camcore

Global partners for the future of our forests

2014 Annual Report

NC STATE UNIVERSITY

2014 CAMCORE ANNUAL REPORT

International Tree Breeding and Conservation

Department of Forestry and Environmental Resources
College of Natural Resources
North Carolina State University
Raleigh, North Carolina 27695-8008, USA

Telephone:	919.515.6424
Fax:	919.515.6430
Email:	info@camcore.org
Gary R. Hodge	grh@ncsu.edu
Juan Luis López	jllopez@ncsu.edu
Juan José Acosta	jjacosta@ncsu.edu
William C. Woodbridge	woodbridge@ncsu.edu
Romeo Jump	rjump@ncsu.edu
Robert M. Jetton	rmjetton@ncsu.edu
W. Andrew Whittier	wawhitti@ncsu.edu
J. Robert McGee	rmcgee@ncsu.edu
Andy R. Tait	artait@ncsu.edu
Elmer A. Gutiérrez	egutierrez3161@gmail.com
Web:	www.camcore.org

Table of Contents

EXECUTIVE SUMMARY

1. Bill Dvorak, Director of Camcore, retired in 2014. Bill was the original Director of Camcore, and served for 34 years. Gary Hodge was appointed Director, and Juan Luis López was appointed Associate Director.

2. Private Forestry Programme (PFP) in Tanzania joined Camcore as an Associate Member in 2014. PFP will work to promote plantation forestry among small landowners and farmers in Tanzania. At the end of 2014, Camcore had 29 active, 7 associate, and 7 honorary members.

3. In 2014, Camcore sent 19 eucalypt trials to members. To date, almost 500 eucalypt tests covering 15 species have been sent to active members. Camcore has genetic resources from eucalypt species for nearly every kind of plantation forestry environment in tropical, subtropical and temperate regions.

4. The first trials in the third series of hybrids from the Camcore Pine Hybrid Project were planted in 2014. Twelve trials in total were planted, including one in Argentina, one in Colombia, four in Brazil, and six in South Africa. From the second series of pine hybrid trials, *P. greggii* x *P. tecunumanii* and *P. caribaea* x *P. tecunumanii* continue to show great commercial potential.

5. A study quantifying the amount of *P. patula* pollen contamination in 2nd generation *P. tecunumanii* breeding populations was completed. The study involved the use of molecular markers to confirm hybridity, and the development of NIR models to rapidly classify hybrids. The results suggest that there is around 10% contamination in low-elevation *P. tecunumanii*, and 46% contamination in high-elevation *P. tecunumanii*.

6. Research on the pulp and handsheet properties of pine hybrids showed that *P. greggii* x *P. tecunumanii* and *P. patula* x *P. tecunumanii* handsheets had satisfactory paper properties, with better burst and tensile strength and worse tear strength than *P. taeda* at the same CSF.

7. A project to transfer NIR models from one machine to another gave very encouraging results. This means that the Camcore global pine NIR model for lignin and cellulose can be used by members in their own labs. Work on the development of a global eucalypt NIR model continued: a two-species model (*E. urophylla* and *E. dunnii*) has been completed, and a third species will be added in 2015.

8. Camcore acquired additional genetic material of teak from 80 mother trees in natural forests in Laos. With these recent collections, Camcore has a total of 336 families from 38 different sources. Research continued on understanding the effects of nutrient deficiencies in teak seedlings, and on methods to select for increased heartwood percentage in teak.

9. A study on the genetics of wood properties of *P. taeda* in southern Latin America was begun. Samples come from 60 families planted on two sites in Argentina and Brazil. The study will look at density, modulus of elasticity, and wood chemistry (assessed with the Resistograph, acoustic velocity, and NIR spectroscopy, respectively).

10. A research project on an application of "Breeding without Breeding" was completed. Computer simulation results suggest that this approach, using molecular markers and pedigree reconstruction, can make substantial genetic gain and save many years of testing at the initiation of a tree improvement program.

11. Much work was done on conservation activities in United States, in conjunction with the USDA Forest Service. New collections of Eastern hemlock (*Tsuga canadensis*) were completed and a study of genetic diversity of Carolina hemlock (*T. caroliniana*) identified three gene pools and their geographic distribution. We initiated a long-term effort to develop silvicultural prescriptions to reintroduce hemlocks to southern Appalachian forests. Seed collections for conservation of Table Mountain pine (*P. pungens*), red spruce (*Picea rubenss*), Fraser fir (*Abies fraseri*), and Atlantic white cedar (*Chamaecyparis thyoides*) continued.

12. Regional technical meetings were hosted by Suzano in Brazil, and Merenksy in South Africa. A one-week data management shortcourse was held in Mexico (hosted by ProTeak), a two-week tree improvement shortcourse was held in South Africa (hosted by Mondi and Sappi). Our 34th Annual Meeting was held in Guatemala, with 30 participants from 9 countries.

RESUMEN EJECUTIVO (Español)

1. Bill Dvorak, Director de Camcore, se jubiló en el 2014. Bill fue el primer Director de Camcore y ocupó este cargo durante 34 años. Gary Hodge y Juan Luis López fueron nombrados como Director y Director Asociado, respectivamente.

2. Private Forestry Programme (PFP) de Tanzania se vinculó a Camcore como Miembro Asociado en el 2014. PFP trabajará para promover plantaciones forestales entre pequeños propietarios y agricultores en Tanzania. Para finales del 2014, Camcore contaba con 29 Miembros Activos. 7 Asociados y 7 Miembros Honorarios.

3. En el 2014, Camcore envió 19 ensayos de *Eucalyptus* a sus miembros. A la fecha, se han enviado casi 500 ensayos de 15 especies de *Eucalyptus* a sus miembros activos. Camcore tiene recursos genéticos de especies de *Eucalyptus* para casi cualquier ambiente forestal en regiones tropicales, sub-tropicales y templadas.

4. Los primeros ensayos de la tercera serie del Proyecto de Híbridos de Pino de Camcore fueron plantados en el 2014. En total doce ensayos fueron plantados, incluyendo uno en Argentina, uno en Colombia, cuatro en Brasil y seis en Sudáfrica. De los ensayos de la segunda serie de híbridos de pino, *P. greggii x P. tecunumanii* y *P. caribaea x P. tecunumanii* continúan mostrando gran potencial comercial.

5. Se completó un estudio que cuantifica la contaminación por polen de *P. patula* en poblaciones mejoradas de *P. tecunumanii* de 2ª generación. El estudio incluyó el uso de marcadores moleculares para confirmar la hibridación y el desarrollo de modelos de NIR para clasificar rápidamente los híbridos. Los resultados sugirieron que hay un 10% de contaminación en *P. tecunumanii* de baja elevación y un 46% de contaminación en *P. tecunumanii* de alta elevación.

6. La investigación de las propiedades de la pulpa en híbridos de pino mostró que *P. greggii x P. tecunumanii* y *P. patula x P. tecunumanii* poseen propiedades satisfactorias, obteniendo mejor resistencia a la tensión y a la explosión que la pulpa comercial de *P. taeda* pero inferior resistencia al rasgado al mismo valor de drenaje (CSF).

7. El proyecto para transferir modelos de NIR de una maquina a otra dio resultados muy alentadores. Esto significa que el proyecto global de Camcore de modelos NIR para lignina y celulosa de pino puede ser usado por los miembros en sus propios laboratorios. Continúan los trabajos para el desarrollo de un proyecto global de modelos NIR para *Eucalyptus:* un modelo de dos especies (*E. urophylla* y *E. dunnii*) se ha completado y una tercera especie será incluida en el 2015.

8. Camcore adquirió material genético adicional de 80 árboles madres de teca procedente de bosques naturales en Laos. Con esta reciente colección, Camcore tiene un total de 336 familias de 38 diferentes fuentes. El estudio para entender los efectos de las deficiencias nutricionales en plántulas de teca continúa, así como el estudio de los métodos para medir el porcentaje de duramen como criterio de selección.

9. Se inició un estudio sobre la genética de las propiedades de la madera de *P. taeda* en Sur América. Las muestras provienen de 60 familias plantadas en dos sitios en Argentina y Brasil. El estudio analizara la densidad, módulos de elasticidad y química de la madera (evaluados con el resistografo, velocidad acústica y espectroscopia NIR, respectivamente).

10. Se concluyó el proyecto de investigación sobre la aplicación "Mejoramiento sin cruzamiento". Los resultados de la simulación computarizada sugieren que esta propuesta, utilizando marcadores moleculares y reconstrucción del pedigrí, puede lograr una ganancia genética sustancial y ahorrar muchos años de pruebas al comienzo de un programa de mejoramiento genetico forestal.

11. Se ha realizado mucho trabajo en las actividades de conservación en los Estados Unidos, conjuntamente con el Servicio Forestal del Departamento de Agricultura de los Estados Unidos. Nuevas colectas de *Tsuga canadensis* fueron realizadas y un estudio de la diversidad genética de *Tsuga caroliniana* identificó tres bancos genéticos y su distribución geográfica. Iniciamos un esfuerzo a largo plazo para desarrollar prescripciones silviculturales que permitan reintroducir hemlocks en los bosques del sur de los Apalaches. Adicionalmente, continúan las colectas de semilla para conservación de la diversidad genética de *Pinus pungens, Picea rubenss, Abies fraseri* y *Chamaecyparis thyoides.*

12. Se llevaron a cabo dos reuniones técnicas regionales organizadas por Suzano en Brasil y Merensky en Sudáfrica. Un mini-curso de dos semanas en manejo de datos se realizó en México (organizado por Pro Teak), otro mini-curso de dos semanas de mejoramiento forestal se llevó a cabo en Sudáfrica (Organizado por Mondi y Sappi). Nuestra 34ª reunión anual se llevó a cabo en Guatemala, con la participación de 30 personas de 9 países.

RESUMO EXECUTIVO (Português)

1. Bill Dvorak, Diretor da Camcore se aposentou em 2014. Bill foi o Diretor da Camcore durante 34 anos. Atualmente, Gary Hodge assumiu a posição de Diretor da Camcore e Juan Luis Lopes assumiu a posição de Diretor Associado.

2. A empresa Private Forestry Programme (PFP) da Tanzânia se associou a Camcore como Membro Associado em 2014. PFP atuará, fomentando os plantios florestais entre os pequenos proprietários de terra na Tanzânia. No final de 2014, Camcore conta com 20 membros ativos, 7 membros associados e 7 membros honorários.

3. Em 2014, a Camcore enviou sementes de *Eucalyptus* para os associados e 19 estudos com as várias espécies de *Eucalyptus* foram estabelecidos. Até agora foram estabelecidos um total de 500 estudos, incluindo 15 espécies de *Eucalyptus*.

4. Em 2014, foram estabelecidos os primeiros estudos da Terceira série dos híbridos de Pinus da Camcore. Doze estudos já foram estabelecidos, 1 na Argentina, 1 na Colombia, 4 no Brasil e 6 na África do Sul. Da Segunda série deste projeto, os híbridos , *P. greggii* x *P. tecunumanii* e *P. caribaea* x *P. tecunumanii* continuam demonstrando um grande potencial.

5. Foi conluído um estudo onde quantificou-se a contaminação de pólen em populações de melhoramento de segunda geração de *P. patula* e *P. tecunumanii*. Este estudo envolveu o uso de marcadores moleculares para confirmar a hibridação como também o desenvolvimento de modelos de NIR para rapidamente se definir a existência de híbridos. Os resultados sugerem que existem 10 % de contaminação nas populações de *P. tecunumanii* de baixa altitude e 46 % de contaminação nas populações de *P. tecunumanii* de alta altitude.

6. Estudos com o objetivo de avaliar as propriedades físicas da polpa e do papel produzidos a partir de híbridos de *P. greggii* x *P. tecunumanii* e *P. patula* x *P. tecunumanii* demonstraram propriedades satisfatórias apresentando melhor resistência à tracção, quando comparados ao *P. taeda*, porém com piores resultados de resistência ao rasgamento quando também comparados ao *P. taeda*.

7. O projeto desenvolvido para transferir os modelos do NIR de um equipamento para outro demonstraram resultados encorajadores. Isto significa, que os modelos globais de NIR para lignina e celulose podem ser utilizados pelos membros da Camcore em seus laboratórios. Trabalhos para desenvolver modelos globais de NIR estão em andamento: um modelo para duas espécies (*E. urophylla* e *E. dunnii*) foi finalizado e uma terceira espécie será adicionada em 2015.

8. A Camcore adiquiriu material genético de 80 matrizes de Teca em florestas nativas do Laos. Com esta aquisição recente, a Camcore possui um total de 336 famílias de 38 procedências distintas. A pesquisa continua, com o objetivo de melhor entender as deficiências nutricionais em mudas de Teca e em métodos de seleção para aumentar o percentual de cerne em Teca.

9. Iniciamos um estudo para avaliar as propriedades da madeira em *P. taeda* na América do Sul. Foram coletadas amostras de 60 famílias plantadas em dois locais na Argentina e Brasil e este estudo tem como objetivo, avaliar a densidade, modelo de elasticidade e química da madeira (utilizando o Resistógrafo, velocidade acústica, e espectroscopia NIR, respectivamente).

10. Finalizamos um projeto de pesquisa na aplicação do conceito "Melhorando sem Melhoramento". Os resultados simulados em computador, sugerem que esta aproximação, utilizando marcadores moleculares e reconstrução de pedigree, podem ser utilizados para obterem-se significativos ganhos genéticos como também podem fornecer ganhos temporáis no início de um programa de melhoramento genético.

11. Em cooperação com o USDA Serviço Florestal, foram aplicados esforços consideráveis em trabalhos de conservação nos EUA. Novas coleções de Eastern hemlock (*Tsuga canadensis*) foram concluídos e um estudo da diversidade genética de Carolina hemlock (*T. caroliniana*) identificou três conjuntos de genes e sua distribuição geográfica. Iniciamos um esforço de longo prazo para desenvolver recomendações silviculturais para reintroduzir hemlocks às florestas Apalaches. Além disso, continuamos com as coleções de sementes para a conservação da diversidade genética do Pinus Table Mountain (*P. pungens*), abeto vermelho (*Picea rubens*), Fraser abeto (*Abies fraseri*) e cedro branco (*Chamaecyparis thyoides)*.

12. A empresa Suzano no Brasil cediou a reunião técnica regional e a empresa Merenksy cediou a reunião técnica regional na África do Sul. Foi realizado no México (cediada pela empresa Proteak) um curso de gerenciamento de banco de dados de uma semana. Na África do Sul, um curso de duas semanas em melhoramento florestal foi cediado pela empresa Mondi e Sappi. Nossa 34 Reunião Anual foi realizada na Guatemala, com a presença 30 participantes de 9 países.

MUHTASARI WA TAARIFA KUU (Kiswahili)

1. Bill Dvorak, Mkurugenzi wa Camcore, alistaafu mwaka wa 2014. Bill alikuwa mkurugenzi wa awali wa Camcore, na alitumikia kwa muda wa miaka 34. Gary Hodge aliteuliwa mkurugenzi, na Juan Luis López aliteuliwa mshirika mkurugenzi.

2. Private Forestry Programme (PFP) Tanzania ilijiunga na Camcore kama mwanachama mshirika katika mwaka wa 2014. PFP itahusika na kukuza mashamba ya misitu kati ya wamiliki wa ardhi ndogo na wakulima nchini Tanzania. Mwishoni wa mwaka wa 2014, Camcore ilikuwa na wanachama 29 watendaji, 7 washirika , na 7 waliotunukiwa heshima kuu

3. Katika mwaka wa 2014, Camcore walituma majaribio ya mikaratusi kwa wanachama. Mpaka leo, takriban majaribio 500 ya mikaratusi ikiwa ni pamoja na aina 15 yametumwa kwa wanachama watendaji. Camcore ina rasilimali ya maumbile na aina ya mikaratusi kwa karibu kila aina ya mashamba ya misitu, mazingira katika mikoa ya kitropiki, joto na baridi.

4. Majaribio ya kwanza katika mfululizo wa tatu wa mahuluti kutoka Camcore Pine Hybrid Project ilipandwa katika mwaka wa 2014. Majaribio kumi na mbili kwa jumla ilipandwa, ikiwa ni pamoja na moja Argentina, moja Colombia, nne Brazil, na sita nchini Afrika Kusini. Kutoka mfululizo wa pili wa majaribio ya miseto ya msindano , *P. greggii* x *P. tecunumanii* na *P. caribaea* x *P. tecunumanii* yaendelea kuonyesha uwezo mkubwa kibiashara

5. Utafiti wa kuonyesha kiasi cha poleni ya *P. patula* kuchafuliwa katika kizazi cha pili cha *P. tecunumanii* kuzaliana wakazi kilikamilika. Utafiti ulishiriki matumizi ya upimaji wa molekyuli kuthibitisha uhuluti, na maendeleo ya mifano ya NIR kwa haraka kuainisha mahuluti. Matokeo zinaonyesha kwamba kuna karibu 10% uchafuzi katika *P. tecunumanii* ya mwinuko wa chini, na 46% uchafuzi katika *P. tecunumanii* ya mwinuko wa juu.

6. Utafiti juu ya miundo msingi ya massa na karatasi kutoka mahuluti ya msindano ilionyesha kuwa karatasi ya *P. greggii* x *P. tecunumanii* na *P. patula* x *P. tecunumanii* ilikuwa na miundo msingi ya kuridhisha karatasi, na ubora wa kupasuka na nguvu na tena nguvu zaidi kuliko masaa ya *P. taeda* massa sokoni.

7. Mradi wa kuhamisha mifano ya NIR kutoka mashine moja hadi nyingine ilitoa matokeo ya kutia moyo sana. Hii ina maana kuwa msindano wa NIR wa Camcore kimataifa wa kuigwa kwa lignina na selulosi inaweza kutumika na wanachama katika maabara yao wenyewe. Kazi inayohusiana na maendeleo ya kimataifa ya mikaratusi ya mfano wa NIR iliendelea kwa aina ya mifano miwili (*E. urophylla* na *E. dunnii*) imekamilika, na aina ya tatu itaonezeka katika mwaka wa 2015.

8. Camcore iliongezea maumbile ya nyenzo ya teak kutoka miti 80 katika misitu ya asili huko Laos. Kwa makusanyo hayo hivi karibuni, Camcore ina jumla ya familia 336 kutoka vyanzo 38 mbalimbali. Utafiti uliendelea kuelewa madhara ya upungufu wa madini katika miche ya teak, na juu ya njia ya kuchagua kwa ajili ya kuongeza asilimia ya ng'arange katika teak.

9. Utafiti kuhusu adili ya genetikia ya miti ya *P. taeda* kusini mwa Amerika ya Kusini ilianzishwa. Sampuli zinatoka familia 60 kupanda juu ya maeneo mbili katika Argentina na Brazil, na utafiti kuangalia wiani, thamini ya ustahimilivu , na kuni kemia (tathmini na Resistograph, muenekano wa udongo, na NIR spectroskopia , kwa mtiririko huo)

10. Mradi wa utafiti juu ya matumizi ya 'Uzalishaji bila uzalishaji' ulikamilika. Matokeo katika tarakilishi thiata zinaonyesha kwamba mbinu hii, kutumia alama Masi na ujenzi asili, inaweza kuwa na manufaa katika kufanya faida kubwa maumbile na inaweza kuokoa miaka mingi ya kupima katika uanzishwaji wa mpango wa uboreshaji wa miti.

11. Kazi nyingi ilifanyika kwenye shughuli za hifadhi katika Umoja wa Mataifa, kwa kushirikiana na USDA Forest Service. Mikusanyo mipya ya mbaruti ya Mashariki (*Tsuga canadensis*) ilikamilika na utafiti wa tofauti za maumbile ya Carolina mbaruti (*T. caroliniana*) kutambuliwa kwa change ya mabwawa na usambazaji yao ya kijiografia. Tulianzisha juhudi ya muda ya kuendeleza maagizo ya silvicultural kwa kuanzisha tena mberoshi kwa misitu ya Appalachian kusini. Aidha, mikusanyo ya mbegu kwa ajili ya hifadhi ya utofauti ya maumbile ya msindano wa Table Mountain (*P. pungens*), spruce nyekundu (*Picea rubenss*), Fraser fir (*Abies fraseri*), na Atlantic mwerezi mweupe iliendelea

12. Mikutano ya kiufundi ya Mkoa ilikuwa imeandaliwa na Suzano nchini Brazil, na Merenksy nchini Afrika Kusini. Usimamizi wa kozi fupi ya data kwa muda wa wiki moja ulifanyika nchini Mexico (ulisimamiwa na Proteak), kozi fupi ya uboreshaji wa miti kwa muda wa wiki mbili ulifanyika nchini Afrika Kusini (ulisimamiwa na Mondi na Sappi). Mkutano wa mwaka 34 ulifanyika nchini Guatemala, na washiriki 30 kutoka nchi tisa.

Message From the Director

Camcore had an eventful year in 2014. First, and foremost, was the retirement of Bill Dvorak, who has been Camcore's only director since its inception in 1980. Camcore began as a small program at North Carolina State University, with four industrial members and a focus on conserving the pine species of Central America and Mexico. Some 34 years later, Camcore has 29 active, 7 associate, and 7 honorary members. We work with 26 pine species, 15 eucalypt and *Corymbia* species, as well as numerous hardwood species including the commercially important *Gmelina arborea* and *Tectona grandis* (teak). Much of the growth and success of Camcore is attributable to Bill's passion, leadership, and untiring effort. Today Camcore is unquestionably a world leader in the tree improvement and gene conservation of tropical and subtropical forest trees. Bill's retirement was effective in August 2014, and I (Gary Hodge) was appointed as Director after serving with the program as Quantitative Geneticist for 18 years. After 34 years, this is the very first Message from the Director that is not from Bill Dvorak!

There were some other major changes in Camcore staffing. Juan Luis López completed his Ph.D. and was promoted to Associate Director of the program. I am fortunate to have such a capable and hard-working associate on the team. In July 2014, we also hired Juan José Acosta as Geneticist and Tree Breeder. Juan José completed his Ph.D. at the University of Florida in 2014, and for 5 years prior to beginning his Ph.D. program, he worked in breeding and tree improvement at Smurfit Kappa Colombia. With that background, he brings experience both in traditional breeding and molecular genetics, and we are confident he will make great contributions to the program.

Although we have had some changes in the staff, we are all committed to continuing our mission to be a world leader in tree improvement and conservation of forest genetic resources. Support from the members continues to be strong. We have some very exciting breeding and research programs underway, of which I will mention a few:

- In our pine hybrid breeding testing program, we continue to see some hybrid combinations with great commercial potential, and the Camcore *P. patula* x *tecunumanii* project is focused on collaborative breeding and testing of full-sib families of this hybrid.
- A collaborative eucalypt hybrid breeding project has produced seed from 11 different hybrid combinations, and seed will be distributed for testing in 2015.
- Great progress was made in testing of 15 eucalypt and *Corymbia* species with Camcore genetic resources, material strategically acquired by Bill Dvorak as one of his last major accomplishments with the program.
- We made progress with the development of NIR models for eucalpyt wood chemistry, and methodology to transfer NIR models from Camcore labs to company NIR machines where they can be used for internal breeding programs.
- We are investigating how to utilize molecular marker technology for applied breeding programs, using pedigree reconstruction and an approach called "breeding without breeding".

Camcore continues to attract interest from forestry organizations around the world. In 2014, we added an associate member, the Private Forestry Programme (PFP) in Tanzania. PFP is a joint effort of the governments of Tanzania and Finland with the objective to support small tree growers. We anticipate additional growth in 2015.

In November 2014, we had a succesful and productive 34th Annual Meeting in Guatemala, hosted by associate member Grupo de Guate. Many of Camcore's early seed collections were in Guatemala, so it was a great location to celebrate the past and look forward to the future. In my new position as Director, I am excited about the work and the challenges in front of us. It is an honor to work with such a good staff here at NC State University, and with the wonderful people on the research and management teams of our member organizations around the world. I look forward to a great year in 2015.

Many thanks for your support,
Gary Hodge
Director, Camcore

2014 Camcore Membership

Active & Associate Members

Argentina
- Alto Paraná, SA 1999
- Bosques del Plata, SA 2004

Australia
- CSIRO (Associate) 2009

Brazil
- ArborGen do Brasil (Associate) 2013
- Klabin, SA 1987
- Rigesa, Celulose, Papel e Embalagens Ltda 1993
- Suzano Pulp and Paper 2011

Chile
- Arauco Bioforest 1991
- CMPC Forestal Mininco 1991

China
- Guangdong Academy of Forestry (Associate) 2013

Colombia
- Cementos Argos/Tekia, SA 2010
- Forestal Monterrey Colombia SAS 1983
- Smurfit Kappa Colombia, SA 1980

Guatemala
- Grupo DeGuate (Associate) 2006

East Africa
- TBPT - KEFRI 2005

Mexico
- Proteak Uno SA de CV 2011
- Uumbal Agroforestal 2012

Mozambique
- Chikweti Forests 2008
- Florestas de Niassa Limitada 2010
- Green Resources AS - Moçambique 2012

Republic of South Africa
- Cape Pine - MTO Forestry Pty Ltd 2006
- Komatiland Forests, Ltd 1983
- Merensky Pty Ltd 2004
- Mondi South Africa 1988
- PG Bison Holdings Pty Ltd 2006
- Sappi Forests 1988
- York Timbers 2010

Tanzania
- Green Resources AS - Tanzania 2013
- Private Forestry Programme (Assoc.) 2014

United States of America
- MeadWestvaco (Associate) 2010
- USDA Forest Service (Associate) 2006

Uruguay
- Montes del Plata - Stora Enso Uruguay SA 2006
- Weyerhaeuser Company 1980

Venezuela
- Maderas del Orinoco, CA 2010
- Masisa Terranova de Venezuela, SA 2000
- Smurfit Kappa Venezuela, SA 1986

Honorary Members

Belize
- Ministry of Natural Resources

El Salvador
- Centro Nacional de Tecnología Agropecuaria (CENTA)

Guatemala
- Instituto Nacional de Bosques (INAB)

Honduras
- Escuela Nacional de Ciencias Forestales (ESNACIFOR)

Mexico
- Instituto de Genética Forestal, Universidad Veracruzana
- Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP)

Nicaragua
- Instituto Nacional Forestal (INAFOR)

The 2014 Annual Meeting in Guatemala

Traveling to Guatemala for the 2014 Annual Meeting felt a little like going "home", back to the highlands of the Chuacus mountains in the Sierra Madre where some of Camcore's first seed collections were made in the early 1980s. The last annual meeting to be held in Guatemala was in 1991, so for most participants this was their first visit to Camcore seed collection sites in natural forests. Thirty participants from 16 members in 9 countries convened in Antigua, Guatemala which served as the base for the 7-day event in mid-November.

The first day, Sunday, began with sessions of the technical and executive committees followed by a welcome dinner sponsored by INAB at the Porta Hotel in Antigua. Monday was spent in technical sessions with ten presentations from Guatemalan foresters and Camcore representatives. On Tuesday the group traveled north to the department of El Progreso to visit wood processing plants operated by companies that are part of Camcore member Grupo DeGuate. The first stop was Efiforest, a factory that converts round wood into bed frame kits, and uses about 7 million board feet of maximinoi, caribaea and oocarpa pine per year. We visited the log yard to discuss the challenges of keeping freshly harvested trees pest free and watched logs being sawn into the various frame components. The second stop was Lignum, an operation making a variety of lumber and finished products. Using mostly native pines, they produce and sell kiln-dried and preservative-treated lumber as well as finished products ranging from tomato plant support boxes to playground sets and picnic tables. Tuesday night was spent at the Park Hotel in Santa Crúz, Alta Verapaz and Wednesday, the bus took us to spend the day in Baja Verapaz. The morning began with a rainy but pleasant walking tour of an 1150-acre conservation area, the Biotopo del Quetzal. The annual rainfall is 3800mm, and yes, we did see a Quetzal, the country's rare and elusive national bird! At first a female, high in the trees, then later, for those that were patient, a male also appeared. Later that morning the group traveled to the natural forest in San Jerónimo where Camcore has made a number of collections of tecunumanii, maximinoi and oocarpa pine since the early 1980s. We reached the forests in a caravan of pickup trucks, some of which required repeated attempts to climb the steep, muddy slopes. Elmer Gutiérrez knows these areas very well and led us to several mother trees. It was a thrill to visit these 100 to 200-year-old trees whose progeny have been planted on Camcore members' lands all around the world. After the day in the field, the bus brought us back to Antigua to prepare for the next day's trip. Thursday was another day in the field,

The log yard at Efiforest, the leading bedframe manufacturer in Central America.

Elmer Gutiérrez and Gary Hodge of Camcore with one of the original selections of *P. tecunumanii* at San Jerónimo, Guatemala.

A rare glimpse of the Quetzal, the national bird of Guatemala, at the Biotopo de Quetzal in Baja Verapaz.

starting with a trip to Finca El Espinero in Tecpán, Chimaltenango. We visited both natural and planted stands of *Pseudostrobus* pine, and saw the damage being done by *Dendroctonus* beetles. Uphill from the forest were plantations of fir (*Abies guatemalensis*) being grown for Christmas trees, and the last stop was a beautiful old stand of cypress (*Cupressus lusitanica*). It was a cold, misty morning but it was interesting to see these lesser-known conifers being grown in their natural range at an elevation of over 3000 meters. Just south of Tecpán lie the ruins of Iximche, the capital of the Kaqchikel Mayan Kingdom. We enjoyed visiting this Guatemalan national monument which was inhabited until the early 1500's. We then returned to Antigua for Friday's full day of technical sessions. We heard 20 presentations on pines, eucalypts and teak in a wide variety of topics, including wood and pulp properties, NIR models for estimating wood chemistry, seed collections, hybrid potential, nutrient deficiencies, frost risk mapping, and even the use of drones in forest management. At the end of the day, we received an invitation from John Johnson of Mead Westvaco to the 2015 annual meeting in Texas. The meeting closed on Saturday with the business meeting and a farewell dinner hosted by Grupo DeGuate.

The 2015 Annual Meeting was a wonderful trip that combined visits to natural forests, industry factories and cultural sites. The people in Antigua are accustomed to tourists (though maybe not foresters), and were friendly, courteous, and helpful. Like all annual meetings, much planning and work is needed before and during the event. We want to thank INAB and the members of Grupo DeGuate that helped sponsor and plan the trip. Special thanks are also due to several individuals who made the trip possible: Mike Mussack of Grupo DeGuate, Edwin Oliva of INAB, Susan Riojas from CS Representaciones, and Juan López, Elmer Gutiérrez, Romeo Jump and Robert McGee of Camcore. It was a fantastic trip, and now we have Texas on our minds for 2015.

The 2014 Camcore Annual meeting attendees, enjoying the beauty of native pine forests of Guatemala.

Developments in Camcore

Camcore staff made a number of member visits in 2014 to look at Camcore trials, to discuss breeding strategies and research questions, and to assist with on-going Camcore research projects. Below is a brief summary of the visits and other developments.

Argentina

Gary Hodge and Romeo Jump visited Argentina in May to help take wood samples of the *P. taeda* GxE study at **Bosques del Plata** (BDP). A team of people from BDP and **Alto Paraná** (AP), and Weyerhaeuser (Uruguay) came to assist (see full article later in this Annual Report). When the sampling was completed, we had the opportunity for a short visit to some 2^{nd} generation pine trials, a BDP pine hybrid trial, and a visit to BDP's new seed extraction facility and nursery. In the nursery, BDP is investigating a switch from potted mother plants to a hydroponic system for the production of cuttings.

Brazil

Gary Hodge, Juan Luis López and Juan José Acosta visited **Suzano** in October. Suzano hosted the Southern Latin America Regional meeting in 2014. Field visits were made to clonal seed orchards, trials and commercial areas of *Eucalyptus*. We also visited FuturaGene (a biotech

Matías Martin (Bosques del Plata) discusses *P. taeda* hedge management with German Raute and Juan Schapovalov (Alto Paraná) at the BDP nursery in Argentina.

Fabricio Biernaski (Klabin, Brazil) is investigating the impacts of different container sizes on nursery growth and subsequent field performance of *P. maximinoi*.

company owned by Suzano) and took a look at their facilities and the process of genetic transformation they are developing for their target material.

On that same trip, Juan Luis López and Juan José Acosta visited **MWV Rigesa**, to conduct a wood characterization study in *Pinus taeda*. They used the IML-Resistograph to evaluate density differences, and the TreeSonic acoustic tool to measure wood stiffness. They also visited a five-year-old Camcore pine hybrid trial, located on the Zaniollo farm. At this site, the hybrid of *P. greggii* var. *australis* x *P. tecunumanii* (high-elevation) is showing good potential as an alternative species, with its early growth substantially superior to *P. taeda*. On the trial site, Ricardo Paím mentioned that they are having problems with populations of Brazilian primates called “macacos”, which are girdling the terminal section of trees. Interestingly, pine hybrids are not being girdled by “macacos”.

Gary Hodge visited **Klabin** in October. Klabin is increasing emphasis on *P. maximinoi* as a commercial species. The company has established 3 progeny tests from seed collected from their own seed production area in Telemaco Borba, and has also established tests of *P. maximinoi* from Colombia and South Africa. Klabin has also established a new clonal seed orchard of *P. maximinoi*, using airlayering as a vegetative propagation method to avoid problems with graft incompatibility. In addition, Fabricio Biernaski has begun a Ph.D. research program looking at the effects of different container sizes and configurations on root development and field survival.

Chile

Both **CMPC Forestal Mininco** and **Arauco Bioforests** continued to make contributions to the Camcore program in 2014. Both organizations participated in the NIR Model Transfer Project, and the Eucalypt Hybrid Project. CMPC provided wood samples for a study on within-tree density variation in *E. globulus* and *E. nitens* and the *E. nitens* x *E. globulus* hybrid.

Colombia

Bill Dvorak and Gary Hodge visited **Smurfit Kappa Colombia (SKC)** in April, Bill's focus was on visiting pine hybrid trials to identify trees to be used in the Camcore pine hybrid wood quality research project, whereas Gary spent much of his time in discussions about breeding and testing strategies and wood quality. Camcore proposed two studies: first, a study to determine if a "resting" period for the hedges will improve the pine cutting production; second, a study to assess the genetic variation in wood chemical properties in the SKC elite populations of *E. grandis* and *E. grandis x E. urophylla*, which will provide important genetic rankings of the top 50 clones, as well as genetic parameter estimates. We also discussed modifications in the SKC strategy to sample wood properties in genetic trials, targeting only the better-growing families.

Hugo España and Elizabeth Rojas (SKC, Colombia) visit a very nice full-sib 2nd generation progeny trial of low-elevation *P. tecunumanii*.

In September, Juan José Acosta made a follow up visit to SKC. Juan José discussed with the research group alternative ways to analyze phytosanitary information on genetic trials as well as the design of a screening study for several *Eucalyptus* species. An introductory course on programming with the "R environment" was given to nine members of the research and planning teams. The basic objectives of the course were: to give an overview of the R programming environment, to perform simple analyses with databases, to download and use packages created by other users of R, and to know how to find help.

This year **Tekia** planted two new Camcore provenance/progeny trials of teak in its forestry land in Colombia. Camcore is helping the company obtain quick gains in commercial plantations through the implementation of a clonal program. In their visit in March, Juan López and Romeo Jump gave recommendations for the implementation of a mass selection project to quickly identify clones for the establishment of multiple clonal trials. The goal is deployment of clones in commercial plantations in the short term. The development of the tree breeding and clonal programs will increase productivity of teak plantations in the midterm. Camcore is also helping Tekia with the development of a *Eucalyptus* tree breeding program for energy production.

Forestal Monterrey Colombia (FMCo) continues to make progress in its clonal program with *Gmelina arborea*. Several clonal trials with both Camcore and FMCo material have been established by the company. Camcore has been helping FMCo with data analyses for making selections and deployment on a commercial scale. Juan López and Romeo Jump visited FMCo and recommended some silvicultural practices for the *Eucalyptus* and *Corymbia* programs. Camcore continues to add to FMCo's genetic base with the shipment of several trials of different species.

Romeo Jump (Camcore), Juan Ramón Aguilar, Omar Carrero, and Oscar Martinez (Proteak) in a *E. urophylla* clonal trial at Predio El Bufalo, Veracruz, Mexico.

East Africa

Bill Dvorak visited **East Africa** in February. This membership is a joint membership between KEFRI (Kenya) and TAFORI (Tanzania), coordinated by the Tree Biotechnology Programme Trust. The 2014 visit was hosted by TAFORI. Field stops included a teak trial in Longuza, a mixed eucalypt trial with some drought-hardy species at Kwamaranga, a *E. pellita* trial in Sao Hill, and a *E. urophylla* trial at Mafinga. The TAFORI researchers and field staff are enthusiastic and hardworking.

Guatemala

Juan López and Romeo Jump visited **Grupo** DeGuate in Guatemala in August. They went to Escuintla to see the Camcore teak provenance/progeny trial in Valle Verde farm. Juan gave instructions to Guillermo García for the thinning and fertilization of the trial. Response to fertilization by family will be evaluated and the thinning operation will be used to measure heritability of heartwood proportion.

Mexico

Proteak acquired the *Eucalyptus urophylla* plantations from Fomex in Tabasco and is building an MDF plant in Mexico. Camcore is helping the company increase the productivity of its eucalypt plantations, making quick progress in the tree breeding program with the species. Camcore made selections of the best families of *E. urophylla* in the trials that will be used for deployment in operational plantations and for the establishment of clonal trials. Two 1st generation progeny trials of teak were planted by Proteak with genetic material from Camcore. In August, Proteak hosted a Data Management short course taught by Willi Woodbridge in Villahermosa.

Uumbal has done a great job planting the progeny trials with different species of pines provided by Camcore. The main interest of the company is to establish plantations of fast growing trees with high resin quality. During his visit in August, Juan López recommended a study on production and quality of resin in *P. caribaea* assessed by provenance, family, and tree in an 11-year-old trial owned by Proteak in Tabasco. Different sources of *P. elliottii* and *P. caribaea* are being sent by Camcore to create the genetic base to be used for the production of improved hybrid seeds.

Mozambique

Camcore continues to help **Green Resources Mozambique** to implement its tree breeding program with pines and eucalypts and to build a broad genetic base in Lichinga and Nampula. Juan López visited both provinces in September, inspecting Camcore field trials and helping the foresters write a tree improvement plan. Green Resources has 38 active Camcore provenance/progeny trials that will lead to great potential for operational deployment of selections in the near future. Camcore is also helping with trial designs and statistical analyses of data.

Juan López made a visit to **Florestas de Niassa** in Mozambique in September. The purpose of Juan's visit was to help the company take

José Manteiga of Florestas de Niassa (FDN) looks at pollen strobili on a 3.5-year-old *P. maximinoi* at Lichinga, Mozambique. The species grows very well and flowers prolifically in this area.

advantage of the great forestry potential existing in the region. Camcore made some growth projections for the main species of pine based on good silvicultural practices and good genetic improvement. The company continues to make progress building its own genetic base and established several Camcore provenance/progeny trials.

South Africa

Camcore recently acquired a new IML Resistograph machine to measure density profile in standing trees. The machine is basically a motorized drill with a needle-like bit, and a computer that measures resistance as the needle passes through the stem. **Sappi Forests** and **Mondi South Africa** collaborated on a study to test the Resistograph on populations of *E. dunnii*, to determine optimal sampling techniques, and genetic parameters, including genetic correlation with core and disk density. The Resistograph is very fast: a single person can measure 240 trees/day, while a two-person crew can only sample about 50 cores or 25 wedges per day. Final analysis of this project will be completed in 2015.

Bill Dvorak visited **Cape Pine** in May. The use of *Pinus radiata* as the primary commercial species for the company is at risk from *Fusarium circinatum*. Cape Pine has done a good job building up the genetic base of a number of potential replacement species including *P. maximinoi, P. greggii*, and *P. patula* x *tecunumanii* hybrid. Cape Pine is also in the midst of establishing a new *P. elliottii* seed orchard in Zululand. Bill also spent time with Andre van der Hoef confirming pine hybrids at the trial in Kruisfontein in preparation for a Camcore research project on pine wood quality sampling. Bill Dvorak also visited **Komatiland Forests** to confirm pine hybrids in their trial s in the Sabie region.

Gary Hodge visited **Merensky** at Tzaneen in August to discuss their eucalypt breeding. In this region, *E. grandis* is suffering significantly from *Leptocybae* gall wasp, and this is having an impact both in plantations and in their 4th generation seed orchard. We spent some time visiting the Camcore *E. urophylla* trials and discussed plans for thinning and making selections to include in the Merensky breeding population, for growth and form, and also for splitting. We also discussed opportunities to use NIR to look for chemical signatures of low splitting in a Merensky *E. grandis* population.

Steve Verryn (left) next to a row of *Corymbia citriodora*, and Sonia du Boisson (right) next to a row of *E. longirostrata* in a Merensky planting of a mixed Camcore species trial in Tzaneen, South Africa.

Bill Dvorak visited **York Timbers** in mid-July to inspect and verify the identity of pine hybrid crosses in Camcore trials. York Timbers has also made a number of interesting (and sometimes unique) pine hybrid combinations in addition to those provided by the Camcore membership and the results of their many field trials should provide excellent information to guide future breeding efforts.

Tanzania

Green Resources Tanzania has made great progress during the last two years in the establishment of pine and eucalypt species and progeny tests. Camcore is helping the company to develop its tree improvement program, sending genetic material and giving strategic guidance. The vegetative propagation program the company has in place will be very useful for the commercial deployment of selections in the genetic trials in the short term. In his visit this year, Juan López gave some recommendations to improve this process.

Juan López made the first technical visit to **Private Forestry Programme** (PFP), Tanzania, a new associate member that joined Camcore in July 2014. PFP is a program to help small farmers grow trees. Juan helped PFP structure a tree breeding program to increase productivity of teak, pines and

Simon Bayo and Prosper Wilbright of Green Resources Tanzania in a 1.5 year-old Camcore *E. urophylla* trial.

eucalypts, based on what other forest organizations have available. PFP is just starting to operate in Tanzania with the guidance of Camcore in genetic improvement.

Uruguay

Robert Jetton visited Uruguay in April. **Weyerhaeuser** has done an excellent job with the establishment and management of Camcore trials at Quebrachal. Provenance/progeny trials of *P. greggii* and *P. maximinoi* are both growing well at age 3. While *P. maximinoi* may lack sufficient frost tolerance for Uruguay, *P. greggii* is expected to have the good growth and frost tolerance needed to be a successful species for the country. The South African *Eucalyptus* benchmark trials and *E. dorrigoensis* provenance/progeny trial at Quebrachal all were damaged in a severe wind storm where the tops were broken out of some trees and others were blown over at the roots. While this is disappointing, we are still hopeful that survival is high enough for the trials to provide some valuable selections for Weyerhaeuser. Robert also visited field trial sites for the *Thaumastocoris* impact study which continues to develop nicely and is already providing information on the potential impacts of this insect pest on the productivity of *E. benthamii i*n Uruguay.

While in Uruguay Robert attended and participated in Uruguay's first country-wide forest health field tour organized by INIA. Personnel from both Weyerhaeuser and **Montes del Plata (MDP)** participated in this important training event to learn more about the detection, evaluation, and management of the many established and emerging insect and disease issues facing the forest industry in Uruguay. Gary Hodge also worked with MDP on the analysis of *E. dunnii* provenance/progeny trial data that will help the company advance their breeding and production programs with the species.

Venezuela

Camcore continues to help **Smurfit Kappa Venezuela** with the development of its *Eucalyptus* tree breeding program. Emphasis on new species for hybrids has been made and the company has established new genetic trials with different species. Selections of *E. urophylla* in the Camcore provenance/progeny tests have been made and the material will be used for the establishment of clonal tests. Second-generation progeny trials of *E. urophylla* will be planted to obtain additional gains in the program.

Terranova de Venezuela has expanded the objectives of its forestry strategies developing a new line of research to evaluate other forest species useful for the production of biomass for energy and timber for its MDF plant. Together with Camcore, the company has initiated the evaluation of several species of *Eucalyptus*. The company has already established several progeny trials with *E. camaldulensis, E. urophylla* and *E. brassiana* in the eastern plains of Venezuela. Both pure species and hybrids have potential across much of the company's landbase.

Maderas del Orinoco's seed orchard of *Pinus caribaea* in Santa Cruz de Bucaral has been used by the company to make hybrid crosses with improved pollen of *P. tecunumanii* from Brazil and Colombia, and unimproved pollen of *P. pringlei* from South Africa provided by Camcore. The purpose is to produce hybrid seeds for the establishment of pine hybrid trials by family in Venezuela and other countries. The company continues to make progress in its *P. caribaea* tree breeding program with the help from Camcore.

Regional Technical Meetings

The Regional Technical Meetings gather together breeders, researchers and managers from Camcore organizations in the local region. At these meetings, we discuss various Camcore matters, review progress over the past year, report on ongoing research projects and make plans for future work. In addition, we spend a day in the field looking at operations and research of the host organization.

In southern Latin America, the Regional Meeting was hosted by Suzano in October at Itapetininga, in the state São Paulo, Brazil. Attending the meeting from the region were representatives of Alto Paraná, Weyerhaeuser, and Klabin, as well as representatives of Uumbal and ProTeak from Mexico. Our field day included a visit to FuturaGene, a molecular genetics group affiliated with Suzano, and visits to some *E. grandis* progeny tests and seed orchards, as well as some of their experiments with polyploids.

In August, the African Regional Meeting was hosted in Weza, South Africa by Merensky. In attendance were representatives from Sappi, Mondi, Komatiland, PG Bison, York, and Cape Pine, as well as representatives from Florestas de Niassa, Green Resources Mozambique and Green Resources Tanzania. Our field visits included stops at hybrid trials, the *P. patula* seed orchards, 2nd generation *P. tecunumanii* tests, and the plantings of *E. urophylla* at the Merensky conservation park.

These Regional Meetings are very valuable – since travel costs are low, many people can attend and participate in Camcore activities. This gives us the opportunity to have a large local group and discuss many issues of mutual interest. Many thanks to the teams from Merenksy and Suzano for hosting these meetings in 2014.

The Regional Technical Meeting hosted by Suzano at Itapetaninga, São Paulo, Brazil, visiting a seed production area of *E. dunnii* planted in 1985.

The Regional Technical Meeting hosted by Merensky at Weza, South Africa, visiting the Camcore Conservation Park.

Eucalyptus Breeding Program

Camcore began collecting seed and planting trials of *Eucalyptus urophylla* in 1996. For this species, more than 170 field tests with 61 provenances and 1104 families have provided valuable information for growth and wood quality to our members. At the 2008 annual meeting in Indonesia, the Camcore Advisory Board recommended the expansion of our work with eucalypts. Camcore started collecting genetic material of tropical, subtropical and temperate *Eucalyptus* species so that our members could include them in their breeding programs. An expanded genetic base will help companies select material that is more resistant to diseases, drought or frost, identify new species that can be used as hybrid partners and increase the productivity of operational plantations for pulp, paper, sawtimber and bioenergy.

Table 1. Camcore eucalypt trials distributed to members from 1996 to 2014.

Species	Latin America	Africa	Total
E. urophylla	113	61	174
E. pellita	14	19	33
E. dorrigoensis	12	6	18
E. grandis	0	6	6
E. brassiana	6	4	10
E. badjensis	13	0	13
E. globulus	4	2	6
E. nitens	4	2	6
E. camaldulensis	10	5	15
C. torelliana	6	10	16
E. benthamii	13	10	23
C. citriodora	6	12	18
C. maculata	6	13	19
E. longirostrata	6	8	14
E. dunnii	0	6	6
Subtropical	14	11	25
Temperate	21	10	31
South African Benchmark	18	8	26
Tropical Benchmark	9	8	17
Drought Hardy	9	9	18
West Australia Species	2	2	4
Total	**286**	**212**	**498**

Platiel Chilaule (Green Resources Mozambique) in a 2.5 year-old *Eucalyptus longiostrata* planting on the the Lichinga Plateau in Mozambique.

To date, 498 tests have been sent to our active members (Table 1). About 57 % of them have been distributed to members in Latin America and 43 % to African members. Great effort has been made in the last five years in *Eucalyptus* breeding and testing; between 2010 and 2014, Camcore distributed 337 eucalypt tests which represent about 68 % of the total number of trials (Figure 1), 187 sent to Latin America and 150 to Africa.

In 2014, Camcore distributed 19 eucalypt trials to its members: twelve to Africa (2 to Green Resources Mozambique, 2 to Green Resources Tanzania, 2 to Merensky, 4 to Florestas de Niassa and 2 to Cape Pine – MTO Forestry) and seven to Latin America (6 to Proteak and one to Monterrey Forestal - GWR SAS).

Partial results at three years of age in some of the Camcore trials in Green Resources Mozambique are showing great commercial potential. Species like *E. dunnii*, *E. longirostrata, E. brassiana, E. propincua, E. punctata* and *Corymbia*

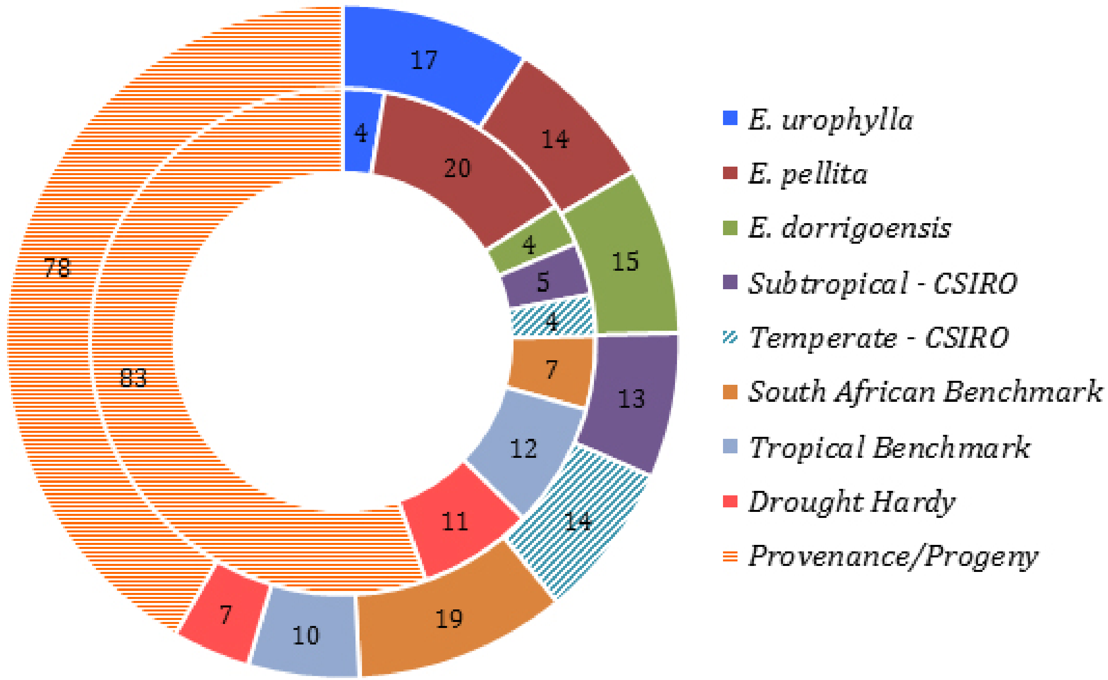


Figure 1. Eucalypt trials sent to members 2010 – 2014. Outer ring represents the number of trials sent to Latin America, while the inner ring relates to the trials sent to Africa.

maculata are growing well at early ages. *Eucalyptus dunnii* has good growth and cold resistance, and has excellent properties for the pulp industry. The hybrid *E. grandis* x *E. dunnii* shows great potential in some areas in Brazil with better growth, wood density, and pulp yield than the hybrid *E. urophylla* x *E. grandis*. *Eucalyptus brassiana* is a species with high adaptability to dry land, so it has potential for Camcore members in areas with low rain and sandy soils. Another species with potential is *E. pellita,* which has high wood density, and seems to have good resistance to a number of common eucalypt pathogens. Unimproved material is doing well at a many locations in the tropics, and we hope this species will be very valuable as a hybrid partner.

Some members are also starting to explore the potential of eucalypt species for energy production. Tekia in Colombia established two provenance/progeny trials of *E. urophylla* and *E. camaldulensis* at low elevation in the northern part of the country. Eucalypt wood for energy might be an economic option for the cement industry of Tekia's parent company Cementos Argos.

Left to right, Rodrigo López, Ovidio Orrego, Nhora Isaza, Carlos Andrés Orozco, Nicolás Pombo (Smurfit Kappa Colombia) in a trial of unimproved *E. pellita* from Indonesia growing at Vanessa Farm. The species has good disease tolerance and might be valuable in the future as a parent in hybrid crosses at SKC.

Eucalypt Hybrid Project Update

In 2011, Camcore initiated a cooperative Eucalypt Hybrid Breeding Project. The objective of this project was to produce full-sib families of a wide array of eucalypt hybrids, and a total of 13 Camcore members agreed to participate: Arauco Bioforest, CMPC Forestal Mininco, Komatiland, Merensky, Mondi, Forestal Monterrey, Rigesa, Sappi, Smurfit Kappa Colombia, Smurfit Kappa Venezuela, Suzano, Weyerhaeuser, and York Timbers. By the end of 2014, 12 crosses had been attempted and 11 were successful in the production of at least some seed. One cross (*E. globulus* x *E. camaldulensis*) was delayed due to difficulties in collecting and importing pollen, but this cross will be made in 2015. All of the hybrids include as a parent species at least one of the following group of commercially important species: *E. grandis*, *E. urophylla*, *E. dunnii*, *E. globulus*, and *E. nitens*. The idea was to produce some hybrids with potential in any geographic region or climate, and the goal for each hybrid was to produce 20 full-sib families of each hybrid. The rationale was that this would be sufficient to test the commercial potential of the hybrid, to explore the patterns of genetic variation, and to provide a genetic base for the selection of progeny or clones for hybrids which demonstrated commercial potential. Table 2 below shows the hybrids made, the number of seeds produced, and the numbers of families and parents. In 2015, we will distribute the hybrid seed to the participating members, who will then begin test establishment. We are very pleased with the results of this first eucalypt hybrid crossing program, and we are sure that we will find some very interesting hybrid combinations and genotypes.

Camcore began collecting *E. urophylla* in Indonesia in 1996, and by 2003 we had the world's largest genetic base of this species. However, at the time this Hybrid Project began, we did not have a Camcore genetic base of other species with which to make hybrids, so the participants in this project used their proprietary genetic material as parents. As of 2014, Camcore has built a substantial genetic resource of eucalypt species (see the article on Eucalypt Breeding and Testing, in this Annual Report). These new eucalypt genetic resources have been distributed widely among all Camcore members, putting us as a group in a very strong position going forward. We are excited about a future Phase 2 of Eucalypt Hybrid Breeding - it is not too early to start planning!

Table 2. Status of the crosses being produced in the Camcore Eucalypt Hybrid Program.

Female	Male	Status	Families (female x male)	Seed
grandis	*benthamii*	Seed collected	20 (13 x 4)	25,600
grandis	*pellita*	Seed collected	20 (10 x 6)	19,806
grandis	*dunnii*	Seed collected	13 (4 x 4)	9,863
grandis	*globulus*	Seed collected	17 (12 x 5)	8,956
urophylla	*pellita*	Seed collected	16 (5 x 6)	7,566
grandis	*smithii*	Seed collected	21 (8 x 11)	4,750
urophylla	*brassiana*	Seed collected	28 (5 x 6)	3,116
grandis	*brassiana*	Seed collected	36 (9 x 8)	2,136
GC, GU, GT	*saligna*	Seed collected	3 (1 x 3)	1,231
grandis	*nitens*	Seed collected	28 (10 x 6)	151
nitens	*pellita*	Cross completed	20 (10 x 5)	5,000
globulus	*camaldulensis*	Crossing in 2015		

Pine Hybrid Project Update

Camcore members involved in the pine hybrid program continued making crosses, seed collections, hedge growing, and trial planting in 2014. This year, Bosques del Plata in Argentina, Arauco in Chile, Weyerhaeuser in Uruguay, and York in South Africa made seed collections of different hybrid crosses using *P. taeda*, *P. elliottii, P. radiata* and *P. tecunumanii* as mother trees. Additional hybrid seeds of full-sib families will be collected in 2015 for the establishment of hybrid trials by family. Twelve new hybrid trials were established in 2014 with the seeds of the third series: one in Argentina, one in Colombia, four in Brazil, and six in South Africa. To date, a total of 78 field trials have been planted in the program, 31 in South America and 47 in Africa.

One of the pine hybrids showing great commercial potential in the Camcore program is the *P. greggii* var. *australis* x *P. tecunumanii* high elevation. This hybrid has shown quick growth at early ages in Brazil, Colombia, and South Africa. Research conducted by Juan López (Camcore) has shown that the hybrid has high wood density and high pulp yield when compared to the pure species, which makes it very valuable for pulp production. Another advantage of this hybrid is that *P. greggii* provides the frost resistance necessary to grow in cold places.

Another pine hybrid with great potential is *P. caribaea* var. *hondurensis* x *P. tecunumanii* as seen in several hybrid trials in Argentina, South Africa and Venezuela. Controlled crosses between the two species were made in the *P. caribaea* seed orchard owned by Maderas del Orinoco in Santa Cruz de Bucaral, Venezuela at the beginning of the year and seeds should be collected in 2015.

Pine Hybrid Wood Properties

Camcore members have planted 78 pine hybrid trials in the field since 2007. Now that some of the trials are approaching 8 years of age, Camcore will start measuring wood properties in some of the oldest ones. Several trials are in good condition and have between 6 and 12 different hybrids. Twenty “hybrid” trees from each hybrid combination in each trial will be sampled with the tree sonic and resistograph and wood shavings will be collected and sent to Camcore for NIR analysis. Density and MOE will be assessed and cellulose and lignin percentages will be estimated by NIR scanning at Camcore.

Camcore labeled seedlings from interspecific crosses as “hybrids” when at least 50% of the seedlings produced in the greenhouse at NC State University indicated hybridity based on molecular marker assessment. This suggests that some “hybrid” seeds distributed to the regional coordinators were pure species and therefore, not all the trees in every plot in our pine hybrid trials are true hybrids. To reduce the bias in our measurements of “hybrids” for growth and wood properties, all trees in the pine hybrid trials selected to be included in the wood study were visually inspected by Bill Dvorak prior to extraction of the wood samples in order to separate pure species from the putative hybrids. Five different trials were assessed in 2014, two in Colombia (Smurfit Kappa Colombia), and three in South Africa (Cape Pine, KLF and Mondi). Twenty trees in each hybrid combination that morphologically looked like hybrids were graded and marked. The graded hybrids in all the trials were: *P. caribaea* x *P. tecunumanii* LE, *P. caribaea* x *P. oocarpa*, *P. elliottii* x *P. caribaea*, *P. elliottii* x *P. tecunumanii* HE, *P. patula* x *P. elliottii*, *P. patula* x *P. greggii*, *P. patula* x *P. oocarpa*, *P. patula* x *P. pringlei*, *P. patula* x *P. tecunumanii* HE, *P. patula* x *P. tecunumanii* LE, *P. tecunumanii* LE x *P. caribaea*, *P. tecunumanii* HE x *P. oocarpa*.

The study of the wood properties will start in 2015 with the sampling and measurement of two tests in Colombia and one test in Argentina. In the following years, 10 more studies in other countries will be sampled for wood properties.

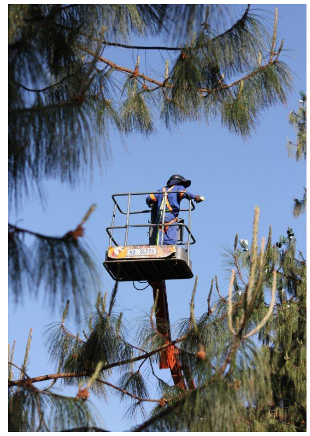
Camcore *P. patula* x *P. tecunumanii* Hybrid Breeding

The *P. patula* x *P. tecunumanii* hybrid is of great interest as a commercial variety for southern Africa. The hybrid combines the fast growth, *Fusarium* resistance and good wood properties of *P. tecunumanii* with the cold tolerance and good form of *P. patula*. A sub-group of Camcore members in Africa approved a *P. patula* x *P. tecunumanii* hybrid breeding program in 2012, and began work in 2013. In 2014, we completed the second year of a planned three-year effort in breeding.

The workplan set a challenging goal of producing 320 full-sib hybrid families, using 64 *P. patula* parents, and 80 *P. tecunumanii* parents. The 80 *P. tecunumanii* parents were equally divided between high and low elevation sources, as the two sub-populations will likely bring different advantages to the hybrid. For example, low-elevation *P. tecunumanii* has better *Fusarium* resistance, but lower frost tolerance. The plan is to cross each *P. patula* parent with 5 *P. tecunumanii* (3 high-elevation and 2 low-elevation selections, or vice versa), and to cross each *P. tecunumanii* with 4 *P. patula* selections. The goal for each hybrid cross is to produce about 150 seeds. All of the crossing is being done in Sappi's Lions River seed orchard, and the cost of the work is being shared among the participating organizations: Cape Pine, Komatiland, Merensky, Mondi, PG Bison, Sappi, and York from South Africa, and Green Resources Tanzania.

The crossing work began in 2013. In South Africa, high-elevation *P. tecunumanii* produces pollen prolifically, but only a few low-elevation selections had pollen available. A total of 57 *P. patula* x *P. tecunumanii* crosses were completed, 45 with high-elevation selections, and only 12 with low-elevation sources. In 2014, 111 hybrid crosses were made, 57 with high-elevation selections and 54 with low-elevation selections. Across both years, 33 *P. patula* females were crossed with 32 *P. tecunumanii* high-elevation males, and 23 *P. tecunumanii* low-elevation males. There was a total of 168 hybrid crosses completed, 102 of patula x tecHE, and 66 of patula x tecLE. This was very good progress.

Unfortunately, a very heavy hail storm hit the Lions River orchard on October 16, 2014. This was the day after all of the 2014 crosses had been debagged. The hail did significant damage to both the one-year-old cones from 2013, and the new cones pollinated in 2014. Based on survey counts conducted after the storm, it appears that up to 75% of the expected one-year-old cones have been lost. Impact on the 2014 crosses was also severe, with 57% of recently debagged cones lost. The survey counts were based on only a few trees, but assuming these results are representative, this was a major setback. Complaining about the weather won't bring back the lost cones, so we must press on and do our best to recover in 2015. The good news is that pollen production and female cone production is increasing each year as the trees get older, so we may be able to make up for the loss.




P. patula x P. tecunumanii breeding work being done in the Sappi Lion's River seed orchard, Tweedie, South Africa.

A severe hail event at the seed orchard in October, 2014, caused significant loss of hybrid cones.

Pollen Contamination in *Pinus tecunumanii* Breeding Populations

In both Colombia and South Africa, the predominant commercial pine species is *P. patula*. In both countries, high- and low-elevation *P. tecunumanii* have shown great commercial potential. Camcore members have made progeny selections in 1st generation trials, and collected open-pollinated seed from the selections to establish 2nd generation tests. The problem is that flowering times of *P. patula* and *P. tecunumanii* overlap (particularly for high-elevation sources). In 2013, we initiated a study to try to quantify the extent of the problem. There were four phases to this study:

- Phase 1: Confirm molecular markers for *P. patula* and *P. tecunumanii*
- Phase 2: Identify pure species and hybrids in 2nd generation *P. tecunumanii* trials.
- Phase 3: Develop NIR models from foliage scans.
- Phase 4: Use NIR models to quantify contamination.

For each of the four phases, we will briefly describe the methods and the results. For convenience, the following shorthand notation will be used throughout this report: pat = *P. patula*, tecLE = *P. tecunumanii*, low-elevation sources, tecHE = *P. tecunumanii*, high-elevation sources, tecLE x pat = hybrid *P. tecunumanii* (low elevation) x *P. patula*, and similarly for other hybrids.

Phase 1

Camcore worked with Dr. Zander Myburg and his staff at the Forest Molecular Genetics Programme (FMG), University of Pretoria, and confirmed that microsatellite markers can distinguish between *P. patula*, *P. tecunumanii* and the hybrid. Kitt Payn, Biotechnology Programme Leader at Mondi, coordinated needle collections of selected provenances of LE and HE *P. tecunumanii* and *P. patula* growing in Camcore 1st generation trials in South Africa. A total of 150 trees were genotyped to broaden and refine the molecular database to ensure that it would be useful across all provenances of *P. patula* and *P. tecunumanii*.

Phase 1 Results

The molecular markers did a very good job in identifying samples (Figure 2). For *P. patula*, 87 of 87 samples were correctly classified as *P. patula*. For *P. patula* var. *longipedunculata*, a variety found in the southern end of the *P. patula* native distribution, 10 of 10 samples were classified as *P. patula*. For the tecLE samples, 74 to 76 samples out of 77 were classified as *P. tecunumanii* (depending on one's criteria for the boundary between pure and hybrid). For the tecHE samples, 37 of 37 samples were correctly classified as *P. tecunumanii*.

Phase 2

The molecular markers developed at FMG were then used to verify putative tecHE and tecHE x pat, and tecLE and tecLE x pat sampled in trials belonging to Cape Pine and Komatiland Forests (KLF) in South Africa and Smurfit Kappa Colombia (SKC). Both high- and low-elevation *P. tecunumanii* 2nd generation trials were sampled. The goal in the sampling was to identify a pure species and a hybrid from the same family whenever possible. In addition to the above samples, at the KLF site, samples were taken from a nearby hybrid trial containing pat x tecHE and pat x tecLE progeny produced by control crossing.

Foliage samples were taken from "pure" and "hybrid" trees in the same open-pollinated *P. tecunumanii* families. These were confirmed with molecular markers and used to build NIR models. Photos by Harold Campo, Smurfit Kappa Colombia.

Phase 2 Results

For tecLE and tecLE x pat, the molecular markers seemed to work very well. This was confirmed by the fact that 22 of 23 pat x tecLE produced by controlled crossing were identified as hybrids by the markers. Most of the trees that had been visually identified as pure tecLE in the progeny tests were confirmed as tecLE by the markers (48 of 52). Approximately half of the trees that had been visually identified as tecLE x pat in the field were confirmed to be hybrids (23 of 52).

For the tecHE and tecHE x pat, the molecular markers also seemed to work well, at least for the samples from South Africa. Once again, for the pat x tecHE hybrids produced by controlled crossing, 13 of 13 samples were identified as hybrids. Most of the trees that had been visually identified as pure tecHE in the South Africa progeny tests were confirmed as tecHE by the markers (26 of 32). Most of the trees that had been visually identified as tecHE x pat in the field were confirmed to be hybrids (24 of 26).

For the samples from Colombia, the molecular markers were less useful. This may be due to the fact that the SKC high-elevation *P. tecunumanii* seed orchard, from which the progeny tests were derived, has a number of non-typical *P. tecunumanii* parents. Some clones in the orchard are from Rancho Nuevo and Napite provenances. These perform very well in Colombia, but these provenances are known to have some introgression from *P. patula* and/or *P. pringlei*. The orchard also contains selections from Juquila provenance. This provenance is an excellent performer in Colombia, but its molecular marker profile resembles *P. herrerae* more than *P. tecunumanii*. There was no pattern in how the molecular markers classified either the putative tecHE or the putative tecHE x pat: over 80% of both putative types would have been classified as hybrids. For this reason, we did not carry any of the SKC samples into Phase 3: NIR model development.

Phase 3

Using the verified pure species and hybrid samples, NIR models were built to classify tecLE *vs.* tecLE x pat, and tecHE *vs.* tecHE x pat. Green needles were collected from each tree and scanned with a hand-held NIR microPHAZIR in the field, and a subsample of needles from the same trees were oven dried and sent to NC State to be scanned on a desktop FOSS 6500 NIR machine. The goal with the handheld NIR was to determine if future assessments of hybridity could be conducted in the field. Each NIR model was built as a two-class model, i.e., A vs B, using only A and B samples. For each model, we tried six mathematical transformations of the spectra, and three sets of NIR wavelengths, and chose the model with the best results.

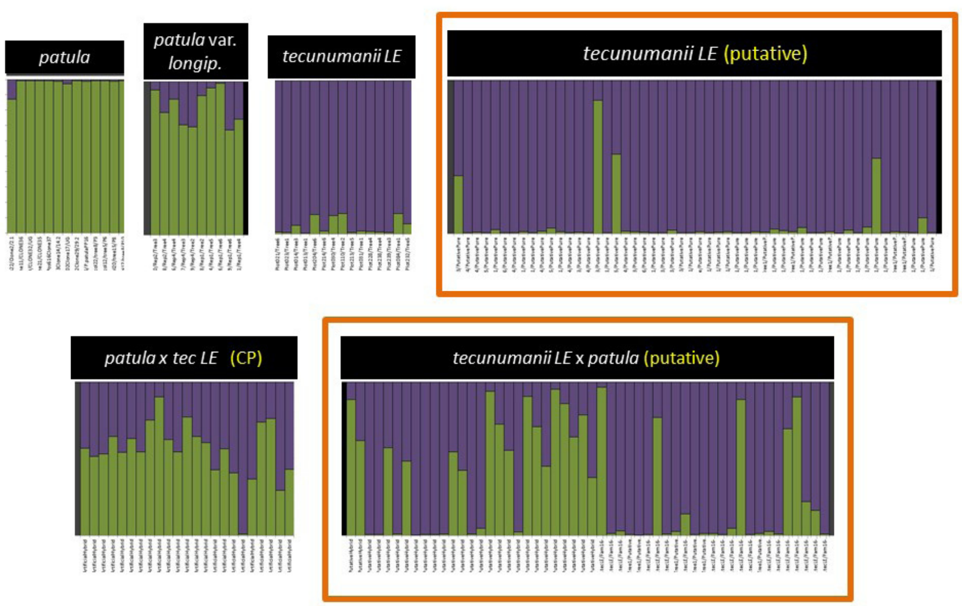


Figure 2. Sample results of molecular marker analysis to classify trees by the percentage of *P. patula* genome (green) and *P. tecunumanii* genome (purple). Marker analysis was done by the Forest Molecular Genetics Programme (FMG), University of Pretoria. The marker results were used to classify trees in the orange boxes as "pure" or "hybrid", and foliage samples from these trees were used to build NIR models.

Phase 3 Results

For the desktop NIR, the models were moderately good. For the comparison of tecHE *vs.* tecLE, the model classified samples with 96% accuracy. For tecLE *vs*. pat x tecLE, and for tecHE *vs.* pat x tecHE, the model classified samples with 97 to 100% accuracy. The controlled-cross *P. patula x P. tecunumanii* hybrids were one year younger than the pure species samples; and perhaps age-related foliage differences might have improved the classification accuracy. Nevertheless, for the comparison of tecLE *vs.* tecLE x pat, the model was 90% and 82% accurate for classifying tecLE and tecLE x pat, respectively. The results for tecHE *vs.* tecHE x pat were similar, with 85% and 83% accuracy for classifying tecHE and tecHE x pat, respectively.

Phase 4

The NIR models were used to classify every tree in an entire 2nd generation progeny test to quantify the percent of hybridity, and to examine variation in percent hybridity among families.

Phase 4 Results

Figure 3 illustrates the range in percent hybridity (or percent *P. patula* contamination) for a sample of tecLE and tecHE families. Mean hybridity in the tecLE population is relatively low, averaging around 10%. The data suggest that around 85% of the families have less than 15% hybridity, and around ¼ of the families have hybridity near zero. However, some families have hybrid percentages above 20%. For the tecHE population, mean hybridity is much higher, averaging 46%, and ranging from 18% to 86% hybrid.

Discussion

The presence of *P. patula* hybrids in the Camcore 2nd generation *P. tecunumanii* trials is a challenge. We want to breed *P. tecunumanii* as a pure species, because it has significant commercial potential, and we also want pure *P. tecunumanii* to use as a potential hybrid partner with species like *P. greggii*, *P. caribaea*, and *P. patula*.

The presence of nearly 50% hybrids in the Camcore high-elevation *P. tecunumanii* trials makes it difficult to know how to use that data. We know that *P. tecunumanii* x *P. patula* hybrids will have a growth advantage on most sites in South Africa. In theory, we could classify every tree in every 2nd generation *P. tecunumanii* test as either tecHE or tecHE x pat, perhaps using NIR models. We could then use the data appropriately to predict a pure-species genetic value and a hybrid genetic value. But this would be a time consuming and somewhat expensive process. For the low-elevation population, with around 10% hybrids, the problem is less serious, but the presence of hybrids would introduce noise into the analysis.

Another approach would be to abandon an open-pollinated mating strategy, and focus only on some type of controlled-cross strategy, either with full-sib or polymix breeding. Smurfit Kappa Colombia has already done some full-sib breeding of their tecLE population, and this will work – but it is time consuming and expensive.

At this time, it is not clear what is the best approach to breeding *P. tecunumanii,* but we now know more about the situation, and we also learned something about the potential of NIR technology to help us address the problem.

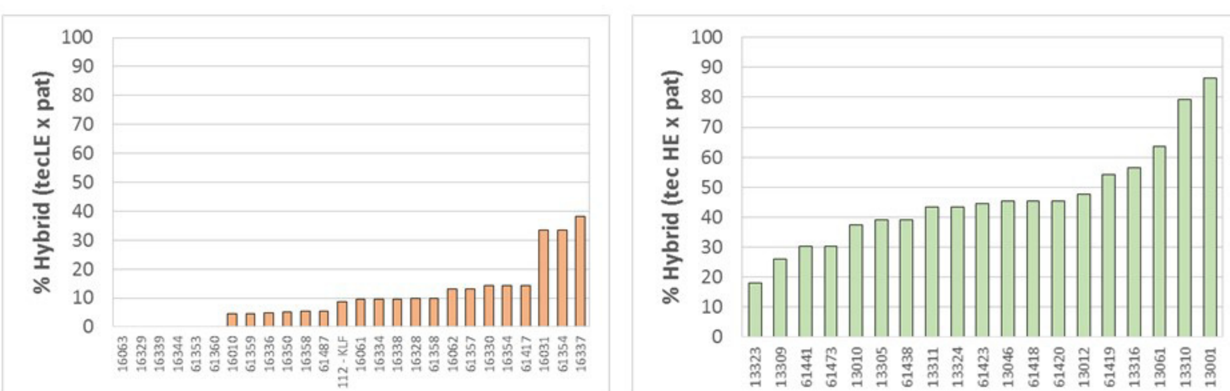


Figure 3. Pollen contamination in *P. tecunumanii* families: percentage of *P. tecunumanii* x *P. patula* hybrids as estimated by NIR models. Left = Low-elevation *P. tecunumanii*, Right = high-elevation *P. tecunumanii*.

Tectona grandis Update

Camcore continues to increase the genetic base of teak through acquisition of seeds from different sources. Increasing the genetic diversity of the species will improve the potential for larger genetic gains. Our most recent collection of seeds came from 80 trees selected in natural forests of Laos from four different provenances: Tonepheg, Hovaysiuy, Pakthar, and Parouden, located in the province of Bokeo. In addition to these seed lots, a bulk lot from Myanmar was also received. With these recent collections, Camcore has a total of 336 families from 38 different sources. A number of these seed collections are from provenances in India, Thailand, Myanmar, and Laos, where teak is native, and we hope to collect additonal seed from natural stands in these countries to ensure we have captured as much of the natural genetic diversity as possible. Our teak genetic base also includes seeds from selected trees in commercial plantations, seed orchards, and genetic trials from Indonesia and Bangladesh in Asia, Tanzania and Mozambique in Africa, and from Colombia, Guatemala, Mexico, and Venezuela in Latin America.

This year, four new trials were planted by Camcore members, two by Proteak in Mexico and two by Tekia in Colombia, making a total of eight Camcore Teak trials planted by Tekia, Proteak, and Grupo DeGuate in Guatemala. In 2015, four more trials will be planted, including the Laos' provenances that have not yet been included in any trial.

The oldest trials were planted in Guatemala four years ago. They will be measured at the beginning of 2015, and growth data will be analyzed by Camcore at four years of age. After the measurement, 50% of the trees will be thinned, leaving three out of the six trees per family per plot. The purpose of the thinning is to reduce competition among trees in the trial. Half of each trial will be fertilized and response to fertilizer by family will be measured.

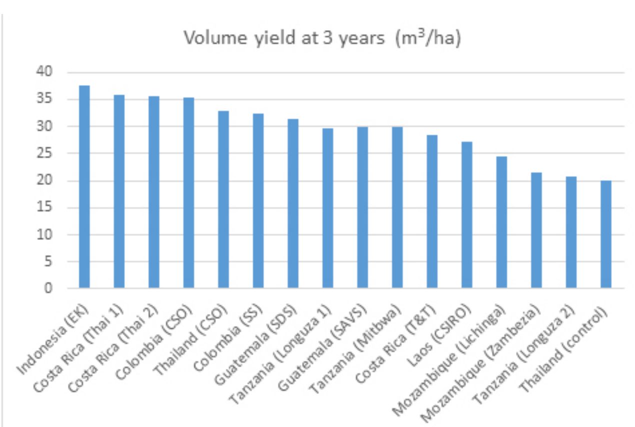
A Camcore - Grupo deGuate teak progeny trial (age 3 years) on the Valle Verde Farm in Guatemala. Left to right: Oscar López, Rodrigo Yurrita, Juan López, Guillermo García, and Romeo Jump.

We also plan to take advantage of the thinning treatment to conduct a study to evaluate heritability of teak heartwood proportion. Once we learn how heritable this trait is, we will decide whether we can use it as part of a selection index in genetic trials. This research project will include trees from two trials in Colombia and two trials in Guatemala.

Camcore will conduct a similar study of heritability of this trait in three of Proteak's clonal trials in Mexico. In this case, the heritability will be calculated at the clone level which will provide very valuable information.

Results of growth at three years of age in the provenance/progeny trial of Valle Verde farm in Guatemala are presented in Figure 4. These early results start to show volume growth performance at the provenance level. Three families from Sumalindo in Indonesia were the best of the 65 families evaluated in this test.

Figure 4. Volume growth results at age 3 years in a Camcore provenance/progeny trial in Valle Verde farm in Guatemala.



Genetic Control of Wood Properties in *Pinus taeda*

Introduction

In 2006, seven Camcore members in Argentina (Alto Paraná, Bosques del Plata), Brazil (International Paper, Klabin Paraná, Klabin Santa Catarina, Rigesa) and South Africa (Sappi), initiated a Genotype x Environment (GxE) interaction study for *Pinus taeda*. The objectives for this study were to determine the size, pattern and causes of GxE, and to examine if GxE was low enough to permit collaborative breeding and testing across the entire region. Five-year results showed that there is relatively small GxE interaction among sites either at the provenance or family-within-provenance level (Annual Report 2012), which indicates that there is an opportunity to exchange genetic material, and work together to select families or clones.

At the Southern Latin America Regional Meeting in 2013, it was agreed that we would continue to use this study for another collaborative project to assess the genetic variation of wood properties among the *P. taeda* GxE population, and to rank the top half of the families (based on growth) for important wood traits.

Materials and methods

Two eight-year-old trials were phenotyped for this project: trial 5548G06A1 belonging to Bosques del Plata (Argentina) evaluated in May 2014, and trial 5527G06A1 belonging to Rigesa (Brazil) evaluated in October 2014. In both trials, we took samples and measurements at breast height to assess three wood traits:

1. Modulus of Elasticity (MOE): This property, which measures wood stiffness, was estimated using the TreeSonic. This tool measures the stress wave propagation time in the stem of the standing tree. With this time and the distance between the device sensors, acoustic wave velocity is calculated, which correlates well with MOE and yield strength of wood.
2. Density: The IML-Resistograph tool was used to measure the density profile of the trees. Specifically, the Resistograph measures the drilling resistance as a thin needle is inserted into the wood under constant drive. This resistance is directly proportional to the density of the tree.
3. Cellulose/Lignin content: For each tree, we used hand drills to take wood shavings from just inside the bark to just short of the pith. These shavings will be ground into woodmeal and assessed with NIR spectroscopy to predict cellulose and lignin content using our Global Pine models.

As an additonal research project, for each tree we used the microPHAZIR handheld NIR to scan the outerwood on the standing tree through a window we opened in the bark. The idea is to examine the



Left: Romeo Jump (Camcore) using the IML Resistograph to measure density.
Center: José Roberto and Rodrigo Jordão (Rigesa) using the TreeSonic to measure wood stiffness.
Right: Ana Paula Burzminski (BDP) taking wood shavings for NIR analysis to measure cellulose and lignin content.


First-rate wood sampling teams! Left photo: Ricardo Gonçalves, Marcieli Bovolini, Waldemar A. Veiga, and Rodrigo Jordão of Rigesa. Right photo: Santiago Marchesi (BDP), Paola Molina (Weyerhaeuser), Raúl Schenone (BDP), German Raute, Juan Schapovalof (Alto Parana), Gary Hodge (Camcore), and Juliana Ivanchenko (Weyerhaeuser).

potential of the handheld NIR to measure these traits on standing trees.

Statistical analysis for this project included the estimation of covariance parameters and the calculation of genetic parameters (single-site heritability (h^2_b), across-site heritability (h^2) and type B genetic correlation (r_{Bg}).

Results and Discussion

Here we present preliminary results for TreeSonic (MOE) and Resistograph (Density). NIR analysis to predict wood chemistry is ongoing, and will be completed in 2015. Single-site heritability values for TreeSonic velocity were h^2_b = 0.33 and 0.43 for the BDP and Rigesa tests, respectively. For mean Resistance (functionally equivalent to mean density), single-site heritability estimates were $h^2_b = 0.62$ and 0.36 for the BDP and Rigesa sites, respectively. All of these values are in accordance with what we expect for wood traits, that is, moderate to high heritability.

Combined site analyses were done for both traits. For TreeSonic, across-site heritability was $h^2 = 0.40$ with zero GxE for TreeSonic ($r_{Bg} = 1.00$). For Resistance, across-site heritability was h^2 = 0.35 with moderate GxE ($r_{Bg} = 0.71$). These results are in agreement and support what we concluded for growth traits when those trials were 5 years old, and suggest that there is a great opportunity to exchange genetic material between members of Argentina, Brazil and Uruguay, and to create a joint breeding program for the species.

It appears that wood stiffness and growth are inversely related. For volume growth, the sources Alto Paraná (AP) and Bosques del Plata (BDP) were consistently superior across all sites, averaging 31% and 12% more volume at 5 years than the mean of the seven provenances (see the 2012 Annual Report). However, for MOE, these two sources rank at the bottom (Table 3). It is important to note that there is considerable family variation within source, and it is possible to identify families from these sources with high MOE. For example, AP_151 had the third highest MOE among the 60 families tested. This suggests that it should be possible to select families and individuals with both fast growth and good wood strength.

In 2015, we plan to complete the NIR analysis for cellulose and lignin content, and complete the analysis of the microPHAZIR data.

Table 3. Modulus of elasticity (MOE) for the 8 sources of *P. taeda* and the top 10 out of 60 families as estimated by acoustic velocity with the TreeSonic.

Source	MOE (Gpa)		Top 10 Families	MOE (Gpa)
RIG	8.42		RIG183	9.62
SAP	8.25		SAP163	8.90
KPR	8.15		AP_151	8.76
KSC	8.13		SAP175	8.73
INP	8.02		BDP122	8.71
BDP	7.76		RIG185	8.66
AP_	7.74		INP222	8.59
			KSC244	8.53
			BDP131	8.53
			KPR215	8.51

Teak Seedling Nutrient Disorder Study

Copper deficient teak (*Tectona grandis*) seedling at 7 weeks, 2.66 ppm foliar Cu.

In 2014 Andy Whittier made significant progress on his research of nutrient disorder symptoms in teak (*Tectona grandis*) seedlings. Preliminary studies in 2013 investigated different strengths, pH levels, and buffering bases of nutrient solutions. Results from these studies were utilized in 2014 in a larger nutrient study. During the summer and fall of 2014 a total of 276 teak seedlings were grown in a horticulture greenhouse in a sand culture hydroponic system. These seedlings were subjected to 14 different nutrient regimes for two months. During seedling growth, numerous photographs were taken in order to capture different deficiency symptoms. These photographs will be incorporated into a diagnostic guide for distribution to Camcore members working with teak. In addition to photographs, foliar nutrient analyses were done on each treatment as seedlings exhibited a deficiency symptom in order to have a quantiative measure of nutrient content at the time when deficiencies become apparent.

During seedling growth, several of the nutrient deficiencies produced expected symptoms. A few of the deficiencies, most notably Copper, resulted in unexpected symptoms, and may be investigated at a later date in an environmental chamber in a traditional liquid culture setup. Similar to the sand culture hydroponic study, regular photographs and foliar nutrient samples will be taken during the experiment. When available, results from this second study will be incorporated into the diagnostic guide.

In conjunction with the nutrient deficiency study, another project was conducted looking at whether we could develop NIR (Near Infrared Spectroscopy) models to estimate levels of Nitrogen, Phosphorus, and Potassium in teak seedlings. For this study 280 plants were grown in a greenhouse where they were subjected to one of 14 different nutrient regimes. The regimes include four levels each of Nitrogen, Phosphorus, and Potassium and two control treatments. Once every three weeks, a subset of 70 samples were scanned with a handheld microPHAZIR™ NIR scanner. Leaves from these 70 seedlings were then destructively sampled and ground for use in NIR analysis using the table top FOSS NIRSystems™ 6500. Using two different NIR techniques will allow us to compare the results from the cheaper and less labor-intensive handheld scanner to the more precise but costly and time-consuming laboratory machine. By late 2014, all plants had been scanned with the handheld scanner and destructively sampled for laboratory analysis. Final NIR scanning is scheduled to be done early 2015. Descriptions of models developed from these NIR studies will be included in the diagnostic guide.

The bulk of the research has been completed and we are excited to finish up this study and begin analyzing the data and describing the results. Work on the diagnostic guide has begun and will continue during the first half of 2015 with a goal of distribution to members by early 2016.

Properties of Handsheets Made with Pine Hybrid Pulp

As part of his Ph.D. research on the economic value of pine hybrids, Juan López analyzed properties of pulp and handsheets produced from *P. patula* x *P. tecunumanii, P. greggii* x *P. tecunumanii,* and *P. taeda* x *P. tecunumanii* grown in South Africa. The work was done at the Forest Biomaterials Lab at NC State University. Bleached-Kraft pulp was produced and handsheet properties were measured at three levels of refining (1000, 2000, and 3000 RPM in a PFI mill). Refining is a mechanical treatment to improve fiber-to-fiber bonding in paper. However, during the refining, some fibers are cut and the shorter individual fibers are weaker. Some pulp properties such as tensile strength and burst depend more on fiber-to-fiber bonds and are enhanced by increased refining (up to a certain point). Other pulp properties, such as tear strength, that depend largely on the strength of individual fibers, decrease with increased levels of refining. An increase in the level of refining also results in lower values for freeness and thickness. Freeness is defined as the rate at which water drains through the pulp and is measured as the Canadian Standard Freeness (CSF). When the drainage is fast, the CSF is high. Refining reduces the pulp freeness, an undesirable condition, given that lower freeness translates to slower speed in the paper machine. There is a trade-off between the level of refining and the freeness. Freeness showed negative correlations with tensile strength and burst, but positive correlation with tear strength and thickness (Table 4).

In order to compare handsheet properties among the different taxa with respect to *P. taeda* market pulp, the values of tensile strength, tear index and burst index were determined at similar values of freeness. These values of freeness varied between 473 for *P. greggii* x *P. tecunumanii*, and 482 for the *P. taeda* market pulp. The freeness values for *P. patula* x *P. tecunumanii* and *P. patula* were obtained at 3000 RPM of refining, while the freeness values for the rest of the taxa were determined at 2000 RPM of refining. Figure 5 shows the pulp properties of the five taxa examined. In general, all of the subtropical pines had better tensile and burst strength than the *P. taeda*, and lower tear strength.

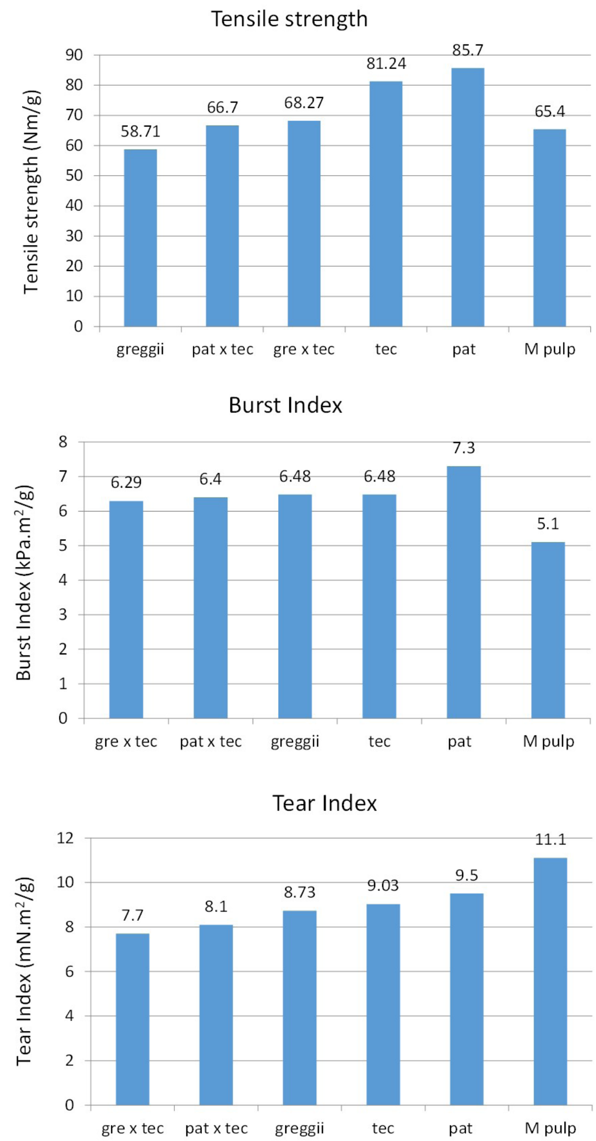


Figure 5. Comparison of tensile strength (top), burst index (middle), and tear index (bottom) for *P. patula*, *P. tecunumanii*, *P. greggii*, and some hybrids versus *P. taeda* market pulp. Subtropical pines were grown in South Africa, *P. taeda* was grown in the southeast USA. All values are for CSF = 473 to 482.

The *P. taeda* market pulp used in this study was from an unknown source available in the NC State Forest Biomaterials Lab. It is likely that this sample represents trees older than the subtropical pines used in this study, since the typical rotation length in the southeast USA is over 18 years. Because of the longer rotation, the percentage of mature wood should be high, improving the values of the handsheet properties with respect to those of the younger tropical and subtropical pines. The market pulp was dried before testing its properties, which may result in hornification (physical change that takes place in a papermaking fiber upon drying) and a consequential decrease in values for some pulp properties. It is difficult to assess the magnitude of the opposing effects of maturity and hornification on pulp properties, but it is assumed that they are similar in magnitude, and that the sample used in the study is representative of *P. taeda* market pulp.

The two pine hybrids tested in this study, *P. patula* x *P. tecunumanii* and *P. greggii* x *P. tecunumanii*, have shown great growth potential in a number of Camcore trials and in different environments. These results suggest that the wood quality of the hybrids will be also be satisfactory for paper production.

Table 4. Correlation coefficients for handsheet properties of pulp with values over 0.50.

Property	Tear	Burst	Thickness	Freeness
Tensile strength		0.85		-0.70
Tear Strength	1.00	0.68	0.74	0.79
Burst		1.00	-0.74	-0.78
Thickness			1.00	0.67

Density Profiles in Eucalypt Trees Grown in Chile

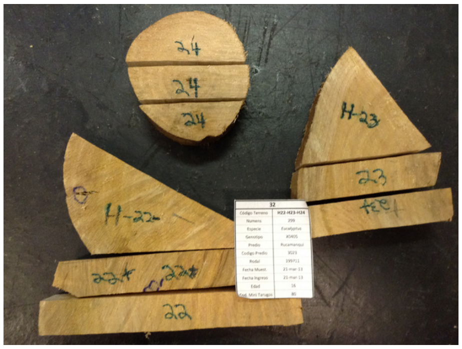
Introduction

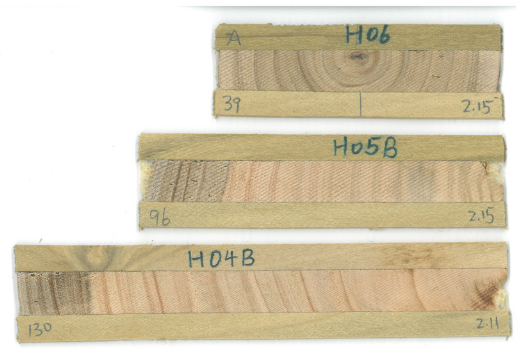
While Camcore members continue to plant trials to compare volume growth rates and adaptability of different species, provenances, families, and hybrids, there is increasing interest in research to assess wood properties of various genetic groups and understand the genetic control of these traits. Density has always been the single most important wood property and is one of the most easily measured. However, with the gravimetric methods typically used to measure density, resolution of density measurement along a bark-to-pith profile is fairly coarse. X-ray densitometry is a method that has been used for decades and makes measurements at a sub-millimeter scale. X-rays are beamed through a thin slice of wood and the proportion of radiation that passes through the sample can be used to estimate density.

CMPC Forestal Mininco grows several eucalypt species for a variety of products. They have questions about the optimal rotation length for various species so they want to know what the density of the outer growth rings is and how much these later rings influence the density of the entire stem. At 15 to 20 years, these rings are rather narrow and would be very difficult to assess, so this situation is a good use for the X-ray densitometry method.

Material and Methods

CMPC collected wood samples from 34 trees of three species: *Eucalyptus globulus*, 14 trees, age 15; *E. nitens,* 10 trees, age 20; and *E. globulus* x *E. nitens,* 10 trees, age 15. From each tree, 5-cm-thick disks were cut from the stem at 3 heights: base (breast height), top (height where diameter was 10 cm), and mid height (the midpoint of the other two). The disks were dried and shipped to Raleigh for processing. Sections from each disk were cut with a band saw with the following protocol: from each base and mid-height disk, one radial wedge and 2 rectangular bark-to-pith sections were marked. From the top disk, a single bark-to-bark rectangular section was excised (see photo, p.36). The wedges are for gravimetric density measurements and the rectangular sections are for X-ray densitometer and NIR scanning. After more cutting, each disk yielded two rectangular bark-to-pith "planks" (for a total of 6 per tree) for X-ray analysis and additional material that was ground into wood meal for NIR scanning. The planks were glued onto wooden holders and resawn with a custom blade setup that produces 2-mm-thick sections that can be loaded into the densitometer (see photo, p.36). A total of 204 samples were scanned; 2 reps each of 3 disks from 34 trees. The rest of this article describes results only from the X-ray scans.





Left. Samples cut from disks from one tree at base, mid and top heights. Subsamples for X-ray and NIR analysis were cut from the rectangular pieces.

Right. Wood planklets ready for X-ray scanning. The upper sample, from the top height, contains both bark-to-pith samples.

Results and Discussion

Scans from the densitometer provide density estimates every 0.04 mm along the sample length. This creates profiles of very high resolution output in both graphical and numeric form. For trees with distinct densities between latewood and early wood, annual rings are clearly delineated. In the ring-porous eucalypt species used in this trial, however, rings were not reliably discernable (Figure 6). The large lumens in the vessels create a lot of noise in the density readings and obscure changes in density due to annual rings. In order to be able to combine values from different trees to get species-level ring densities, "pseudorings" were delineated by dividing the samples into segments of equal width. A sample from the base of a 20-year-old tree should have 18 to 20 rings but in this case, the sample was divided into only 12 "rings" to reduce the amount of variation that would occur from segments having incomplete rings. Samples at the base of 15-year-old trees were divided into 9 pseudorings and mid-height samples were divided into 8 or 6 pseudorings. Strips from the top were divided into 3 segments (Figure 7). For each ring segment, values from the two replications were averaged to estimate tree-level values for each stem height. For species-level values, averages were calculated at each sampling height from tree-level values. Average density values for the 3 species at the base height are shown in Table 5. These values were based on 10 or 14 trees with two samples per tree. This sample is the equivalent to a breast-height increment core; past research has shown that increment cores are good representations of overall tree density. The 3 species do not show large differences and in the small sample size of this study; there is more variation within species than between them. Figure 8 shows the density profiles at the base for the 10 trees of the hybrid. This graph shows that generally, the ranking of density within the group is constant along much of the profile. One tree in particular, H07, has unusually high density along the entire profile and this was present in both samples at all 3 heights. The patterns of density profiles for the mid and top disks were similar to the base. Figure 9 shows the summary of all data for the 3 species measured at 3 heights. These graphs reveal a number of patterns in the trees in this study: 1) density is similar for all three species although there is considerable variation among

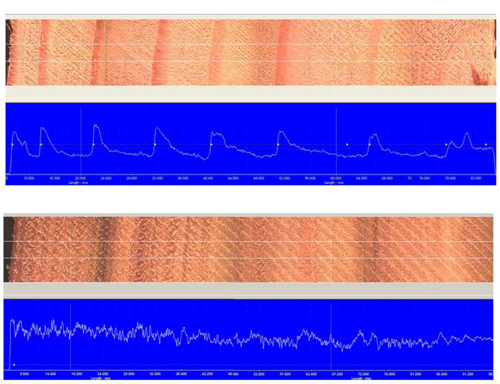


Figure 6. Density profiles of pine (top) and *Eucalyptus globulus* (bottom).

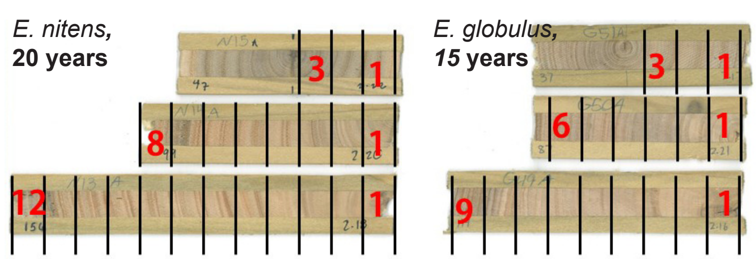


Figure 7. Schematic for "pseudorings". Base samples were divided into 9 or 12 "rings" depending on age, mid samples into 6 or 8 and top samples into 3.

Table 5. Density of 3 eucalypt species at the base of the tree. Values are averages of all readings across 2 sample strips from 10 or 14 trees.

Species	Trees	Min	Max	Avg
E. globulus	14	497	609	563
E. nitens	10	509	596	555
Nitens x globulus	10	509	754	557

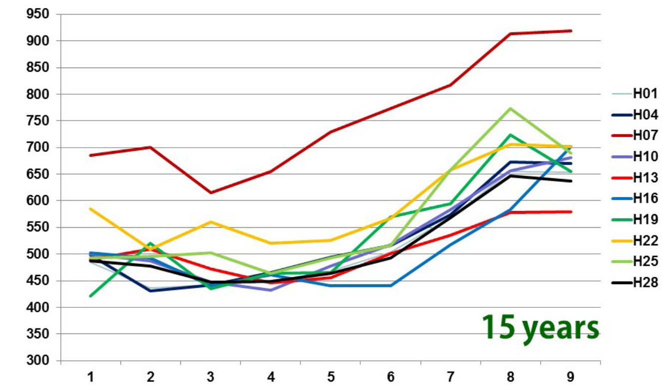


Figure 8. Density profiles of the base disk for ten 15-year-old trees of *E. globulus x E. nitens* hybrid. Density values for 9 equal-length segments are averages of 2 samples from each disk.

trees, 2) density increases up the stem, 3) at all heights, density decreases from the pith for 3 to 6 years, then steadily increases 4) there may be a tapering off and decrease in density in the later years for *E. nitens* (age 20) and the hybrid (age 15). This result is tentative since the decrease occurred only in the last segment which is always difficult to assess due to incomplete growth rings and splitting found in the outermost wood. Perhaps more work on trees of even older age should be performed before making decisions about optimal rotation ages.

Future work

Although the X-ray method is robust for measuring relative density, the absolute values are sensitive to proper calibration. Standard values from the literature were used to calibrate the X-ray readings for the species in this study, but gravimetric density measurements on the wedges will refine the values. We have scanned wood meal that came from material adjacent to the X-ray strips with both table-top and handheld NIR spectrometers. We will use these scans to estimate chemical components of the wood but we can also test the value of spectral data for estimating density.

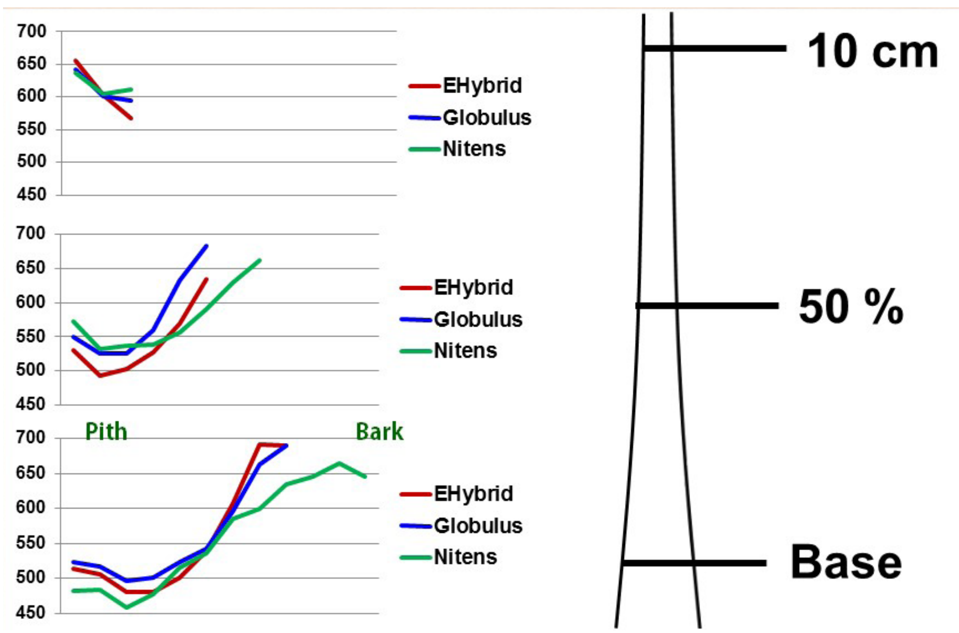


Figure 9. Density profiles of samples from 3 stem heights of *Eucalyptus globulus, E. nitens,* and *E. globulus x E. nitens.* Values are averages of 10 or 14 trees (2 samples from each tree). The profiles for *E. nitens* are longer because these trees are 20 years old while the other species are 15.

Eucalyptus Pathogen Screening

As the importance of *Eucalyptus* species to forestry operations continues to grow world wide, so does the number of threats to their success. Of particular concern are a number of insects and diseases that have emerged during the past decade with the potential to cause significant growth losses in eucalypt plantations. At the 2014 Camcore Annual Meeting in Guatemala, the Camcore Technical Committee approved a new research project on the screening of eucalypts for resistance or susceptibility to several important pathogens affecting *Eucalyptus* plantations on members' lands in South America and Africa. The target diseases are the myrtle rust pathogen *Puccinia psidii*, and the stem canker pathogens *Botryosphaeria* and *Coniothyrium.* Initially, as the protocols for each pathogen are developed, screening will be at the species level and, depending on seed availability, focus on all or a subset of the 21 tropical, subtropical, temperate, and winter rainfall species in Camcore's eucalypt program. As the project develops further, screening at the family and clonal levels will occur for those species where species-level screening results indicate additional testing is needed. This project is in the early development stages, but tentative plans are for seedling production and pathogen screening to be conducted in cooperation with Smurfit Kappa Colombia, and Weyerhaeuser and Instituto Nacional de Investigación Agropecuaria (INIA) in Uruguay.

Foliar damage caused by *P. psidii* infection on *E. grandis* in Uruguay.

Stem cankers caused by *Botryosphaeria* infection on *Eucalyptus* sp. in Uruguay. (Photo by Jorge Martinez Haedo, Weyerhaeuser.)

Stem canker caused by *Coniothyrium* infection on *E. badjensis* in Uruguay.

Transfer of Global Pine NIR Models to Other Machines

Camcore has developed a number of Near-infrared spectroscopy (NIR) models that can be used to assess wood properties rapidly and efficiently. We have a global NIR model for pines to predict lignin and cellulose content using woodmeal samples, and models to predict wood density, microfibril angle, and modulus of elasticity on wood strips from pine increment cores. We are also working on the development of similar NIR models for eucalypts. Our current model (described elsewhere in this Annual Report) predicts pulp yield, lignin and sugar content and composition for *E. urophylla* and *E. dunnii*. These kinds of NIR models can be of great utility in breeding programs to screen many hundreds of genotypes for wood properties.

Once an NIR model is developed, application of the model in the real world is fast and easy. However, the development of a good robust NIR model can be time consuming and expensive. It would be useful if the NIR models that Camcore develops could be directly transferred to other organizations so they could avoid the time and cost of model development. The objective of this project was to attempt this transfer for our global pine models, to determine how successful such a transfer would be (that is, how accurate would the models be on the Secondary machines), and finally to examine how many samples are needed to accomplish a successful transfer. Here we report on preliminary results from this study.

Materials and Methods

Wood samples in the form of thick wedges were received from 200 trees of different species (*P. taeda*, *P. maximinoi*, *P. patula*, *P. tecunumanii*, *P. greggii*, and some *P. elliottii* hybrids), from multiple geographic regions. The wedges were sawn into thin slices (labelled A-G) in order to try to have "identical" samples to process in the different labs and scanned on different machines (Table 6). Two "identical" sets (slices D and G) were scanned by Camcore on the "Original" machine, a Foss 6500. An "identical" set of 200 samples was sent to each participant for processing and scanning on their "Secondary" machine. Some members received a mix of slices (A, B, C, E, and F), while Arauco received slice H for all 200 samples (Figure x). All members used their own normal lab protocols to grind the wedge slices into woodmeal and complete the NIR scanning. In addition, woodmeal from slices D and G, processed by Camcore were sent to Arauco, CMPC, and Mondi for scanning on their own NIR machines. Spectra from all machines were sent to Camcore for spectral comparison, data analysis, and model building.

Model transfer is an active area of research among NIR scientists. The typical approach is to take a population of spectra scanned on the "Original" and "Secondary" machines and look for mathematical functions (i.e., matrix equations) to convert the Original spectra to the Secondary spectra. If this can be done, then the appropriate linear regression weights for the "Secondary NIR model" are easy to derive. This will be done in this study,

Table 6. Camcore members participating in this project, and the NIR machines in each lab.

Company	Wedge Set	NIR machine	Wavelength information		
			Range used	interval	Number
Camcore	D, G	Foss 6500	1100 to 2500 nm	2 nm	1050
Arauco	H	Foss 6500	1100 to 2500 nm	2 nm	1050
CMPC	Mix of A, B, C, E, F	Foss 6500	1100 to 2500 nm	2 nm	1050
Sappi	Mix of A, B, C, E, F	Bruker	800 to 2782 nm	2 nm	1154
Mondi	Mix of A, B, C, E, F	Bruker	800 to 2782 nm	1 nm	2307
Klabin	Mix of A, B, C, E, F	Shimadzu IR Prestige 21	1000 to 2500	2 nm	779
Weyerhaeuser	Mix of A, B, C, E, F	ThermoScientific microP-HAZIR (handheld)	1600 to 2400 nm	8 nm	100

but for a first attempt, we took a different approach. Since we had a large population of samples (200 trees, many species, many regions), we tried to build NIR models directly for the Secondary machines. In other words, we assumed that we had the correct "lab" values for lignin and cellulose percentage for the 200 samples. Since the original Camcore NIR model is very accurate for lignin and cellulose, we used the average of two NIR predictions for slice D and slice G as the correct "lab" value for that sample.

When building NIR models, an array of mathematical pre-treatments (transformations) can be applied to the spectra. For example, some transformations help reduce "noise" in the absorbance patterns due to differences in particle size. For wood chemistry models, we have found that a standard pre-treatment of Standard Normal Variate followed by a Savitzy-Golay 2nd derivative (SNV-SG2) has worked very well. This SNV-SG2 transformation was used for all datasets. However, it is possible that other transformations might perform better for particular labs or NIR machines.

At the time of this report, we have not completed analyses for the two handheld NIR scans, so here we focus on the desktop NIR machines (the first six entries in Table 7).

Results and Discussion

Using the Camcore NIR predictions as "lab" values, very good NIR models were fit for all datasets for both lignin and cellulose. As an example, the lignin and cellulose models for the CMPC wedge dataset is shown in Figure 10.

For lignin, the Original Camcore model had an R2 = 0.97 and a standard error of cross-validation (SECV) of ± 0.43%. On the various Secondary machines, NIR models for lignin had R2 ranging from 0.92 to 0.96, with SECV ranging from ± 0.29 to 0.96% (Table 7). There was no apparent difference between models based on slice position (A-H), or whether the scans were done on an independent slice or with woodmeal scanned by Camcore. There was a difference between models developed for Foss 6500 scans – these models had lower SECV than models for the Bruker and Shimadzu machines. This suggest that math pre-treatments other than the SNV-SG2 might be superior for other machines.

For cellulose, the results were similar. The Original Camcore model had an R2 = 0.82 and an SECV = ± 1.06%. On the various Secondary machines, NIR models for lignin had R2 ranging from 0.80 to 0.96, with SECV ranging from ± 0.43 to 0.96% (Table 7). These are very good results, in fact, the SECV for the Secondary models was lower than the Original model. This is an interesting result, suggesting that once a good NIR model is developed for a chemical constituent, NIR measurements might be more precise (i.e., have less error) than wet lab measurements.

Since both Arauco and CMPC had a Foss 6500 NIR machine, we examined the possibility of making a direct transfer of an NIR model from an

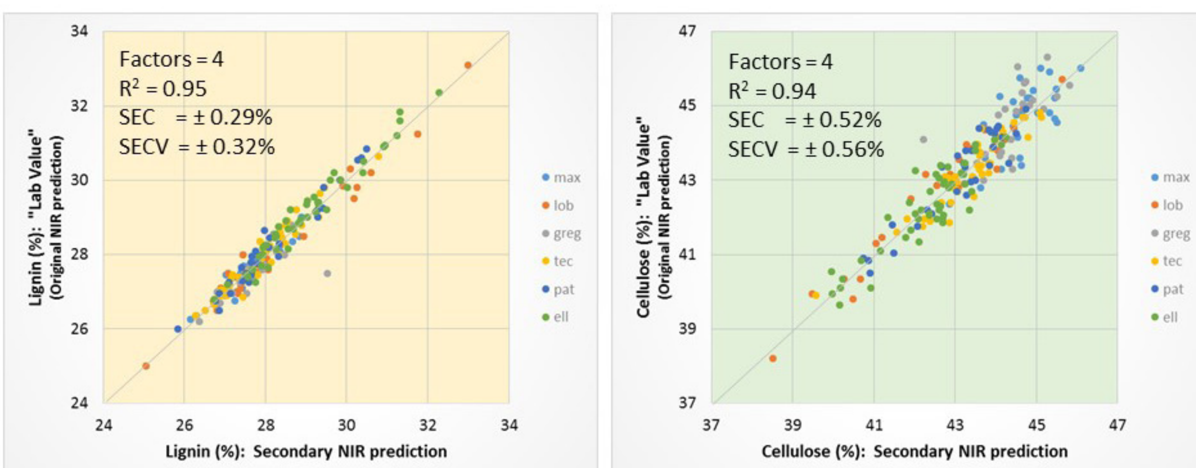


Figure 10. Typical results for NIR models built on "Secondary" NIR machines, using predictions from the "Original" Camcore NIR model as lab values. Results shown for CMPC, mixed wedge set.

Table 7. Model statistics for NIR models built on "Secondary" NIR machines, using predictions from the "Original" Camcore NIR model as lab values.

Variable = lignin						
Dataset	**Samples**	**R**	**R^2**	**SEC**	**SECV**	**Factors**
Original Camcore Global Model		0.98	0.97	0.43	0.43	11
Arauco	wedges (mix)	0.96	0.93	0.38	0.38	4
Arauco	woodmeal (G)	0.98	0.96	0.25	0.29	5
CMPC	wedges (mix)	0.97	0.95	0.29	0.32	4
CMPC	woodmeal (G)	0.98	0.96	0.24	0.28	5
Sappi	wedges (mix)	0.98	0.96	0.26	0.43	5
Mondi	wedges (mix)	0.98	0.96	0.26	0.60	5
Mondi	woodmeal (D)	0.96	0.92	0.37	0.70	5
Klabin	wedges (mix)	0.96	0.92	0.36	0.96	6

Variable = cellulose						
Dataset	**Samples**	**R**	**R^2**	**SEC**	**SECV**	**Factors**
Original Camcore Global Model		0.91	0.82	1.05	1.06	10
Arauco	wedges (mix)	0.92	0.85	0.58	0.63	4
Arauco	woodmeal (G)	0.98	0.96	0.30	0.43	8
CMPC	wedges (mix)	0.94	0.88	0.52	0.56	4
CMPC	woodmeal (G)	0.97	0.95	0.33	0.47	7
Sappi	wedges (mix)	0.94	0.89	0.45	0.65	4
Mondi	wedges (mix)	0.94	0.87	0.52	0.85	4
Mondi	woodmeal (D)	0.97	0.93	0.37	0.84	6
Klabin	wedges (mix)	0.89	0.80	0.65	0.96	4

Original machine to a Secondary machine of the same model. We took the Arauco NIR models, and used those to make predictions of lignin and cellulose using the CMPC spectra directly, and did the same thing in the other direction. In all cases, we had R2 of prediction and standard errors of prediction (SEP) very comparable to the R2 and standard error of the calibration data set.

Next Steps, and Preliminary Conclusions

There is further work to be done on this project in 2015. We plan to analyze the two datasets for the handheld microPHAZIR NIR machines produced by Camcore and Weyerhaeuser. We will also investigate a range of other mathematical pretreatments to see if the models could be improved further. Finally, we will investigate various algorithms to transform spectra directly to see if this is a more efficient approach to model transfer.

Nevertheless, at this point it is clear that we will be able to transfer NIR models from an Original machine to Secondary machines. At a minimum, this could be done by scanning roughly 200 samples on both machines, using the Original model predictions as “lab” values, and fitting new NIR models on the Secondary machines. It may be possible to do this with fewer samples, either using the same approach, or through the use of matrix transformation of the spectra. However it is done, this approach will be much easier than doing the lab work to develop new models for every new NIR machine. In other words, we can share the cost of NIR model development among all Camcore members, and each member can be assured of eventually being able to utilize those models in their own labs.

Non-Destructive Measurement of Teak Heartwood

In 2013, Camcore and Tekia (Colombia) began a project to develop a quick, non-destructive method to evaluate the proportion of heartwood in trees, suitable to use for selection in teak genetic trials. Trees with high proportion of heartwood can be sold for a better price in the wood market, so this is an important trait to measure and select for in a breeding program. The study was performed on a 16-year-old commercial teak stand located in Sucre department, northern Colombia, and it was conducted in two phases in 2013 and 2014.

Juan López using the IML-Resistograph in a 16-year-old teak stand in Colombia to measure the the density profile of the trees.

Phase 1

In February 2013, Camcore and Tekia personnel selected at random 50 teak trees for study. The trees were cut and the first four logs per tree were evaluated (log length was 2.2 meters). A detailed description of methods and results can be found in the Camcore Annual Report 2013. In summary, three instruments were used to take measurements on each log (the Fakopp-TreeSonic, IML Resistograph, and the handheld microPHAZIR NIR). Correlations between tool readings and heartwood percentage were calculated. The results were somewhat disappointing: only moderate correlations were found with the TreeSonic measurements and the handheld NIR scans (R = 0.50 and 0.47, respectively). Correlation between heartwood percentage and IML-Resistograph reading were not estimated due to a malfunction in its electronic system.

Phase 2

In March 2014, a second visit to Tekia was made with the goal to to include the IML-Resistograph readings, and to apply some refinements to the TreeSonic method in an attempt to get more precise measurements and improve correlations. Fifty more trees were randomly selected, and similarly, four logs were cut and correlations between the percentage of heartwood (see photo) and instrument readings were computed

The percentages of heartwood with respect to the total wood volume ranged from 54% to 98% for the logs sampled. For both instruments, the lowest correlations between heartwood and instrument readings were associated with the buttlog, which is usually of irregular shape in the cross section, while higher correlations were found for second, third and fourth logs (Table 8). The Resistograph correlations were quite low, with R = 0.14 and 0.34 for the buttlog and the upper logs, respectively. The TreeSonic acoustic wave velocity gave slightly better correlations, with R = 0.24 and 0.43 for the buttlog and the upper logs, respectively. Even allowing for the fact that these were phenotypic correlations (genetic correlations would likely be higher), the results were not encouraging.

Measurements of internal and external diameters to assess heartwood percentage. Left is a buttlog, right is a more regularly shaped upper log.

Table 8. Correlation values between teak heartwood proportions and instrument readings.

Log Number	TreeSonic	IML-Resistograph
Log 1	0.24	0.14
Logs 2,3,4	0.43	0.34

At this point, we do not have a satisfactory non-destructive method to accurately estimate the proportion of heartwood in a standing tree. The difference between teak sapwood and heartwood is probably much more related to chemical differences than physical differences.

We also evaluated a semi-destructive method to assess heartwood percentage in 11 trees. The method consisted in drilling four holes in perpendicular directions (or extracting four increment cores) in the buttlog, and measuring the distance from the bark to the beginning of heartwood. This distance can be used to estimate the percentage of heartwood of the log (see photo). Under this approach we obtained encouraging results, with estimated correlations of R = 0.72 with the drill and R = 0.69 with increment cores. Although these results are based on a small number of trees, we believe this method can be used on the field to easily estimate heartwood proportion with out significantly affecting the lumber quality.

A drill or increment bore could be used as a "semi-destructive" method to evaluate heartwood percentage in teak.

Thaumastocoris Project

Camcore and Weyerhaeuser continue to collaborate on a study to evaluate the impacts of defoliation by the bronze bug, *Thaumastocoris peregrinus*, on the productivity of eucalypt plantations in Uruguay. The bronze bug is an important world-wide pest of *Eucalyptus* that has been introduced to many of the eucalypt plantation regions of Africa and South America, and has been noted to occasionally cause severe and widespread tree defoliation. The insect was first reported in Uruguay in 2008 where it has caused significant dieback of eucalypts planted along roadsides and on cattle farms. However, widespread decline and defoliation in plantations has rarely been noted and it remains unclear if the pest is a serious threat to forestry operations in the country and warrants investment in management. This study uses stem injections of the systemic insecticide imidacloprid to exclude bronze bug feeding from injected trees, and then compares the growth and productivity of these treated trees to that of untreated trees where bronze bug populations remain intact. The eucalypt species being evaluated are *E. benthamii, E. grandis*, and an *E. grandis* x *camaldulensis* clone. The study was initiated in August 2012 and is ongoing. Two growing seasons of data have been collected at this point, and while results are preliminary they are also promising. In research plots where insect densities are highest, primarily those with *E. benthamii*, the growth of the insecticide-treated trees is better than untreated, indicating the stem injection treatments are working as hoped and that feeding and defoliation by the bronze bug on untreated trees is detrimental to tree growth and productivity. Results for *E. grandis* and the *E. grandis* x *camaldulensis* clone are inconclusive at this point as bronze bug populations have remained low on both treated and untreated trees. Data collection for this study will continue for several more years and final reports will be provided both in a future Camcore Annual Report and a peer-reviewed scientific paper. For more details on the trial design and scope readers are referred to the 2013 Camcore Annual Report.

Uncovering Genetic Information From Forest Plantations

Traditionally, tree breeding programs are initiated by making mass selections in natural stands, or for exotic plantation species, in commercial plantations. This is followed by grafting, seed collection, test establishment, and then waiting a number of years for data from those tests. The time required for this first phase of a breeding program could easily be 10 to 20 years, depending on the species. Advances in molecular genetics have introduced the possibility of new approaches to tree breeding. One of these approaches is pedigree reconstruction, which is the use of molecular data to determine the genealogical relationships among a population of individuals.

Camcore is investigating an approach to uncover or extract pedigree information from existing plantations (or natural stands) to predict breeding values and identify genetically superior individuals at the initial stage of a breeding program. This report summarizes the results of a computer simulation to evaluate how this could be done and to evaluate how much genetic gain could be made with such an approach. This project was done in collaboration with Milan Lstiburek of the Czech Agricultural University, and partially funded by a grant from the Czech government. It has been submitted for publication in *Tree Genetics and Genomes* in 2015, and full details of the study should soon be available there, but here we present a short summary of the work.

Outline of BwB Methodology

Assume that a forestry organization has a species of commercial interest, and some plantations of this species, but no genetic tests. The goal is to use molecular genotyping to reconstruct pedigrees, extract sufficient "progeny-test data" from the commercial plantations to rank families, to identify selection candidates, and to make breeding value predictions for the purposes of selection. This is an extension of an approach called "Breeding without Breeding" (BwB); for convenience, we will adopt this notation here. The approach can be outlined as follows:

1. Select a **Random** subset of the population for phenotypic measurement and genotyping.

   The genotyping results will eventually be used to reconstruct the pedigree of the Random population. The phenotypic measurements will be adjusted with post-hoc blocking or spatial row-column analysis. With a pedigree + phenotypic information, we now have a "progeny test".

2. Measure and/or inspect a large **Candidate** population.

   This population is larger than the Random population, and may consist of all or most of the trees in the plantations. Likely this "inspection" will simply consist of walking through 10 to 50 ha of plantations looking for outstanding trees. The phenotypic measurement will then be adjusted using a neighbor tree comparison, effectively the same as mass selection.

3. Identify a small **Top-Phenotype** population from the Candidate population.

   These are the very best phenotypes available, based on the neighbor comparison. The Top-Phenotype population will eventually be genotyped for pedigree reconstruction.

4. The **Pedigree Reconstruction** is done for the Random and Top-Phenotype population.
5. A **BLUP analysis** is done using the phenotypic data and the reconstructed pedigrees of the Random and Top-Phenotype population.
6. **Select the highest BV individuals** for orchard establishment, full-sib crossing, etc.

   This is analogous to offspring selection in progeny tests. The breeder can place constraints on relatedness as appropriate.

Simulation

Assumed genetic variance components were typical for forest tree populations. For each run in a given scenario, a set of 99 parents was generated with varying breeding values. For the BwB approach, we assumed open-pollinated mating, with parents varying widely in gametic contributions (i.e., fecundity), as has been found for forest trees. To provide a baseline for comparison, a full-sib mating design (FS) was also simulated with the same 99 parents, assuming each parent mated in four crosses and families tested on 6 sites with 20 trees/family/site. For each progeny, a phenotypic observation was generated based on the mid-parent breeding value plus random deviations for genotype x environment variance, dominance variance, and micro-site error variance.

For the BwB approach, a range of different sizes of the Random population (N_R = 0 to 3000 trees), the Candidate population (N_{BwB} = 5940 to 23,760 trees), and the final selected population (N_e = 5, 10, or 20) were examined. The size of the Top-Phenotype population (from which the final selections will be made) was restricted to N_T = 600. Genetic gains were calculated as the average true breeding value of the selected population. These gains were compared to the gains from forward selection out of a full-sib progeny testing program, assuming that each parent was mated with 4 others in a circular mating design, and the progeny tested on six sites, with 20 trees/family/site. For each BwB scenario (different N_R and N_{BwB}), 500 runs were done, and mean genetic gains across the 500 runs was calculated. All simulation was done using the R and ASREML software packages.

Results

Figure 11 presents the genetic gains achieved by the BwB approach for a final selected size of N_e =10. Trends for N_e = 5 and 20 are similar, with gains for N_e = 5 (higher selection intensity) around 3 to 5% higher, and gains for N_e = 20 (lower selection intensity) around 3 to 6% lower. The right axis of Figure x presents the genetic gain scaled as percent volume gain, and the right axis presents gain relative to the amount achieved by the FS approach ($Q_{BwB/FS}$).

A final selected population of N_e = 10 means that we have selected 10 unrelated individuals from the progeny population, and that these would come from some combination of matings of 20 of the 99 parents in the original population. Across 500 iterations, the gain from the FS approach with N_e = 10 averaged 33% gain in tree volume. In comparison, the BwB approach averaged 27% to 32% gain, depending on the size of the Random and BwB populations (N_R and N_{BwB}, respectively). In terms of relative efficiency, $Q_{BwB/FS}$ ranged from 83% to 97%; in other words, BwB was about 83% to 97% as efficient as the FS approach.

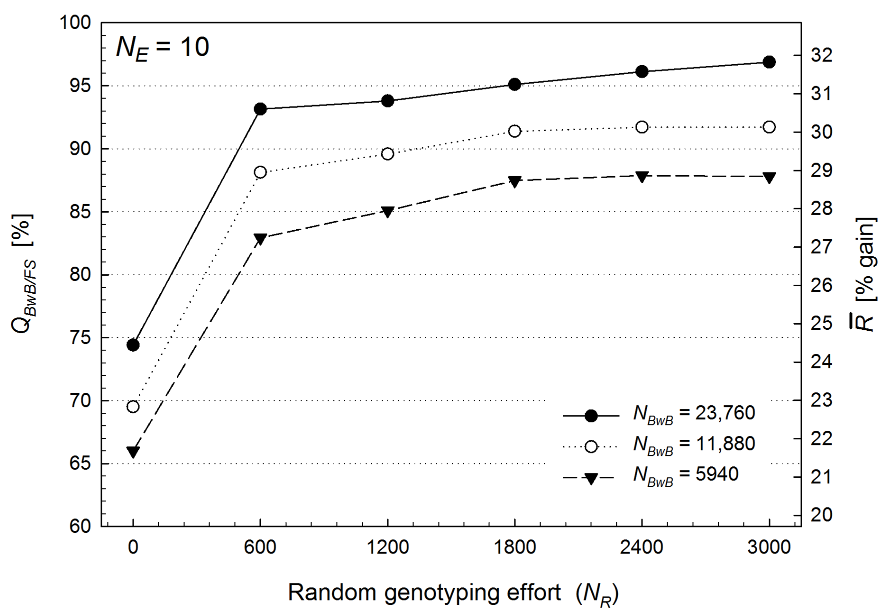


Figure 11. Genetic gains from progeny selection using a BwB strategy compared to gains from a full-sib strategy for a selected population size of N_e = 10. The left axis indicates the relative efficiency compared to the gain from the FS strategy ($Q_{BwB/FS}$), and the right axis indicates absolute genetic gains ($\bar{R}_{BwB}$).

Note that phenotypic selection alone would achieve about 65 to 75% of the gain from the FS approach, as can be seen for the points corresponding to $N_R = 0$ in Figure 11. The addition of the "progeny test" data from the genotyped and measured Random population produces a marginal genetic gain of 6 to 7% volume, and an increase in relative efficiency of around 20%.

Increases in the size of the Random population from $N_R = 600$ to 2400 produces about 2% additional volume gain (or a marginal increase in $Q_{BwB/FS}$ of about 5%). Doubling the size of the BwB population (from 5940 to 11,880, or from 11,880 to 23,760) also produces about 2% additional volume gain. Thus a breeder could get that additional 2% volume by increasing N_R (measuring and genotyping an additional 1800 trees), or by inspecting a few thousand additional candidates in the plantations. Or the breeder could do both.

Discussion and Conclusions

It seems clear that a BwB approach can return a substantial amount of genetic gain. The big advantage is that this approach can save time, that is, it can identify progeny selections and make genetic gain nearly as well as a replicated full-sib testing strategy, with a time savings of many years. It is important to note that this result would be dependent on accurate pedigree reconstruction with molecular markers. This simulation assumed that the pedigree reconstruction was 100% accurate. Results have been reported in the literature for various plant and fish species, and to a limited extent with forest trees. Depending on the numbers and kinds of markers, pedigree reconstruction accuracy can range from 70 to 98%. Larger numbers of markers produce better results, and as costs of molecular markers decrease, it seems possible to approach 100% pedigree reconstruction accuracy.

The next steps will involve additional computer simulations to examine the impact of errors in pedigree reconstruction, and the success of pedigree reconstruction with known full-sib populations of forest tree species of interest to Camcore members.

Potential for NIR to Discriminate Pine Species and Hybrids Based on Resin Samples

Over the last decade Camcore has investigated a number of methods for verifying pine hybrids that would be more effective than relying on morphological characteristics alone. Much emphasis has been placed on the use of chemical and molecular genetic markers such as isozymes, RAPDs, and SNPs, but these approaches tend to be expensive. Near-infrared spectroscopy (NIR) has proven to be very effective for discriminating pure species and hybrids of both pines and eucalypts in several previous studies conducted by Camcore. These studies used fresh or dried and ground foliage samples scanned with the handheld microPHAZIR™ and FOSS NIRSystems™ 6500 NIR scanners, respectively. In the past, taxonomists have used the chemical composition of pine resin as a useful trait to distinguish pine species and naturally occurring hybrids. In 2014, Camcore conducted a preliminary study of the potential of NIR to discriminate pine species and hybrids using pine resin samples (in contrast to foliage). Samples were collected from 36 *P. patula* and 108 *P. patula* x *pringlei* in Mondi's Camcore pine hybrid trial at Woolstone. and scanned on the FOSS NIRSystems™ 6500 desktop NIR scanner using the tablet analyzer. Resin samples were scanned in both liquid form and (after drying) gum form. Results for the gum resin samples were inconclusive, but results from the liquid resin samples were encouraging as a single-tree cross-validation discriminant model was able to correctly classify resin samples of *P. patula* and *P. patula* x *pringlei* with 88% and 100% accuracy, respectively. We plan to continue with further studies to determine what resin forms work best and to further refine the cross-validation models.

Camcore Seed Collections 2014

Seed collecting in natural stands of pine in Central America is an ongoing activity at Camcore. New members of Camcore begin building up their genetic base with these native stand collectons. This germplasm is also used for the establishment of conservation parks by Camcore members to maintain the genotypes for the long term. This year, Elmer Gutiérrez and Josué Cotzojay made collections of seeds from 108 trees of three species from six different provenances in two countries (Table 9).

Seed collections made in Mexico and Guatemala more than 25 years ago were used by Camcore members to establish genetic trials in several countries. Seeds from these trials have been collected by Camcore and sent back to Guatemala and Mexico for the establishment of "reintroduction studies". Five reintroduction studies have been planted in Guatemala, four of *P. maximinoi a*nd one of *P. tecunumanii*, and three reintroduction studies have been planted in Mexico, two of *P. patula* and one of *P. greggii* var. *greggii*. Selection of the best trees will be made in these trials to convert them into seed production areas.

Table 9. Summary of seed collections completed in Central America and Mexico in 2014.

Country	Species	Provenance	Conservation Status	Latitude	Longitude	Trees
Guatemala	*P. tecunumanii HE*	San Jerónimo	Endangered	15°00'	90°15'	14
Guatemala	*P. tecunumanii HE*	Km 33	Critically endangered	14°32'	90°20'	8
Guatemala	*P. tecunumanii HE*	Chiquival Viejo	Vulnerable	15°07'	91°32'	13
Guatemala	*P. maximinoi*	San Jerónimo	Endangered	15°00'	90°15'	15
Honduras	*P. caribaea*	Gualjoco	Vulnerable	14°55'	88°23'	15
Honduras	*P. caribaea*	La Brea	Vulnerable	15°45'	86°00'	21
Honduras	*P. caribaea*	Sta. Cruz de Yojoa	Vulnerable	14°56'	88°55'	16

Conservation of Hemlock Genetic Resources

This year was Camcore's eleventh collaborating with the USDA Forest Service (USFS) on the genetic resource conservation of Eastern hemlock (*Tsuga canadensis*) and Carolina hemlock (*Tsuga caroliniana*). These ecologically important species are native to the eastern United States where they face a significant threat of genetic degradation and population loss due to the invasive insect pest Hemlock Woolly Adelgid, *Adelges tsugae* (HWA). To date, this project has resulted in the collection of seed from 728 mother trees and 72 populations of Eastern hemlock and 134 mother trees and 19 populations of Carolina hemlock (Figure 12); the establishment of hemlock conservation banks by Camcore and its members in Brazil (Rigesa), Chile (Arauco-Bioforest), and the United States (Camcore); the submission of seeds to the USDA National Center for Genetic Resources Preservation for long-term conservation in cold storage; the publication of 23 peer-reviewed and technical scientific papers; and numerous oral and poster presentations at professional conferences and workshops. This has all been accomplished with more than $700,000 in grant funding provided by the USFS and in cooperation with USFS Forest Entomologist James "Rusty" Rhea.

It was a productive year for Camcore's hemlock project. We published three peer-reviewed and one technical paper, and Robert Jetton gave an invited presentation on the conservation and genetics of Carolina hemlock at the Annual Meeting of the Entomological Society of America. Graduate student Lia Campbell completed her M.S. research on Carolina hemlock population genetics (see article on this project in this annual report), and we continued our collaboration

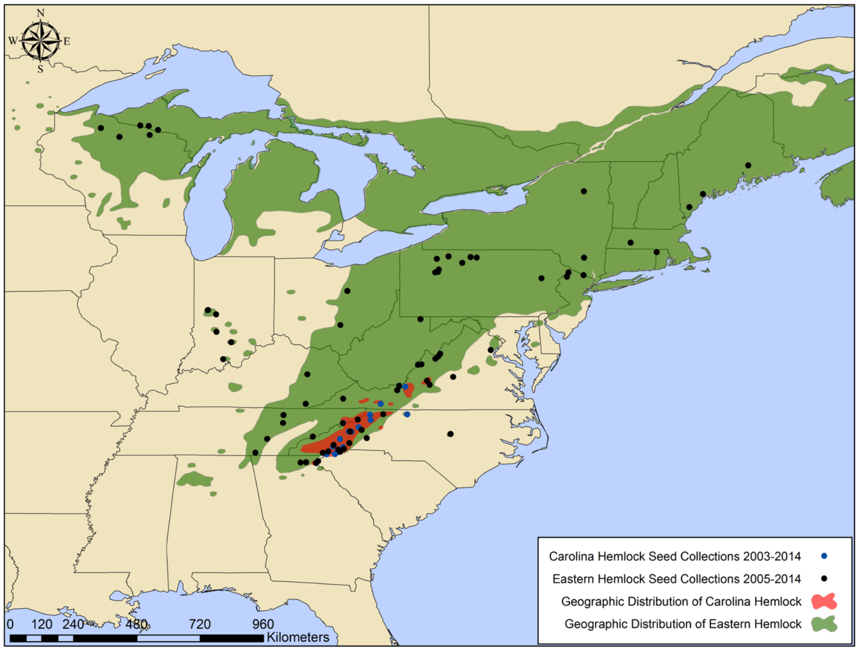


Figure 12. Locations of provenance seed collections of Eastern hemlock and Carolina hemlock made by Camcore 2003-2014.

with USFS Research Entomologist Albert "Bud" Mayfield on two research projects. One project is an ongoing study on the effects of temperature and light on the success of hemlock woolly adelgid infestations on potted hemlock seedlings, and the second is a new study on silvicultural strategies for hemlock restoration in the southern Appalachian Mountains that is being led by new Camcore Research Assistant Andy Tait (see article on the new hemlock restoration project in this annual report). Finally, through the hard work of our collaborators in New Jersey, Pennsylvania, and West Virginia, Eastern hemlock seed collections were completed from 23 mother trees in four new populations.

In 2015, with additional funding from the USFS, Camcore will initiate a new research project titled "Assessing Carolina Hemlock Health on National Forests in the Southern Appalachian Mountains Following Hemlock Woolly Adelgid Infestation." There is a perception among hemlock scientists that individual trees and populations of Carolina hemlock are not succumbing to HWA at the same rate as those of Eastern hemlock, although there is no data to confirm this phenomenon. Similarly, although it is known that Carolina hemlock occurs in a relatively small number of small isolated populations, the number of Carolina hemlock trees that exist and the full extent of the populations remains unclear. Over the next several years, we will attempt to answer these questions in a multi-phase project that will be led by Andy Tait. The project has the following objectives:

1. Delineate and census all known and newly identified populations of Carolina hemlock distributed throughout the species' geographic range.
2. Quantify the levels of hemlock woolly adelgid infestation and related tree decline and mortality in each population to provide a current picture of the conservation status of the species, and determine the efficacy of previous HWA-targeted insecticide applications in those populations that have received treatment.
3. Establish long-term monitoring transects in a subset of 10 populations, five that have received insecticide treatments for the adelgid and five that have not been treated, to document the progression of hemlock woolly adelgid infestation, patterns of tree decline, and stand responses to the loss of Carolina hemlock, and define environmental characteristics associated with hemlock woolly adelgid infestation and related tree decline and mortality.

Carolina Hemlock Genetic Diversity

For the last two years Camcore has been working on a collaborative research project with the USDA Forest Service (USFS) to describe patterns of genetic structure and diversity across the range of Carolina hemlock (*Tsuga caroliniana*). This project is important for Camcore to refine our ongoing seed collection and gene conservation strategies. The research was conducted by Camcore graduate student Lia Campbell who was advised by Robert Jetton and successfully defended her M.S. thesis in August 2014. Her work was accomplished with an $83,316 grant from the USFS. Collaborators on the project included Dana Nelson and Sedley Josserand from the USFS Southern Institute of Forest Genetics (SIFG). Kevin Potter (NCSU) assisted with the data analysis and served as Lia's co-advisor, and Andy Whittier played an important role in helping Lia with the field collection of samples for project.

Lia used 16 highly polymorphic microsatellite markers (SSRs) to assess genetic structure and diversity in foliage samples collected from 439 trees distributed across 29 Carolina hemlock populations encompassing the entire geographic range of the species. The results indicate that Carolina hemlock has moderate levels of genetic diversity for a conifer, a high level of inbreeding within populations (F_{IS}=0.464), populations that are highly differentiated (F_{ST}=0.496), and little gene flow between populations (N_m=0.9116). These all indicate that the species is highly vulnerable to genetic degradation and population loss due to disturbances such as the hemlock woolly adelgid, and highlight the importance of Camcore's genetic resource conservation efforts for the species. Genetic structure analysis revealed the existence of three gene pools for Carolina hemlock (Figure 13): one that dominates the northern populations (red), a second among the southwestern populations (blue), and a third among the southeastern populations (green). The higher levels of diversity and existence of a unique gene pool in the southeastern portion of the species' range is an important result because these populations have not been thoroughly sampled for seed and should be a focus for future seed collection efforts. Lia is currently preparing a manuscript for submission to a peer-reviewed journal for publication in 2015.

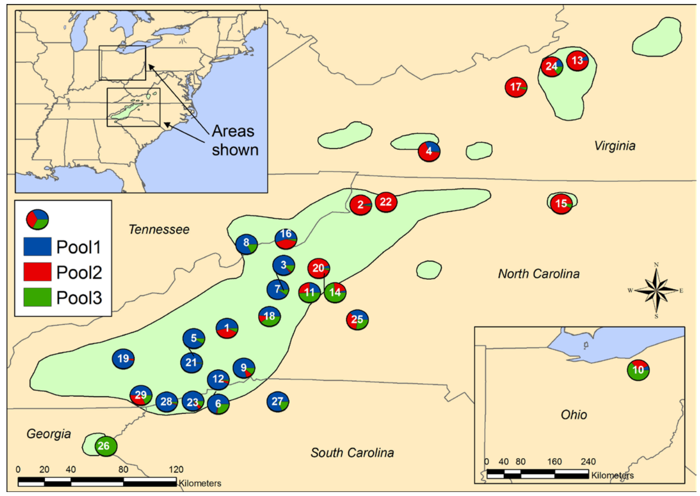


Figure 13. Map of the Carolina hemlock range (light green) and 29 populations sampled for genetic diversity analysis depicting the distribution of the three gene pools identified by the software program STRUCTURE.

Lia Campbell making foliage collections of Carolina hemlock *(Tsuga caroliniana)* at Kentland Farm in Virginia.

Hemlock Restoration Research

This was the first year of a proposed long-term, 3-phase cooperative research project with the USDA Forest Service (USFS) to develop a hemlock restoration strategy to reintroduce hemlocks to southern Appalachian forests. The initial work of Phase 1 was done in partnership with USFS Research Entomologist Albert "Bud" Mayfield, and was funded by a $50,000 grant from the USFS.

Eastern and Carolina hemlock (*Tsuga canadensis* and *T. caroliniana*) are ecologically critical in riparian and upland ecosystems, but are being functionally eliminated from southern Appalachian forests by the hemlock woolly adelgid, *Adelges tsugae* (HWA). To date, HWA management has focused on chemical and biological control, conservation of hemlock genetic resources, and host resistance breeding, with significant progress in each of these areas. In contrast, reintroduction of hemlocks to forests where it has been lost has received almost no attention. Although HWA-resistant native hemlocks are not yet available and biological, chemical, and integrated control is still developing, restoration protocols should be developed in advance so that seedlings can be rapidly and properly established once they can survive long term. The objectives of the study are:

Phase 1 (current): Develop an optimal silvicultural establishment method for Eastern hemlock.

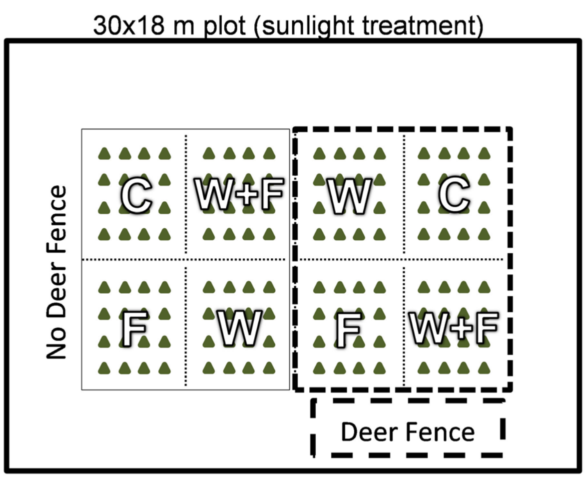


Figure 14. Plot design for hemlock restoration. W=weed control, F=fertilization, W+F= weed control+fertilization, C=control. Each triangle represents a hemlock seedling.

Andy Tait and Robert Jetton in a "Low" light (thinned) plot of newly planted hemlocks at DuPont State Forest in North Carolina.

Phase 2 (future): Develop an integrated biological/chemical control strategy on the hemlocks from Phase 1. Establish new, local-source Eastern and Carolina hemlock restoration plots.

Phase 3 (future): Use Phase 2 results to optimize biological/chemical control on local-source hemlocks.

In 2014, 12 research plots for Phase 1, each measuring 18x30 m (Figure 14), were established at sites in western North Carolina where HWA had caused significant hemlock decline or mortality. Six plots were clearcut to allow full sunlight, and six were thinned to be "low" sunlight treatments. Within each plot, 8 subplots were planted with 16 Eastern hemlock seedlings each (Figure 14).

In 2015, all seedlings will be protected with imidicloprid insecticide through Phase 1 to prevent colonization by HWA. Deer fencing will be erected to exclude deer from half of each plot. Four treatments will be studied: weed control by herbicide (W), fertilization (F), weed control + fertilization (W+F), or no treatment (C) (Figure 14). Each year, subplots will be treated and seedling growth will be measured. Effects of site (geographic variability), sunlight, deer exclusion, fertilization, weed control, and interactions on establishment and seedling growth will be analyzed.

Table Mountain Pine Conservation and Genetic Diversity

This year Camcore completed work on the Table Mountain pine (*Pinus pungens*, TMP) genetic resource conservation project that has been ongoing since 2009 in collaboration with the USDA Forest Service (USFS). TMP is endemic to the central and southern Appalachian Mountain regions of the eastern United States where natural populations are threatened by wildfire suppression, periodic bark beetle outbreaks, and climate change. Through five field collection seasons, Camcore acquired seed from 262 mother trees distributed across 38 populations (Figure 15). In total, 390,530 seeds were collected for conservation; this represent the largest genetic resource for TMP that exists outside of natural stands. Seeds have been distributed as follows: 193,395 seeds representing 242 mother trees and 36 populations reside at the USFS Ashe Nursery Facility for use in seed orchard and reforestation activities; 55,828 seeds representing 257 mother trees and 38 populations have been placed into cold storage at the USDA National Center for Genetic Resources Preservation for long-term conservation; and 135,361 seeds representing 262 mother trees and 38 populations have been retained by Camcore for conservation and research activities. An additional 5,946 seeds were utilized for germination testing and genetic diversity studies. These seed collection and distribution activities were completed with $76,300 in grant funding from the USFS and in partnership with USFS southern regional geneticist Barbara Crane. A paper detailing the results of this gene conservation project has been accepted for publication in the USFS journal Tree Planters' Notes and will appear in 2015.

In addition to seed conservation, Camcore and the USFS are also collaborating on a genetic diversity study of TMP. The objectives of this project are to describe patterns of genetic structure and diversity in natural stands and the seed sample, and to use this data to assess if Camcore's seed collection efforts did a good job of representing the genetic diversity of the species. This project is being accomplished with approximately $50,000 in leverage funds from the USFS and $5,000 from the 2014 Camcore research budget. Camcore has completed collection of foliage samples for the natural stand portion of the study. These samples represent 346 mother trees and 33 populations and were collected by Andy Whittier. Seedlings for the seed portion of the study are currently being germinated in Camcore's Method Road greenhouse at NCSU. TMP-specific SSR markers have been developed by the USFS Southern Institute of Forest Genetics (SIFG) in collaboration with Dana Nelson and Craig Echt, and DNA extractions from all field samples have been completed at the USFS National Forest Genetics Laboratory in collaboration with Valerie Hipkins. In 2015 Camcore will harvest and send foliage samples from greenhouse seedlings to NFGEL for DNA extraction where lab analysis of all natural stand and seed samples will be conducted. Camcore will collaborate with Kevin Potter (NCSU) on data analysis and the preparation of a manuscript for publication.

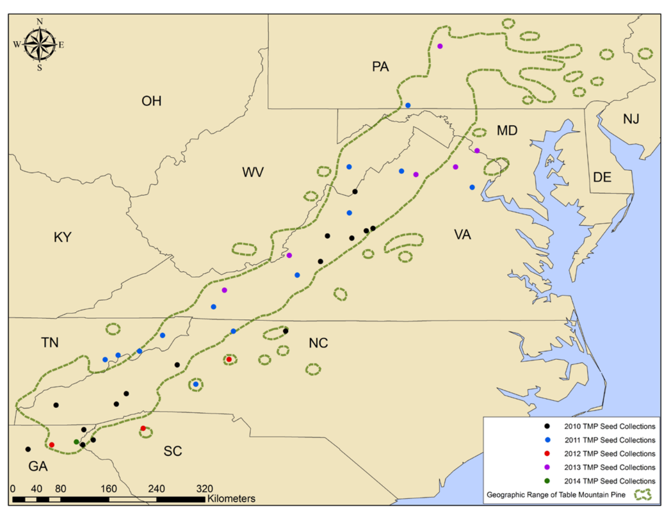


Figure 15. Locations of provenance seed collections of Table Mountain pine made by Camcore 2010-2014.

Genetic Conservation of Red Spruce and Fraser Fir

In June of 2014 Camcore was awarded a two-year grant of $70,000 by the USDA Forest Service to conserve genetic resources of red spruce (*Picea rubens*) and Fraser fir (*Abies fraseri*) in the southern Appalachian Mountains. This project marks the third collaborative effort between Camcore and USFS regional geneticist Barbara Crane. Populations of both red spruce and Fraser fir are endemic to higher elevations in Virginia, West Virginia, North Carolina, and Tennessee where they experienced severe declines in the early 1900's due to overharvesting and wild fires. More recently, climate change and acid deposition have been cited as negatively impacting the size of populations. Lastly, the exotic balsam woolly adelgid (*Adelges piceae*), accidently introduced in the 1950s, has been responsible for significant reductions in the number of Fraser fir trees.

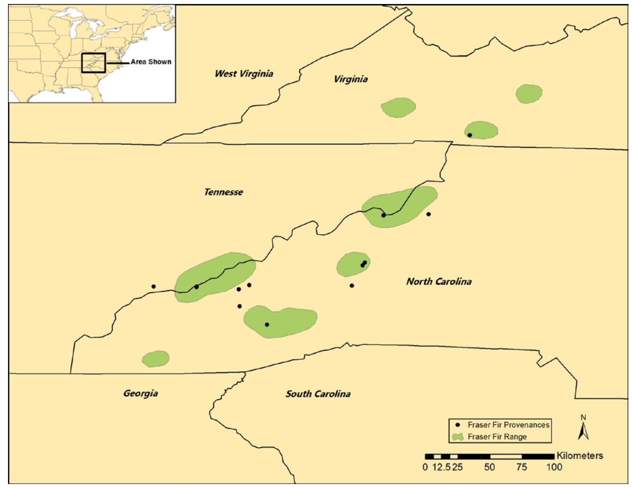


Figure 16. Location of proposed provenance seed collections of Fraser fir (*Abies fraserii*).

For Fraser fir we have determined seven known populations from which we are hoping to collect a total of 240 trees (Figure 16). The two largest of the seven populations will be further divided into smaller provenances during our collections. Our goal for red spruce is to collect cones from 20 trees in 20 individual populations across the range (Figure 17). Representative samples of collected seed will be sent to both the USFS Ashe Seed Facility in Brooklyn, Mississippi for establishment in seed orchards and reforestation initiatives, and to the USDA National Center for Genetic Resources Preservation in Fort Collins, Colorado for long-term conservation.

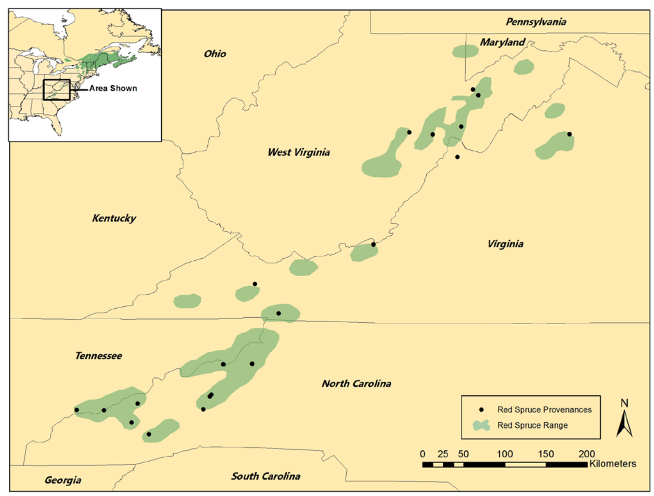


Figure 17. Location of proposed provenance seed collections of red spruce (*Picea rubens*).

Reports of low cone production for both red spruce and Fraser fir in 2014 prevented us from initiating seed collections. Proposed explorations during the summer of 2015 will determine whether cone collections will be possible in the fall of 2015. However, the donation of significant amounts of Fraser fir seed by the North Carolina Christmas Tree Program from their orchard collections in both 2012 and 2014 allowed us to make significant progress on securing genetic material from this species. This donated seed will be inventoried and cleaned before being distributed between Camcore and the USFS. Preliminary germination studies indicate low germination in this seed which should be mitigated by the copious amounts of seed donated.

Similar to our genetic diversity studies with other domestic conservation species we will partner with the USFS to investigate how well our seed collections represent the genetic diversity of natural populations.

Genetic Conservation of Atlantic White Cedar

In 2014 we continued with our efforts to conserve genetic resources from Atlantic white cedar (AWC, *Chamaecyparis thyoides*) populations. AWC is found in and around freshwater swamps and bogs along the coast of the eastern United States from Maine down to the Gulf Coast. A history of overharvesting, wetland drainage for agriculture and development, and wildfires has reduced natural AWC populations from 200,000 ha to less than 40,000 ha. In 2011 concern by the USDA Forest Service over population reduction and loss resulted in Camcore being awarded a $250,000 grant through USDA Regional Geneticist Barbara Crane to conserve genetic material from stands located across the range of the species.

Using the climatic mapping software FloraMap™ we identified four AWC seed zones that we classified as Gulf Coast, Southern Atlantic, Central Atlantic, and Northern Atlantic seed zones (Figure 18). Our initial collections in 2012 focused on populations from Virginia, North Carolina, and South Carolina in the Southern Atlantic seed zone. In 2013 we continued our collections in the Gulf Coast seed zone. During November of 2014 we collected material from New Jersey and Maryland in the Central Atlantic seed zone. Our focus in 2015 will be to secure material from the Northern Atlantic seed zone with additional collections throughout the range in areas in which we would like to secure additional genetic material.

In April of 2014 we visited 25 AWC sites in the Northern and Central Atlantic seed zones from which we determined 16 would be suitable for seed collections. During November we revisited five of these sites in New Jersey and Maryland from which we were able to collect cones from 14 individual trees. For each of the 14 trees sampled we collected foliage for use in a future genetic diversity study to be done with the USFS. In addition to the Camcore collection, material from another 10 trees was collected for us by our cooperators in Maryland. To date we have collected seed from 145 trees in 21 different populations. A total of 234,476 seeds comprised of material from all 120 trees collected in 2012 and 2013 has been sent to the USDA Forest Service Ashe Seed Facility in Brooklyn, Mississippi for eventual establishment in seed orchards. Another 45,547 seeds from all 120 families were sent to the USDA Forest Service National Seed Lab in Fort Collins, Colorado for cold storage. From our 2012 and 2013 collections Camcore has retained 277,190 seeds in cold storage from all 120 families.

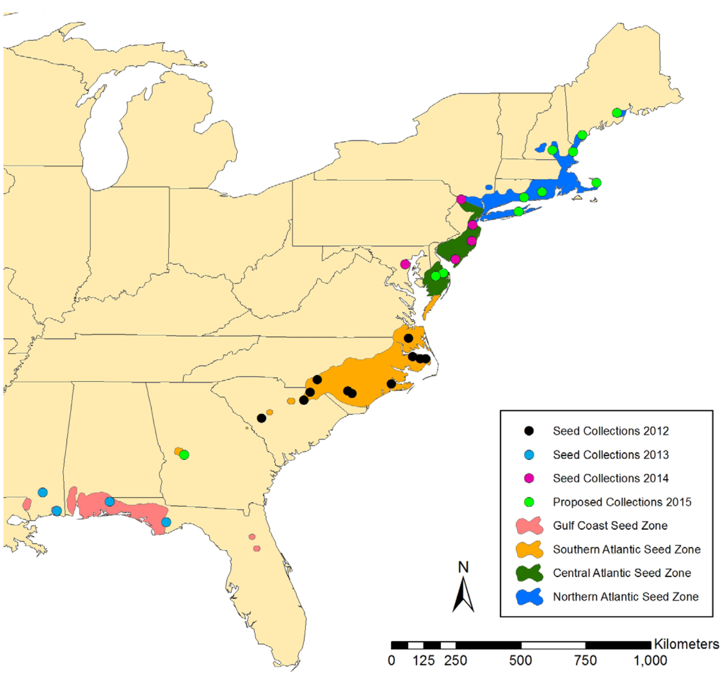


Figure 18. Location of provenance seed collections of Atlantic white cedar (*Chamaecyparis thyoides*) made by Camcore in 2012, 2013, and 2014.

Cone collections of Atlantic white cedar (*Chamaecyparis thyoides*) at Arlington Echo Outdoor Education Center, Maryland.

Tree Improvement Shortcourse in South Africa

Bill Dvorak and Gary Hodge visited South Africa in February to participate in the second Camcore Tree Improvement Shortcourse held in southern Africa. The course was hosted by **Sappi Forests** and **Mondi**, and was attended by 16 students from Camcore members in South Africa, Mozambique, Kenya and Tanzania. Gary and Bill taught many sections in the course, but a number of scientists and breeders from South African organizations also taught, including Arnulf Kanzler, André Nel, Geoff Galloway, Nicci Jones, Wayne Jones, and Wesley Naidoo (Sappi), Kitt Payn, Francois van Deventer, and Gert van den Berg (Mondi), Glen Mitchell (York), and Brett Hurley and Jolanda Roux (FABI). In addition to the indoor lectures, there was a one-day field visit in Zululand, and another day in the field in the Midlands. The course went very well, and everyone learned a lot, even the teachers!

Students in the Camcore Southern Africa tree improvement shortcourse visit the Sappi *P. patula* seed orchard at Tweedie.

Data Management Shortcourse in Mexico

The 2014 Data Management short course took place in Mexico at Proteak's offices in Villahermosa and Huimanguillo. The group was comprised of staff form Proteak and Uumbal in Mexico and Smurfit Kappa Colombia. This annual course is offered by Camcore to member companies to train staff in data handling techniques. The objective is to improve the efficiency and accuracy of the participants' manipulation of data coming from genetic trials. Much of the work is learning and practicing advanced spreadsheet management. Tools such as filtering, logical formulas, pivot tables, and macro recording are useful for cleaning and verifying data and for creating relational databases. Other topics include: trial design, data coding and organization, and the use of electronic data recorders.

The week-long course taught by Willi Woodbridge consists of lectures, demonstrations, and lots of hands-on exercises. The eight participants kept busy throughout the week with activities such as writing Excel formulas, finding and correcting problems with measurement data sets and merging measurements from different ages. The students began the course with different levels of experience but all learned new tools to enhance their work with various types of data. The techniques that the students found most useful were filtering tools, pivot tables and macro writing.

Thanks are due to Omar Carrero and the Proteak staff for organizing and hosting the workshop. The participants were: Erick Morales, Jacquelin Hernández, Kete Mirena, and Manuel Mápula from ProTeak; Alejandro Hernández , Carlos Gioia, and Juan Quintero from Uumbal, and Martha Clemencia Salas from Smurfit Kappa Colombia.

Students in the Camcore Data Management shortcourse hosted by Proteak.

Changes in Camcore

Bill Dvorak retired from NC State University after 34 years of service as Director of Camcore and Professor in the Department of Forestry and Environmental Resources. Bill was the only director from 1980 when the program was founded until September 2014. Bill's dedication, creativity, intelligence, and friendship will always be missed by Camcore staff and members. We want to thank Bill for his great leadership and wish him a well-deserved and happy retirement.

Gary Hodge was named as the new Director of Camcore. Gary decided to take the challenge as director after 18 years with the program as a breeder and quantitative geneticist. This is a great opportunity for Gary to broaden his professional experience and his working relationship with the members. Congratulations Gary.

Juan López took an active role as Associate Director of Camcore, working with Gary on several management activities of the program. Juan has been in charge of the pine hybrid project, the teak project, and several other projects in Camcore over the past 10 years.

Juan José Acosta joined Camcore as a Research Assistant Professor with primary responsibilities for tree improvement of eucalypts and implementation of initiatives in tree species genomics. Juan José graduated in August 2014 with a Ph.D. in Forestry from the University of Florida where he did research on genomics of *Pinus taeda*, *P. elliottii,* and *Eucalyptus grandis*. He also worked in tree breeding and research at Smurfit Kappa Colombia for five years (2004–2009). We welcome Juan José to the Camcore team.

Andy Tait joined the Camcore staff as a Research Assistant in September 2014 as part of the domestic conservation program. He is based with the USDA Forest Service in Asheville, NC as the project leader for the new hemlock restoration study.

Rudolf Rahn, Chairman of Camcore, left the Forestry Division of Smurfit Kappa Colombia (SKC) and was promoted as Vice President of Sales and Marketing of the corrugated division within the company. Thanks to Rudolph for all his service as Chair of Camcore and his strong support of the program. Rudolph was replaced by **Nicolás Pombo**, who is now the General Manager of Forestry in SKC and a new member of the Advisory Board of Camcore. Welcome, Nicolas.

Bob Purnell, Weyerhaeuser, was elected as Chair of Camcore. Bob has served on the Advisory Board for a number of years, and knows the program very well. We want to thank Bob for his willingness to serve.

Miguel Rodríguez was named as the General Manager of Forestal Monterrey Colombia SAS (FMCo). FMCo is owned by Pizano SA and Global Timber Spain SLU, and will continue the longterm membership of Pizano / Forestal Monterrey. Miguel will continue to be a great support to the Camcore program.

Carlos Rodas, Smurfit Kappa Colombia, received his Ph.D. from the University of Pretoria in 2013. His dissertation was titled " *Important pests and diseases of plantation grown pines and Eucalyptus in Colombia and their control"*.

Carlos Gioia left Alto Paraná in Argentina and moved to Mexico where he is employed by Uumbal. Carlos is in charge of forestry research and nursery management, and he will continue to be involved with Camcore activities.

Sangito Sumari left Green Resources Tanzania, where he worked with the company as the General Manager. Sangito is now working as the Manager of the Private Forestry Programme in Tanzania, a new associate member of Camcore.

Glen Mitchell left York Timbers to work with a South African consulting group in Malaysia. Glen has always been a great supporter of Camcore projects, and made signficant conttributions to the southern Africa region and the whole program. We wish Glen great success in his new endeavors.

James Luckhoff left Chikweti in December after more than three years working with the company in Mozambique. James made great contributions to the research program and the operational management of the company.

John Mudekwe left Chikweti to pursue new opportunities in forestry. John did great work planting and managing many Camcore genetic trials in his time with Chikweti.

Francisco Ferreira left Montes del Plata in Uruguay and is now working with EcoPlanet Bamboo Group. Francisco has always been an enthusastic supporter of Camcore activities, and we wish him the best in his new position.

Barry Goldfarb stepped down as the Head of the Department of Forestry and Environmental Resources at NC State after ten years in that position. Barry will return to work as a full-time professor in tree physiology. Barry was replaced by **Stith "Tom" Gower** who is an internationally recognized forest ecosystem ecologist who worked for the University of Wisconsin-Madison for 26 years. We welcome Dr. Gower to NCSU and Camcore.

Graduate Programs and Training

Juan López (Camcore) sucessfully defended his Ph.D. dissertation on the growth, wood properties and economic potential of pine hybrids.

Andy Whittier (Camcore) continues to make progress on his M.S. degree and his thesis project entitled "Genetic/nutrient interactions and deficiency symptoms in teak raised in growth chambers".

Juan Pedro Posse (Weyerhaeuser) began a Ph.D. program at NC State University (Camcore). His research will focus on the genetic control of several important wood properties of *E. dunnii.*

Lia Campbell completed her M.S. thesis project with Camcore under the direction of Robert Jetton entitled, "Assessing Carolina Hemlock (*Tsuga caroliniana* Engelm.) Population Genetic Structure and Diverstiy in the Southern Appalachians Using Microsatellite Markers."

John Hastings began his M.S. degree program working with Robert Jetton and Kevin Potter. His research will assess climate change and hemlock woolly adelgid risks to Eastern hemlock and identify areas where additional genetic resource conservation is needed.

Hannél Ham, Stellenbosch University, South Africa, continues her Ph.D. research on "Protocol for successful hybridization of *Pinus radiata* with other *Pinus* species". Her research is partially funded by the Camcore membership.

Mmoledi Mphahlele (Research Scientist, Mondi Forests) continues his Ph.D. program at the University of Pretoria. Mmoledi is working with Dr. Zander Myburg, and also with with Gary Hodge (Camcore) and Fikret Isik (NCSU-TIP).

Grants

Camcore continued its work with the USDA Forest Service (USFS) in 2014 on the conservation of genetic resources and related research on threatened tree species native to the eastern United States. We have projects with the hemlocks, Table Mountain pine, and Atlantic white cedar that have collectively been funded by $504,767 in grants to Camcore from the USFS. Camcore was also awarded two new grants from the USFS in 2014; $70,000 to conserve genetic resources from declining populations of red spruce and Fraser fir in the southern Appalachian mountains, and $50,000 to study silvicultural strategies for reintroducing eastern hemlock to areas where is has been eliminated by the invasive insect the hemlock woolly adelgid.

Milan Lstiburek, Professor of Forestry at the Czech Agricultural University, continued work with Gary Hodge on a three-year $34,000 grant from the Czech government to work on projects related to "Breeding-Without-Breeding" .

Bill Dvorak Retires as Camcore Director

Bill Dvorak, founding director of Camcore, retired in 2014 after 34 years of service in that position.

Bill began his career in forestry with a B.S. in forestry at Michigan State University. Upon completing his undergraduate degree, Bill spent two years working in the Fiji Islands with the US Peace Corps. It was in Fiji that Bill first developed his love for forest genetics and tree improvement, and his passion to put the right species, provenances and genotypes into forest plantations across the globe. Bill continued his education at NC State University, beginning an M.S. program. He took the position of Director of Camcore in 1980, and while working as Director he continued his graduate studies, completing his Ph.D. in 1990.

Many people know Bill as an extremely productive researcher. From 1981 to 2014, he has published some 120 manuscripts, book chapters and papers, covering topics ranging from conservation genetics, phylogenetics, quantitative genetics, tree breeding, ecology and silviculture. During his time at NC State University, Bill mentored numerous graduate students who now hold leadership positions in universities, governmental forestry agencies, and forest industry throughout the world.

Bill examines the soil profile in a stand of *P. maximinoi* in Honduras in 1988.

Bill on a *P. caribaea* seed collection trip in El Pinal, Guatemala in 2001.

Bill has long been recognized as an international leader in the area of forest genetics and conservation. He served as an Advisory Board Member to the International Centre for Research on Agroforestry Species (ICRAF), Nairobi, Kenya. He has been active in IUFRO, serving on various working groups. In 2007, Bill was elected Vice-Chair of the FAO Panel of Experts on Forest Genetic Resources, Rome, Italy. In addition, he has served as an Associate Editor in the area of forest genetics for two journals, New Forests and Southern Forests.

Those are highly noteworthy accomplishments, but it was always the work of Camcore that Bill was most passionate about. The idea behind Camcore was to form a partnership between the university and forest industry in the area of genetic conservation and genetic improvement of forest trees. When Bill first took the position of Camcore Director in 1980, the program had 4 industrial members. Few people (other than Bill) thought the program would survive more than a few years. After 34 years, Camcore today has 36 active and associate members from 22 countries, and for all of its history the program has been funded almost entirely by forest industry. This speaks to Bill's effectiveness in communicating to the leaders of forest industry the long-term benefits of gene conservation tree improvement, and the need for forest industry to be full participants and leaders in this area. Indeed, Bill could

Gary Hodge, Bill Dvorak, and Elmer Guttierez of Camcore at a tree improvement shortcourse in Guatemala in 2003.

Bill visits the Smurift Kappa Colombia nursery at Restrepo in 2014.

communicate effectively with almost anyone, from corporate executives to university professors to field foresters to the man on the street.

Bill loved being in the field – doing explorations, making seed collections, visiting species and genetic trials, and conducting research. He was an excellent "practical forester". His detailed understanding of silvics, soils and climate made him unparalleled in site-species matching. His recall of tree morphology made him brilliant at species identification in the field. He had a tremendous memory for the features of nearly every provenance where Camcore has made seed collections. But in addition to remembering a myriad of details, he always kept the big picture in mind, thought about the long term, and asked thought-provoking and challenging questions.

The accomplishments of Camcore over the past 34 years are due in large part to Bill's passion, leadership, and untiring effort. He fostered a strong spirit of collaboration and community in the program, and he continually emphasized that more can be accomplished by working together than can by working alone. Forestry companies may compete in the marketplace, but when industry, universities and governments work together in research, everyone benefits. This is easy to say, but hard to make happen. Bill Dvorak made it happen. The Camcore staff joins all of Bill's colleagues and friends around the world in offering our thanks, and wishing him all the best in his retirement.

Bill in a grafted clonal seed orchard of *P. greggii* belonging to Klabin, Santa Catarina, Brazil in 2008.

Bill and Laurie Dvorak enjoy a river cruise at the Camcore Annual Meeting in Chile in 2012.

Publications and Papers

Publications

Acosta, J.J., 2014. Genetic diversity and genome-wide selection studies in pines and *Eucalyptus*. Ph.D. dissertation, School of Forest Resources and Conservation, University of Florida. Gainesvile, FL.

Amborella Genome Project (Acosta, J.J.), 2014. The Amborella genome and the evolution of flowering plants. Science. 2013 Dec 20;342:1467-1477.

Campbell, A.R. 2014. Assessing Carolina hemlock (*Tsuga caroliniana* Engelm.) population genetic structure anddiversity in the southern Appalachians using microsatellite markers. M.S. Thesis, NC State University, Raleigh, NC. 73 p.

Gapare, W.J. 2014. Merging applied gene conservation activities with advanced generation breeding initiatives: a case study of Pinus radiata D. Don. New Forests 45:311-332.

Hodge, G.R, and W.S. Dvorak. 2014. Breeding southern US and Mexican pines for increased value in a changing world. New Forests 45:295-300.

Jetton, R.M. 2014. Collecting seeds and managing insects: my career as a forest conservation biologist. CCES Highlights Magazine 2014 (1): 27-29.

Jetton, R.M., Mayfied III, A.E., Powers, Z.L., 2014. Development of a Rain Down Technique to Artificially Infest Hemlocks with the Hemlock Woolly Adelgid (Hemiptera: Adelgidae). Journal of Insect Science. 14:106 1-12.

Jetton, R.M., Robison, D.J., 2014. Effects of Artificial Defoliation on Growth and Biomass Accumulation in Short- Rotation Sweetgum (*Liquidambar styraciflua* L.) in North Carolina, USA.. Journal of Insect Science. 14:107, 1-14.

Jetton, R.M., Whittier, W.A., and Dvorak, W.S., 2014. Evaluation of stratification treatments for germinating seeds of *Tsuga canadensis* and *Tsuga caroliniana* for ex situ gene conservation. Southeastern Naturalist. 13: 168-177.

Kanzler, A., A.Nel, and C. Ford. 2014. Development and commercialisation of the *Pinus patula* × *P. tecunumanii* hybrid in response to the threat of *Fusarium circinatum.* New Forests 45:417-438.

Mayfield III, A.E., Reynolds, B.C., Coots, C.I., Havill, N.P., Brownie, C., Tait, A.R., and Hanula, J.L.,. Joséph, S.V., Galloway, A.B. 2014. Establishment, hybridization and impact of Laricobius predators on insecticide-treated hemlocks: Exploring integrated management of the hemlock woolly adelgid. Forest Ecology and Management. 335 (2015) 1-10.

Nel, A., G.R. Hodge, K.E. Mongwaketsi, and A. Kanzler. 2014. Genetic parameters for *Fusarium circinatum* tolerance within open-pollinated families of *Pinus patula* tested at screening facilities in South Africa and the USA. Southern Forests 2014: 1–6.

Oten, K.L.F., Merkle, S.A., Jetton, R.M., Smith, B.C., Talley, M.E., and Hain, F.P. 2014. Understanding and developing resistance in hemlocks to the hemlock woolly adelgid. Southeastern Naturalist. 13:147-167.

Powers, Z.L. 2014. Evaluating techniques for artificially infesting hemlocks (*Tsuga* spp.) with the hemlock woolly adelgid (*Adelges tsugae*) for genotype resistance screening. M.S. Thesis, NC State University, Raleigh, NC. 151 p.

Papers in Press or Submitted

Lstiburek, M. Hodge, G.R., Lachoout, P. Uncovering genetic information from commercial forest plantations -- making up for lost time using "Breeding without Breeding". Submitted to Tree Genetics and Genomes.

Hodge, G.R., Dvorak, W.S. Genetic parameters and provenance variation in *Eucalyptus urophylla* across 126 test sites in Brazil, Colombia, Mexico, South Africa and Venezuela. Submitted to Tree Genetics and Genomes.

Presentations

Dvorak, W.S. 2014. (Keynote Address) The Efficacy of *Ex Situ* Conservation of the Mexican and Central American White Pines, *Pinus ayacahuite* and *Pinus chiapensis*, in Developing Countries IUFRO Meeting on the Genetics of Five-Needle Pines and Rusts in Mountain Landscapes: Conservation, Utilization and Evolution in a Changing Climate. Ft. Collins, Colorado, U.S.A. June 15-20

Dvorak, W.S. 2014 (Guest Speaker) "The Past & the Future of Cooperative Research: An Anecdotal Account of the Way Things Were and Some Day, the Way They Might Be" South African Institute of Forestry (SAIF) AGM meeting, Hilton College, KwaZulu-Natal. July 28.

Dvorak, W.S. 2014 (Keynote Address) "Traditional Tree Breeding: What we still do not know, but should, what we sometimes think is new, but isn't and why we are forgetting the basics". 6th Forest Science Symposium. The Institute for Commercial

Forestry Research & the Department of Agriculture, Forestry & Fisheries, Hilton College, KwaZulu-Natal. July 29-30.

Hodge, G.R. (Invited Presentation) Collaborative breeding of pine and eucalypt hybrids for plantation forestry: Questions and more questions. Keynote presentation at IUFRO Forest Tree Breeding Conference, Prague, Czech Republic, August 25-29, 2014.

Jetton, R.M., Campbell, L., Potter, K., Mayfield III, A.E., Whittier, W.A., Dvorak, W.S., and Rhea, R. 2014. Hemlock woolly adelgid, Carolina hemlock, and genetic resource conservation: planning for species restoration under novel environmental conditions. Oral presentation at the 6th Annual Meeting of the Entomological Society of America, November 16-19, Portland, OR.

Jetton, R.M., Haedo-Pons J.M., Gomez, D., and Martinez, G. 2014. Evaluating the impacts of the *Eucalyptus* bronze bug, *Thaumastocoris peregrinus*, on the productivity of eucalypt plantations in Uruguay. Oral presentation at the 56th Southern Forest Insect Work-Conference, July 22-25, Charleston, SC.

Posters

Acosta, JJ; Neves, LG; Fahrenkrog, AM; Davis, JM; Holliday, J and Kirst, M. Demographics Events and Genome-Wide Genetic Diversity of Loblolly (*Pinus taeda*) and Slash Pine (*Pinus elliottii*). Poster presented at: International Plant and Animal Genome Conference. January 10-15, 2014. San Diego, CA

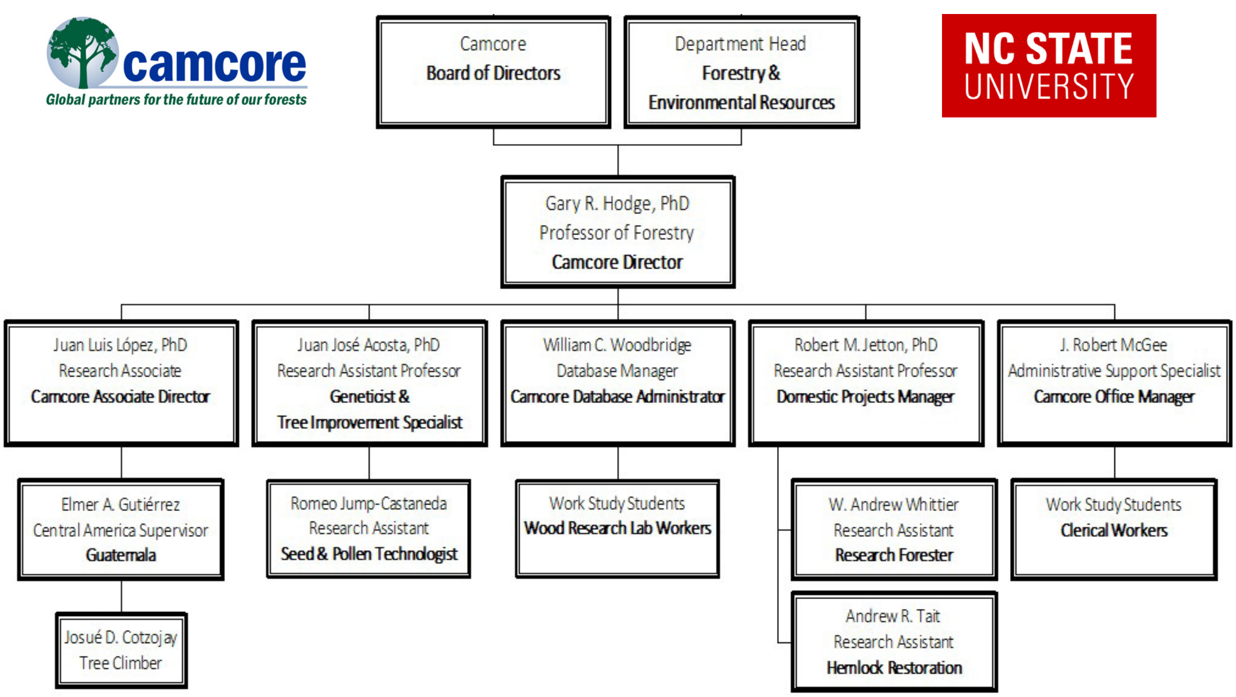
Fahrenkrog, AM; Neves, LG; Acosta, JJ; Barbazuk, B and Kirst, M. Genotyping *Populus deltoides* By Exome Resequencing. Poster presented at: International Plant and Animal Genome Conference. January 10-15, 2014. San Diego, CA

Jetton, R.M., Whittier, W.A., Dvorak, W.S., and Rhea, J.R.. Genetic Resource Conservation for Threatened & Endangered Tree Species in the Eastern United States. Poster Presented at: 25th USDA Interagency Forum on Invasive Species, January 7-10, 2014. Annapolis, MD

Mayfield III, A.E. and Jetton. R.M., 2014. A shady situation: evaluating the effect of shade on hemlock woolly adelgid densities on potted hemlock seedlings. Poster presented at the 25th USDA Interagency Forum on Invasive Species, January 7-10, 2014, Annapolis, MD.

Mayfield III, A.E., Reynolds, B.C., Coots, C.I., Havill, N.P., Brownie, C., Tait, A.R., Hanula, J.L., Joséph, S.V., andGalloway, A.B. 2014. Establishment, hybridization and impact of *Laricobius* predators on insecticide-treated hemlocks. Poster Presented at: 56th annual Southern Forest Insect Work Conference, July 22-25, 2014, Charleston SC

Camcore Personnel



CAMCORE BOARDS AND COMMITTEES

The 2014 Camcore Advisory Board

Ricardo Austin, Alto Paraná, Argentina

Claudio Balocchi, Arauco Bioforest, Chile

Enver Mapanda, Border Timbers, Zimbabwe

Raúl Pezzutti, Bosques del Plata, Argentina

Cassie Carstens, Cape Pine - MTO Forestry, South Africa

Sergio Andrés Osorio, Cementos Argos, Colombia

James Luckhoff, Chikweti Forests, Mozambique

Vernónica Emhart / Jean Pierre Lasserre, CMPC Forestal Mininco, Chile

Benson Kanyi, East Africa

Tonderai Kachale, Florestas de Niassa, Mozambique

Mads Asprem, Green Resources AS, Mozambique and Tanzania

Carlos Augusto Santos / Mario Cesar Gomes Ladeira, Klabin, Brazil

Nico Oliver, Komatiland Forests, South Africa

Ricardo Camacho / Luis Gonzalez, Maderas del Orinoco, Venezuela

Eric Cantor, Masisa Terranova de Venezuela

Johan de Graaf, Merensky Pty Ltd, South Africa

Ben Pienaar, Mondi South Africa

Pieter de Wet, PG Bison Holdings, South Africa

Miguel Rodríguez, Forestal Monterrey Colombia

Jurgen Stock, Proteak Uno Sapib de CV, Mexico

Ricardo Paím, Rigesa, Celulose, Papel e Embalagens, Brazil

Arnulf Kanzler, Sappi Forests, South Africa

Nicolás Pombo, Smurfit Kappa Cartón de Colombia

Carlos Coll, Smurfit Kappa Cartón de Venezuela

Francisco Ferreira, Stora Enso - Montes del Plata, Uruguay

Leandro de Siqueira / Edival Zauza, Suzano Papel e Celulose, Brazil

Eloy Sánchez, UUMBAL, Mexico

Robert Purnell, Weyerhaeuser Company, Uruguay

Glen Mitchell, York Timbers Pty Ltd, South Africa

College of Natural Resources, North Carolina State University

Mary Watzin, Dean, College of Natural Resources

S. Tom Gower, Professor and Head, Department of Forestry and Environmental Resources

The 2014 Camcore Associate Members

Mike Cunningham, ArborGen do Brasil, Brazil

Simon Southerton / Jeremy Brawner, CSIRO, Australia

Michael Mussack / Francisco Escobedo, Grupo DeGuate, Guatemala

Wenbing Guo, Guangdong Academy of Forestry, China

John Johnson, Mead Westvaco, USA

Asa Tham / Sangito Sumari, Private Forestry Programme, Tanzania

Barbara Crane / Rusty Rhea, USDA Forest Service

The 2014 Executive Committee

Chair: Rudolf Rahn, Smurfit Kappa Cartón de Colombia

Claudio Balocchi, Arauco Bioforest, Chile

Benson Kanyi, East Africa

Ricardo Paím, Rigesa, Celulose, Papel e Embalagens, Brazil

Ben Pienaar, Mondi South Africa

Robert Purnell, Weyerhaeuser Company, USA

Miguel Rodríguez, Forestal Monterrey Colombia

Glen Mitchell, York Timbers Pty Ltd, South Africa

The 2014 Technical Committee

Chair: Claudio Balocchi, Arauco Bioforest, Chile

Raúl Pezzutti / Raúl Schenone, Bosques del Plata, Argentina

Verónica Emhart, CMPC Forestal Mininco, Chile

Ricardo Paím, Rigesa, Celulose, Papel e Embalagens, Brazil

Arnulf Kanzler, Sappi Forests, South Africa

Byron Urrego, Smurfit Cartón de Colombia

Robert Purnell, Weyerhaeuser Company, USA

Glen Mitchell, York Timbers Pty Ltd, South Africa

The 2014 Camcore Honorary Members

Alirio Mendoza, CENTA, El Salvador

Emilio Esbeih, ESNACIFOR, Honduras

Josué Morales, INAB, Guatemala

Bernabé Caballero, INAFOR, Nicaragua

Luis Fernando Flores, INIFAP, México

Miguel Armando López, Instituto de Genetica Forestal, Universidad Veracruzana, México

Liselle Alamilla, Ministry of Forestry, Fisheries and Indigenous People, Belize

Bill Dvorak looking out over beautiful Lake Niassa in Mozambique. In 2014, Bill retired from NC State University after 34 years as Director of Camcore.

Front Cover: Eloy Sánchez, Juan Quintero, José Rosales of Uumbal in a plantation of *P. elliottii* near the town of Xicotepec in the state of Puebla, Mexico. The trees are being grown for resin production, and are intercropped with coffee.