of the genetic quality of the seed harvest, iii) the genetic diversity of the seed harvest, iv) base information for genetic thinning of the seed orchard. In a longer perspective, molecular markers could possibly be used for e.g. evaluation of long-distance pollen transfer and identification of individual trees for forward selection in operational plantations from a certain seed orchard.

Clonal fertility variation and its effects on the effective population size in a seed orchard of dioecious species, *Fraxinus rhynchophylla*

Kyu-Suk Kang[1,3], Chang-Soo Kim[1], Eul-Sun Baik[1] and Jin-Taek Kang[2]

[1] Department of Forest Resources Development, Korea Forest Research Institute, 44-3 Omokcheon, Suwon 441-847, Kyonggi, Republic of Korea

[2] Forest Seed and Variety Center, Korea Forest Service, 670-4 Suheo, Chung-ju 380-941, Chungbuk, Republic of Korea

[3] Correspondence to kangks@forest.go.kr

Abstract: The numbers of female and male flowers were assessed in a clonal seed orchard of *Fraxinus rhynchophylla* for four consecutive years from 2004 through 2007. The female and male flowers of the grafts were counted individually over the crown. Fertility variation was calculated by sibling coefficient that is related to the coefficient of variation in parental fertility. Estimated maternal and paternal fertilities based on the flower assessment were not constant but vary from year to year, and they were also found to be weakly correlated each other. Effective numbers of parents for mother and father were calculated from the sibling coefficients of maternal and paternal fertility variation. Clonal effective population sizes were estimated based on fertility variation ($N_e^{(c)}$) and gender balance (N_e). The values of $N_e^{(c)}$ were higher in the years with good flower and seed production, while sibling coefficients were lower. On average (pooled), the values of $N_e^{(c)}$ were calculated to be 17.3, 21.0 and 38.1 for maternal, paternal and clonal fertility, respectively. The $N_e^{(c)}$ for maternal gamete pool was ranged from 9.8 to 16.7. The values of N_e for paternal gamete pool were generally higher (ranged from 14.9 to 21.9) than those for maternal. When pooled, the N_e was 47.3 and the values of N_e were higher when the gender ratio was more balanced. An option of equal seed harvest might be good to mitigate fertility variation and to improve gene diversity of seeds.

Key words: fertility variation, status number, sibling coefficient, gene diversity, equal seed harvest, *Fraxinus rhynchophylla*

Estimation of productions for reproductive characters in seed orchards of *Pinus sylvestris* by Fuzzy logic model approaches

Nebi Bilir[1,3] and Aytul Sofu[2]

[1] Forestry Faculty, Suleyman Demirel University, Isparta, 32260, Turkey

[2] Environmental Engineering Department, Suleyman Demirel University, Isparta, 32200, Turkey

[3] Correspondence to nebilir@orman.sdu.edu.tr or nebilir@hotmail.com

Abstract: There are many genetical and environmental factors on productivity of seed orchards. Estimation of effects of these factors is not easy especially for their combination and each of them on reproductive characters. These factors are also play important role to determine establishment area of seed orchards. In this study, strobili, cone and seed production were estimated by fuzzy logic model in Turkish Scots pine seed orchards based on breeding zone, growth period, altitude and age. In this context, a software tool was structured based on these factors expressed as fuzzy values to compute reproductive characters. Results of the study were discussed for establishment (i.e, selection of establishment area of seed orchards) and management (i.e., estimation of strobili, cone and seed production based on age) of seed orchards.

Key words: Artificial neural network, Scots pine, cone, strobili

Quality management in seed orchards by genetic investigations

Wilfried Steiner[1,2]

[1]Nordwestdeutsche Forstliche Versuchsanstalt
[2]Correspondence to Wilfried.Steiner@NW-FVA.de

Abstract: The Northwestern Forest Research Station is responsible for more than 200 seed orchards and clonal archives on more than 400 ha. They comprise 8 coniferous species and 30 broadleaved species containing trees and shrubs. These orchards have been established during the last 6 decades by different organizations. Usually, selected plus trees have been grafted and planted in orchards or archives with varying number of ramets. A considerable proportion is used for seed harvesting for forest practice and also for nature conservancy measures.

In order to ensure the high quality of the seed orchards, genetic investigations are performed especially for two aims: 1. Assessing the clonal identity of the ramets. The main sources for mistakes are mixing up clones or labels during production of grafts (handling of plus tree scions, grafting, raising, transplanting, transporting) and later on the unrecognized replacement of the graft by a developing rootstock. 2. Assessing the genetic variability. Usually the intention is to provide reproductive material of high genetic variability in order to ensure adaptational capacity to the populations derived from it.

Isoenzymes are used for the investigations because they are fast, cheap and easily to analyse. The results so far show that in general the quality of seed orchards is quite good. The mistakes detected by genetic investigations mount up to less than 10 % on average. A part of these mistakes are due to a mislabeling of plants which does not affect the quality of the seeds. The genetic variability in general is considered as sufficiently high. Comparison to seed harvesting stands the seed orchards often show increased values of genetic variability.

Economic returns from intensive management of loblolly pine seed orchards in the Southeastern United States

Steve McKeand[1,2], Patrick Cumbie[1] and J.B. Jett[1]

[1]NC State University Cooperative Tree Improvement Program, Department of Forestry and Environmental Resources Box 8002, NCSU, Raleigh, NC 27695-8002 USA

[2]Correspondence to Steve_McKeand@ncsu.edu

Abstract: Loblolly pine (*Pinus taeda* L.) seed orchards in the southeastern United States started producing significant quantities of seed in the early to mid-1970's, and the impact on forest productivity and profitability to forest landowners has been impressive. Operational gains from the first generation of orchards were modest for volume production, but improvements in stem form and log quality were substantial. In the late-1980's, 10-15% of the seeds harvested came from 2nd-generation orchards, and harvest of advanced-generation seed has been increasing ever since. Volume improvement of 15-20 % over non-improved sources and value improvements of 25% to 40% from some specific families were realized on hundreds of thousands of hectares planted annually with 2nd-generation trees. Today, about one-quarter of the 400,000 ha planted each year in the southern US come from the third cycle of improvement, and an increasing number of hectares are planted with clones and specific full-sib families. We estimate gains in volume of 35% to 50% from the best material and even higher increases in value due to improvement in sawlog quality.

In our analyses, we combine data on the number of hectares planted annually over the past 40 years and the economic value of these plantations to show the value of loblolly pine breeding and seed orchard programs to the region. Even modest gains in productivity and value result in substantial financial improvement to landowners. We emphasize that there is never enough of the best seed available to plant, and intensive management of seed orchards is a key to producing the best genetics for future timber harvests.

Key words: Breeding, genetic gain, *Pinus taeda* L., tree improvement, silviculture

Establishment of a quasi-field trial in *Abies nordmanniana* – test of a new approach in forest tree breeding

Ole K. Hansen[1,2] and Lea V. McKinney[1]

[1]Danish Centre for Forest, Landscape and Planning, University of Copenhagen, Hørsholm Kongevej 11, 2970 Hørsholm, Denmark

[2]Correspondence to okh@life.ku.dk

Abstract: We will present a study in which DNA-markers were used to establish a quasi-field trial, thereby avoiding some drawbacks of traditional tree breeding. The study object was a clonal seed orchard (CSO) comprising 99 clones of *Abies nordmanniana* – an exotic conifer used for Christmas tree production in Denmark. A total of 660 offspring from the CSO, standing in a production stand of Christmas trees, were genotyped with 12 microsatellites. Parentage analysis gave a success rate of 93% in assignment of parentage with 95% confidence and 98% if the confidence level was relaxed to 80%. Sequential removal of markers with the lowest information content (PIC) showed that assignment rate was nearly at the same level when the number of markers was reduced to 10. The distribution of parentage to the offspring among the CSO clones was highly skewed. The most successful clone was assigned parent in 7% of the cases, and only 92 of the 119 potential parental genotypes were assigned parentage.

The obtained pedigree was used to estimate breeding values for the CSO clones for five characters which are relevant for Christmas tree breeding. For high heritability traits like flushing accurate breeding values could be estimated for a considerable fraction of the clones. Low heritability traits like Christmas tree quality score will require more genotyped offspring. The largest drawback of the method seems to be the highly skewed distribution of parentage among the parents in the seed orchards, making it difficult to get breeding values for all clones. The approach seems well suited for altered ways to conduct tree breeding – putting more emphasis on pure selection of parental genotypes on the basis of production stands, and less on estimation of quantitative genetic parameters.

Major achievements of tree breeding in Korea

Jung Oh Hyun[1,3], Eui-Rae Noh[2] and Kyu-Suk Kang[2]

[1]Department of Forest Sciences, Seoul Nat'l University, Seoul 151-742, Republic of Korea
[2]Department of Forest Resources Development, Korea Forest Research Institute, Suwon 441-350, Republic of Korea
[3] Correspondence to kangks84@snu.ac.kr

Abstract: There were plenty of good formed and big trees in the mountains until 1800s in Korea before Korea had been under Japanese colonial regime for 36 years since 1910. During the Japanese occupation, many forests were destroyed by exploiting indiscriminately. In addition, Korean War broke out and lasted for three years from 1950 to 1953. After the War, social disorder was so serious that every body entered into the forests and cut the trees without any permit from the authority. At that time, therefore, almost every mountain except remote area of Korea was denuded so severely that the mountains looked red. After that, Korea needed desperately a good tree species for the devastated land. Early 90s, Korea met a great scholar and research advisor whose name was Dr. Sin Kyu Hyun. It is very hard to talk about tree breeding history without mentioning him in Korea. In fact, the late Dr. Hyun was a founder of tree breeding work in Korea, establishing the Forest Genetics Research Institute (Department of Forest Resources Development now) in Suwon in 1956. The Institute has done much of hybrid breeding such as hybrid pines and hybrid poplars. In addition, seed orchard establishment was one of the main duties for appropriate improved seed supply. The whole selection breeding programs including plus tree selection, progeny test and clone bank were reviewed by the late Dr. Gene Namkoong who was a world-widely known forest tree geneticist. Fruit tree breeding was also one of the main breeding programs of the Institute and it resulted in development of many cultivars of chestnuts, walnuts and some wild fruit trees. More recently, biotechnology and gene conservation were added to the breeding programs.

A low-cost approach to deploying hybrid pine in southern China

Zheng Yongqi[1,2]

[1] Chinese Academy of Forestry, Beijing 100091

[2] Correspondence to zhengyq@caf.ac.cn

Abstract: The hybrids of *Pinus eliottii* x *P. caribaea* have displayed advantages in southern China due to its evident hybrid superiority in growth, however its deployment in plantation forestry is still of limit due to the prohibitive cost of producing hybrid seeds by artificial controlled pollination, which is attributable to the low productivity of viable seeds and the low germination rate of hybrid seeds. As a consequence of shortage of F_1 hybrid seed supply, use of F_2 hybrid was sought. Field experiments indicated that the hybrid superiority can be maintained in the F_2 population on average although the F_2 population is more variable.

A low-cost strategy was developed to make use of the F_2 hybrids. The F_2 hybrid seeds were imported from Queensland Australia, collected from clones of F_1 trees which were selectively thinned on progeny performance. Seeds were germinated and most vigorous plants were used to establish cutting orchards, in which routing hedging was applied to keep juvenility of the stocks for production of cutting scions. Cutting scions were harvested regularly from the cutting orchard and used for cutting propagation. Trials were established using plant stocks produced by cutting propagation and the trials will be evaluated on performance including growth and survival. The results of assessment will then be used to thin the cutting orchard by removing those mother trees producing poor plant stocks.

This practice is somewhat similar to the traditional progeny test (which may be similarly called clonal-progeny test). The mother trees in the cutting orchard are selected based on performance of their clonally propagated offspring. There are several advantages of this strategy: 1) The overall cost of producing plant stocks is much reduced compared to normal approach to production of hybrid plants; 2) Technical requirement is much simpler by producing open-pollinated F_2 hybrid seeds ; 3) Hybrid superiority can still be satisfactory and can even be enhanced by thinning the mother trees based on assessment of the progeny obtained by cutting propagation; 4) The approach is particularly useful when productivity of hybrid seeds through controlled pollination and germination rate of the hybrid seed are both very low. Further studies may be conducted to quantify the cost that can be reduced by this approach.

Keywords: *Pinus eliottii*, *Pinus caribaea,* Hybrid pine, Cutting orchard

Annual fluctuation of mating parameters in a seed orchard of Japanese red pines revealed by DNA markers

Yong-Pyo Hong[1,3], Young-Mi Kim[1,2], Ji-Young Ahn[1] and Jae-In Park[2]

[1] Division of Forest Genetic Resources, Korea Forest Research Institute, Suwon 441-837, Republic of Korea

[2] Department of Forest Science, Chungbuk National University, Cheongju 361-763, Republic of Korea

[3] Correspondence to yphong@forest.go.kr

Abstract: To monitor any annual fluctuation in such mating parameters in a seed orchard of Japanese red pines, outcrossing rates, proportion of pollen contaminants, and number of potential pollen contributors were estimated from seeds collected in consecutive years of 2006 and 2007 using DNA data including 4 nSSR and 6 cpSSR markers. Five single clones of showing unique cpSSR haplotypes were selected from a total of 47 individual trees within a plot (95m×90m) of a orchard at Anmyeon island established in 1977. Haplotypes for each mother tree and corresponding half sib seeds were identified by PCR analyses with six cpSSR primers. From the seeds collected in 2006, estimates of outcrossing rates were averages of 98.9% on the basis of the analysis of cpSSR haplotypes and 95.9% on the basis of the analysis of nSSR genotypes. Seeds generated by pollination with introduced pollens from outside of seed orchard was verified by comparing nSSR genotypes of maternal tree, embryo, and potential paternal clones within the seed orchard (i.e., 160 genotypes) using computer program of Cervus v2.0 and further cross checking of haplotypes of cpSSR markers. Estimate of pollen contamination was an average of 47.9%. Potential pollen contributor for each seed within a study block was determined by comparing both pooled cpSSR haplotype and nSSR genotype of each seed, which resulted in verification of mean of 16 pollen contributors. From the seeds collected in 2007, estimates of outcrossing rates were averages of 97.7% on the basis of the analysis of cpSSR haplotypes and 95.3% on the basis of the analysis of nSSR genotypes. Estimate of pollen contamination was an average of 41.9%. Mean of 14.6

pollen contributors was verified. There has been little annual fluctuation in the level of overall outcrossing rates. Relatively more annual fluctuation was observed in number of pollen contributors (mean of 16 for 2006 and 14.6 for 2007). Such annual fluctuation might be resulted from different degree of pollen contamination between compared years. For example, in 2007, lower degree of pollen contamination was observed (i.e., 41.9%) than that in 2006 (i.e., 47.9%), that might result in reduction of the number of unidentified pollen donors from the outside of the '77 plot of a seed orchard at Anmyeon island. Although annual fluctuation in degree of pollen contamination and number of pollen donors was observed, considering little annual fluctuation in high level of outcrossing between clones within a seed orchard, it may be expected that a fairly good genetic potential of the seeds produced in '77 plot of a seed orchard at Anmyeon island may be guaranteed. Observed results from the analyses of mating systems for the consecutive years of 2006 and 2007 in a '77 plot of the seed orchard may also provide useful information for the management in other plots of the seed orchards of Japanese red pines.

Key words: mating parameters, annual fluctuation, seed orchard, Japanese red pines, cpSSR, nSSR

The Result of Clonal Test of Teak (*Tectona grandis* L.f) at 9 Years Old in Ciamis and Cepu Perhutani State Owned Companies, in Java Island, Indonesia

Bintarto W.W.[1] and Mohamad Na'iem[1]

[1]Faculty of Forestry, Gadjah Mada University

Abstract: Clonal test is an essential method in tree improvement program in order to determine good genetically improved materials selected from plus trees. These selected clones will be developed as material for clonal forestry. The research was aimed to identify the best clones in two clonal tested sites and estimated the genetic gain on tree height, diameter at breast height (dbh) and stem form characters. The research was conducted two clonal test sites, namely Ciamis, West Java (volcanic, latosol/inceptisol soil, 2,740 mm/year rain-fall) and Cepu Central Java (limestone, vertisol soil, 1,436 mm/year rain-fall) of Perhutani Forest District in Java. These clonal test plantations was established in 1999 as joinly corporation research between Perhutani State Owned Company and Faculty of Forestry. Universitas Gadjah Mada, Yogyakarta. Clones with good performance in sprouting and rooting ability as genetic materials were selected from the hedge orchard of teak in Cepu. The clonal tests was designed using a Randomized Complete Block Design, 4 tree-plots, 5 blocks, 3 x 3 meters initial spacing. There were 50 clones tested in Ciamis and 65 clones tested in Cepu. Data of height, dbh and stem form were measured. A score system (1-6) was applied to observe the stem form. The results showed that genetic variation among tested clones in Cepu and Ciamis sites and combination of both sites on tree height, dbh and stem form characters. Clone-site interaction showed significant different of height and stem form but no different in dbh traits. The best 7 clones based on selection index of tree height, dbh and stem form traits in Cepu were: 97, 110, 24,20, 91, 72 and 37. Whereas in Ciamis were 97,207,6317,24 and 96 respectively. Broad-sense heritabilities of tree height, dbh and stem form were 0.65, 0.55 and 0. 61 in Cepu; 0.68, 0.52 and 0.54 in Ciamis and 0.79, 0.58 and 0.61 in both sites, respectively. The best 7 clones selected on diameter trait showed the highest genetic gain, i.e., 13.27% in Cepu, 13.51% in Ciamis, and 13.82% in both sites respectively. Positive genetic correlations were indicated among traits i.e., dbh - tree height, dbh - stem form and tree height – stem form. It was concluded that the genetic factor played more important role compared to environmental factor in dbh trait, and the best 7 clones potentially can be used for increasing productivity of large scale teak clonal forestry in Indonesia.

Key words: clonal test, heritability, genetic gain, genetic correlation, clonal forestry

Screening for effectiveness of fourteen ectomycorrhizal fungi on growth of *Eucalyptus pellita* F. Mull seedlings

Nelly Siababa-Aggangan[1,3], Heung-Kyu Moon[1], Mu Seok Han[1] and Sim-Hee Han[2]

[1,2]Biotechnology Division and Department of Forest Genetic Resources, respectively, Korea Forest Research Institute, Suwon 441-350, Korea

[3]National Institute of Molecular Biology and Biotechnology (BIOTECH), University of the Philippines Los Baños 4031, College, Laguna, Philippines

Abstract: This study aimed to determine the effectiveness of fourteen ectomycorrhizal (ECM) fungi namely, *Amanita pantherina*, *Hebeloma cylindorsporum*, *Leccinum* sp., *Ramaria botrytis*, *Lyophyllum shimeji*, *L. fumosum*, *L. decastes*, *Tricholoma porderosum*, *T. portentosum*, *T. matsutake*, *Tuber puberulum* and two isolates of *Pisolithus tinctorius* in promoting growth and nutrient uptake of *Eucalyptus pellita* under glasshouse conditions. One month old *E. pellita* seedlings inoculated with ECM mycelia during transplanting into pots filled with autoclaved peat perlite vermiculite medium. Mycorrhizal plants grew better than the control counterpart. *Amanita*, *Hebeloma*, *Leccinum* sp. and *Ramaria* promoted significantly better plant growth than the control. *Amanita* promoted the highest leaf N, P, K and Na uptakes. *Lyophyllum decastes* promoted the highest root N, K, Mg, Ca and Na uptakes whereas PtMKACC promoted the highest root K, and leaf Mg, Ca and Na uptakes. *Tricholoma potentosum* was ineffective in promoting growth and nutrient uptake. Growth and nutrient uptake of plants inoculated with this fungus were lower than the control. Chlorophylls a, b and a+b were highest in plants inoculated with *Amanita* but comparable with the control. *Pisolithus* PtMKACC inoculated plants gave the highest carotenoid content which was significant as compared with the control. Transpiration rates and stomatal conductance were highest in the control plants. The results indicate that *A. pantherina, L. decastes* and *Pisolithus* PtMKACC can effectively promote growth of *E. pellita* seedlings under glasshouse conditions and that field trials should be conducted.

The status and prospect of forest tree breeding in China

Shen Xihuan

Beijing Forestry University, Beijing 100083 CHINA

Correspondence to shenxh@bjfu.edu.cn

Abstract: Tree breeding is a subject of technology, which strongly links with forest practice and its ultimate task is to provide superior planting materials for reforestation and afforestation. It has become a characteristic, well-formed branch of plant breeding. Traditional tree breeding comprises selection, testing and multiplication, which are well integrated into each other. Looking back to the past, forest tree improvement in China started with the introduction of exotic species, and inter-specific hybridization was carried out at the end of 40s of the last century. The first seed orchards of *Cunninghamia lanceolata* and *Pinus elliottii* were established in 1964. Forest tree improvement was rapidly and steadily developed during the period from 70s to 80s of the last century. Significant achievements have been made, which includes: Conservation of genetic resources; Introduction and reforestation of exotic species; Investigation of genetic variation within a species and selection of superior provenances; Setting up the key breeding cycle, *i.e.*, selection of plus trees - progeny testing - establishment of seed orchards; Selection of clones and setting clonal orchards up; Construction of a system producing improved stock all over the country. Up to now 15,000 hectares of seed orchards for more than 30 species, including conifer and angiosperm, indigenous and exotic species have been established. The facts clearly show that traditional tree breeding is an effective and strong means for forest plantation, it still plays an essential role in creating superior planting stocks at present time, although it itself should be improved with new, advanced techniques. The achievement, problem and solution are discussed in the paper.

Key words: China, tree breeding, seed orchard

Pathogenicity of the pitch canker fungus, *Fusarium circinatum* isolated from Japanese black pine and branch inoculations of mature *Pinus* x *rigitaeda* in a seed orchard

Kwan-Soo Woo[1,2]

[1] Department of Forest Resources Development, Korea Forest Research Institute, Suwon 441-847, South Korea

[2] Correspondence to woo9431@forest.go.kr

Abstract: A half-sib family of two 4-year-old seedlings of *Pinus* x *rigitaeda* was inoculated with each of 20 Japanese black pine isolates of *F. circinatum* (syn. *Fusarium subglutinans* f. sp. *pini*) from two pitch canker damaged sites in Jeju island, South Korea. Pathogenic variation of the isolates was determined based on the lengths of lesions developing on main stem subjected to the mechanical inoculations. Initial symptoms of needle damages were visible on most of the seedlings inoculated with FT isolates at two weeks after inoculation. There was no significant difference in mean lesion lengths among 20 isolates ($p = 0.217$). The mean lesion length on seedlings inoculated with isolate FS-8 was the shortest (1.28 cm) and that on seedlings inoculated with isolate FT-7 was the longest (4.49 cm), which was 82% greater than total mean (2.47 ± 0.9 cm). Some seedlings began to die 42 days after inoculation. All but one seedling inoculated with each of isolates FS-2 and FS-13 were dead by 68 days after inoculation. Using the most virulent isolate FT-7, 38 years old 11 natural selection *Pinus* x *rigitaeda* trees in a seed orchard in Jeju island were inoculated on branch to determine its variation in susceptibility to the pathogen. The 11 trees differed significantly ($p < 0.001$) in susceptibility to *F. circinatum* based on average lesion lengths measured 56 days after inoculation. However, there was no significant difference between the southern and northern branches ($p = 0.53$). We reisolated the fungus from inoculated branches of all trees tested.

Key words: pathogenic variation, fusarium, seed orchard, susceptibility

Complementary strategies for meeting future challenges of seed orchards

Yill–Sung Park[1,2]

[1]Natural Resources Canada, Canadian Forest Service, Canadian Wood Fibre Centre PO Box 4000, Fredericton, New Brunswick, E3B 5P7 Canada

[2]Correspondence to ypark@nrcan.gc.ca

Abstract: In the past 30 years, tree improvement programs around the world have contributed greatly to forest productivity and wood quality attributes of plantation forestry. The delivery of such improvement has been through seed orchards and this will continue to be the primary means of providing genetic improvement. However, seed orchards are often associated with several inefficiencies such as pollen contamination and unequal parental contributions. In addition, conventional breeding programs are usually long-term efforts involving multi-generation recurrent selection and testing that are generally expensive and time consuming.

The seed orchard concept must be modified in order to meet future challenges, including (1) flexibility to adapt to changing climate and product goals and (2) ability to manage genetic gain and plantation diversity. With recent developments and refinements in tree biotechnology, complementary and/or alternative breeding, testing and deployment strategies to meet these challenges have become available for several conifer species. Somatic embryogenesis, cryopreservation, and molecular genetic markers are such technology that can be used for conducting clonally replicated genetic tests, implementing Multi-Varietal Forestry (the use of tested tree varieties in high-value plantation forestry), simplifying breeding and selection schemes, studying pollen dynamics of seed orchards, providing an additional dimension for species conservation and restoration, and in research elucidating genetic response to biotic and abiotic factors. In addition to conventional seed orchard management procedures, the application of new technology and strategies for tree improvement and seed orchard programs will be discussed.

Establishment of plant regeneration protocols via somatic embryogenesis for three species in Araliaceae family

Heung Kyu Moon[1,3], Sun Ja Kim[2], So Young Park[1] and Yong Wook Kim[1]

[1] Forest Biotechnology Division, Korea Forest Research Institute, Suwon, Gyounggido 441-870, Republic of Korea

[2] National Gwacheon Science Museum, Gwacheon, Republic of Korea

[3] Correspondence to hkmoon@forest.go.kr

Abstract: The family Aaliaceae contains a number of valuable cash crop species. Some of the important members endemic to Korea are *Oplopanax elatus*, *Aralia elata*, and *Kalopanax septemlobus*. Among them, *O. elatus* has been over-harvested from the wild population and become endangered since it is a medicinal plant. The other two species are highly demanded as expensive spring vegetables in the market and thus over harvested too. Therefore, it is necessary to develop propagation system for the species so that farmers can cultivate them instead of harvesting wild population. Attempts have been made to develop an efficient propagation method via somatic embryogenesis. In the beginning, we developed the system for juvenile tissues including immature and mature embryos since the age of the tissue appeared to be critical for successful induction of embryogenic tissue. At present, we are modifying the system to be suitable for mature tissues by artificially rejuvenating them by either serial gratings or tissue selection. As for *A. elata*, somatic embryogenesis was induced from young leaves and petioles of juvenile trees in the beginning and now are induced from those of mature trees of 50 years old.

In *O. elatus*, a SE system was developed using immature and mature zygotic embryos. However, ET induction appeared to be dependent on the individual plant lines rather than on the SE medium used. One problem was a very low induction rate in ET induction from zygotic embryos. This problem was resolved by adopting a thin cell layer (TCL) culture system in which we prepare thin layered tissue from in vitro raised plants and culture them in the medium.

In *Kalopanax septemlobus*, SE system was developed using serial grafted tissues. Mature tree tissues more than 40 years old have shown the ET induction after 3rd consecutive graftings onto juvenile root stock. The ETs proliferated well and could be mass produced via normal somatic embryogenesis system. The efficiency of this culture system could also be dramatically improved when combined with a temporary immersion bioreactor culture system.

Key words: somatic embryo, rejuvenation, mature tree

Somatic embryogenesis of Korean fir (*Abies koreana*), a rare conifer in Korea

So-Young Park[1, 4], Sun-Ja Kim[3], Heung-Kyu Moon[1], Jeong-Ho Song[2] and Yong-Wook Kim[1]

[1] Forest Biotechnology division, Korea Forest Research Institute, Suwon, Republic of Korea

[2] Forest Genetic Resources division, KFRI, Suwon, Republic of Korea

[3] National Gwacheon Science Museum, Gwacheon, Republic of Korea

[4] Correspondence to soypark7@forest.go.kr

Abstract: Korean fir, one of the important Korean native conifers, grows in the southern Korea, especially on the tops of the Halla, Jiri and Songni Mts.. In recent years, it has been degenerating possibly due to climate change. For the conservation of this rare species, somatic embryogenesis could be used as an attractive option. In an attempt to establish somatic embryogenesis (SE) of Korean fir, fifteen seed families collected from Halla and Jiri Mts. as mature zygotic embryo (ZE) culture materials, and two from Korean National Arboretum as immature ZE culture materials were tested on various media to induce embryonal masses (EMs). Embryogenic cell lines were initiated from both immature and mature ZEs and maintained as proembryonal masses (PEMs) in the presence of cytokinin only. Many of the ZEs originated from Jiri Mt. were polyembryony and less than 4% of them produced EM while up to 15% of the ZEs from Halla Mt. produced EM from 7 of 10 seed families. Compared to mature ZEs, around 40% of immature ZEs produced EM that could be easily maintained. Among them, eight lines were transferred on maturation medium, and SEs developed from PEMs after withdrawal of cytokinins. However, three lines were developmentally arrested at the PEM-SE transition and thus could not lead to SE production. To help better understand the developmental aberrations at the late stage of embryogenesis, these arrested cell lines, together with normal lines, were used for studying the gene expression and cytological analysis. This work provides the somatic embryogenesis protocol of Korean fir that may be helpful to breeding and conservation strategies. Additionally it may contribute to the understanding of normal developmental process of SE in conifers.

Key words: embryonal mass, polyembryony, maturation

Top grafting of Scots pine – a tool for increased efficiency in the breeding program

Curt Almqvist

Skogforsk, Uppsala Science Park, S-751 83 Uppsala, Sweden

Abstract: In top grafting, new genetic material is grafted into the crown of ramets of older, reproductively mature clones. The resulting ramet consists of three parts with different genotypes, the rootstock, the inter-stock, and the top graft. The hypothesis is that the reproductive competence of the inter-stock will be transferred to the top graft scion.

Results on inter-stock effects, the effect of GA treatment of inter-stocks of top graft flowering, effect of top graft age, and effect of pretreatment of seedlings to be top grafted will be presented. Examples of how the method can be utilized to reduce time to flowering in different breeding strategies will be presented.

Effects of picking time on availability of seeds of *Cryptomeria japonica*

Seog-Gu Son[1*], Hyo-Jeong Kim[1], Chan-Soo Kim[1], Young-Je Kang[1], Kwang-Ok Byun[1] and Wan-Yong Choi[2]

[1]Warm-Temperature Forest Research Center, Korea Forest Research Institute, Seogwipo 697-050, Korea

[2] Korea Forest Research Institute, Seoul 130-712, Korea

[3] Correspondence to sonsak@forest.go.kr

Abstract: Sound seeds should have good germination rates and seed germination could be influenced by some factors. Seed picking time is regarded as one of the elements to obtain sound seeds. From a clonal seed orchard of *Cryptomeria japonica* located in southern part of Korean peninsular, cones were picked every about 10 days from 30th of July to 30th of October. From picked cones, seeds were collected and seed germination ability, seed size and embryo shapes were investigated according to cone picking time. The weight of one seed picked at 18th of August, and at 30th of September, was 3.3 g, and 5.3 g, respectively. The size of seeds picked from 18th of August to 30th of September was increased from 19.3 mm to 21.3 mm in length and from 15.8 mm to 18.5 mm in width. Depending on picking time, various shapes of embryos such as liquid material, something jellied one and fully matured ones were observed. Germination aspects also varied throughout the test days. About two weeks later of seeding in a glass petri-dish, germinal apparatuses appeared from the each test seeds sets which had been picked from after at the 10th of August. The germination rates could be calculated started from 13.3 % from seeds picked 20th of August. The highest germination rate was 34.3 % from the seeds picked from 30th of September and after that it was decreased. The results implied that, in Korean *C. japonica* seed orchard, the best cone picking time could be around the end of September.

Key words: seed orchard, seed size, germination rate, sound seed

Increased seed productivity of *Pinus koraiensis* seed orchard trees through stem pruning without seed component change

Jae-Seon Yi[1,5], Chul-Woo Kim[1], Huyn-Suk Lee[1], Chan-Hoon An [1],Jeong-Ho Song[2], Kyu-Suk Kang[2], Chang-Soo Kim[2], Sang-Urk Han[2], Tae-Su Kim[3] and Tae-Heum Shim[4]

[1] College of Forest and Environmental Sciences, Kangwon National University, Chuncheon 200-701, Republic of Korea

[2] Department of Forest Resources Development, Korea Forest Research Institute, Suwon 441-850, Republic of Korea

[3] Korea Forest Seed and Variety Center, Chungju 380-941, Republic of Korea

[4] Gangwon Institute of Health and Environment, Chuncheon 200-822, Republic of Korea

[5] Correspondence to jasonyi@kangwon.ac.kr

Abstract: The investigated seed orchard was established in 1982 and leader shoots were pruned at the height of 1m or 2m above the ground in 1996. To investigate the effect of stem-cut on seed production and quality, some characteristics of cone, seed and seed component of stem-cut trees were analyzed and compared with those of un-cut trees in the same seed orchard. Cones were collected from 1999 to 2004, and traits were measured and analyzed later, while every trait was not investigated every year. The general component analysis followed the methods of AOAC and fatty acids were investigated by gas liquid chromatography. The results obtained in percentage (%) were changed to angles following the arc sine transformation and then analyzed. The combined results were summarized as follows:

Regarding cone traits, cone fresh weight, width and seed weight per cone were significantly different among crown control methods. Cone fresh weight, length and width were 204.5~420.0g, 11.5~16.6cm, 6.4~8.4cm, respectively. Seed number per cone and seed weight per cone were 100.5~177.6 and 57.6~124.2g, respectively. In all these traits, un-treated trees showed the best performance among three treatments, while trees pruned at 2m above soil performed better than those at 1m. However, the highest observation was found throughout the traits in the data collected from trees pruned at the height of 2m.

Seed length, width and weight were 13.7~15.7mm, 9.1~10.4mm and 0.41~0.59g, respectively. The trend was found that trees pruned at the height of 2m produced in general the smallest seed, while the un-cut trees the largest seed. For three seed characters, high variation was observed in the seeds of the former trees; and small variation in the latter. A highly positive correlation was observed between seed and cone traits.

Number of cones per tree ranged from 18.3 (un-treated) through 31.7 (stem-cut at 1m above) to 40.4 (stem-cut at 2m above). However, there was a huge variation, that is, from 0 to 107 cones per tree. For 2m top-pruned trees, 1m top-pruned ones and un-cut ones, total seed production per tree (seed weight per cone × number of cones per tree) was around 3773g, 2580g, and 1870g, respectively, which indicates that stem pruning can improve cone productivity of a tree.

No significant differences were found among treatments and among years in ash (1.67~2.48%), crude lipid (56.57~72.53%), crude protein (12.75~19.55%), and carbohydrate (3.77~8.41%). Linoleic acid (18:2) (46.26~55.25%) and oleic acid (18:1) (27.19~32.45%) were the most common components of the fatty acids. All seeds from each treatment contained two essential fatty acids, i.e., linoleic acid and linolenic acid (18:3) (12.78~14.21%). Difference among treatments was detected only in palmitoleic acid (16:1) (0.00~0.08%) and 8,11,14-eicosatrienoic acid (20:3n6) (0.00~0.12%) in 2000 and in linolenic acid in 2001. However, there were no differences in all fatty acids analyzed among treatments in 2002. In every seed, 5,9,12-pinoleic acid [18:3 (γ)] characteristic to Korean white pine seed was found. It may be concluded that stem-pruning gave no significant influence on general seed component and fatty acid composition.

It is highly encouraging to develop crown control methods as those in fruit trees to increase the productivity and facilitate the collection of cones in Korean white pine seed orchards together with research on early maturation and apical dominance control for the future generation seed orchard.

Key words: Korean white pine, cone, seed, trait, general component, fatty acid, crown control

Global warming and seed orchards with special reference to Sweden

Dag Lindgren[1,2]

[1]Department of Forest Genetics and Plant Physiology, The Swedish University of Agricultural Sciences, SE 90 183 Umeå, Sweden
[2]Correspondence to Dag.Lindgren@genfys.slu.se

Abstract: Global warming is on every-ones mind, what are the genetic consequences for plant production and seed orchards in Sweden? Man's activities add considerably to the uncertainty about future environments compared to variations in the past. A warming the next century should be regarded a sufficiently safe prediction to motivate immediate actions. More seed orchards constitute a recommended response to global warming, as they supply a more robust, predictable, reliable and controllable seed source. Seed orchards can be modified for climate prognosis immediate before seed harvest by rouging, selective harvest, supplementary pollination or artificial crosses. Natural regeneration cannot be regarded as well-adapted any more, seed orchards now become more competitive. The addition of around 20 percent to forest production added by improved material means a better utilization of the forest resource, which is a major component for a future sustainable world supported by renewable resources.
The recruitment population is routinely tested at several localities covering a range of environments, and is accumulated over several generations of testing at different times. This means that forest tree breeding produces seed orchard clones, which are plastic and adapted over a range of environments. The clones can be drawn from a range as a response to a predicted wider uncertainty.

Current recommendations for use of seed sources are based on provenance experiments deployed and analyzed several decades ago, neither considering the warming, which has already occurred, nor the predicted additional warming in the future. The speed of temperature rise in Sweden relevant to seed sources I set to one degree 1991-2040 starting 1990. Other factors are also likely to change also

(maritimity, precipitation, patterns of pests and pathogens), but quantitative predictions are highly uncertain and the response for seed source within species can not be safely predicted, so the only safe-guard to these other possible associated changes is to make seed orchard crops robust to change. Half a degree warming (quarter of a century) may already have happened or occur in the near future. At planting, the critical period is the years immediately after planting, if the forest establishes well, it will probably grow acceptable in a warmer climate, at least where drought is not serious. In response to global warming it is recommended that seed sources are deployed at a higher elevation than now rather than transferred longer north, as north transfer also affect light climate. When establishing new seed orchards, the foreseen planting is several decades ahead and my recommendation is to care for a one degree warmer climate. A principle should be that changes seem safe, that they are unlikely to over-compensate for global warming and they will have marginal effects. The consequences of a one degree change will limited. But if no change is made now and it becomes still warmer, there is a penalty for waiting with the change. Besides that, it is politically correct to respond to global warming.

Long term procurement of Swedish improved seed with respect to climate change

Finnvid Prescher[1,2]

[1]Svenska Skogsplantor AB, Seed production, SE-340 14 Lagan, Sweden

[2]Correspondence to finnvid.prescher@skogsplantor.se

Abstract: It seems now undoubtly that a climate change will affect our future forests. When the temperature rises, it is likely that other species, e.g. larch, Douglas fir and different broadleaved species will be more interesting in southern Sweden. A positive effect in northern Sweden will be that the survival when planting rises. Another positive effect is that the possibility for seed maturation in the northernmost parts increases, which gives a possibility to establish seed orchards in more northern locations then today. A northern establishment means that the penalty of contaminating pollen will decrease. Negative factors that are likely to affect the forests are e.g. increased risk for drought and/or precipitation, occational storms etc.

In this paper an outline of the long term procurement of improved seed for our company is presented and how the climate change affects our decisions. The rotation age in Swedish forests is between 60 and 120 years for southern and northern Sweden respectively. During this rotation age the temperature will probably rise with two degrees if the global warming continues as today. However, since the optimal life time of a Swedish seed orchard, with respect to genetic progress, only is 30 years for Scots pine and 40 years for Norway spruce it is not worthwhile to adapt the seed to the climate during the whole rotation age. Thus, the produced seed from orchards established today should be adapted to a one degree higher temperature at planting between years 2025-2045 for pine and years 2030-2055 for spruce.

A programme with establishing new seed orchards is ongoing, and ends at 2014. Approximately half of the planned orchards are already planted or started with cutting propagation or grafting. But for the remaining orchards in the programme it is still possible to take the climate change into account when selecting clones. Consequently, a continuous programme for establishment of new seed orchards should start directly after 2014 for replacement of the orchards established earlier.

Poster presentation

Fertility variation and gene diversity in seed crops of *Eucalyptus* and *Casuarina* seedling seed orchards in southern India

Kamalakannan, R[1], Varghese, M[1], Chezhian, P[2], Ghosh, M[3]. and Lindgren, D[4]

[1]ITC R&D Centre, Spark Tower, SP Biotech Park, Shameerpt, Hyderabad 500 078, India, kamalakannanr@yahoo.com, mvarghese1@rediffmail.com

[2]Tamilnadu News Print and Papers Ltd, Kagithapuram, Karur 639 136, India, chezhian2724@gmail.com

[3]Institute of Forest Genetics and Tree Breeding, P.B. No. 1061, Coimbatore 641002, India, modhumitaghosh@hotmail.com

[4]Department of Forest Genetics and Plant Physiology, Swedish University of Agricultural Sciences, SE 901 83, Umeå, Sweden, dag.lindgren@genfys.slu.se

Abstract: Four seedling seed orchards each of Eucalyptus (two each of *E. camaldulensis* and *E. tereticornis*) and Casuarina (two each of *C. equisetifolia* and *C. junghuhniana*) located at climatically different sites in southern India were evaluated at four years for fertility variation and its impact on the seed crop. Diversity of the seed orchard crops was compared with that of natural provenances and local land race seedlots using DNA (Inter simple sequence repeat) markers.

The frequency of flowering trees was low in the Eucalyptus orchards (less than 30%) except in one orchard which had 73% flowering trees. The sibling coefficient (Ψ) in the orchards varied from 2.2 to 17.4 and the corresponding relative effective population size, *Nr,* varied from 0.45 to 0.06. Casuarina orchards on the other hand had high fertility with more than 80% fertile trees except in one *C. junghuhniana* orchard which had only 45% flowering trees. Fertility variation in Casuarina was higher in the inland location (Ψ=5.8 & 7.6) compared to the coastal site (Ψ=2.7 & 2.9). *Nr* values ranged from 0.17 to 0.36.

Analysis of molecular variation in the Eucalyptus seed lots revealed that 65% of the variance was between seedlots and 35% occurred within the seedlots. In Casuarina seed crops it was 54 % and 46% between and within the seedlots. Cluster analysis and principal component analysis revealed 3 major groups in each

genus with the orchard seedlots of each species clustering separately from the natural and local land race seedlots.

The percentage polymorphic loci in the Eucalyptus seed orchard crops was higher (26.1 to 30.7%) than for a bulk seedlot of natural *E. camaldulensis* provenances (17.9 %). In Casuarina, the % polymorphism in the orchard seedlots varied from 8.3 to 29.9%. The local land race had comparatively lower molecular diversity than the orchard seedlots in both genera. Remarkable genetic differentiation and low levels of gene flow was detected in native provenances due to geographic isolation. In contrast there was low genetic differentiation between the seed orchard crops. The natural provenance seedlots of both genera clustered independently, which supports the need for adequate isolation distance for breeding orchards.

Key words: Casuarina, Eucalyptus, Seed orchard, Fertility variation, Genetic diversity

Facing future needs of wood production with improved material of the third conifer in Swedish forests

Johan Kroon[1,2], Ola Rosvall[2] and Tore Ericsson[2]

[1]Department of Forest Genetics and Plant Physiology, Swedish University of Agricultural Sciences, 901 83 Umeå, Sweden

[2]Skogforsk, Box 3, SE-918 21 Sävar, Sweden.

Abstract: Planting lodgepole pine (*Pinus contorta,* LP) is the most efficient way of increasing the forest production in northern Sweden (+30–40%). LP is already by far the most planted exotic tree species in Swedish forests. A large-scale introduction started around 1970 and was accompanied by thorough collections of seed material and comprehensive research. The use of LP peaked in the late 1980s, but the annual planting area has decreased significantly since then. LP plantations cover today about 600 thousand hectares. Now, reforestation with LP is again increasing. LP is easy to handle in any breeding strategy, due to the early, male and female, flowering and good capability to root cuttings. LP is suitable for strategies employing clone testing and short generation turnover. Significant breeding activities in LP in Sweden began in the end of the 1970s, when a seed orchard program was initiated with intention to make Sweden self-supporting with genetically good LP base material and seed sources. The program included plus tree selection in Canada, genetic testing of open-pollinated families in field tests in Sweden, and establishment of six seedling seed orchards for genetic rouging. Also, a limited number of plus trees that were grafted earlier in the very first Swedish seed orchards were incorporated in the new program. After 10 years the field tests were evaluated and close to 3000 F1-candidate trees were phenotypically selected among the best op-families and grafted into breeding archives. The candidate trees originate from about 940 Canadian mother-trees and an unknown number of op fathers representing a huge gene pool. Currently, pair crosses are carried out among the candidate trees (F1), using positive assortative mating (PAM) with regard to mother breeding values, and the first F2-field trials have been planted. This strategy allows for combined

backward and forward selection, best utilizing resources already invested giving good options for further long term breeding and selection for seed orchards. With clone tests a new generation is formed with little time delay by forward selection among and within families. The clonal testing is applied on a large scale and will substantially increase the accuracy of forward selection in the F2-tests. The LP breeding meta-population will be structured following a multiple population strategy with 11 separate breeding populations that cover climatic differences of Sweden. Each closed population has at least 50 parents giving a meta-population of more than 550 trees. In order to immediate secure future needs of improved seeds, while awaiting the next breeding step, the second round of seed orchards is now being established using grafted seed orchards to replace the seedling seed orchards. By using result from the field test, high gain is reached by combining progeny tested (backward selection) old plus trees with phenotypically tested (forward selection, within-family) young plus-trees. The gain is estimated to be 23%. In 15 years, after evaluation and selections in currently planted clone tests, new seed orchards are estimated to give 32-36% genetic gain.

History and breeding program of exotic tree species in Korea

Hyung-Soon Choi[1,2], Keun-Ok Ryu[1], In-Sik Kim[1], and Do Hyun Cho[1]

[1]Dept. of Forest Resources Development, KFRI, Suwon, 441-847, Republic of Korea

[2]Correspondence to forgene@forest.go.kr

Abstract: Exploitation of forests during the Japanese rule over and Korean War, the most forests of Korea were heavily devastated, so introduction tree species from other countries was required for afforestation and restoration. Breeding program for exotic tree species has been started from 1924 in Korea. A series of adaptation tests of exotic tree species has been established for 415 exotic tree species were introduced from 38 countries during 1958 to 1995 and tested for the adaptability at about 230 experimental locations. However, under the absence of the consideration of the environmental conditions (distributional range, growth characteristics, soil conditions, and climate conditions, and so on), the hasty introduction from other countries and plantations of exotic species had many problems. Thus most tree species were rejected to be wrong introduction. Among those tested, 392 species were regarded as unsuccessful introduction due to bad adaptation (cold tolerance, damaged by insect attacks, etc.) and had poor growth performance in Korea. Some of them, several tree species had very good performance. *Populus euramericana* (I-214 and I-476 from Italy, V-211 from Belgium), *Alnus inokumai* (Japan*),* Pines (*P. taeda*, *P. virginiana*, and *P. strobus*, USA), red oaks (*Q. rubra* and *Q. palustris,* USA), and *Lirodendron tulipifiera* (USA) were approved to be successful introduction species in Korea. With the standard process (test plantation→ provenance test with small scale→ provenance test with large scale), these promising species have been studied. For the future of forest, the researches for the selection of a superior provenances and the development of seed orchards (seed production stands) of good species are in process.

Key words: exotic tress species, provenance tests, development of seed production, adaptation and performance

Comparison of pollination efficiency on different pollination methods in yellow poplar (*Liriodendron tulipifera* L.)

Keun-Ok Ryu[1,2], Hyung-Soon Choi[1], Hae-Yun Kwon[1] and Do-Hyun Cho[1]

[1] Dept. of Forest Resources Development, KFRI, 441-847, Suwon, Korea

[2] Correspondence to koryu95@forest.go.kr

Abstract: Yellow poplar (*Liriodendron tulipifera* L.) is an insect-pollinated species with large, perfect flower. The fruit is an elongated cone composed of 60 to 100 overlapping carpels. Individual carpels have the potential for producing two seeds, but in most cases one of the embryos aborts. Natural seed sets average only about 10 percent. In controlled pollination of yellow poplar, pollination bags are usually taken to prevent unwanted pollination. However, bagging is an expensive and time-consuming process, especially if an extensive breeding or seed production effort is contemplated. Therefore, this study was conducted to determine the effect of the pollination bag on seed set following controlled pollination and estimate how much pollination would occur if emasculated flowers were not protected by pollination bags. Six mother trees (25~30 years old) and four pollen trees (37 years old) with high growth performance were selected at Suwon and Pochun plantations, respectively. Four different pollination methods were applied to this experiment; i.e. 1) open pollination as a reference, 2) open pollination; emasculated (removing sepal, petal and stamen), without bagging, 3) controlled pollination; emasculated, with bagging and 4) controlled pollination; emasculated, without bagging. In typical open pollination (method 1), full seed rate was 8.6%, similar to that of place of origin. In method 2, the lowest value of full seed rate (0.2%) was observed. It was suggested that removing stamen and petal restrict the activity of pollen vectors like bee. In emasculated controlled pollination, the full seed rate of method 3 (with bagging) and method 4 (without bagging) were 27.9% and 24.0%, respectively. It was thought that conventional controlled pollination method (method 3) has the lower pollen contamination rate than method 4. However, pollen contamination rate of method 4 was low at about 0.2%. This level of contamination would be acceptable in a large scale seed production. Thus, controlled pollination without bagging was an alternative method for extensive breeding and mass production of seeds in yellow poplar.

Key words: pollination, bagging, pollen contamination, seed quality

Different growth pattern between superior and inferior family of *Pinus densiflora*

Chang-Young Oh[1,2], Sang-Urk Han[1], Kyu-Suk Kang[1], Chang-Soo Kim[1] and Byoung-Hwan Cheon[1]

[1] Dept. of Forest Resources Development, Korea Forest Research Institute, Suwon 441-847, Republic of Korea

[2] Correspondence to chang05@forest.go.kr

Abstract: We compared growth pattern between superior and inferior family of open-pollinated *Pinus densiflora* progenies to figure out their growth responses to environmental conditions. We planted three different sites, Chuncheon, Gongju, and Naju, in 1981. Family rank was determined from our previous study, CB2 is superior and KW19 is inferior family. We collected wood disk to perform stem analysis in 2008. And we analyzed soil properties in 2007 and collected climatic data from 1981 to 2008. Soil properties for plant growth were proper in Chuncheon and the other sites were unsuitable. And climatic factors were not suitable in Naju, there were extremely drought period from 1994 to 1996. There was not significant difference in height growth between superior and inferior family in Chuncheon site, but in Naju superior family showed almost 2-times higher to inferior family. On the other hand, diameter growth showed different pattern to height growth. CB2 in Gongju showed highest growth amount and KW19 in Gongju also showed higher than the other sites. There was no difference of planting density among sites, so these different in growth patterns were caused by genetic factors and it's interaction with environmental conditions. There are different mechanisms which control height and diameter growth. So we can establish the sublines for purpose of use.

Key words: *Pinus densiflora*, growth pattern, stem analysis, height growth, diameter growth

Variation of $\delta^{13}C$ in tree-rings between superior and inferior family of *Pinus densiflora*

Chang-Young Oh[1,2], Sang-Urk Han[1], Kyu-Suk Kang[1], Chang-Soo Kim[1] and Byoung-Hwan Cheon[1]

[1] Dept. of Forest Resources Development, Korea Forest Research Institute, Suwon 441-847, Republic of Korea

[2] Correspondence to chang05@forest.go.kr

Abstract: We compared the variation of $\delta^{13}C$ in tree-rings between superior and inferior family of open-pollinated *Pinus densiflora* progenies to figure out their physiological responses to environmental conditions. We planted three different sites, Chuncheon, Gongju, and Naju, in 1981. Family rank was determined from our previous study, CB2 is superior and KW19 is inferior family. We collected wood disk at breast height to analyze carbon stable isotope composition in 2008. Then we compared each data to climatic factors (annual mean temperature and annual mean precipitation) from 1981 to 2008 and soil properties. For past 30 years $\delta^{13}C$ showed decreasing pattern. In Naju, there were extremely drought period from 1994 to 1996 and that times temperature showed higher degrees. So $\delta^{13}C$ of CB2 and KW19 increased in that period. In Gongju site, $\delta^{13}C$ of CB2 decreased continuously but $\delta^{13}C$ of KW19 increased during early 1990s and 2000 when there were drought conditions. Inferior family showed more sensitive response to environmental conditions. And *Pinus densiflora* is the frontier species which is low demand of soil fertility. In our results *Pinus densiflora* showed sensitive to climatic factors, especially drought. But superior family is less sensitive than inferior family. In the situation of global warming and climatic change, we need breeding our native species to conservation and increase wood production.

Key words: *Pinus densiflora*, $\delta^{13}C$, drought, physiological response

Within-plot selection for production of quality seeds in seedling seed orchard of *Dalbergia sissoo* (Roxb.)

Ashok Kumar[1], R. K. Luna[2], Shivani Dobhal[1] and Vijay Kumar[2]

[1]Division of Genetics and Tree Propagation, For. Res. Inst., Dehradun 248 195, India

[2]Research Wing, Punjab Forest Department, Forest Campus, Hoshiarpur, Punjab, India

Abstract: *Dalbergia sissoo* (Roxb.) is grown historically in Indian sub-continent as one of the most reliable timbers found in India, and well recognized for its elasticity, strength and durability. The native species thrives well upto 900 m in sub-Himalayan tracks between latitude 21.17^0 N to 32.06^0 N and longitude of 74.8^0 E and 93.4^0 E along the rivers and streams. Main limitations in its plantations pertain to poor stem form (crooked stem), forking, ramicorn branching and poor growth. Though considerable research has been carried out on various aspects of its utilization, physical and mechanical properties, durability, seasoning behaviour, wood making and finishing properties, there is little known about its successful genetic improvement work. The availability of improved seed for various afforestation programmes has therefore been a limitation. Keeping this in view, systematic selection of plus trees was carried out in the natural populations of its growing range of India and Nepal. The selected trees were established in the gene banks and propagated clonally to establish in the clonal gardens. In 1997-98, a seedling seed orchard (SSO) consisting of most promising thirty four progenies was established at Mattiwara, Punjab (India) in completely randomized block design with six replications and five plants in a row. The mid term assessment of SSO was carried out during 2007-08 by developing selection index using five traits *viz.* DBH, Height, CBH, Straightness and Health for each of the progeny. Within plot selection was conducted with around 50% selection intensity and the selection differential was recorded to 2.25, 1.48, 0.51, 0.60, and 0.64 for DBH, Height, CBH, Straightness and Health, respectively. Two most promising traits of height and diameter at breast height (DBH) were used for further analysis of different genetic parameters both in base populations and retained population after culling of undesired individuals. The low narrow sense heritability was recorded for height (0.0525) and DBH (0.1186) in base population and had improved to 0.3008 and 0.3843, respectively in retained population. Similarly, the genetic advance was improved from 2.43 to 5.14 and from 9.29 to 11.68 respectively for height and DBH with net genetic gain of 10.20 and 13.47 %. Thus the seed collected from the rouged SSO is expected to produce quality seed to meet the demands of the growers.

Key words: *Dalbergia sissoo* (Roxb.), seedling seed orchard, heritability, within plot selection, genetic advance, genetic gain

Progress and developing strategy of masson pine improvement in Fujian province in China

Wang Zhangrong[1,3] and Qiu Jinqing[2]

[1] Key Laboratory of Forest Genetics and Biotechnology, Nanjing Forestry University, Nanjing Forestry University, 159# Longpan Road, Nanjing 210037, China

[2] General Station of Forest Tree Seeds and Seedlings of Fujian Province, Fuzhou 350003 China

[3]Correspondence to zrwang@njfu.edu.cn, pzrwang@126.com

Abstract: Masson pine (*Pinus massoniana* Lamb.) is indigenous species in southern China with the important commercial species. It has a widely distributed in 18 provinces from Zhejiang, Fujian in the south-east to Guizhou, Sichuan in the south-west China and has an area of 2,000,000 hm^2. In Fujian Province, masson pine is one of the most representative trees, and holds an important position in forest ecology and commercial timbers production. Since the beginning of the last century 80's has been a comprehensive improvement of provenance research, selection of plus trees, progeny testing and establishment of seed orchards in Fujian province. Through first breeding cycle, the masson pine trees improved from mix seedlots of unrogued and rogued the first generation seed orchard exhibited a 10-15 percent gain in volume when compared to the unimproved materials. Now there must be a quick turnover of generations combined with backward selection and forward selection, from the first generation to second and third generation of the conversion period. Composition and establishment of breeding population, selection of mating designs, genetic testing procedures as well as science and technology collaboration arrangement are focused on in this paper.

Key words: Tree Improvement, Breeding Population, *Pinus massoniana*, Mating Designs, Progeny Testing

The variation of leaf characteristics among 35 half-sib families in a seed orchard of *Quercus acutissima*

Byoung-Hwan Cheon[1], Kyu-Suk Kang[1,3], Sang-Urk Han[1], Chang-Young Oh[1], Chang-Soo Kim[1] and Kae-Hwan Kim[2]

[1] Dept. of Forest Resources Development, Korea Forest Research Institute, Suwon 441-350, Korea

[2]Division of Forest Science, Forest Resources Major College of Agriculture and Life Sciences, Chonbuk National University, Chonju 561-756, Korea

[3]Correspondence to kangks@forest.go.kr

Abstract: In the present study, leaf morphological characteristics among 35 open-pollinated families were analyzed in a seedling seed orchard of *Quercus acutissima*. Leaves were collected from three different positions (upper, middle and lower part of crown position) and four different directions (east, west, south and north) at the middle part from a progeny of 35 families, and leaf morphology was analyzed. On the positions, there was a highly significant difference among families, and interaction between family and position was statistically significant. Significant differences were found between three positions in most leaf characteristics except depth of serration, ratio between serration number and leaf length, and leaf area. On the directions, the significant differences were also found and statistically significant among families but there was no significant difference among directions in the leaf characteristics. Interaction between family and direction was statistically significant.

Key words: leaf characteristics, genetic variation, breeding seed orchard, sawtooth oak, open-pollinated family

Genetic variation of height and root collar diameter growth in an early-age of *Agathis loranthifolia* in west Java, Indonesia

Kyu-Suk Kang[1,4], Song-Hee Nam[2], Eduardo P. Cappa[3] and Eul Sun Baik[1]

[1]Department of Forest Resources Development, KFRI, Suwon 441-350, Republic of Korea

[2]Hongcheon National Forest Managment Station, Kore Forest Service, Hongcheon 220-719, Republic of Korea

[3]Instituto Nacional de Tecnología Agropecuaria (INTA), Instituto de Recursos Biológicos, Los Reseros y Las Cabañas s/n, 1712, Castelar, Buenos Aires, Argentina

[4] Correspondence to kangks@forest.go.kr

Abstract: Early results from a field trail of *Agathis loranthifolia* are reported from a progeny test of 100 open-pollinated families in west Java, Indonesia. The average of height and diameter at root collar (DRC) growth was 40.18 cm and 0.518 cm at age 15 months, respectively. Family survival rate decreased from 86.5 % at age 10 months to 81.7 % at age 15 months. As expected, family means of 10 best and 10 poorest families for each trait indicated that there was a large difference of growth performances among individual families. For height and DRC growth, the poorest groups had averages of 33.979 cm and 0.4343 mm while the averages of the best groups were 47.352 cm and 0.6239 mm at age 15 months, respectively; a difference of 39.36 % and 43.65 %. Differences between the best group and the test population mean, which is the selection differential, were implying that genetic gain from selection for the improvement of height and DRC growth would be achieved. Highly significant difference of height and DRC growth at ages of 0, 10 and 15 months, among the 100 families were found. The family variances of DRC and height were relatively small compared to replicate and residual variances. Family heritabilities for both studied traits were fluctuated, and the genetic coefficients of variation for DRC and height at age of 15 months were 7.19 % and 5.22 %, respectively. Highly significant phenotypic correlations were found between DRC and height for all ages. Based on the progeny performances, it would be expected that there would be the greatest opportunity to improve the genetic gain by increasing selection differential.

Key words: genetic component, heritability, correlation, breeding strategy

Estimation of aboveground biomass for mature *Castanopsis cuspidate* var. *sieboldii* natural stand

Jin-Kie Yeo[1,4], Hanna Shin[1,3], Yeong-Bon Koo[1], Hyun-Chul Kim[1], Jung-Hyun Park[1] and Young-Jae Kang[2]

[1] Department of Forest Resources Development, Korea Forest Research Institute, Suwon 441-350, Korea

[2] Warm-temperature Forest Research Center, Korea Forest Research Institute, Jeju 697-050, Korea

[3] School of Forest Sciences, Seoul National University, Seoul 151-921, Korea

[4] Correspondence to jkyeo@forest.go.kr

Abstract: Measurement of forest biomass plays an important role to understand the global carbon and nutrition budget. *Castanopsis cuspidate* var. *sieboldii* is one of the dominant evergreen broad-leaved tree species in the southern part of Korea. To assess biomass of *Castanopsis cuspidate* var. *sieboldii* natural stand, a total of ten trees in Jeju Island were selected by stratified random sampling, which ranged from 4.5 to 34 cm in DBH and 5.9 to 13.0 m in height. The trees were harvested for development of regression equation to estimate aboveground biomass (AGB). The percentage of live stem bole, branch and leaf were 67.8 %, 25.3 % and 6.9%, respectively, and these components were positively correlated with DBH. The regression between DBH and AGB showed high r^2 (r^2=0.997) with statistical significance ($P<0.01$). Standing AGB was estimated in 77.9 Mg ha^{-1} by the regression model. Annual standing AGB was estimated from 2.5 to 4.3 Mg ha^{-1} $year^{-1}$ based on annual changes in DBH for the latest five years.

Key words; *Castanopsis cuspidate* var. *sieboldii*, aboveground biomass, annual biomass

Interspecific and interclonal evaluation of poplars for short-rotation biomass production

Hanna Shin[1,2,3], Jin-Kie Yeo[1], Yeong-Bon Koo[1], Hyun-Chul Kim[1] and Jung-Hyun Park[1]

[1]Department of Forest Resources Development, Korea Forest Research Institute, Suwon 441-350, Korea

[2] School of Forest Sciences, Seoul National University, Seoul 151-921, Korea

[3] Correspondence to hannashin@forest.go.kr

Abstract: Twelve cloens of six hybrid poplars (*Populus alba* × *glandulosa*, *P. nigra* × *maximowczii*, *P. euramericana*, *P. koreana* × *nigra* var. *italica*, *P. deltoides* × *deltoides* and *Salix alba*) were compared to select superior clones producing maximum aboveground biomass under three different rotation times for eight years. Biomass production varied with clones as well as rotation times applied. Survival rates were decreased in all plots by years and the annual rotation plot showed drastic mortality after the first harvest. *P. koreana* × *nigra* var. *italic* showed excellent biomass production in all rotation times ranged from 10.2 to 18.9 Mg ha^{-1} $year^{-1}$. *Populus alba* × *glandulosa* demonstrated maximum dry weight in biannual rotation plot (19.4 Mg ha^{-1} $year^{-1}$). Biannual roation was the most optimal harvesting time when considering average annual biomass production, however, it was very varied by species and clones.

Key words: poplar biomass, short-rotation harvest, dry weight, rotation time

Growth characteristics of fast growing tree species treated with swine wastewater

Hyun-Chul Kim[1], Jin-Kie Yeo[1,2], Yeong-Bon Koo[1] and Jung-Hyun PArk[1]

[1]Department of Forest Resources Development, Korea Forest Research Institute, Suwon 441-350, Korea

[2] Correspondence to jkyeo@forest.go.kr

Abstract: This study was conducted to analyze the growth responses of fast growing tree species (8 clones of hybrid-poplars, *Salix alba*, *Metasequoia glyptostroboides*, *Liriodendron tulipifera*, *Acer okamotoanum*, and *Quercus palustris*), the chemical characteristics of soil, NO_3-N concentration of groundwater in a plantation irrigated with swine wastewater. Concentration of nitrogen and phosphorus in the soil treated with swine wastewater was higher than those of the soil treated without swine wastewater. With the exception of *S. alba*, diameter at breast height (DBH) growth of all the fast growing tree species treated with swine wastewater was higher than that of the species treated without swine wastewater. In swine wastewater treatment group, *P. euramericana* 'Eco28' clone showed the best performance in DBH growth. Concentration of nitrogen in the leaf with swine wastewater was higher than that of the leaf treated without swine wastewater. All the fast growing tree species removed 58 Mg of swine wastewater for 5 months in treatment group. Based on the NO_3-N concentration of groundwater analyzed during the experimental period, there was no evidence that groundwater was polluted by the swine wastewater applied at the plantation.

Key words: poplar, clone, fast growing tree species, swine wastewater, growth performance, groundwater contamination, NO_3-N

Effects of NaCl concentration on growth of native willow species selected in a coastal reclaimed land

Jung-Hyun Park[1], Jin-Kie Yeo[1,2], Yeong-Bon Koo[1] and Hyun-Chul Kim[1]

[1]Department of Forest Resources Development, Korea Forest Research Institute, Suwon 441-350, Korea

[2] Correspondence to jkyeo@forest.go.kr

Abstract: We tried to know the extent of salt-resistance in native willow species (*Salix koreensis* Anderson) selected in a coastal reclaimed land. Current year cuttings from six individuals of the species were cultivated in greenhouse for two months after cutting. NaCl solution with three different concentrations (0.1, 0.5 and 1.0%) and groundwater were treated to rooted cuttings for one month. Survival rate showed 100% in groundwater and 0.1% NaCl treatment, however, it decreased in the treatments of higher NaCl concentration (73.2% in 0.5% NaCl and 58.8% in 1.0% NaCl, respectively). In groundwater and 0.1% NaCl treatment, height and diameter at root collar of rooted cuttings showed no difference and the number of leaf increased constantly for experimental period. On the other hand, height growth of both 0.5% and 1.0% NaCl treated cuttings was bad compared to groundwater treatment at the rate of 43.8% and 88.9%, respectively. Also, the leaves that treated with 0.5% and 1.0% NaCl turned into brown color and finally were shed.

Key words: *Salix koreensis*, clone, growth performance, NaCl

The early test results of some promising provenances of *Pinus densiflora* at age 4 in Korea

In-Sik Kim[1,2], Hae-Yun Kwon[1], Keun-Ok Ryu[1] and Hyung-Soon Choi[1]

[1] Dept. of Forest Resources Development, Korea Forest Research Institute, 441-847, Suwon, Korea

[2] Correspondence to kimis02@forest.go.kr

Abstract: *Pinus densiflora* is naturally distributed in temperate regions of Korea. It is the most widely distributed conifer species and an important timber species in Korea. Its range extends from Hambuk province in North Korea to Jeju province in South Korea. A range wide provenance test for *P. densiflora* was established in 1996 by Korea Forest Research Institute to address seed transfer zoning and to determine the suitable seed sources for reforestation programs. The seed sources were systematically selected to cover whole geographic range, i.e. a point of intersection between latitudinal and longitudinal line was selected as a sampling site. The planting sites were also selected in similar manner. According to these sampling strategies, some promising provenances were not included in that test. Therefore, we sampled the additional six promising provenances such as Whajinpo, Junkyungreung, Daekwanryung, Chuneunsa, Kwaneumsa, Youngsil in 2004. To compare their growth performance with previous provenance trials established in 1996, five reference provenances such as Joongwon, Kyungju, Taean, Wanju, Uljin-seo were also included in the test. In 2007, provenance trails were established at seven different sites such as Whasung, Chungju, Gangreung, Chuncheon, Chungwon, Jinju, Jeju. The seed characteristics and the seedling growth at nursery stage were significantly different among provenances. The survival rate and seedling growth at test sites were also significantly different among provenances. Among tested provenances, Junkyungreung showed the higher growth performance than others in all test sites. However, the geographic pattern of variation and GxE interaction were not observed in this early test results yet.

Key words: seed characteristics, seedling growth, adaptation, provenance test

Altitudinal variation among *Pinus densiflora* seed sources from the same region at Mt. Seorak in Korea

In-Sik Kim[1,2], Hae-Yun Kwon[1], Keun-Ok Ryu[1] and Hyung-Soon Choi[1]

[1] Dept. of Forest Resources Development, Korea Forest Research Institute, 441-847, Suwon, Korea

[2] Correspondence to kimis02@forest.go.kr

Abstract: *Pinus densiflora* has a large natural distribution in temperate forests of Korea. It was naturally distributed from Hambuk province in North Korea to Jeju province in South Korea. Although it is observed at alpine region (up to 1,300m in inland), its main distribution range is low to moderate elevation. It was reported that altitudinal difference of provenances was one of the important factors affecting growth characteristics in many tree species. However, there were no reports on the altitudinal variation of *P. densiflora* provenances in Korea. Thus, this study was conducted to examine the pattern and the magnitude of altitudinal differences of seed sources from the same provenance region. Wind-pollinated cones were collected from 15 randomly selected trees from each of six *P. densiflora* natural populations distributed along an altitudinal gradient at Mt. Seorak in Korea. The altitudinal range of populations was from 50m to 680m. The common garden test was established in Chungju, Chungbuk province located at 300m above sea level. The height growth of each seed sources were measured at 4 years after planting. The seedlings from populations from the lowest and the highest altitude tended to grow less than that of populations from middle altitudes (190~490m). Seedling growth and absolute value of transfer distance of altitude were negatively correlated (r=-0.55). Although the effect of altitudinal transfer was weak, there was decreasing tendency of seedling growth when the absolute value of altitudinal distance was increasing.

Key words: common garden test, transfer distance, altitude

Water content and disease development of seedlings of *Pinus densiflora* and *Pinus* x *rigitaeda* inoculated with pine wood nematode, *Bursaphelenchus xylophilus*

Kwan-Soo Woo[1,2] and Jun-Hyuck Yoon[1]

[1] Department of Forest Resources Development, Korea Forest Research Institute, Suwon 441-847, South Korea

[2] Correspondence to woo9431@forest.go.kr

Abstract: Three-year-old seedlings of susceptible *Pinus densiflora* and resistant *Pinus* x *rigitaeda* were each inoculated with the pinewood nematode, *Bursaphelenchus xylophilus*, to compare disease development. Needle dehydration was evident on seedlings of *P. densiflora* by 20 days after inoculation, 10 days earlier than this symptom was observed on *P.* x *rigitaeda*. Xylem drying was more frequent in seedlings of *P. densiflora* than in that of *P.* x *rigitaeda* between 20 and 60 days after inoculation. No significant differences were found between *P. densiflora* and *P.* x *rigitaeda* for stem water content or for stem and leaf relative water content in current-year branches after nematode inoculation, but the average number of *B. xylophilus* recovered from stems differed significantly between the two groups. The number of *B. xylophilus* recovered from stems was negatively correlated with the stem water content and with stem and leaf relative water content. By the time the experiment was terminated at 60 days after inoculation, all 3 of the last group of *P. densiflora* seedlings had died, but 2 of the 3 remaining *P.* x *rigitaeda* hybrid seedlings were still alive. Additional studies are needed to further explore the specific mechanisms preventing nematode multiplication in the seedlings of resistant *P.* x *rigitaeda*.

Key words: *Pinus densiflora*, *Bursaphelenchus xylophilus*, water content, nematode

Identification of genes up-regulated by pinewood nematode inoculation in Japanese red pine

Hanna Shin[1,2], Hyoshin Lee[1,3], Kwan-Soo Woo[1], Eun-Woon Noh[1], Yeong-Bon Koo[1] and Jun-Hyuck Yoon[1]

[1] Department of Forest Resources Development, Korea Forest Research Institute, Suwon 441-350, Korea

[2] School of Forest Sciences, Seoul National University, Seoul 151-921, Korea

[3] Correspondence to hslee@forest.go.kr

Abstract: Pine wilt disease, caused by the pinewood nematode (PWN), *Bursaphelenchus xylophilus*, has destroyed huge areas of pine forest in East Asia, including Japan, China and Korea. No protection against PWN has been developed, and the responses of pine trees at the molecular level are unrecorded. We isolated and analyzed up-regulated or newly induced genes from PWN-inoculated Japanese red pine (*Pinus densiflora*) by using an annealing control primer system and suppression subtractive hybridization. Significant changes occurred in the transcript abundance of genes with functions related to defense, secondary metabolism and transcription, as the disease progressed. Other gene transcripts encoding pathogenesis-related proteins, pinosylvin synthases and metallothioneins were also more abundant in PWN-inoculated trees than in non-inoculated trees. Our report provides fundamental information on the molecular mechanisms controlling the biochemical and physiological responses of Japanese red pine trees to PWN invasion.

Key words: pine wilt disease, pinewood nematode, Japanese red pine, up-regulated genes

The variation in needle characteristics of natural populations of *Abies nephrolepis* Maxim. in Korea

Jeong Ho Song[1,2], Kyung Hwan Jang[1] and Jae Cheon Lee[1]

[1] Department of Forest Resources Breeding, KFRI, Suwon 441-847, Korea

[2] Correspondences to SJH8312@forest.go.kr

Abstract: The aim of this study was to examine geographic variation to support a genetic resource conservation plan of rare endemic *Abies nephrolepis* (Trautv.) Maxim. Ten populations of *A. nephrolepis* were analyzed using multivariate analysis for nine characteristics of needle morphology and anatomy. In the morphological and anatomical characters, nine characters of needle were 21.91 ㎜ in width for needle arrangement of terminal shoot (TNW), 13.96 ㎜ in height for needle arrangement of terminal shoot (TNH), 1.73 in needle arrangement index (TNW/TNH), 18.17 ㎜ in needle length (NL), 1.75 ㎜ in needle width (NW), 10.51 in needle index (NL/NW), 0.39 ㎜ in needle thickness (NT), 0.53 ㎜ in distance between resin duct and vascular (DSV), 14.1 ea. in number of stomata row (NSR), respectively. Nested analysis showed that was statistically significant differences among populations as well as among individuals within populations in nine quantitative characters. In NL/NW, NT, NSR and DSW characters, variance components among populations were higher than those among individuals within populations. Cluster analysis using complete linkage method showed three groups to Euclidean distance 1.4. Group Ⅰ consist of Mt. Sobaek population, Group Ⅱ comprises Mt. Baikdoo populations, and Group Ⅲ contains other eight populations. The populations close geographically did not show the tendency of clustering into the same group. The results of principal component analysis for needle characteristics showed that the first for principal components (PC's) explained 51.0% of the total variation. Primary 3 principal components appeared to be major variables because of the loading contribution of 93.0%. The first PC was TNH and NT; the second PC was DSV and NSR; the third PC was TNW and NL, respectively. Latitude was negatively correlated with TNH and NW, but positively correlated with TNW/TNH and NL/NW. Longitude was positively correlated with NW and altitude was positively correlated with TNW/TNH.

Key words: *A. nephrolepis*, needle, morphology, anatomy, multivariate analysis

Aging in *Pinus thunbergii* seeds: Changes in viability and antioxidant enzymes

Du Hyun Kim[1,2], Sim Hee Han[1], Jae Cheon Lee[1], and Jeong Ho Song[1]

[1] Department of Forest Resource Development, Korea Forest Research Institute, Suwon 441-847, Korea

[2] Correspondence to dhkim@forest.go.kr

Abstract: Aging of *Pinus thunbergii* seeds leads to changes in seed quality, such as loss of germinability, and antioxidant enzymes, and increase of electrolyte conductivity (EC) from seed soaked solution. The aim of the present study was to analyze the physiological characteristics of seeds stored for 1, 5, 9 and 17 years at -18 ℃ to identify the changes of antioxidant enzymes and their correlation with traditional seed quality parameters such as germinability and EC. The germinability study showed a loss of germination percentage and germination value in the 17 year stored seed (64% and 24.4) in contrast with an excellent performance for the 1 year old seeds (98% and 92.7). There was only 10% decrease of germination percentage until 9 year of storage at -18℃. EC shortest was higher more than 2.6 times in 17 years old seeds (53 μS/g) compared with 1 year old seeds (20.8 μS/g). There was high correlation (r^2=0.91) between seed age and EC. Antioxidant enzyme activities indicated gradual reduction during the aging process of pine seeds. Superoxide dismutase (SOD) activity increased until 9 years of storage and then decreased in 17 years stored seeds. Ascorbate peroxidase (APX), glutathione reductase (GR), and catalase (CAT) activities in 17 years stored seed were decreased 13%, 36%, 8% comparing with the youngest, respectively. As a result, naturally aged pine seeds showed increase of EC and decrease of germination percentage and antioxidant enzyme activities according to seed age.

Key words: *Pinus thunbergii*, seed storage, seed longevity, natural aging seed, antioxidant enzymes

Evaluation of the inorganic compound leakage and carbohydrates as an indicator of physiological potential of *Ulmus parvifolia* seeds

Du Hyun Kim[1,2], Sim Hee Han[1], Hyun Suk Kim[1], and Jae Cheon Lee[1]

[1] Department of Forest Resources Development, Korea Forest Research Institute, Suwon 441-847, Korea

[2] Correspondence to dhkim@forest.go.kr

Abstract: Inorganic compound leakage from seed soaked solution and change of carbohydrates were measured in *Ulmus parvifolia* seeds throughout accelerated aging under 35℃ and 75% relative humidity (RH) to investigate whether these indicators can be used as a rapid vigor test for efficient seed bank management. Accelerated aging seeds treated for 0-14 days exhibited loss of germinability in the longest aged seeds (11%, 14 days) in contrast with a good performance of 52% for control (0 day) seeds. The increase of leachate electrical conductivity had relation with seed vigor loss in *U. parvifolia* and its correlation value was -0.9. On the other hand, magnesium ion concentration in electrolyte leakage from artificial aged seeds showed negative correlation (r=-0.92) with seed vigor. The ratios of inorganic ions showed that K^+/Mg^{2+}, Mg^{2+}/Ca^{2+}, and Na^+/Ca^{2+} were inversely correlated with germination and their correlation values were -0.92, -0.82, and -0.91, respectively. Change in carbohydrate indicates that, increase of starch and total soluble sugar content in aged seeds was associated with a decrease in seed vigor. In conclusion, EC, leakage of magnesium ion, K^+/Mg^{2+}, Mg^{2+}/Ca^{2+}, and Na^+/Ca^{2+} ratios and changes of starch and total soluble sugar content were highly correlated with seed vigor. Thus, these changes could provide more sensitive and accurate index for the assessment of *U. parvifolia* seed vigor.

Key words: seed storage, viability, seed accelerated aging, electrical conductivity, K^+/Na^+ ratio, glucose

Seed storage physiology of *Acer pycnanthum* an endangered maple species

Du Hyun Kim[1,3], Sim Hee Han[1], Chan Soo Kim[2], and Jae Cheon Lee[1]

[1] Department of Forest Resource Development, Korea Forest Research Institute, Suwon 441-847, Korea

[2] Warm-temperate Forest Research Institute, KFRI, Jeju 697-050, Korea

[3] Correspondence to dhkim@forest.go.kr

Abstract: To understand the seed storage physiology of *Acer pycnanthum*, mature seeds were stored at different combinations of relative humidity (13, 33, 46, 60, and 81% RH) and storage temperature (RT, 4, -20, and -196℃). Storability was quantified by different viability up to 690 days of storage. The seeds stored 60% RH and room temperature (RT) for 3 months decreased germination percentage from 87% (before storage) to 33%. The seed vigor during storage quantified by mean germination time (MGT), electrical conductivity (EC) from seed leachates, and germination value revealed that the consideration of 13% RH was the best for 4 ℃ storage. The germination responses of freeze stored seed at -20℃ was not significantly different depending on storage RH when seed moisture content (MC) was less than 20%, however, 30% of MC seeds decreased germination percentage to 17%. *A. pycnanthum* seed was not sensitive for liquid nitrogen since there was no germination reduction in seed moisture ranged between 6 and 15%. The study reveals that *A. pycnanthum* seeds are short lived, if it was stored under RT and above 46% RH (SMC=9.2%) that lost germinability within 2 years. Electrical conductivity (EC) from seed leachates did not show correlation with seed viability. However, *A. pycnanthum* seeds can be stored for long period at cryopreservation conditions. From the overall response of storage behavior of *A. pycnanthum* it may be concluded that this species possess orthodox storage physiology.

Key words: *Acer pycnanthum*, seed storage, water content, relative humidity, cryopreservation

Genetic diversity and trace of migration of *Camellia sinensis* in Korea revealed by I-SSR markers

Byeong-Hoon Yang[1,3], Yong-Pyo Hong[1], Kab-Yeon Lee[1], Jung-Joo Lee[1] and Young-Goo Park[2]

[1]Department of Forest Resources Development, Korea Forest Research Institute, Suwon 441-847, Korea

[2] Department of Forestry, Kyungpook National University, Daegu 701-702, Korea

[3] Correspondence to time1124@forest.go.kr

Abstract: Knowledge on the genetic diversity and distribution pattern of a tree species is crucial to the effective *in situ* conservation of genetic resources because current genetic status may not only tell us about the past history of foundation but also the likelihood of sustainability of populations in future environmental changes. In addition, understanding the genetic structure in a tree species will make it possible to prepare effective strategy for *ex situ* conservation via determining the target populations and the size of sample extracts to ensure conserving existing genetic variations as much as possible. Tea (*Camellia sinensis* L.) is the most popular non-alcoholic soft beverage in the world. To monitor the trace of populations of tea, I-SSR markers were analyzed in 38 populations (10 individuals per population) in Korea. A total of 32 I-SSR amplicons were counted using 4 primers. Shannon's index (*S.I.*) indicating genetic diversity ranged from 0.201 (Baekyoungsan) to 0.442 (Gunyusan) with the mean of 0.343. Although level of genetic diversity was relatively low compared to other woody plants, population differentiation was somewhat pronounced, in which relatively high level of genetic differentiation among populations was estimated (Φ_{ST} = 0.1339). This suggested that there might be repeated introductions from various sources into duplicated progenitor populations. At least 9 groups originated from an independent progenitor population could be postulated on the basis of topology of UPGMA. As expected from the introduced and cultivated tree species, genetic relationships among the populations were not

coincided with geographic affinity. Of the 9 geographic groups, the biggest one composed of 14 populations showed highest level of genetic diversity (mean *S.I.* = 0.382). Under the assumption of a single origin for the whole Korean populations, it could be postulated that the most probable progenitor candidate belongs in this group. To trace divergence of populations, NJ tree was reconstructed being rooted with outgroup of the candidate group, in which the second biggest group (mean *S.I.* = 0.32, the 5^{th} highest of the nine groups) was turned out to be another progenitor candidate. On the basis of the observation, it could be postulated that these 2 biggest groups might be originated from different sources and served as founders for rest of the groups. Although multiple introduction routes could be postulated on the basis of topology of NJ tree, the biggest group showing the highest level of genetic diversity might be served as a major founder of most tea populations in Korea based on the hypothetical consideration of the level of genetic diversity among populations of progenitor and descendants (i.e., progenitor > descendants). Further consideration on preparing strategy for genetic conservation of tea populations in Korea will be discussed in poster.

Key words: *Camellia sinensis*, genetic diversity, genetic relationship, I-SSR markers, progenitor, divergence

Effect of osmotic priming treatments on the germination and viability of Korean pine (*Pinus koraiensis*) Seeds

Hyun-Suk Kim[1], Sim-Hee Han[1,3], Du-Hyun Kim[1] and Jae-Seon Yi[2]

[1]Department of Forest Resources Development, KFRI, Suwon 441-350, Korea

[2]College of Forest and Environmental Sciences. Kangwon National University, Chuncheon, 200-701, Korea

[3] Correspondence to simhee02@forest.go.kr

Abstract: Korean Pine seed takes more than three months to germinate and decreases seed vigor after 2 year of storage under room temperature or 5 years at 4 ℃. Osmotic priming treatment increases the rate of germination and decreases undesirable effects of stress by instantaneous environmental change such as high temperature and drought during seed germination. In present study, we investigated effects of osmotic priming treatments in different osmotic potential using polyethylene glycol (PEG) solution (0, 0.3, -0.6, -0.9, -1.2, and -1.5MPa) and period of priming (0, 1, 2, and 4 days) in two temperatures (15 and 25℃) on responses of Korean Pine seed germination percentage, mean germination time(MGT), and electrical conductivity (EC) from seed leachate solution. Osmotic Primed Korean pine seeds for 4 days in -1.5 MPa at 15℃ (43.0%), and in -0.9, -1.2 and -1.5 MPa at 25℃ (55.5%, 52.5% and 55.0%) resulted higher germination percentage than that of control seeds (41.7%). MGT was shortened following priming treatment for 4 days at 25℃, and germination rate was faster than control seeds after priming treatment for 4 days in -1.5 MPa at 15℃, and -0.9, -1.2 and -1.5 MPa at 25℃. In addition, germination uniformity increased following priming treatment for 4 days at 25℃. Following priming treatment, ion conductivity in seed leachate solution decreased in comparison with control at 15℃ and 25℃, regardless of the length of priming treatment duration. This result was associated with the reduction of potassium concentration in leachate solution from primed seeds. In conclusion, seed vigor and germination of Korean Pine seed increased following priming treatment and most appropriate priming water potential, period and temperature were -0.9 MPa, 4 days, and 25℃, respectively.

Key words: germination, ion conductivity, leachate solution, potassium

Phytogeographic and Taxonomic Characteristics of *Abies koreana*

Chan-Soo Kim[1,2], Young Jae Kang[1], Seog Gu Son[1], Ji-Eun Kim[1] and Kwang Ok Byun[1]

[1]Warm-Temperate Forest Research Center, KFRI, Seogwipo Jeju 697-050, Korea

[2]Correspondence to daram@forest.go.kr

Abstract: The distributions of *A. koreana* E. H. Wilson start from Shoreline Mountains in Russia stretch to Jeju along the high altitude mountains in Korea. In most high mountains, it is not congregating and a few individuals occurred sporadically so it is recorded on Red Data list composed by IUCN. The population of *A. koreana* distributing in Mt. Halla in Jeju Island, is the only and largest pure forest of the species. Although some variations present on each side of mountain, its distribution on Mt. Halla ranges from 1,300m above sea level up to the summit and covers an area of 603.3 ha. More than 87% of *A. koreana* are growing in the region of 1500m through 1800m and its size represents 526.9 ha. The species are found almost every where in the mountain however it is concentrated on the eastern and northern slopes. *Abies* Mill. is distinguishable by ovulate cones erect, the seeds falling away at maturity together with the ovuliferous scales, abscission-scars round, and leaves without pulvini from other genera of Pinaceae. And the genus contains 45 species. As closed region phytogeographically to Korea, 5 species in North America (Hitchcock and Cronquist, 1996), 9 species in Russia, 5 species and 1 hybrid in Japan, 21 species and 6 varieties in China contains 2 species in East-North region closed to Korea are distributed. Three species, *Abies holophylla* Maxim., *A. nephrolepis* Maxim., and *A. koreana* distributed in Korea. *Abies koreana* was firstly described of specimens collected in Mt. Halla by E. H. Wilson in 1920. He showed that *A. koreana* was distinguishable by its pyramidal habits, its deeply furrowed rough bark, and by its cones with exserted bracts from other related taxa. And also, it combines most of the characters of the three related species *A. nephrolepis* Maxim., *A. sachalinensis* Mast., and *A. veichii* Lindl. The first has similar but less rough bark, longer leaves with median resin-ducts, and the bracts of the cone are included; *A. sachalinensis* has a cone with exserted reflexed bracts but is greenish purple in color; the leaves have median resin-ducts and the bark is perfectly smooth with prominent

resin pustules; *A. veichii* has a similar habit and leaves with lateral resin-ducts, but in this species the bark with always smooth and the bracts of the cone scales are shorter or only slightly longer than the scales. *A. koreana* is certainly very distinct and its very rough bark is unique among the species of its groups. Nevertheless, *A. koreana* and *A. nephrolepis* are not easy to distinguish because measured values of taxonomic characters had not given, and also detailed illustration had not showed. Therefore, this study was to investigate differences in morphological characters between two species. We analyzed the quantitative and qualitative characters of cone bearing twigs of the two species collected in natural habitats (*A. koreana* - Mt. Halla, 1550m and Mt. Jiri, 1800m; *A. nephrolepis* - Mt. Odae, 1200m and Mt. Seorak, 1600m). *Abies nephrolepis* has a narrowly pyramidal crown and smooth bark. Its needles point forward on the twigs and their apices are rounded or lanceolate. The adaxial surface of the needle is grooved and the abaxial surface is plane. The cones are cylindrical and pointed with a short nipple-like apex. The cone scales are horizontal and the bracts are slightly exerted. The color of the cone is green or and violet-purple. *Abies koreana* had a broadly pyramidal crown and furrowed bark. Its crowded needles spread upward or outward, and their apices were blunt. The adaxial surface of the needle was plane and the abaxial surface was keeled. The cone scales were reniform. The bracts were mostly reflexed, but a few were not exerted. The color of the cone was various with green or and purplish-black to green. Significant differences were observed in other characters including ovary scales, seeds and leaf scars, especially in the length and width of the leaves, the width of the leaf scar, the diameter of the cone, the length, width and number of cone scales, the base angle and length of the bracts, the petiole length, bract tip length and length and width of seed and seed wings. The two species were clearly separated in cluster analysis of the morphological data. The species belong to *Abies* family in Northeast Asia are important constituting the subalpine and the subarctic. Scientists have been warning its decrease due to the global warming. *A. koerana* is also predicted to be one of the species suffering the decrease procedure. Therefore constant monitoring system is crucial to conserve the biodiversity.

Key words: Abies Mill. Phytogeoeography, Taxonomy, Morphological character

GA_{20} level in the seedling as an important metabolic marker for early selection of *Pinus densiflora*

Wi Young Lee[1,4], Eung-Jun Park[1], Sang Urk Han[2], Richard P. Pharis[3] and Eun-Woon Noh[1]

[1]Division of Forest Biotechnology, Korea Forest Research Institute, Suwon 441-350, Korea

[2]Division of Forest Tree Improvement, Korea Forest Research Institute, Suwon 441-350, Korea

[3]Deptartment of Biological Science, University of Calgary, Canada

[4]Correspondence to lwy20@forest.go.kr

Abstract: Early selection in plant breeding can produce more genetic gains per unit time (year) if there is strong genetic correlation between early and mature traits. In this study, 12 open-pollinated families of *Pinus densiflora* were used to evaluate the potential of early selection. The growth performances (DBH and growth index) of 12 families (35-year-old) showed significant correlations ($P < 0.05$) with nursery grown 1-year-old seedlings in terms of height (cm), total weight (g DW), and weight of shoots and hypocotyls (g DW), respectively. Furthermore the endogenous levels of GA_{20} in the seedlings were also significantly correlated with the growth performances of both 35-year-old trees and 1-year-old seedlings ($P < 0.05$). Quantitative analysis of the endogenous GA derivatives in the seedlings revealed that only GA_4, GA_9, and GA_{19} were detectable, indicating that GA biosynthesis in 1-year-old seedlings was directed by the non-hydroxylation pathway. This result showed that the GA_{20} levels in one-year-old seedlings were an important metabolic marker, which may enhance early selection efficiency in the *Pinus densiflora* breeding.

Key words: Early selection, *Pinus densiflora*, GA_{20}, metabolic marker

Significant correlation of total nitrogen contents in seedlings with the fast-growing traits in *Pinus koraiensis*

Wi Young Lee[1,3], Eung-Jun Park[1], Sang Urk Han[2], Byoung Hwan Cheon[2] and Eun-Woon Noh[1]

[1]Division of Forest Biotechnology, Korea Forest Research Institute, Suwon 441-350, Korea
[2]Division of Forest Tree Improvement, Korea Forest Research Institute, Suwon 441-350, Korea
[3]Correspondence to lwy20@forest.go.kr

Abstract: In this study, a comparative study was conducted on genetic correlation between 10 open-pollinated families (35-year-old) and their 1-year-old seedlings for early selection on the fast-growing trait in *Pinus koraiensis*. Interfamily differences of 1-year-old seedlings on the basis of height (cm), total weight (g DW), shoots and hypocotyls weight (g DW) were significant with regard to the height, DBH, and volume of 35-year-old trees. Ring widths of 35-year-old trees were also significantly correlated with the contents of $\delta^{13}C$ (r^2 = 0.3138) and total nitrogen (r^2 = 0.5701), and C/N ratio (r^2 = 0.4022) in their xylem. Interestingly the growth traits in the adult trees showed significant correlations with the nitrogen contents (r^2 = 0.7032)and C/N ratio (r^2 = 0.6370) but not with the $\delta^{13}C$ content in the cotyledonary needles of seedlings, indicating that there may be differences in the physiological adaptation of *Pinus koraiensis* seedlings to water stress. Our results showed that the nitrogen content in seedling was an important factor on determining the fast-growing trait in adult trees, suggesting that such parameter may be useful to shorten the breeding cycle of *Pinus koraiensis* through early selection.

Key words: Early selection, *Pinus koraiensis*, nitrogen content, fast-growing trait

Enhanced drought tolerance by expression of *DHN*-5 in poplar

Mu Seok Han[1,2], Young Im Choi[1], Jae Soon Lee[1], Jae Ik Nam[1], and Eun Woon Noh[1]

[1]Forest Biotechnology Division, Korea Forest Research Institute, Suwon 441-847, Korea

[2]Correspondence to mshan99@forest.go.kr

Abstract: Late Embryogenesis Abundant (LEA) proteins are associated with tolerance to water-related stress. A barley dhn5 is a group 2 LEA protein, known also as dehydrin (*DHN*-5) and has been previously shown to be induced by salt and abscisic acid (ABA). We cloned the gene from barley and engineered. The construct containing the engineered *DHN-5* gene was stably incorporated into poplar (*Populus alba* x *P*. *glandulosa* Leaf segments were cultured on callus inducing medium containing different levels of PEG. Among five transgenic lines tested, three (*dhn5-1*, *dhn5-3*, and *dhn5-6*) grew much better than did control plants at 10% PEG. However, there was no significant difference between transgenic and nontransgenic plants at 15% PEG. Stem segments with a shoot apex were also cultured on rooting inducing medium containing different levels of PEG. Among five transgenic lines tested, only two (*dhn*5-1 and *dhn*5-3) rooted 30 to 50% in the presence of 15% PEG. Only 10% of the nontransgenic plants and the other transgenic plants (*dhn*5-*6* and *dhn*5-*9*) rooted in the same conditions. After four week treatment with 20% PEG, the height growth of the transgenic plants reduced much less than did nontransgenic plants. The leaves of nontransgenic plant showed severe chlorosis and necrosis. In contrast, transgenic plants developed the symptoms to a less extent in the same conditions. There was no difference in electrolyte leakage between nontransgenic and transgenic plants under normal conditions. However, after 48hr with 20% PEG treatment, it increased 1.43- and 1.12- to 1.24-fold in nontransgenic and transgenic plants, respectively. Taken together, the transgenic plants attained drought tolerance through the expression of *dhn*-5 gene.

Key words: *Dhn-5*, drought tolerance, poplar, transgenic plant

Japanese red pine (*Pinus densiflora* Zieb. et Zucc.) somatic embryogenesis - Initiation of embryogenic suspensor mass (ESM) from megagametophyte containing immature zygotic embryo

Yong Wook Kim[1,2], Hanna Shin[1] and Heung Kyu Moon[1]

[1]Division of Forest Life Science, Korea Forest Research Institute, Suwon, Kyonggido, 441-350, Republic of Korea

[2] Correspondence to dragonkim@forest.go.kr

Abstract: To initiate embryogenic suspensor mass (ESM) in *Pinus densiflora*, immature seeds were collected from May 31 to July 20 and zygotic embryos at different developmental stages were determined. Four developmental stages were distinguished and the response of megametophyte including the zygotic embryos at each of the four developmental stages was compared. In experiment of 2004, the highest frequency (0.88%) of ESM initiation was obtained with seeds collected on June 28, and the seeds contained zygotic embryos at proembryo stage (100%). In addition, the best ESM initiation frequency was obtained with 0.88% (June 28, 2004, Suwon), 1.4% (July 1st, 2005, Suwon), 2.31% (July 1st, 2005, Anmyeon) and 0.91% (July 1st, 2006, Suwon), respectively and the all excised embryos were at the proembryo stage regardless seed collection year (2004, 2005 or 2006) or collection location (Suwon or Anmyeon). The developmental stages of zygotic embryos had much significant effect on initiation of ESM in *P. densiflora*. In analysis of microsection of seeds, no significant differences found in the stage of zygotic embryos (proembryos) collected weekly or yearly when compared with collection time or location. Albeit it has well known that seed development may vary in climate, from year to year by latitude and elevation, the initiation frequency of ESM in relation with histological result suggests that the optimum yearly collection time for seeds can be based on the collection dates (June 28, July 1st and July 5), at least for *Pinus densiflora,* in Korea.

Key words: Collection date, ESM initiation, Histological observance, somatic embryogenesis zygotic embryo developmental stage

Plant regeneration through somatic embryogenesis in Japanese red pine (*Pinus densiflora* Zieb. et Zucc.)

Yong Wook Kim[1,2], Heung Kyu Moon[1] and So Young Park[1]

[1] Division of Forest Life Science, KFRI, Suwon, Kyonggido, 441-350, Republic of Korea

[2] Correspondence to dragonkim@forest.go.kr

Abstract: Different concentrations of L-glutamine in the medium were also compared for their effect on embryogenic suspensor mass (ESM) proliferation. The highest proliferation rate (9.8 fold) was obtained from ½LM medium supplemented with 3.42 mM L-glutamine. In contrast, the lowest rate was noted when 0.84 mM L-glutamine (0.6 fold) added to the medium. Brassinolide (BL), one of brassinosteroids, is a new natural plant growth regulator that is found in many plant species. It has functions that including the stimulation of cell elongation and increasing resistance to abiotic stress. The highest growth ratio with BL was observed in 1.0 μM (2.3 fold, line 05-21) and 0.05 μM (2.9 fold, line 06-22). However, in the ESM line of 05-21 and 06-22, the treatments without BL were also marked high ESM growth rate (2.3 fold, line 05-21 and 2.1 fold, line 06-3), when compared with 1.0 μM in the line 05-21 or 0.05 μM in the line of 06-22. The degree of proliferating ESM which were cultured on BL-added medium has been shown to have diverse, genotype-specific effects. For somatic embryo maturation with 0.05% activated charcoal (AC), the highest number (798/g^{-1} FW) of cotyledonary somatic embryos (line 06-29) was obtained on a maturation medium supplemented with AC. The influence of light-emitting diodes (LED) sources on the germination somatic embryos of four genotypes in this species was studied. The effect of LED sources on the somatic embryo germination was strongly genotype dependent. In the germination of somatic embryos from ESM line 05-3, the frequency was strongly inhibited by fluorescent lamp and red+blue light (0%, respectively) for that. On the other hand, other lines (05-12, 05-29 and 05-37) reacted in a similar germination pattern to five LED sources, particularly red light was most responded with somatic embryo germination.

Key words; somatic embryo, brassinosteroids, charcoal, L-glutamine, LED

Effects of treatments on the green-wood cutting of mature *Prunus yedoensis* and growth characteristics of transplanted cuttings in nursery

Chang-Soo Kim[1,4], Kyu-Suk Kang[1], Sang-Urk Han[1], Chang-Young Oh[1], Kwan-Soo Woo[1], Jin-Taek Kang[2], Jun-Hyuck Yoon[1] and Zin-Suh Kim[3]

[1]Department of Forest Resources Development, KFRI, Suwon 441-847, Korea

[2]Korea Forest Seed and Variety Center, Korea Forest Service, Chungjoo 380-941, Korea

[3]Division of Biotechnology, College of Life Sciences and Genetic Engineering, Korea University, Seoul 136-701, Korea

[4] Correspondence to jskim20@forest.go.kr

Abstract: This study was conducted to develop an efficient method for the propagation of mature *Prunus yedoensis* (45 to 55 years old). Green wood cuttings were collected from the upper and lower parts of normal branches. The cuttings were treated with three different kinds of auxin (Rootone: 1-naphthylacetamide 0.4%, IBA 100ppm and control) and two different kinds of fog systems (0.9ℓ/min and 0.54ℓ/min). After that, the cuttings were transplanted at the nursery. Growth, survival and root development were surveyed and compared grafts and seedlings. There were significant differences among cutting times, showing that cutting of June 1 was the best rooting percentage. But the position of cutting did not significant in the rooting ability. The treatment of IBA 500ppm+talc showed the best rooting percentage (82.1%) while the control was 13.6% rooting. For the fog systems, the misting of 0.54ℓ/min showed 66.0% rooting while 0.54ℓ/min showed 38.9%. The interactions of cutting times, cutting positions, and hormone and fog treatments were statistically significant in the rooting percentage. The best rooting (96.7%) came out from the combination of cutting on June 1, cuttings from lower part, fog misting of 0.54ℓ/min and IBA 100ppm treatment. The growth of cuttings was significantly different from grafts and seedlings at the nursery. The number of roots for cuttings ranged 5.6 to 8.6, which is more than grafts or seedlings. The newly developed cutting method could thus be promising for mass propagation and afforestation.

Key words: *Prunus yedoensis*, mature tree, green-wood cuttings, fog system, auxin

Conservation of an endanger orchid species, *Gastrodia elata*, using symbiotic mycorrhizal associations

Eung-Jun Park[1,3], Seung Taek Kim[2], Jin Kwon Ahn[1] and Wi Young Lee[1]

[1]Division of Forest Biotechnology, Korea Forest Research Institute, Suwon 441-350, Korea

[2] Department of Horticulture, Kyunghee University, Yongin 446-701, Korea

[3] Correspondence to pahkej@forest.go.kr

Abstract: In Korea, *Gastrodia elata* has been designated as a “rare and endangered” species by Korea Forest Service, mainly due to unsustainable collection of wild plants for medicine and commercial trade. In this study, symbiotic germination and subsequent vegetative growth by using mycorrhizal associations were utilized in the production of *G. elata* immature tubers. We first self-or cross-pollinated over 5,000 flowers and germinated the seeds on the medium containing hardwood leaves infected with *Mycena* species. Seed-derived protocorms were developed within 2 months although they became brownish and degenerative in another two months. To overcome this problem, protocorms (more than 0.8 cm in length) were applied on the PSH medium containing peptone 2g, sucrose 20g, and hyponex powder 2g per liter. Protocorm culture on the PSH medium for 4 weeks stimulated the production of the secondary branches and the elongation of the primary corms. Furthermore peptone and sucrose had the effects of rhizomorph attraction and protocorm thickening, respectively, upon response to subsequent infection with *Armillaria sp*. Within total 6 to 7 months of *in vitro* culture, we were able to produce immature rhizomes of *G. elata* (more than 4 cm in length) which can be directly used for plant reintroduction program as well as the commercial field production. We therefore suggest that this system is an efficient way not only to overcome the rapid loss of native habitat but also for the mass and rapid production of the immature tubers of *G. elata*.

Key words: *Gastrodia elata*, *Mycena sp*, *Armillaria sp.* protocorm

Effect of plant growth regulators on the induction of nutritive corms from the immature tubers of *Gastrodia elata* via *in vitro* culture

Jin Kwon Ahn[1,2], Seung Taek Kim[1], Wi Young Lee[1] and Eung-Jun Park[1]

[1]Division of Forest Biotechnology, Korea Forest Research Institute, Suwon 441-350, Korea

[2]Correspondence to ahnjk@forest.go.kr

Abstract: *Gastrodia elata* Blume, a parasitic herbaceous plant, belongs to *Orchidaceae*, and its dried roots (tubers) have been used as a traditional Chinese medicine for various human diseases such as vertigo, blackout, headache, hemiplegia and convulsions epilepsy. *G. elata* is devoid of chlorophyll and exhibits symbiosis with the fungus *Armillaria mellea* (myco-heterotropy). However the yields of *G. elata* have been decreased, mainly due to the degeneration of spawn tubers caused by repetitive asexual reproduction. This study was conducted to know the possibility of micropropagation through *in vitro* culture of *G. elata* immature tubers. The field-grown immature tubers were first surface-sterilized with various levels of $HgCl_{2.}$ prior to investigating the contamination and growth rates. The optimal result was obtained by sterilizing twice with either 0.2 or 0.5% $HgCl_2$ for 2 minutes. When the tubers were cultured on water agar medium supplemented with various plant growth regulators, thidiazuron induced the largest number of nutritive corms per tuber. The diameter and length of tubers also showed positive correlation with the induction and the growth of nutritive corms. In this study, we showed a new micropropagation method of *G. elata* through *in vitro* culture system, which might be an effective strategy to overcome the economical loss in the production of G. *elata*.

Key words: *Gastrodia elata*, *Armillaria mellea*, *in vitro* culture, thidiazuron

An efficient shoot multiplication using different bioreactor culture system for a rare and endangered species, Tsuru-rindo *(Tripterospermum japonicum)*

Sun-Ja Kim and Heung-Kyu Moon

Forest Biotechnology Div., Korea Forest Research Institute, Suwon 441-847, Korea

Abstract: To develop an efficient shoot proliferation system for a rare and endangered plant, *Tripterospermum japonicum,* four different biorector culture systems were compared in a single node culture. The culture systems tested were temporary immersion with net (TIN) or without net (TI), continuous immersion with net (CIN) and alternate use of both systems (TINR; TIN for 2wks then CIN for 3wks). TINR culture system appeared to give the best results after 5 weeks in culture: the highest fresh weight, shoot length and rooting rate were achieved by TINR, and it was followed by TIN> TI and CIN. Shoot growth appeared to be suppressed in both TI and CIN culture systems due to lack of oxygen and high water potential. Generally, active shoot growth accompanied with spontaneous rooting and normal leaf photosynthesis was achieved in TINR at the early stage of culture. However, delayed shoot growth and poor leaf photosynthesis were shown in the other culture systems. Above results demonstrated that an efficient mass shoot production was possible for the rare plant, *Tripterospermum japonicum*can, by the TINR bioreactor culture system.

Key words: bioreactor culture system, rare plant, Tsuru-rindo

Growth response of yellow poplar (*Liliodendron tulipifera*) microplants to arbuscular mycorrhizal fungi in sterile and non-sterile medium

Nelly Siababa-Aggangan[1,3], Yong-Wook Kim[1], Heung-Kyu Moon[1] and Sim-Hee Han[2]

[1,2]Biotechnology Division and Department of Forest Genetic Resources, Korea Forest Research Institute, Suwon, 441-350, Korea

[3]National Institute of Molecular Biology and Biotechnology (BIOTECH) University of the Philippines Los Baños 4031, College, Laguna, Philippines

Abstract: Yellow poplar (*Liliodendron tulipifera*) microplants (line 06-4) produced via bioreactor were inoculated with arbuscular mycorrhizal (AM) fungi *Glomus macrocarpum, G. etunicatum* and *Gigaspora margarita* and grown in non-sterile or in sterilized peat perlite vermiculite medium. The plants were initially under growth room conditions for six weeks and later transferred in a glasshouse. Generally, mycorrhizal plants grew better with greener and broader leaves than the non-mycorrhizal counterpart. Plant growth was better in sterile than in non-sterile medium throughout the five months observation period. *Glomus etunicatum* consistently promoted the highest plant height, diameter, leaf length, leaf width, and dry weight (leaf, stem, root and total plant dry weight) and nutrient uptake (N, P K, Mg, Ca, Na, Zn) in both sterile and non-sterile medium, though, growth and nutrient uptake was higher in sterile than in non-sterile medium. On the other hand, control plants consistently had the lowest growth and nutrient uptake particularly in the non-sterile medium. *Glomus macrocarpum* and *G. margarita* produced higher percent root colonization than *G. etunicatum* but these were less effectiveness in promoting growth and nutrient uptake of yellow poplar. In conclusion, the results clearly show that AM inoculation is important in improving growth of yellow poplar. The effectiveness of AM inoculation was better in sterile than in non- sterile medium. *Glomus etunicatum* promoted the highest leaf, stem, root and total plant dry weight of yellow poplar grown in both sterile and non-sterile medium. Thus, this fungus can be used for further inoculation trials particularly under field conditions.

‘Yorjong’, a New dwarf Variety of *Hibiscus syriacus* L., Suitable for Indoor Growing

Hyung Soon Park [1, 2], and Hae Yun Kwon[1]

[1]Department of Special Purpose Trees, Korea Forest Research Institute, Suwon, 441-350, Korea

[2]Correspondence to parkh@forest.go.kr

Abstract: ‘Yorjong’, a new variety of *Hibiscus syriacus* was selected from the progenies of artificial breeding between ‘Andong’, as a mother plant, and ‘Dowon’, as a pollenizer, at the Korea Forest Research Institute(KFRI) in 2008. The preliminary, advanced and regional trials for evaluation and selection of this variety were carried out from 2003 to 2008. The maternal parent, ‘Andong’ is a dwarf white flowering variety selected from among progenies derived from artificial crosses between Baekdanshim(maternal) and Gyeongbuk1(paternal), and the pollen parent, ‘Dowon’ is an introduced cultivar from Japan blooming small pink bell-shaped flowers. Seedlings of their progenies were annually managed with transplanting and 5 to 6 times in weeding. Leaves, flowers, branches and growth characteristics on the selected tree were investigated. Results of morphological characteristics showed that ‘Yorjong’ has funnel shape in open type of corolla, and simple flower in flower type. The diameter of flower is 46.5mm; it is very small as compared with that of the mother tree, ‘Andong’. The petal is not folded and diameter of eye zone is 10.75mm. Leaf type is in oval shape, and leaf length and width is long(67.4mm) and narrow(37.0mm), respectively. Leaf width to width of leaf shoulder ratio(1.7) is similar to that of mother tree(1.67). Leaf thickness, glossy level and the shape of leaf base is medium, medium and rounded, respectively. Quantity of bloom is medium in normal condition and changes in the flower number by seasons are small. In addition to being a short height shrubby tree, it has very short internodes and compact branching. According to all these characteristics, the new variety ‘Yorjong’ could be useful for a pot plant growing indoors and for a small garden tree.

Key words: *Hibiscus syriacus,* artificial cross, progenies, ‘Yorjong’, Indoor growing

A new high yield Korean raisin tree (*Hovenia dulcis* var. *koreana* Nakai) Cultivar, "Poong-Sung 3"

Sea-Hyun Kim[1,2] and Jingyu Han[1]

[1]Korea Forest Research Institute, 44-3 Omockcheun, Kwonseon, Suwon, 441-350 Republic of Korea

[2]Correspondence to goldtree@forest.go.kr

Abstract: For the purpose of breeding a high-yield superior variety of Korean raisin tree(*Hovenia dulcis* var. *koreana* Nakai), whose value as an edible and medicinal resource is increasing, tree candidates for superior individuals were selected from its 11 habitats in Korea from 1996 to 1998. A clone bank preserve was created in 1998 with 70 clones proliferated by grafting.

From 2003 to 2005, five clones were selected and screened by analyzing flowering and fruiting characteristics of 47 clones in the clone bank. "Poong-Sung 3", a new high-yield superior *H. dulcis* var. *koreana* Nakai cultivar was finally selected from the 5 clones. The final selection focused on fruiting characteristics such as the number of fructify lateral (NFL), the number of average bunch per one fructify lateral (NABFL), the number of average bunch per fruiting lateral (NABPFL), the weight of fruit petiole per individual (WFPI) and the yield of individual (YI). Fruit petiole of "Poong-Sung 3" has dark brown skin color and fruit flesh color. Fruiting characteristics of "Poong-Sung 3" showed large better results and selection effects with an average of 16.8Ea (NFL), 3.47Ea (NABFL), 58.3Ea (NABPFL), 3.9kg (WFPI) and 9.70kg (YI) which are 137.7%, 107.4%, 148.8%, 354.5% and 380.4% superior compared to the mean of 47 clones, respectively. And "Poong-Sung 3", middle-growth with a demonstrated difference in the maturity period was selected through the investigation and analysis of the fruit petiole maturity period.

Key words: *Hovenia dulcis* var. *koreana* Nakai, High yield, Poong-Sung 3

New cultivars with larger, high-yielding and cold tolerance fruit of the hybrids 'Hayward'×*Actinidia arguta*

Youngki Park[1,2], Suk-In Hwang[1] and Moon-Ho Lee[1]

[1] Department of Special Purpose Trees, Korea Forest Research Institute, Suwon, 441-350, Korea

[2] Correspondence to ykpark@forest.go.kr

Abstract: *Actinidia arguta,* native to north China, Korea, and Japan and called hardy kiwifruit, has an edible smooth skin and contains high amounts of sugar and vitamin C. *A. deliciosa* are known as kiwifruit and originated in Southwest China. The fruit of *A. deliciosa* appreciated for its sweet, slightly acidic flesh and high nutritional value, especially due its high content in vitamin C like *A. arguta.* The cultivar 'Hayward' of *A. deliciosa* occupies the majority of the world kiwifruit cultivated surface, and is the cultivar commercially produced in Korea. The Bower Actinidia (*A. arguta* (Sieb. & Zucc.) Planch. ex Miq.) is one of the valuable species due to their edible fruit, high content of nutritious substances, especially abundant of vitamin C, and distinctive flavor and medicinal usage. However, the kiwifruit producing areas are limited to warm climates region, it can be cultivated in the southern parts of Korea. In our research, several hybrids have been developed to enhance cold tolerance by crossing 'Hayward' with domestic species (*A. arguta*). To make new cultivars with larger and high yielding and cold tolerance characteristics, we have been crossed 'Hayward' with *A. arguta.* The new hybrid cultivars ('Hayward'×*A. arguta*) were 'Dae-Myung', 'Hwang-Oak', and 'Ja-Wang'.

Key words: *Actinidia arguta, A. deliciosa,* Dae-Myung, Hwang-Oak, Ja-Wang

Microsatellite DNA fingerprinting and genetic relationships of 29 chestnut (*Castanea spp.*) cultivars and varieties widely cultivated in Korea

Uk Lee[1], Hae Yun Kwon[1,2] and Yong Pyo Hong[1]

[1] Dept. of Forest Resources improvement, Korea Forest Research Institute (KFRI), 441-847 Suwon, Republic of Korea

[2] Correspondence to kwonhy@forest.go.kr

Abstract: Accurate identification of chestnut cultivars and varieties is essential for effective selection, breeding, and genetic resources management of the species. For identifying the genotypes and investigating their genetic relationships, total 29 chestnut (*Castanea* spp.) cultivars and varieties were selected and analyzed with 7 simple sequence repeat(SSR) loci. All 29 cultivars could be uniquely fingerprinted based on their single- or multilocus microsatellite genotypes, and polymorphism in analyzed SSR loci was revealed on the basis of number of allele(*Na*, mean: 6.9), expected heterozygosity (*He*, mean: 0.7165), and Polymorphic information content(*PIC*, mean: 0.6788). Resulting from clustering analysis using microsatellite genotypic similarities, 'Hyogo57' was evaluated as the most distinct in all cultivars analyzed, and a UPGMA dendrogram separated the remaining 28 cultivars into three major groups. It is very likely that confused genetic exchanges have occurred between the cultivars derived from Korean, Chinese and Japanese wild types as a result of continual trade and artificial cross. Information including SSR profiles of these important chestnut cultivars will be useful for identification of synonymic cultivars, parentage analysis and legal protection.

Key words: DNA fingerprinting, genetic relationships, *Castanea* spp., SSR

Selection of Korea native chestnut tree as pollinizers and roasted chestnut for improvement of nut qualities

Uk Lee[1,2], Yong Hee Kwon[1], Suk In Hwang[1], Kabyeon Lee[1], Eul Sun Baik[1], Mahn Jo Kim[1]

[1] Division of Special-purpose Trees, Korea Forest Research Institute (KFRI), 441-847, Suwon, Republic of Korea

[2]Correspondence to rich26@korea.kr

Abstract: The chestnut had been a very close relationship with our lives through a specialty food item for wedding and funeral as well as a famine relief food in the past. Recently, the chestnut is getting popular as a health food, so new chestnut cultivars are needed to develop for satisfying customers who seek high qualities with reasonable price. The objective of this study was select pollinizers and roasted chestnut cultivars among Korean native chestnut tree for improving chestnut quality. A total of 9 cultivars were used in this study: new cultivars 'Daehan', 'Mipung', 'Daebo', main cultivated cultivars 'Tanzawa', 'Tsukuba', 'Arima', and superior individuals of roasted chestnut 'Hongcheon8', 'Uljin3', 'Gwacheon3'.To select roasted chestnuts cultivar from the Korea native chestnut, the character of 'peeling' was used. The artificial cross between the roasted chestnut cultivars (as pollinizers) and new cultivars as well as main cultivated cultivars (as parents) was conducted among 12 different combinations. The following criteria were applied to select pollinizers: 1) flowering time of staminate and pistillate flower, and fruiting characteristics 2) nut characteristics like as soluble solid content and nut hardness, percentage with the pericarp split, and percentage of polyembryonic nut. A total of two clones were selected based on peeling: Jangwon and Jahong. Both cultivars showed high percentage of pollination and fertilization and produced high quantity of chestnut. The full blooming time for staminate and pistillate flowers were a middle of June. The seeds and nuts from the newly selected chestnut cultivars showed ca. 2-3% higher sugar contents than their parents. In addition, they showed a very low percentage of nut with pericarp split and poly-embryonic. The sugar contents of nuts derived from all crossed combinations were increased ca. 4-29.4% and the hardness

also increased ca. X – 24.4% except a combination between Mipung×Jahong(-3.2%). The newly selected cultivars (‘Jangwon’ and ‘Jahong’) can be used as pollinizers because their nuts showed high qualities and values through increased uniformity and stability (i.e., coefficients of nut weight, soluble solid content and nut hardness: 0.04-0.26).

Key words: roasted chestnut, pollinizer, nut qualities, native, solid soluble content, hardness

Development of prototype for seed orchard management system using RFID

KyoungMin Kim[1,5], CheolMin Kim[2], JinTaek Kang[3], TaeWoong Jung[4], YunHee Seo[1]

[1] Div. of Forest Resources Information, Korea Forest Research Institute, 57, Hoegiro, Dongdaemun-gu, Seoul, Korea

[2] Warm-Temperate Forest Research Center, Korea Forest Research Institute, 20, Donnaeko, Seagwipo, Jejudo, Korea

[3] Korea Forest Seed & Variety Center, Korea Forest Service, 670-4, Suhwari, Suanbo, Chungjoo, chungchong-bukdo, Korea

[4] Dep. of Advanced Technology Fusion, KonKuk University, 1 Hwayang-dong, Gwangin-Gu, Seoul, Korea

[5] Correspondence to greenann@forest.go.kr

Abstract: Maintenance of records and plus tree identities is an important part of seed orchards management. Orchards must be mapped and each tree must be tagged with its parent identity number. But actually there have been some problems in the existing seed orchard management such as a loss of identification label, tedious data management by excel-based sheet, difficulty in the revisit to the exact location of a plus tree due to the lack of database management system. In this study we developed a prototype for a seed orchard management system using RFID and GIS to solve these problems. RFID means Radio Frequency Identification. This technology uses radio waves to automatically identify individual items. We attached RFID tag to the trees instead of existing identification label. The prototype structure for RFID system consists of RFID tag, handheld RFID reader and database server. In this study we used a passive tag with 900MHz frequency and EPC class 1 Gen 2 protocol. The unique ID number for the RFID tag designed with UFID (Unique Feature IDentifier) standard and forest GIS standard in Korea was used as a Key field. Then each tree attribute data was joined with a unique ID. From the RFID tag reading, we can see on the reader various management information such as planting year, species, coordinates, parent tree, fertilization, pesticide application and so on. Especially coordinate data of plus tree can be effectively used as route

information to access exactly. Also we designed that update function for management information and real time transmission function to the main server using CDMA or wireless network. Namely, it is possible to read easily clone and plus tree information and to check the location information from RFID prototype system. We expect that this RFID system can promote efficiency of seed orchard management.

Key words: seed orchard, management system, RFID, GIS

Seed orchard of loblolly pine in Hang Zhou of China: genetic basis and some troubles in seed production

Qifu Luan[1,2], Jingmin Jiang[1] and Zhaoxi Liu[1]

[1]Research Institute of Subtropical Forestry, CAF, Daqiao Road 73#, Fuyang county, Zhejiang Province, China, 311400

[2]Correspondence to luanqifu@hotmail.com

Abstract: A loblolly pine seed orchard in Hangzhou of East China was constructed in 1993 with 561 clones from selected elite trees from natural resources and plantations (of provenance) introduced from the USA. Now the orchard is facing some troubles such as low seed production, difficulty in cone collection and flowering asynchronism although the genetic gain was significant. How to overcome these problems is a big challenge.

Keywords: loblolly pine, seed orchard, seed production, flowering asynchronism

The influence of climate on seed production

Bazargur Solongo

Euro-Asia University, Ulaanbaatar, Mongolia

Abstract: Unique long-term agro-meteorological measurements of Mongolian grasslands enabled us to investigate the relationship between the phenology of *Stipa* spp., one of the dominant perennial species (such as emergence, heading, flowering, maturity, and senescence), and moisture conditions for three stations representative of the major vegetation zones, during 1993 to 2002.

The results showed that the emergence date relates neither to a specific temperature nor to an effective accumulative temperature, but to the presence of precipitation that occurs within five days prior to the emergence in most cases. For a northern-most wettest forest steppe region (Bulgan), the precipitation amount, and period of days from emergence to heading are significantly correlated (r = 0.93), while a southward typical steppe region (Arvaikheer) also exhibited a positive correlation (but not exceeding the 5% significance level). The positive correlation occurred at Bulgan most likely, because for drought years, *Stipa* spp. tended to switch a phenological stage from the vegetative growth (that is, a biomass increase), to reproductive phase (that is, seed production) earlier than for a normal year. One possible trigger for the switching is a decreased soil moisture, associated with a break of the rainy season.

Climate change could have devastating effects on the well-being of people already living on the edge of poverty - with limited financial and technical capacity, yet dependent on climate sensitive sectors for their life and livelihoods, communities must rely on their own ability to adapt and survive in constantly changing conditions.

Climate change severely affects Mongolia. By the last census which took place in 2004, in total 683 rivers, 1484 springs and 760 small lakes and ponds were dried up. This harsh situation creates a shortage in water supply in the countryside and results

in reducing pastureland utilization rate that in its turn brings pastureland degradation problem in many places.

Mongolia is a dry country. This natural dryness has been affected by strong climate change effects over the last 10-15 years in Mongolia and as a result land, specially pastureland is rapidly being degraded or deteriorated. Grassland becomes scarce/poor year by year. There is an urgent need to improve grass conditions. One solution to this could be cultivation of drought resistant grass.

A climate change study conducted in Mongolia recognized that global climate change has increased the threat of severe winters and droughts. Given the overriding importance of the sector to the national economy, its vulnerability remains a key threat to the country's potential for sustainable development.

Mongolia consists of a unique ecology that includes the southernmost fringes of boreal forests of the Great Siberia, deserts, and vast steppes of Central Asia and the Chains of Altai, Khangai, Khentei, and Khyangan mountain massifs .The Mongolian environment as a whole is characterized by great diversity and a particular complex spatial structure of soil and vegetation cover. Most of the mountain ranges are forested but the plains are dominated by steppe and desert vegetation. In a short distance, one may encounter a variety of features of forest, mountain, steppe, desert, as well as unique ecosystems. Administratively, Mongolia is divided in 22 aimags (states).

In view of the prominent role of local actors in the implementation of climate change adaptation, it is critical that the evaluation of adaptation options incorporate their perspectives and priorities. To obtain local level input to the evaluation, local community workshops were held in different eco-regions, namely the Gobi-steppe region, steppe region, high mountain, and forest region.

Cone, seed and nut characters in *Pinus pinea*

Nebi Bilir

Forestry Faculty, Suleyman Demirel University, Isparta, 32260, Turkey
Correspondence to nebilir@orman.sdu.edu.tr or nebilir@hotmail.com

Abstract: Cone and seed size, weight and number of seed per cone, weight of nut per cone were investigated in a natural stand of Umbrella pine also called stone pine (*Pinus pinea* L.) which is classified as one of the most important forest tree species for Turkish forestry because of its valuable nut and resistance to drought areas such as sandy. Relations among characters and clonal repeatability for the characters were estimated. There were large differences among clones (family) for the characters. While clonal repeatability was above 0.5 for volume of cone, number of seed per cone, seed length and weight, and nut weight, it was opposite in length of cone, bottom diameter of cone and dry weight of seed per cone. There were generally significant correlations among the characters.

Key words: Stone pine, repeatability, variation, cone, seed

Production of inter-specific hybrids in breeding arboretum cum seedling seed orchard of *Eucalypts*

Parveen

Division of Genetics and Tree Propagation, Forest Research Institute, Dehradun 248 195, India

Abstract: A breeding arboretum cum seedling seed orchard (SSO) of *Eucalyptus* was established at the Forest Research Institute, Dehradun, India consisting of 9 species for the production of natural and artificial inter-specific hybrids. The SSO was developed in open pollinated mating design following completely randomized block design with ten replications. The spontaneous hybrids are being tested for hybrid vigour of economic traits. A spontaneous hybrid between *E. torelliana* and *E. citriodora* has fully been characterized for morphological traits and heterosis. The productivity of this hybrid (FRI 14) has been reported to be three times more than best of the parents. The orchard is also being used as the breeding arboretum for the production of controlled hybrids among the species. Another controlled inter-specific hybrid between *E. pellita* and *E. urophylla* has been produced successfully and planted in the field for growth performance, adaptability and stability. Though at the age of six months the hybrid has shown high degree of heterosis for height and collar diameter, its superiority *per se* in different geographical locations needs to be tested. It is emphasized that the hybrid once proven to be exceptional could easily be multiplied clonally for large scale deployment.

Key words: Inter-specific hybrids, spontaneous and controlled hybrids, heterosis

☐ Authors index

G

Ghosh, M.

H

Han, Jingyu
Han, Mu Seok
Han, Sang-Urk
Han, Sim-Hee
Hansen, Ole K.
Hong, Yong-Pyo
Hur, Hyun Koo
Hwang, Suk-In

J

Jang, Kyung Hwan
Jett, J.B.
Jiang, Jingmin
Jinqing, Qiu
Jung, Tae-Woong

K

Kamalakannan, R.
Kang, Jin-Taek
Kang, Kyu-Suk
Kang, Young-Je
Kim, Chan-Soo
Kim, Chang-Soo
Kim, Cheol-Min
Kim, Chul-Woo
Kim, Du Hyun
Kim, Hyo-Jeong
Kim, Hyun-Chul
Kim, Hyun-Suk

Kim, In-Sik
Kim, Ji-Eun
Kim, Jong Han
Kim, Kae-Hwan
Kim, Kyoung-Min
Kim, Mahn Jo
Kim, Sea-Hyun
Kim, Seung Taek
Kim, Sun-Ja
Kim, Tae-Su
Kim, Yong-Wook
Kim, Young-Mi
Kim, Zin-Suh
Klápště, Jaroslav
Koo, Yeong-Bon
Kroon, Johan
Kumar, Ashok
Kumar, Vijay
Kwon, Hae-Yun
Kwon, Yong Hee

L

Lee, Byung Sil
Lee, Huyn-Suk
Lee, Hyo Shin
Lee, Jae Cheon
Lee, Jae Soon
Lee, Jung-Joo
Lee, Kab-Yeon
Lee, Moon-Ho
Lee, Uk
Lee, Wi Young
Lindgren, Dag

Liu, Zhaoxi
Lstibůek, Milan
Luan, Qifu
Luna, R.K.

M

McKeand, Steve
McKinney, Lea V.
Moon, Heung-Kyu

N

Na'iem, Mohamad
Nam, Jae Ik
Nam, Song-Hee
Noh, Eui-Rae
Noh, Eun-Woon

O

Oh, Chang-Young

P

Park, Eung-Jun
Park, Hyung Soon
Park, Yill-Sung
Park, Jae-In
Park, Jung-Hyun
Park, So-Young
Park, Young-Goo
Park, Youngki
Parveen
Pharis, Richard P.
Prescher, Finnvid

R

Rosvall, Ola

Ryu, Keun-Ok

S

Seo, Yun-Hee

Shim, Tae-Heum

Shin, Hanna

Siababa-Aggangan, Nelly

Sofu, Aytul

Son, Seog-Gu

Song, Jeong-Ho

Steiner

T

Torimaru, Takeshi

V

Varghese, M.

W

Woo, Kwan-Soo

X

Xihuan, Shen

Y

Yang, Byeong-Hoon

Yeo, Jin-Kie

Yi, Jae-Seon

Yongqi, Zheng

Yoon, Jun-Hyuck

Z

- The XXIII IUFRO World Congress Scientific Committee invites submission of abstracts for presentations during technical and poster sessions.
- Authors are requested to submit abstracts via the Congress website **(http://www.iufro2010.com)** by 31 December 2009. All presenting authors (oral or poster presentations) must register for the Congress by 30 April 2010. Failure to do so will mean that the presentation will be deleted from the program, as well as from the abstracts volumes and conference proceedings.

More information on abstract submission can be found on the Congress website: http://www.iufro2010.com

PROCEEDINGS

Seed orchards and the link to long-term tree breeding in response to climate change

KOREA FOREST RESEARCH INSTITUTE
57 Hoegi-Ro, Dongdaemun-Gu, Seoul 130-712,Korea
Tel. (031)290-1120
Http://www.kfri.go.kr