camcore

Global partners for the future of our forests

NC STATE UNIVERSITY

2013 Annual Report

2013 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
William S. Dvorak	dvorak@ncsu.edu
Gary R. Hodge	grh@ncsu.edu
Juan Luis López	jllopez@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
Elmer A. Gutiérrez	egutierrez3161@gmail.com
Web:	www.camcore.org

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EXECUTIVE SUMMARY

1. Green Resources (Tanzania) joined Camcore as an active member and ArborGen do Brasil and the Guangdong Academy of Forestry (GAF), Guangzhou, China joined as Associate members. At the end of 2013, Camcore had 30 active, 6 associate and 7 honorary members.
2. A group of eight Camcore members in southern and eastern Africa initiated a *P. patula x P. tecunumanii* breeding project that will eventually produce 300 families for further testing and development.
3. Seeds for twenty-one 2nd generation pine trials were distributed in 2013. To date, 191 advanced generation trials (2nd and 3rd cycle) have been dispatched; 109 in Africa and 82 in Latin America.
4. Between 2010 and 2013, Camcore distributed 320 eucalypt species and provenance/progeny trials. Because of the anticipated increase in breeding and testing work, the new Tree Improvement Specialist being hired by the program will manage the eucalypt program and have skills in both traditional and molecular breeding.
5. Results of electrolyte leakage experiments in the laboratory to quantify cold hardiness of *E. dunnii* families correlated well with field cold hardiness scores. However, whole-tree freeze experiments in the laboratory appeared to be more conclusive than electrolyte leakage experiments when multiple species were being ranked for cold tolerance.
6. Desktop near-infrared (NIR) machines usually do a better job in separating taxa than portable handheld devices because of increased resolution. However, we are finding that the portable handheld NIR device generally does a reasonable job in distinguishing between pure species and hybrids for both pines and eucalypts using green vegetative material in the nursery or the field. Using the handheld NIR, it is possible to separate closely-related low elevation (LE) *P. tecunumanii* from high elevation (HE) sources by scanning green needles in the field. NIR models (confirmend with molecular markers) will be used to separate selections of *P. tecunumanii* from natural (putative) hybrids of *P. tecunumanii x P. patula* in 2nd generation trials. Scanning green eucalypt leaves with the handheld NIR in the nursery and the field also allowed separation of *E. grandis* from the *E. grandis x E. benthamii* hybrid at Mead-Westvaco, USA.
7. We also found that NIR analysis could distinguish among different seed sources of Teak that were grown in a greenhouse at NC State University. Cutting-edge NIR research will allow Camcore members to confirm identities of clones, hybrids, and provenances of different species grown in the nursery or in the field, without molecular verification, once NIR calibration models are constructed and verified.
8. Circumference increments, shoot development, and flowering patterns of *P. maximinoi* were assessed across 20 degrees of latitude in southern and eastern Africa for one year. Results indicate that in some tropical environments, *P. maximinoi* shoots do not have a pronounced resting stage, while in more subtropical regions they do. Despite these difference, flowering and cone maturation times are generally similar across latitudes. More research is needed to determine when flower bud initiation occurs in *P. maximinoi* to fully understand its reproductive cycle and to better time nutrient application in seed orchards to maximize cone and seed production.
9. Wood quality assessments of Camcore's oldest pine hybrid trials are planned for 12 sites in 2014. In addition to *P. patula x P. tecunumanii*, hybrids like *P. greggii x P. tecunumanii, P. caribaea x P. tecunumanii* (and the reciprocal), and *P. patula x oocarpa* all show promise.
10. Conservation activities in the eastern United States, in partnership with the USDA Forest Service, remain an important component of the Camcore program. In 2013, Camcore marked its tenth year of ongoing conservation seed collections for hemlock (*Tsuga* spp.), initiated seed collections for Atlantic White Cedar *(Chamaecyparis thyoides)*, and completed a 4-year project to make conservation seed collections of Table Mountain Pine *(Pinus pungens)*, a project that yielded seed from 254 mother trees and 37 populations.
11. Successful Camcore regional technical meetings were hosted by Smurfit Venezuela, Alto Paraná, (Argentina) and jointly by Chikweti and Florestas de Niassa (Mozambique). An excellent annual meeting was held in South Africa that was sponsored by all seven Camcore members in the country. There were 54 participants attending from 14 countries.

RESUMEN EJECUTIVO (Español)

1. Green Resources (Tanzania) se afilió a Camcore como miembro activo y Arborgen de Brazil y La Academia Forestal de Guangdong, Guangzhou en China se afiliaron como miembros asociados. Al final de 2013, Camcore tenía 30 miembros activos, 6 asociados y 7 honorarios.

2. Un subgrupo de ocho miembros de Camcore en el sur y el este del Africa inició un proyecto de cruzamientos de *P. patula x P. tecunumanii* que eventualmente producirá 300 familias para ensayos y desarrollos posteriores.

3. Camcore distribuyó semillas para 21 estudios de segunda generación en el 2013. Hasta la fecha se han despachado 191 ensayos de generaciones avanzadas (segundo y tercer ciclos); 109 en el Africa y 82 en Latinoamérica.

4. Entre 2010 y 2013, Camcore distribuyó 320 ensayos de especies y procedencias/progenie de eucaliptos. Por el incremento previsto de los estudios y el trabajo de mejoramiento, el nuevo especialista en mejoramiento genético forestal a ser empleado por el programa manejará el programa de eucalipto y deberá tener habilidades tanto en mejoramiento tradicional como en mejoramiento molecular.

5. Los resultados de los experimentos con pérdida de electrolitos en el laboratorio para cuantificar la resistencia al frío en familias de *E. dunnii* correlaciaron bien con los puntajes de resistencia al frío en el campo. Sin embargo, experimentos con plántas completas en el laboratorio parecen haber sido más concluyentes que los experimentos de pérdida de electrolitos cuando multiples especies se clasificaron por tolerancia al frío.

6. Las máquinas de rayos infrarrojos (NIR) de escritorio usualmente hacen un mejor trabajo para separar los taxones que las máquinas portátiles (NIR) por su más alta resolución. Sin embargo, estamos encontrando que el NIR portátil generalmente hace un trabajo razonable, distinguiendo entre especies puras e híbridos para pinos y eucaliptos con el uso de material vegetativo verde en el vivero o en el campo. Usando el NIR portátil, fuimos capaces de demostrar que es posible separar fuentes muy cercanamente emparentadas de *P. tecunumanii* de baja elevación y de alta elevación a través de el escaneo de acículas verdes en el campo. Se están desarrollando modelos de calibración del NIR confirmado con marcadores moleculares que servirán para separar selecciones de *P. tecunumanii* de híbridos naturales (putativos) de *P. tecunumanii x P. patula* en ensayos de segunda generación. Escaneando hojas verdes de eucaliptos con el NIR portátil en el vivero y en el campo se logró la separación de *E. grandis* del híbrido de *E. grandis x E. benthamii* en Mead-Westvaco, USA.

7. También encontramos que el análisis NIR pudo distinguir entre diferentes fuentes de semilla de teca producidas en invernadero en la Universidad Estatal de Carolina del Norte. La investigación avanzada con el NIR le permitirá a los miembros de Camcore confirmar las identidades de clones, híbridos y procedencias de diferentes especies producidas en el vivero o en el campo, sin verificación molecular, una vez los modelos de calibración hayan sido construidos y verificados.

8. Incrementos de circunferencia, desarrollo de yemas, y patrones de floración de *P. maximinoi* fueron evaluados a los 20 grados de latitud en el sur y el este del Africa por un año. Los resultados indican que en algunos ambientes tropicales, las yemas del *P. maximinoi* no tienen un pronunciado período de receso mientras que en regiones más subtropicales si lo tienen. A pesar de estas diferencias, los tiempos de floración y maduración de conos son generalmente similares en diferentes latitudes. Se necesita más investigación para determinar cuando ocurre la iniciación de la yema floral y entender completamente su ciclo reproductivo y para definir mejor el tiempo de aplicación de nutrientes en los huertos semilleros con desarrollo de flores para maximizar la producción de conos y semillas.

9. Evaluaciones de la calidad de la madera de los ensayos de híbridos de pino más viejos de Camcore están planeadas en 12 sitios para el 2014. Adicionalmente al *P. patula x P. tecunumanii,* híbridos como el *P. greggii x P. tecunumanii, P. caribaea x P. tecunumanii* (y el recíproco), y *P. patula x P. oocarpa* se ven promisorios.

10. Las actividades de conservación en el este de los Estados Unidos, en colaboración con el Servicio Forestal (USDA), permanecen como un componente importante del programa Camcore. En 2013, Camcore alcanzó su décimo año de colectas continuas de semillas para conservación del hemlock (*Tsuga* spp.), inició colectas de semillas del Atlantic White Cedar *(Chamaecyparis thyoides)*, y completó un proyecto de 4 años para hacer colectas de semillas de conservación de Table Mountain Pine *(Pinus pungens)*, un proyecto que produjo semillas de 254 árboles madres y 37 poblaciones.

11. Exitosas reuniones técnicas regionales fueron sostenidas en Terranova de Venezuela en Venezuela, Alto Paraná en Argentina, y Chikweti y Florestas de Niassa en Mozambique. Una reunión anual excelente fue realizada en Sur Africa y patrocinada por todos los siete miembros de Camcore en el país. Hubo 54 participantes que asisitieron de 14 países.

RESUMO EXECUTIVO (Português)

1. Durante 2013, as empresas Green Resources da Tanzania e Arborgen do Brasil se filiaram a Camcore como membros ativos. A Academia Florestal Guangdong (GAF) de Guangzhou da China, se filiou a Camcore como membro associado. Desta forma, no final de 2013, a Camcore conta com 30 membros com perfil de ativos, 6 membros com perfil de associados e 7 membros honorários.

2. Um subgrupo de 8 empresas do Sul e Leste da África iniciaram um projeto de melhoramento de *P.patula x P.tecunumanii* com o objetivo inicial de produção de 300 famílias, para posterior teste e desenvolvimento.

3. Durante o ano de 2013, a Camcore distribuiu sementes de 2ª Ger. para o estabelecimento de 21 estudos de *Pinus*. Até agora, foram distribuídos germoplasma de (2º e 3º ciclos de melhoramento) para o estabelecimento de 191 experimentos, sendo 109 para a África e 82 para a América Latina.

4. No período de 2010 a 2013, a Camcore distribuiu sementes de 320 espécies do gênero Eucalyptus para o estabelecimento de testes de progênies e procedências. Em função de uma maior demanda de testes nesta área, o novo Especialista em Melhoramento que está sendo contratado, terá que apresentar conhecimento e domínio em melhoramento clássico e biotecnologia.

5. Os resultados dos testes laboratoriais, onde utilizou-se o vazamento de eletrólitos para quantificar a resistêcia ao frio de famílias de *E. dunnii*, mostraram alta correlação com resultados de campo. Entretanto, os resultados foram mais conclusivos quando efetuou-se testes com mudas formadas e colocadas em câmaras frias, comparativamente aos testes onde utilizou-se vazamento de eletrólitos com o objetivo de avalair tolerância ao frio para múltiplas espécies.

6. Os aparelhos NIR de mesa são geralmente melhores do que os portáteis quando utilizados na separação de taxa, por apresentarem maior resolução. Entretanto, estamos verificando que o NIR portátil geralmente apresenta resultados razoáveis em separar espécies puras de espécies híbridas, tanto para espécies do gênero Pinus, quanto para espécies do gênero Eucalyptus, quando utilizou-se material vegetal no viveiro e no campo. Usando o NIR portátil pudemos separar *P. tecunumanii* provenientes de baixas altitudes de *P. tecunumanii* provenientes de altas altitudes, através da análise de acículas destas duas procedências. Continuamos com o desenvolvimento e calibração de modelos do NIR baseados na confirmação, através de marcadores moleculares de *P. tecunumanii,* de híbridos naturais de *P. tecunumanii x P. patula* em experimentos com material genético de 2ª Ger. Um estudo conduzido na empresa Mead-Westvaco, USA, onde foi utilizado o NIR portátil em viveiro, demonstrou ser possível separar E. grandis de híbridos de *E. grandis x E. benthamii*.

7. Ainda, com a utilização do NIR, foi possível distinguir diferentes fontes de sementes de Teca, cultivadas em viveiro na NC State University. A pesquisa de ponta com NIR vai permitir que as empresas associadas à Camcore confirmem a identidade de seus diferentes clones, híbridos e procedências de diferentes espécies quando cultivadas em viveiro ou ainda a campo e sem a necessidade de confirmação através de marcadores moleculares. Esta aplicação será possível quando os modelos do NIR forem desenvolvidos e verificados.

8. Durante 1 ano, foram analisados incrementos de circunferência, desenvolvimento de brotos vegetativos e padrões de florescimento para *P. maximinoi,* localizados no Sul e Leste da África a 20 graus de latitude. Os resultados indicam que, em áreas tropicais, o crescimento do *P. maximinoi* não apresenta um significativo período de repouso quando comparado ao período de repouso do *P. maximinoi* em regiões subtropicias. Apesar destas diferenças, o período de florescimento e maturação dos cones são geralmente similares nestas latitudes. Há necessidade de mais esforços de pesquisa para determinar quando a iniciação floral ocorre em *P. maximinoi*, com o objetivo de melhor entender o seu ciclo reprodutivo e assim proceder com mais específicas prescrições de nutrientes em pomares que já apresentam desenvolvimento floral. Desta forma, poderíamos maximizar a produção de cones e sementes de *P. maximinoi*.

9. Para 2014, está planejado uma avaliação da qualidade da madeira para os primeiros estudos com híbridos de pinus da Camcore. Além do híbrido de *P. patula x P. tecunumanii*, existe grande potencial para estudos de qualidade da madeira com os híbridos de *P. greggii x P. tecunumanii, P. caribaea x P. tecunumanii* (e seu recíproco) e *P. patula x oocarpa.*

10. Os projetos de conservação no Leste dos EUA, em parceria com o Serviço Florestal Americano, continuam como parte integrante do programa da Camcore. Em 2013, a Camcore completa 10 anos de trabalhos na área de conservação genética, através das coletas de sementes de hemolck (*Tsuga* spp.), e também, com o início de coleta de sementes de Atlantic White Cedar *(Chamaecyparis thyoides)*. A Camcore completou 4 anos com projetos de conservação de Table Mountain Pine *(Pinus pungens)*, um projeto que gerou uma coleção de sementes provenientes de 254 famílias e 37 populações.

11. Durante 2013, tivemos reuniões técnicas regionais, sediadas pelas empresas Smurfit Venezuela, Alto Paraná (Argentina) e em conjunto pelas empresas Chikweti e Florestas de Niassa (Moçambique). A reunão anual foi na África do Sul e sediada pelas 7 empresas membros da Camcore, com a participação de 54 pessoas, representando 14 países.

MUHTASARI WA TAARIFA KUU (Kiswahili)

1. Green Resources (Tanzania) ilijiunga na Camcore kama mwanachama mtendaji na ArborGen do Brasil pamoja na Guangdong Academy of Forestry (GAF), Guangzhou, China zilijiunga kama wanachama washiriki. Mwishoni mwa mwaka wa 2013, Camcore ilikuwa na watendaji 30, washiriki 6 na wanachama 7 waliotunukiwa heshima kuu.

2. Kama mshirika mdogo wa wanachama 8 wa Comcore walioko kusini na mashariki mwa Afrika, walianzisha mradi wa uzalishaji unaoitwa *P. patula x P. tecunumanii* ambao hatimaye utazalisha vizazi vya mbegu 300 kwa ajili ya majaribio zaidi na ufanisi.

3. Camcore ilisambaza mbegu za awamu-ishirini na moja kwa minajili ya vizazi viwili vya mbegu za msindano kwenye majaribio katika mwaka wa 2013. Hivi sasa, majaribio 191 ya utafiti wa awamu ya 2 na 3 tayari umetolewa ili kusambazwa kwa mataifa 109 barani Afrika na mataifa 82 ya Ulatino-Marekani.

4. Kati ya mwaka wa 2010 na 2013, Camcore ilisambaza aina 320 za mbegu za mikaratusi kwa ajili ya majaribio. Hii ililenga mipango iliyopo ya ongezeko la uzalishaji na shughguli za majaribio, huku mtaalamu mpya wa utafiti wa miti aliyeajiriwa katika mradi huo akitazamiwa kuusimamia mradi huo wa mikaratusi, kwani ana ujuzi na tajriba katika uzalishaji wa kitamaduni na ule wa kisayansi.

5. Matokeo ya kuvuja kwa majaribio ya kichanganuoumeme katika maabara kwa lengo la kutathmini ubaridi na ugumu wa mbegu za *E. dunnii*, yaliwiana vyema na majibu ya ubaridi na ugumu wa mbegu hizo. Hata hivyo, kiujumla, majaribio ya kuganda kwa miti katika maabara yalionekana kuwa na uthabiti zaidi yakilinganishwa na majaribio ya uvujaji wa kichanganuoumeme wakati ambapo aina mbalimbali za mbegu zinapoorodheshwa pamoja kama mbegu zinazoweza kustahimili ubaridi.

6. Mashini za kisasa za miale miyekundu za Table-To-near-infrared (NIR) hufanya kazi vyema katika hatua ya kutenganisha taxa ukilinganisha na vifaa ninavyobebwa kwa mikono, hususan kwa sababu ya ubora wa miale hiyo. Hata hivyo, tumegundua kwamba kifaa hicho kinachobebwa kwa mikono kimsingi kinafanya kazi ya kuridhisha kwa kubainisha kati ya aina halisi ya mbegu na mchanganyiko wa mbegu za misindano na mikaratausi kwa kutumia bidhaa za mimea ya kijani kwenye kitalu ama katika eneo tambarare. Kwa kutumia kifaa hicho cha kubebwa kwa mkono, tuliweza kuonyesha kuwa inawezekana kutenganisha vyanzo vya chini vilivyo na uhusiano wa karibu na *P. tecunumanii* na vyanzo vya juu kwa kuchanganua kijani kilichoko katika eneo la utafiti huo. Vipimo vya NIR vya kupimia miali hiyo ya rangi nyekundu vinavyotokana na upimaji wa molekyuli ambao utatenganisha mgawanisho wa mbegu za *P. tecunumanii* kutoka kwa mchanganyiko asili (uliotarajiwa) wa *P. tecunumanii x P. patula* kwenye majaribio ya 2, tayari vinaendelezwa. Upimaji wa matawi ya kijani kibichi ya mkaratusi kwa kifaa cha mkononi cha NIR kwenye kitalu na katika eneo tambarare pia iliweza kutenganisha *E. grandis* kutoka kwa mchanganyiko wa mbegu za *E. grandis x E. benthamii* huko Mead- Westvaco, Marekani.

7. Pia tuligundua kwamba uchanganuzi wa mashini za NIR unaweza kutenganisha baina ya mbegu mbalimbali za Msaji zilizokuzwa katika kitalu cha nyumba ya makaratasi ya joto (greenhouse) kwenye Chuo Kikuu cha NC State University. Utafiti wa kisasa wa NIR utawaruhusu wanachama wa Camcore kuthibitisha msombojeni, katumani, na pia michanganyiko ya aina mbalimbali ya mbegu na miche iliyopandwa kwenye kitalu ama kwenye eneo tambarare bila ya uthibitisho wa molekyuli, baada ya mitambo ya vipimo vya NIR kujengwa na kuidhinishwa.

8. Kwa mwaka mmoja sasa, tathmini iliyofanywa kati ya nyuzi 20 za latitude kwenye maeneo ya kusuni na mashariki mwa Afrika, inaonyesha ongezeko la mzingo ama mzunguko, ongezeko la urefu wa mche, na kadhalika mabadiliko makubwa katika uchanuaji wa maua ya miche ya *P. maximinoi.* Matokeo yanaonyesha kuwa katika baadhi ya mazingira ya kitropiki, mbegu za *P. maximinoi* hazina kiwango maalum cha ukuaji wakati huku maeneo mengine ya tropiki ndogo yakidhihirisha ukuaji huo. Licha ya kuwepo kwa tofauti hizi, muda wa kuchanua maua na kukomaa kwa koni ama mbelewele huwa sawa kwa kila vipimo vya latitude. Utafiti zaidi unahitajika kufanywa ili kubainisha wakati maua yanapoanza kuchipua kwenye mbegu za *P. maximinoi* ili kuelewa kikamilifu mzunguko wake wa uzalishaji na pia kuboresha muda wa kutumia virutubishi kwenye maeneo na vitalu vya mbegu na maendeleo ya uchanuaji wa maua ili kutumia kikamilifu uzalishaji wa koni na mbegu.

9. Majaribio ya kutathmini ubora wa mbao za kitambo za Camcore zilizofanyiwa msimbojeni wa mbegu za msindano yanapangwa kufanyika kwenye maeneo 12 katika mwaka wa 2014. Kwa kuongezea mbegu za *P. patula x P. tecunumanii*, mbegu za kimsimbo kama vile *P. greggii x P. tecunumanii*, *P. caribaea x P. tecunumanii* (na nyinginezo), na *P. patula x P. oocarpa*, zote zinaonyesha kuwepo kwa matumaini makubwa.

10. Shughuli za hifadhi huko mashariki mwa taifa la Marekani, kwa ushirikiano na USDA Forest Service, bado zinabakia kuwa sehemu mojawapo muhimu katika mradi wa Camcore. Mnamo mwaka wa 2013, Camcore alihitimisha miaka 10 ya hifadhi ya ukusanyaji wa mbegu za hemlock *(Tsuga* spp.) walianzisha ukusanyaji wa mbegu za Mkangazi Mweupe wa maeneo ya Atlantiki- Atlantic White Cedar *(Chamaecyparis thyoides)*, na wakakamilisha mradi wa miaka 4 ya kutengeneza hifadhi ya kukusanya mbegu za Msindano wa Mlimani- Table Mountain Pine *(Pinus pungens)* mradi ambao ulizalisha mbegu kutoka miti mikuu 254 na idadi ya miti 37.

11. Mikutano maalum ya kiufundi na ya kimaeneo ya shirika la Camcore iliyofanywa na kuongozwa na Smurfit Venezuela, Alto Parana wa (Argentina) wakishirikiana na Chikweti na Florestas de Niassa wa Msumbiji. Mkutano wa kufana wa mwisho wa mwaka uliodhaminiwa na wanachama wote saba wa Camcore wa nchi hiyo ulifanyika huko Afrika Kusini. Ulihudhuriwa na washiriki 54 kutoka katika mataifa 14.

Message From the Director

This was our 33rd year serving the forest industry and government organizations around the world. One can easily tell what we believe is the future direction of the program by looking at the list of internal research proposals that were approved by the Advisory Board during the annual meeting in South Africa in October, 2013. First, we intend to look at the efficacy of pedigree reconstruction using molecular markers as a breeding tool. This will be both a theoretical modelling and applied project and involves not only Camcore, NC State University, but the Czech University of Life Sciences, Prague. Second, the Camcore Advisory Board funded two genetic diversity projects, one on eucalypts (do hybrid trees generated by controlled crosses possess more genetic diversity than crosses among trees of pure parental species?), and the other on *Pinus pungens* (Table Mountain Pine) in the southern US to partially support an ongoing US Forest Service Project. Third, two projects on wood quality were funded. The first deals with examining the wood quality of new pine hybrid combinations that Camcore is testing in the field in Latin America and Africa, and the second is about quantifying the different types of lignin in *E. dunnii* to build more robust, global, NIR models. These are exciting times.

There were some "firsts" in Camcore in 2013. Our first member from China, the Guangdong Academy of Forestry, joined the program. Their interest and participation in Camcore is most welcome. The Camcore regional technical meeting in southern Africa was held outside of South Africa for the first time. The meeting was in northern Mozambique and sponsored by Chikweti and Florestas de Niassa. The movement of the regional technical meeting to Mozambique reflects a growing maturity of our Mozambican members in genetic test establishment and plantation forestry development. It was the first time (for me) to see male strobili on *Pinus maximartinezii* in the Sappi Conservation Park at the Shaw Research Centre in the Natal Midlands of South Africa. As you might recall, the species only occurs in one location in north-central Mexico and therefore, is very rare and endangered. *P. maximartinezii* produces an edible nut high in protein. The Sappi/Camcore conservation planting is probably the most genetically diverse *ex situ* planting of the species anywhere in the world. I suppose the bad news is that the trees do not start to produce strobili until 17 to 18 years of age in South Africa, but hopefully, these trees will produce mature cones and viable seeds in another three to four years.

Two other joint international projects are worth mentioning. Our collaborative grant (NC State and University of Pretoria) with FABI entitled, *"Anticipating risk to outplanted pine forests: unraveling complex relationships between beetles, fungi and trees"* was completed. Dr. Jeff Garnas at the University of Pretoria took the lead on the project. Camcore and FABI have had great relations for years, but this series of official grants was our first together. Camcore is also now formally working with the Forest Molecular Genetics Programme, headed by Dr. Zander Myburg, at the University of Pretoria. Zander and his team are involved in developing and using molecular markers that distinguish *P. patula* from *P. tecunumanii* and the hybrid as part of our patula contamination project. Finally, remember the support of the USDA Forest Service for Camcore and the conservation of tree species in the United States; we have enjoyed this collaboration for the past 10 years, and it is still ongoing.

Even though many of the Camcore members had tight financial budgets this year, support for the program remained strong. We had 54 participants from 14 countries attend our annual meeting and field tours in South Africa in October. The event was hosted by all seven of our active members in the country. It was linked to an interesting pre-conference tour in the Cape region of South Africa. Both the pre-conference tour and the annual meeting were excellent with very positive discussions about the future direction of the program.

Our vision statement says that Camcore wants "To be a world leader in tree improvement and conservation…". I hope that after reading the annual report, you can say that we are well on our way to reaching this goal.

Thank you again for your support.

Bill Dvorak, Director

2013 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
- Pizano/Monterrey Forestal, SA 1983
- Smurfit Kappa Cartón de Colombia, SA 1980

Guatemala
- Grupo DeGuate (Associate) 2006

East Africa
- Kenya, Tanzania 2005

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

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

United States of America
- Mead Westvaco (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 Cartón de Venezuela, SA 1986

Zimbabwe
- Border Timbers 2009

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 2013 Annual Meeting in South Africa

In October, Camcore gathered in South Africa for the 33rd Camcore Annual Meeting hosted by Cape Pine, Komatiland Forests (KLF), Merensky Timber Ltd., Mondi South Africa, PG Bison, Sappi Forests, and York Timbers Ltd. This year's meeting was attended by 54 participants and five spouses, all who enjoyed 11 days of informative field tours, technical sessions, cultural visits, and delightful meals. The 2013 annual meeting was Camcore's third in South Africa with two previous meetings having been held there in 1990 and 2002.

This year's meeting included a four-day pre-conference tour in South Africa's southern cape hosted by Cape Pine and PG Bison, and organized by André van der Hoef (Cape Pine). Thirteen participants traveled from Wilderness to Port Elizabeth stopping along the way for talks and field tours related to pine forestry in the region. The tour included a visit to the Nelson Mandela Metropolitan University (Saasveld) where, over the years, many of South Africa's foresters have begun their education, and heard an interesting presentation on the geology and soils of the southern Cape from Professor Jos Louw. Over the next three days, the field tour included stops at *P. radiata* genetic trials, Camcore species trials, *P. maximinoi* and *P. tecunumanii* 2nd generation progeny trials, pine hybrid trials, and indigenous forest management in the Auckland Forest Reserve. In addition to the well-organized and informative field stops, the group enjoyed the spectacular scenery of the southern Cape coastline.

Eloy Sanchez (Uumbal) admires some outstanding 2nd generation *P. radiata* in the Cape Pine progeny trial at Lottering.

Following the successful pre-conference tour, the 2013 Annual Meeting got underway on October 20 in Durban at Umhlanga Ridge where the two opening technical sessions were held. These sessions featured a keynote address on the South African sawmill industry by Chris du Toit, Managing Director of Merensky. There were also invited presentations by Mike Wingfield (FABI, University of Pretoria) on the long-term implications of insect and disease attack for plantation forestry in South Africa, Michael Peter (FSA) on the forestry landscape of South Africa, Colin Dyer (ICFR) on silvicultural research at ICFR, Francois Engelbrecht (CSIR) on the implications of climate change for plantation forestry in South Africa, and Andrew Morris (ICFR) on the influence of climate and geomorphology on plantation forestry in South Africa.

The meeting then moved to Hilton for a third technical session and a day of field tours in the Kwa-Zulu Natal Midlands hosted by Mondi and Sappi. The first stop was at Mondi's Mountain Home Tree Improvement facility where participants learned about the company's pine hybrid breeding program, clonal eucalypt breeding strategies, molecular breeding program, seed production capabilities, and research on wood quality and approaches to rooting eucalypt cuttings. Additional field stops included *P. taeda* and *P. pseudostrobus* progeny trials, a Camcore pine hybrid trial, a *P. patula x P. tecunumanii* hybrid trial, and an *E. dunnii* progeny/provenance trial. The day ended with a visit to Sappi's Shaw Research Centre where participants had the opportunity to see the *P. maximartinezii* conservation bank and learn about Sappi research on pine and eucalypt controlled pollination, eucalypt mini hedges, pine and eucalypt seed processing, and wood properties.

Field tours continued the following day in Zululand with field stops to observe mechanical harvesting, Mondi's *E. grandis* CCT trial at Langepan, and a Sappi site to learn about a trial designed to determine the amount of *E. urophylla* contamination in an *E. grandis* breeding population. The day included a field presentation by representatives

Kitt Payn and Noku Sentongo (Mondi) review the production of hybrid cuttings for the third series of Camcore hybrid trials.

from FABI and the Tree Protection Cooperative Program on insect and disease issues in South African forest plantations, a visit to Mondi's Kwambo nursery to learn about operational production of eucalypt cuttings, and ended with an opportunity for us all to see Sappi's Camcore conservation park for tropical pines and eucalypts. Our visit to Zululand ended with the fourth and fifth technical sessions in Richard's Bay, and a brief time to rest, relax, and reflect on the first part of the meeting while enjoying the scenery and wildlife of the St. Lucia Estuary and HluHluwe Game Park.

After traveling north, the meeting continued in Mpumalanga near Sabie with field visits at KLF and York. Stops included Camcore hybrid trials, second generation *P. tecunumanii* and *P. maximinoi* trials, *P. patula x P. tecunumanii*, and *P. chiapensis* trials at Tweefontein, Mac-Mac, Goedgeloof, Klipkrael, and Brooklands. Of special interest to the group were the 1986 progeny trial of *P. chiapensis* at Tweefontein that has been thinned to a conservation bank, and KLF's Camcore conservation park at Brooklands. Following lunch at Klipkraal Dam, we also had the opportunity to hear presentations on improving pitch canker tolerance in *P. patula* and the strategies behind Camcore's conservation parks in South Africa. The group then retired to the hotel in Hazyview for dinner and a performance of traditional Zulu dance.

The 2013 Annual Meeting closed at Skukuza Game Camp in Kruger National Park. In addition to the final business meeting, participants also had opportunities to explore the unique ecology and wildlife of Kruger Park and were treated to a traditional boma braai. The meeting ended with a bush braai farewell dinner sponsored by Camcore where the staff handed out small gifts of thanks to our South African hosts in honor of an excellent trip. We left South Africa with strengthened partnerships and a renewed appreciation for the country, its people, and the excellent forestry research being conducted by our hosts in the region.

Vourinis Coetzee (KLF) with 23-year-old *P. chiapensis* selection at Tweefontein, South Africa.

The 2013 Camcore Annual Meeting attendees in the *E. grandis* CCT trial at Langepan.

Developments in Camcore

Sangito Sumari of Green Resources (Tanzania) next to a nice *E. grandis.*

Green Resources (Tanzania) joined Camcore as an active member and **ArborGen do Brasil** and the **Guangdong Academy of Forestry** (GAF), Guangzhou, China joined as Associate members in 2013. Green Resources (Tanzania) is a sister company of Green Resources (Mozambique) which joined Camcore in 2012. It has a large plantation area of patula pine and a sawmill in the Sao Hill region of central Tanzania and will be expanding its eucalypt plantation program. ArborGen is a major pine seedling producer in the southern USA and is expanding its business in Brazil. The GAF is a public welfare forestry scientific research institution that was founded in 1958. It consists of six research institutes and has 150 full-time researchers. We welcome all three organizations into Camcore.

At the end of 2013, Camcore had 30 active members, 6 associate members and 7 honorary members in 22 countries. The Camcore staff made technical visits to most active members in 2013. Following is a summary of our visits.

Argentina

Bill Dvorak and Jesús Espinoza visited Argentina in June and spent time with Alto Paraná and Bosques del Plata. At **Alto Paraná (APSA),** the local climatic conditions in northern Misiones are sorting out the "winners" from the "losers" in the South African Benchmark eucalypt study and in the CSIRO temperate cold-hardy eucalypt trial. Trees are being damaged not by the mild winter cold (-3°C) but by the hot summer heat. The most promising species at two years of age in these cold-hardy studies appear to be *E. dunnii* and *E. benthamii* but the sites at APSA might be ultimately best suited for the urograndis hybrid or *Corymbia maculata.* The *P. caribaea x P. tecunumanii* hybrid and the *P. greggii x P. tecunumanii* hybrid continue to show much promise.

At **Bosques del Plata (BDP)**, the 2nd generation Camcore *P. greggii* and the *P. greggii x P. tecunumanii* look good. However, the rate of growth of this pine hybrid is very much dependent on the pedigree of the cross. Experience now shows that most Mexican pines and the hybrids

Raul Pezzutti (Bosques del Plata) and Ricardo Paim (Rigesa) with a 3-year-old *P. caribaea x P. tecunumanii* in a APSA-Camcore hybrid trial in Misiones, Argentina.

need to be placed on the red upland soils and not on the swampy sites; the latter are better for the US southern pines. BDP also has suitable sites for eucalypt plantations, but testing is just in the preliminary stage. BDP is doing some very interesting research on water use efficiency in pines and has begun testing clones of *P. taeda* derived from somatic embryos.

Brazil

Bill visited MWV Rigesa, Bill and Gary Hodge met with Klabin, and Gary and Jesús held mainly indoor sessions with Suzano in April.

At **MWV Rigesa**, the young plantings (2.4 years) of *P. patula x P. tecunumanii, P. greggii x P. tecunumanii* and *P. patula x P. oocarpa* hybrids look very impressive. The company has 1st generation Camcore orchards of *P. patula* and *P. greggii*, and therefore, are in a good position to make their own hybrids. Rigesa has also recently established various Camcore eucalypt trials: the SA benchmark series, the CSIRO temperate trial and the *E. dorrigoensis* progeny trial. Having eucalypt species that can tolerate the cold during winter is important for the company. Rigesa plans to genetically thin one of the Camcore *P. taeda* G x E trial to create a seedling seed orchard.

Gary Hodge (Camcore) and Fabricio Biernaski (Klabin) in a 10-month-old 2nd generation *P. maximinoi* trial in Paraná, Brazil.

At **Klabin,** research efforts continue to move *P. maximinoi* to the next cycle of improvement. Because of the warmer temperatures at Klabin land in Paraná State compared to Camcore members further south in Latin America, a number of pine hybrids might be important for the company. These include *P. patula x P. tecunumanii*, *P. patula x P. greggii,* and *P. greggii x P. tecunumanii.* Klabin has Camcore orchards of all three Mexican pines species on its property either in Paraná or Santa Catarina state, and can produce seeds of pure species or make hybrid crosses using their own material.

Gary and Jesús visited **Suzano** and had good discussions about the strategy used for the Suzano *E. grandis* breeding and production population, which might be described as Clonal Bulk Deployment. One might describe this strategy briefly as a variant of Family Forestry, but using selected progeny from a family rather than all progeny from a family. We also discussed various applications of NIR technology, and how they could be used within the Suzano breeding programs.

Chile

Camcore and **CMPC Forestal Mininco** have been working together on two different projects to assess the potential of NIR as an economic and versatile tool to 1) differentiate the wood of *E. globulus, E. nitens* and their hybrid at the mill gate, and 2) assess the patterns of variation of wood density from the pith to the bark and from the base to the top in trees of the same species. Jesús Espinoza visited Chile in March to work on the field measurements with the company foresters, using the handheld NIR. CMPC continues to establish eucalypt studies with Camcore and to take part in the eucalypt and the pine hybrid programs.

Colombia

Juan López and Jesús Espinoza visited **Cementos Argos / Tekia** in the northern part of Colombia at the end of February. Camcore continues to help Tekia with its teak tree breeding program, sending additional families and sources of seeds for the establishment of more progeny trials in 2014. *Eucalyptus* species have potential in some areas of the company not good for teak growth. Tekia will establish some progeny trials with several species of eucalypts with seeds received from Camcore. A teak wood study to predict heartwood proportion for standing trees was initiated by Camcore and will be finished in 2014.

Pizano is making great progress with its *Gmelina arborea* program, measuring new trials and improving its clonal seed orchards. This year Camcore helped Pizano with the data analysis for the clone x site interaction studies established with selections in the Camcore progeny trials. With this action the company will start to use new clones, increasing the productivity of its *Gmelina* commercial plantations. During their visit in February, Juan and Jesús made recommendations on how to establish new eucalypt genetic trials using seeds provided by Camcore.

Ahudrey Leal (Tekia) in a 14-month-old Camcore teak progeny trial in Carmen de Bolivar, Colombia.

Mbae Muchiri and Stephen Omondi (KEFRI) next to a 2-year-old Camcore *P. patula x P. tecunumanii* at Mguga.

East Africa

Bill visited the East African membership in **Kenya (KEFRI)** in February 2013. Most of the KEFRI Camcore trials throughout the country were inspected to see their development. One of the reasons there are great expectations for some of the tropical pines like *P. maximinoi* and *P. tecunumanii* in Kenya is that Camcore believes these will grow better than the commercial species, *P. patula,* on most sites, with the exception of the very highest altitudes. The Camcore pine hybrid trial near KEFRI headquarters is well established with the *P. patula x P. tecunumanii* hybrid showing much promise at an early age. KEFRI will also be planting several Camcore eucalypt trials in the near future. The second purpose of the visit to Kenya was to attend a Tree Improvement Workshop in Nairobi that was hosted by KEFRI and had participants from throughout Eastern Africa. The theme of the conference was, “Towards enhancing competitiveness of the forestry sector in East Africa through a sustainable Tree Improvement Programme”. Next year’s Camcore technical visit to the East African membership will be in Tanzania.

Guatemala

Juan López and Andy Whittier visited **Grupo DeGuate** in Guatemala in August. The main objective of a field visit to the southern coast of the country was to look at a Camcore teak trial established by the member in 2010. Recommendations on measurements and management were given by Juan and Andy. Another progeny trial of *P. tecunumanii,* sent to the National Institute of Forests (INAB) by Camcore a few years ago, was visited in the Department of Jalapa. Camcore is helping with the data analyses. Juan and Andy also spent time with Elmer Gutiérrez to review progress on a Camcore research project investigating paclobutrazol applications to promote flowering in teak. The goal is to determine if the hormone applications will increase flowering, and to identify the optimum time of year to apply the treatments.

Omar Carrero (Proteak) and Juan Luis Lopez (Camcore) discuss hydroponic culture of teak in the nursery in Tabasco, Mexico.

Mexico

During their visit to **Proteak** in Mexico in August, Juan and Andy discussed the options for joint efforts that Camcore and Proteak should take on research in teak genetics, wood and nutrition. Andy described his Masters Degree research project on hydroponics to measure nutrient deficiencies in teak seedlings at NC State. Proteak has the intention to establish a similar study at an operational level in its nursery. Proteak and Camcore will initiate teak wood studies in 2014. Since Proteak purchased the eucalypt plantations of Fomex in the southeast of Mexico, Camcore is helping Proteak to continue to advance in the tree breeding program with eucalypts in its new property.

Elmer Gutiérrez (Camcore) applies paclobutrazol to teak seedlings to investigate its effect on flowering and the optimum month of application.

Camcore is helping **Uumbal** to build a broad genetic base of species and hybrids with high adaptability to the company land in Mexico and with high production potential of good quality resin. This year Camcore provided seeds of *Pinus elliottii* from seed orchards in Georgia for high resin production, *P. caribaea* var. *bahamensis* from Komatiland, South Africa, and *P. caribaea* var. *hondurensis* at the family level from different sources in Central America. In his visit to Uumbal in May of this year, Jesús Espinoza gave several recommendations with emphasis on plantation management. Camcore is planning to help the company to assess resin quality of different pine hybrids.

Mozambique

Juan López visited Mozambique in 2013. **Chikweti** continues making great progress. The company has improved species selection, site preparation and plantation management. Chikweti is following Camcore's recommendations and is building a genetic base for the tree breeding program with pines, eucalypts and corymbias. The Camcore eucalypt benchmark and drought-hardy studies are well maintained and some species like *E. major* and *E. longirostrata* show potential at early ages. These trials will provide a genetic base

James Luckhoff (Chikweti) shows the impressive growth of *Corymbia maculata* at 6 months in Lichinga, Mozambique.

of eucalypt species for breeding of pure species or as hybrid partners with the current commercial species. *Corymbia maculata, C. citriodora* and *C. torelliana* also exhibit impressive initial growth in the Lichinga area.

In his visit to **Florestas de Niassa** this year, Juan gave recommendations in the nursery to develop vegetative propagation protocols and to produce rooted cuttings of eucalypts and pines. Juan also made recommendations on how to manage the pine seedlings in the nursery to produce good quality plants. The *Corymbia* trials are growing well and show potential in the Musa area. The fertilization trials established with eucalypts in the same area will provide important answers to the foresters and the managers in regards to nutrients, doses, application formulations and economic payback in plantation management. *Pinus tecunumanii* and *P. maximinoi* planted in Camcore genetic trials are showing much better growth than *P. elliottii* on the same site.

Camcore is helping **Green Resources** Lichinga and Nampula to build a large genetic base for the tree breeding program with pines and eucalypts. Juan gave recommendations in both planting areas about best plantation management practices for the species to show their genetic potential on different sites. Site preparation, planting, weed control and fertilization studies will help the company to maximize growth at low cost. Several trials of pine species and eucalypts have been sent by Camcore to the Lichinga and Nampula offices.

South Africa

Bill visited **PG Bison** on the northeastern Cape in August. There has been great progress in the last year in the development of Camcore species. Most notable is the development of a 2nd generation *P. patula* clonal orchard that includes some Camcore selections, thinning of the old Camcore *P. greggii* progeny trials for seed production areas and a planned thinning of the old Camcore *P. cooperi, P. arizonica* and *P. engelmannii* trials for a PG Bison conservation park. The past winter was a bit trying in the area, but the Camcore *E. dorrigoensis* seems to have survived well. We look forward to the survival and growth data from the trial.

Bongani Noludwe and Ilse Botman (PG Bison) next to an outstanding 2nd generation selection of *P. greggii* (South) in Eastern Cape, South Africa. The progeny trial will be thinned to convert it into a seed production area for the company.

Bill also visited **Merensky** at Weza, where the 6-year-old Camcore trials of *P. tecunumanii* and *P. maximinoi* look very good. Discussions dealt with the patula contamination problem in Camcore *P. tecunumanii,* the potential stem breakage problem in 2nd generation *P. tecunumanii* and the *P. maximinoi* growth rhythm assessments (see *Growth Rhythms* in this report). Merensky pine breeder, Charles Kempthorne, reports good success in airlayering of *P. maximinoi*. Similar to results in Colombia, Charles found that the airlayer needs to be on the tree for about 7 months before harvesting and re-potting. Merensky also has some very good Camcore pine hybrid trials, one of which we hope to sample for wood properties in 2014.

The visit to **Cape Pine** concentrated mainly on collecting needle samples in a Camcore 2nd generation *P. tecunumanii* trial at Kruisfontein as part of the patula contamination project (see *Pollen Contamination* in this Report). Some of the Camcore pine hybrids are doing exceptionally well in the area, notably the *P. patula x P. tecunumanii* (LE) and the *P. tecunumanii x P. caribaea* hybrids. Cape Pine has both swampy lands and some upland soils. It appears that *P. taeda* (from Florida) and *P. elliottii x P. caribaea* are best suited for the wet sites, and some of the Mexican pines and their hybrids might do very well in areas that are at slightly higher elevation on better-drained soils. The involvement of Cape Pine in the *P. patula x P. tecunumanii* breeding project will help the company find and develop good individual crosses.

Andre van der Hoef (Cape Pine) in a 4-year-old block of *P. tecunumanii x P. caribaea* at Kruisfontein in the southern Cape, South Africa.

Bill and Gary visited Sappi and Mondi in May. **Mondi** is doing a good job hedging and multiplying the third series of pine hybrids, and seedlings for the first tests of this series are expected to be dispatched early in 2014. We spent time in the field looking at 2nd generation trials of *P. tecunumanii, P. patula, and P. maximinoi.* These pine hedges are being managed in a new set of greenhouses at the Mountain Home Nursery. These state-of-the-art greenhouses have also had a tremendous impact on the efficiency of the cold-hardy eucalypt program. In addition to the field visits, we also spent one full day with all three Mondi breeders reviewing SAS data analysis techniques and BLUP protocols.

The **Sappi** visit covered a wide array of topics, ranging from the Sappi *P. patula x P. tecunumanii* breeding program, the *E. dunnii* 2nd generation breeding, the impact of heavy flowering in eucalypt seed orchards on outcrossing and expected genetic gain, and strategies for *E. grandis x E. urophylla* and *E. grandis x E. nitens* breeding. At Sappi, we also spent a day reviewing BLUP analysis with the breeding team.

Following the African Regional Meeting in Mozambique, Gary visited Komatiland and York.

At **York Timbers,** we spent time discussing grafting and nursery issues and hybrid breeding. York and KLF are cooperating on grafting selections of *P. tecunumanii, P. patula, P. maximinoi,* and *P. chiapensis* for conservation parks at both companies. York is also investing heavily in hybrid breeding, and plans to make about 150 full-sib hybrid crosses per year. The company is making improvements in their nursery to increase efficiency of producing *P. patula x P. tecunumanii* and *P. patula x P. oocarpa* cuttings for operational plantations. The goal for 2014 is for 90% of new plantations to be established with hybrid cuttings.

At **Komatiland Forests,** much of the visit was taken up with collection of foliage samples and handheld NIR scanning of foliage as part of the *P. tecunumanii - P. patula* pollen contamination project. KLF supplied a team of nine workers to help with the field work for this effort, and it was much appreciated as the work went very smoothly. Gary also had time to visit the 2nd generation *P. tecunumanii, P. maximinoi,* and *P. chiapensis* trials and the Camcore conservation park at Brooklands. In the office discussions, Gary reviewed the results of a BLUP analysis done on seven KLF *P. patula x P. tecunumanii* trials, and recommended some specific full-sib families for commercial production.

Tanzania

Bill visited **Green Resources, Tanzania** in late February. The main purpose of the visit was to develop a three-year program of test establishment of the Camcore pines and eucalypts. In 2013, the company established Camcore trials of *E. grandis, E. urophylla, P. tecunumanii and P. maximinoi.* A number of additional Camcore eucalypt trials will be established by Green Resources in 2014.

Uruguay

Gary Hodge and Robert Jetton visited **Montes del Plata (MDP)** and **Weyerhaeuser** in April. For both companies, the commercial potential of *E. benthamii, E. dorrigoensis,* and possibly *E. badjensis* seems quite high.

The Montes del Plata research staff has done a good job establishing a number of Camcore trials over the past few years. The *E. dorrigoensis* provenance/ progeny trials are growing very well, and should provide some valuable selections for MDP within the next 3 to 5 years. *Eucalyptus benthamii* is also doing very well, and is producing flowers at age 2 in some of the trials. At Weyerhaeuser, both *E. benthamii* and *E. dorrigoensis*, and also *E. badjensis* are showing consistent good growth and good frost tolerance across a number of sites.

The 2nd generation pine progeny tests of *P. greggii* and *P. maximinoi* at Fraile Muerto (Weyerhaeuser) are doing very well at age 2½ years. *Pinus maximinoi* may not have sufficient frost tolerance for Uruguay, but *P. greggii* may be an ideal combination of good growth and good frost tolerance for conditions in the country. In addition, the *P. greggii x P. tecunumanii* hybrid may do well in Uruguay; it looks good in the young pine hybrid trial at Yvyraóga. Also during this visit, Robert Jetton spent time on the research project to quantify *Thamastocouris* damage. The Weyerhaeuser research staff worked hard on the installation of the trials and the initial insecticide applications.

Cristian Montouto (Montes del Plata) visits the two-year-old *E. dorrigoensis* trial at Los Cespedes, Uruguay.

Venezuela

Juan López and Jesús Espinoza made a visit to **Smurfit Kappa Cartón de Venezuela** in April. Four new trials of eucalypt species were growing in the nursery. This material will allow the company to increase its species and provenance portfolio and will also be used for hybrid crosses. Following the interest of the company to increase the eucalypt plantation area, Jesús and Juan gave recommendations to match sites and species. Smurfit Venezuela is actively planting 2nd generation studies of *P. caribaea* as well as taking part in the pine hybrid program of Camcore.

Terranova de Venezuela is working as the regional coordinator for the Camcore pine hybrid program and is growing several hybrids in its nursery. Pollen of 13 families of *P. tecunumanii* were sent to Venezuela this year to start making crosses by family with *P. caribaea* in the Santa Cruz de Bucaral seed orchard, owned and managed by Maderas del Orinoco. Juan and Jesús gave recommendations to manage this material so that full-sib families of the hybrid can be planted in field trials. Camcore is helping Terranova look for eucalypt species with commercial potential on their land in Venezuela as pure species and as hybrids. Provenance/progeny trials of *E. urophylla, E. camaldulensis,* and *E. brassiana* have been planted in the last two years.

In this year's Camcore visit to **Maderas del Orinoco** in April, Juan and Jesús had the opportunity to meet with the new President of the company, Ricardo Camacho and his forestry team. In the one-day visit, Juan and Jesús gave a presentation about Camcore in the morning, emphasizing the trial research protocols, eucalypts and pine hybrid studies. In the afternoon, two *P. caribaea* progeny trials were visited, one recently established with Camcore seeds and the other planted in 1996. Camcore has been helping the company with data analyses of the progeny trials to make selections of the best parents and rogue the clonal seed orchard in Santa Cruz de Bucaral.

Regional Technical Meetings in Argentina, Mozambique, and Venezeula

Regional technical meetings were held in three counries in 2013: Argentina, Mozambique, and Venezuela. The objective for all of these meetings is to discuss Camcore research and breeding projects, exchange information among regional foresters, and to develop collaborative work plans and research proposals for discussion at the annual meeting. In addition to indoor meetings, a one-day field tour generates good interaction among the participants.

The northern Latin America tropical regional meeting was hosted by **Terranova de Venezuela** and attended by Camcore representatives from companies in Colombia, Mexico and Venezuela. The Southern Africa regional meeting was held in northern Mozambique (Niassa province) and was hosted by **Chikweti** and **Florestas de Niassa**. Representatives from Kenya, Mozambique, Tanzania, South Africa and Zimbabwe attended the meeting. The southern Latin America meeting was held in Argentina and hosted by **Alto Paraná** and was attended by representatives from Argentina, Brazil, and Uruguay. Many thanks to the host organizations for helping promote communcation and collaboration among the Camcore membership!

The 2013 Camcore Regional Technical Meeting for northern Latin America was hosted by Terranova, Venezuela. In the foreground are rooted cuttings of *P. caribaea* var. *hondurensis.*

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

The *P. patula x P. tecunumanii* hybrid is quickly becoming a preferred plantation species in southern Africa. Both Camcore hybrid trials and internal company trials indicate that this hybrid offers a number of advantages, combining the fast growth, *Fusarium* resistance and good wood properties of *P. tecunumanii* with the cold tolerance and good form of *P. patula*. In 2012, the African members of Camcore approved a joint breeding project for *P. patula x P. tecunumanii* hybrids in order to share the breeding and testing load. The plan called for large numbers of crosses using Camcore *P. patula* selections and Camcore *P. tecunumanii* selections. Use of Camcore *P. patula* means that all Camcore members will have access to any outstanding *P. patula* and *P. tecunumanii* identified in the testing. The parents can be grafted into breeding orchards and the best hybrid families can be mass produced for operational use in the future.

At the beginning of 2013, we finalized a workplan and estimated timelines and costs. The workplan was circulated among all Camcore members to invite interested participants. Eight organizations committed to support the project financially, and to participate in the future testing of the hybrid families. The eight organizations are: Cape Pine, Komatiland, Merensky, Mondi, PG Bison, Sappi, and York from South Africa, and Green Resources Tanzania.

The workplan calls for approximately 320 full-sib hybrid families to be produced, using 64 *P. patula* parents, and 80 *P. tecunumanii* parents. The 80 *P. tecunumanii* parents are equally divided between high and low elevation sources, as the two subpopulations will likely bring different advantages to the hybrid. For example, low-elevation *P. tecunumanii* has better *Fusarium* resistance, but lower frost tolerance. Each *P. patula* parent will be crossed with 5 *P. tecunumanii* (3 high-elevation and 2 low-elevation selections, or vice versa), and each *P. tecunumanii* will be crossed with 4 *P. patula* selections.

The goal for each hybrid cross is to produce about 150 seeds, which will allow distribution of about 50 seeds per cross to three Regional Coordinators who will be responsible for hedging and multiplication of the genetic material. All of the crossing will be done in Sappi's Lions River seed orchard, and the cost of the crossing work is being shared among all participating organizations.

The expected timeline of the project is 5 years, with 3 years of crossing, and final seed collections to be done in year 5. There are also funds in the budget to do some molecular marker work on the selected parents so that in the future we can confirm the identity of the top crosses.

The crossing work began in 2013. We identified 42 of the 64 patula parents, 40 of 40 high-elevation *P. tecunumanii* parents, and 24 of the 40 low-elevation *P. tecunumanii* parents. Additional selections of *P. patula* and low-elevation *P. tecunumanii* will be done in 2014, primarily based on genetic quality and flower and pollen availability, but also with an eye on ensuring that the selections represent most of the provenances from the natural range of the species. A total of 64 crosses were made in 2013, mostly with high-elevation *P. tecunumanii* parents due to pollen availability. In South Africa, low-elevation *P. tecunumanii* selections seem to be less prolific pollen producers than high-elevation selections. We hope that 2014 and 2015 will be better for pollen production, as our goal is to make about 130 crosses per year for the next two years.

Marius du Plessis (Mondi) and Washington Gapare (CSIRO) at the corner of a 5-year-old plot of *P. patula x P. tecunumanii* (low-elevation) in a hybrid trial in Mpumalanga, South Africa.

Pollen Contamination in *Pinus tecunumanii* Breeding Populations

In the 2012 Annual Report, we mentioned that Camcore members in South Africa and Colombia were working together to quantify the percentage of *P. tecunumanii x P. patula* natural hybrids in our 2nd generation base population of *P. tecunumanii* using NIR analysis. In both countries, *P. patula* (the predominant commercial species) and high-elevation (HE) *P. tecunumanii* flower at the same time, and we are observing natural hybrids in most of our 2nd generation OP progeny trials of *P. tecunumanii.* It appears that natural hybrids of low-elevation (LE) *P. tecunumanii* x *P. patula* are not as common as *P. tecunumanii* (HE) x *P. patula* in our trials, most likely because the flowering period of the LE ecotype begins a month earlier than *P. patula* and HE *P. tecunumanii* in South Africa.

In 2013, Camcore worked with Dr. Zander Myburg, Director of the Forest Molecular Genetics Programme (FMGP) and his staff at the University of Pretoria, and confirmed that microsatellite markers can distinguish between *P. patula, P. tecunumanii* and the hybrid. Kitt Payn, Pine Breeder at Mondi, coordinated needle collections in Camcore 1st generation trials of selected provenances of LE and HE tecunumanii and *P. patula* growing in South Africa. Fifty trees from each group (150 trees in total) were genotyped at the FMGP to broaden our molecular database.

To develop an NIR calibration data set to distinguish hybrids, 200 trees were selected in our 2nd generation *P. tecunumanii* trials and were also genotyped. These included 50 trees each of pure *P. tecunumanii* (HE), pure *P. tecunumanii* (LE), putative *P. tecunumanii* (HE) x *P. patula*, and putative *P. patula x P. tecunumanii* (LE) sampled at Smurfit Colombia, Cape Pine and KLF. In addition, 25 trees each derived from artificial crosses of *P. patula x P. tecunumanii* (LE) and *P. patula x P. tecunumanii* (HE) of known parentage were sampled at KLF. Prior to genotyping the 250 trees, green needles from each tree were 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 table-top FOSS 6500 NIR machine. The reason for the duplication in NIR scanning was to determine if future assessments of hybridity could be conducted with a hand-held device in the field. The NIR model, based on DNA confirmation, will then be used on a verification data set of needle samples from all trees in two OP 2nd generation *P. tecunumanii* trials in Colombia and South Africa. These trials have between 750 and 1000 trees each.

The results presented here should be considered preliminary, in that all trees are putative hybrids or pure species, and have been classified based on field inspection of morphology. However, at this time, the results are encouraging: it appears that the handheld NIR microPHAZIR can easily discern between all combinations of *P. patula* and *P. tecunumanii.* The one exception is *P. tecunumanii* (LE) and the putative *P. tecunumanii* (LE) x *P. patula* natural hybrid, where separation is sometimes unclear (see Figures 1, 2 and 3). We hope that discrimination between these two taxa will be improved when samples of ground, oven-dried needles are scanned on the desktop NIR because it utilizes a broader spectrum of infrared frequencies than the handheld device. Oven-dried needle samples from all trees in the two progeny trials are currently being scanned at NC State with the desktop NIR. In a short time, we should be able to determine if the degree of natural hybridity in our *P. tecunumanii* 2nd generation breeding populations is a serious issue that might affect future tree improvement efforts in countries where both *P. patula* and *P. tecunumanii* are being planted in close proximity to each other. At the conclusion of the study, Camcore will have a useful and robust NIR model to separate *P. tecunumanii* from putative natural hybrids with *P. patula*.

Bundles of pine foliage being scanned with the handheld microPHAZIR NIR machine.

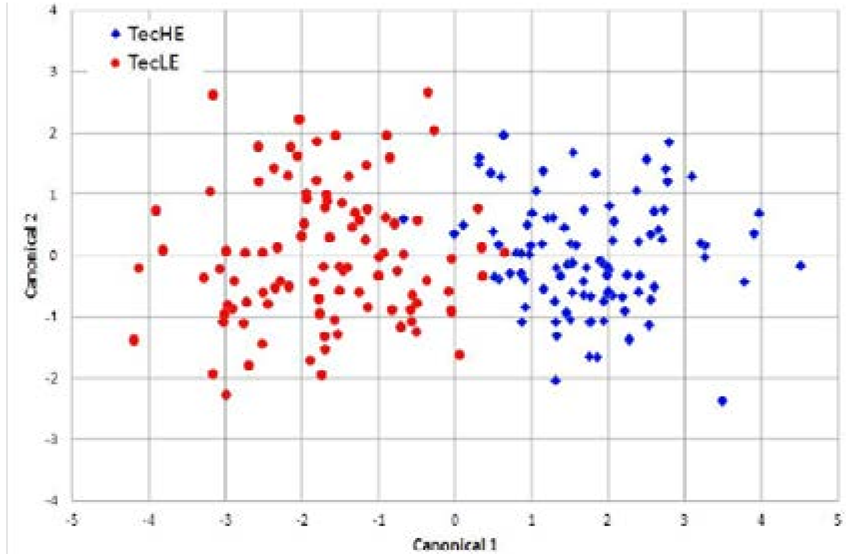


Figure 1. Canonical analysis showing separation of *P. tecunumanii* LE & HE in Camcore 2nd generation trials in South Africa using the handheld NIR microPHAZIR. The percentage of trees of each putative genotype classified correctly using an NIR discriminant analysis model was 96% and 95%, respectively.

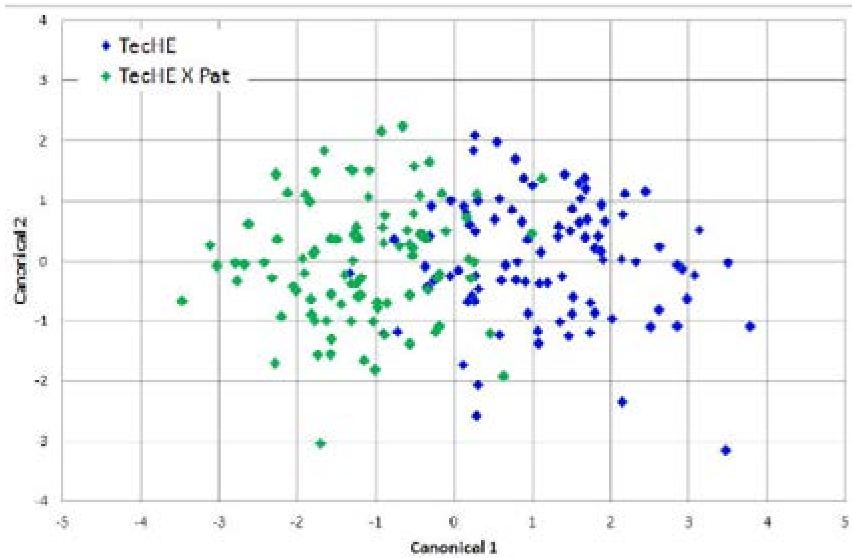


Figure 2. Canonical analysis showing separation of *P. tecunumanii* HE and the natural hybrid *P. tecunumanii* HE x *P. patula* in Camcore 2nd generation trials in South Africa using the handheld NIR microPHAZIR. The percentage of trees of each putative genotype classified correctly using an NIR discriminant analysis model was 84% and 93%, respectively.

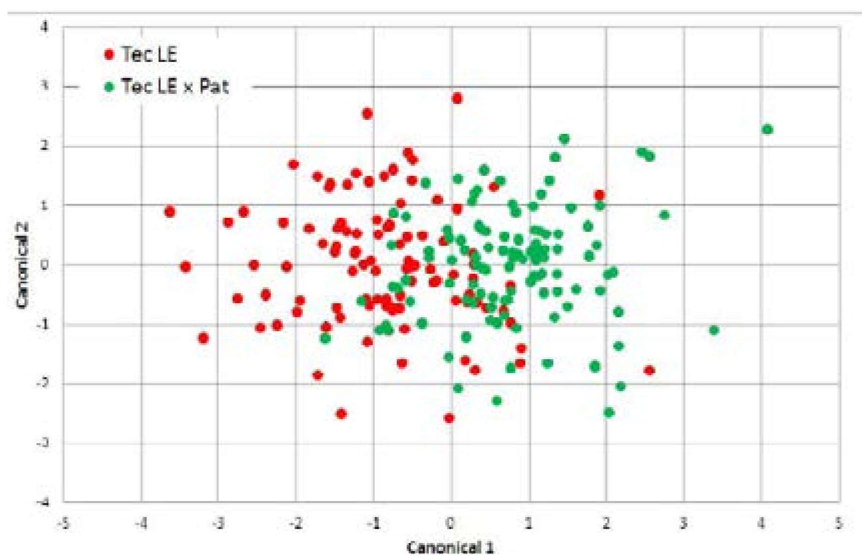


Figure 3. Canonical analysis showing separation of *P. tecunumanii* LE and the natural hybrid *P. tecunumanii* LE x *P. patula* in Camcore 2nd generation trials in South Africa using the handheld NIR microPHAZIR. The percentage of trees of each putative genotype classified correctly using an NIR discriminant analysis model was 59% and 56%, respectively. After DNA marker confirmation and scanning oven-dried material on the table-top NIR, greater resolution between the two groups is expected.

Status of the Pine Hybrid Project

Camcore members continue to work actively on the pine hybrid program, making new crosses, collecting seeds, establishing field trials and propagating material in the nursery through pine hedges. A second phase of the program is in progress in which full-sib family seeds of hybrids will be produced to establish hybrid tests by family. The purpose of the second phase is to start a breeding program with pine hybrids, while the main purpose of the first phase was to identify hybrid crosses with high commercial potential (e.g., see Figure 4).

We are still working on some activities of the first phase, bulk-hybrid testing, which will continue for several years. Two new hybrid trials were planted in the field in Argentina in 2013. This planting brings the total number of trials to 66, with 25 planted in Latin America and 41 in Africa. These last two trials belong to the third series of seeds produced by Camcore members with bulk hybrids, including hybrid crosses not present in the first two. Some of these new hybrids bring interesting crosses with species like *P. maximinoi (P. maximinoi x P. pseudostrobus, P. taeda x P. maximinoi, P. greggii* S *x P. maximinoi, P. radiata x P. maximinoi* and *P. elliottii x P. maximinoi)* and *P. radiata (P. radiata x P. patula, P. radiata x P. pringlei* and *P. radiata x P. maximinoi)*, opening possibilities for new areas of plantation forestry. We estimate that at least a total of 10 new trials of the third series will be planted in Argentina, Brazil, Colombia, and South Africa in 2014. In 2013, twelve trials planted in 2008 were measured at five years of age. These results, along with those obtained from the seven trials planted in 2007, will better illustrate the potential of some of the hybrid crosses in different regions. Wood properties of pine hybrids will be assessed in selected trials in South America and Africa over the next two years.

In addition to the above work, some three-way crosses were attempted in 2013, both to see if such crosses could be made sucessfully, and to see how they grow in field tests. The three-way crosses attempted were: *P. taeda x (P. patula x P. greggii)* and *P. taeda x (P. patula x P. pringlei)* by Klabin, and *P. patula x (P. patula x P. tecunumanii* (LE) by Sappi. Other crosses made with a polymix in South Africa were *P. patula x P. pringlei* by Merensky and *P. patula x P. leiophylla* by York.

Pollen collections of selected trees of *P. patula, P. greggii* var. *australis* and *P. tecunumanii* were made in Camcore progeny trials and kept separate by tree. The pollen of the two first species was used to make controlled crosses on selected *P. taeda* mother trees in Brazil. The pollen of *P. tecunumanii* that was collected by Smurfit Kappa Cartón de Colombia will be used to make crosses on *P. caribaea* trees in the seed orchard of Maderas del Orinoco in Venezuela. Additional crosses by family of *P. taeda x P. maximinoi* were made by Klabin, of *P. radiata x P. maximinoi* and *P. radiata x P. oocarpa* by Arauco and CMPC in Chile, and of *P. taeda x P. oocarpa* by Weyerhaeuser in Uruguay.

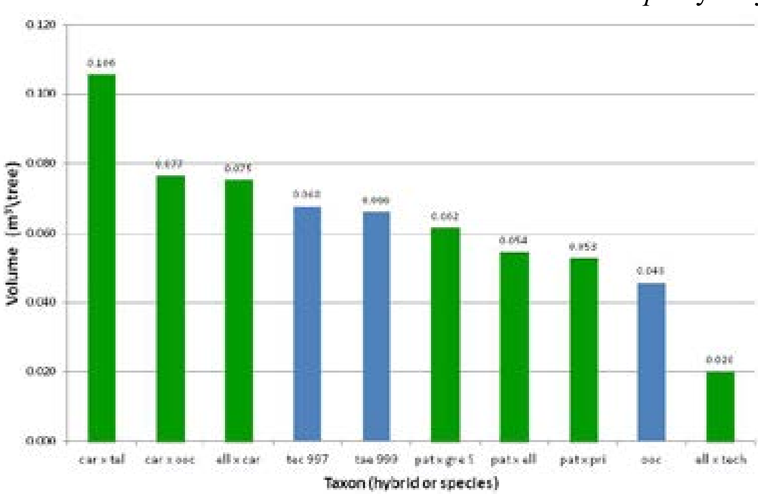


Figure 4. Least square means for volume growth of pine hybrids in three trials in Argentina (ages 3.5, 4.5, and 4.8 years). The hybrid *P. caribaea x P. tecunumanii* low elevation shows great potential at an early age.

Eucalyptus Breeding and Testing

Since 2010, Camcore has distributed seeds for 320 eucalypt trials; 56% destined for organizations in Latin America and 44% for our African members (Table 1). Since Camcore trials average about two hectares in size, this means an additional 640 hectares of studies comprised of 563,000 trees that will need to be measured at each assessment, assuming average survival of 80%.

At the 2013 annual meeting, several Camcore members reported on preliminary assessments of *E. dorrigoensis* in Uruguay (Weyerhaeuser and Montes del Plata), the South African Benchmark and CSIRO temperate species trials at CMPC in Chile, and the Tropical Benchmark and the drought-hardy trials at Chikweti in northern Mozambique. What kinds of things are we learning?

On the Lichinga plateau in Mozambique (1000 to 1400 m altitude; 13°S latitude), Research Director John Mudekwe reports that *E. grandis, E. urophylla* and the hybrid between the two are showing fast growth at two years of age in the tropical benchmark studies planted at two different locations. Performance is very much dependent on the level of improvement of the introduction. Of the drought-hardy species, *E. longirostrata* shows promise and (surprisingly) so do some provenances of *E. major,* based on a combination of growth and survival. The early performance of various *Corymbia* species on the Lichinga plateau is also noteworthy. Species like *E. moluccana* and *E. cladocalyx* show no potential.

Camcore planting of *E. dorrigoensis* at Weyerhaeuser, Quebrachal, Uruguay. The average height of the trees in this study was 7.3 m at two years of age *(Photo courtesy of Paola Molina)*.

Four progeny trials of *E. dorrigoensis* have been planted in Uruguay (80 to 200 m altitude; 31 to 33° S latitude). Two-year (preliminary) results presented by the Uruguayan Camcore members indicate that the Cloud Creek provenance (NSW) of the species develops most rapidly across all sites, that there is large family (provenance) G x E interaction, and that stem defects can be a problem. *Eucalyptus dorrigoensis* has withstood temperatures as low as -9.0°C in winter in several trials, and based on the Uruguayan tests plus those estab-

Table 1. List of eucalypt trials for nine different projects sent to Camcore members since 2010.

Project	Species	Number of tests sent to members		
		S. America	Africa	Total
1	Urophylla	12	4	16
2	Pellita	12	18	30
3	CSIRO (Temperate)	14	4	18
4	CSIRO (Subtropical)	13	5	18
5	Dorrigoensis	15	4	19
6	SA Benchmark	19	7	26
7	Tropical Benchmark	10	12	22
8	Drought Hardy	7	11	18
9	Prov./progeny trials	78	75	153
Total		180	140	320

lished in cold regions of South Africa, the species can be grouped with *E. benthamii, E. macarthurii*, and *E. badjensis* in terms of its good cold hardiness.

Three SA Benchmark and two CSIRO temperate species trials have been planted by CMPC on distinct soil types (160 to 830 m altitude; 36 to 38°latitude). Two-year height results show that the local controls of improved *E. globulus, E. nitens* and the G x N hybrid were superior to material of *E. benthamii, E. dunnii, E. marcarthurii, E. nitens, E. saligna,* and *E. smithii*, from seedling seed orchards and seed stands in South Africa and wild material from Australia, when planted in winter rainfall areas of Chile. Of the many eucalypt species studied, the most promising of the introductions in the two trial series at this time are *E. benthamii, E. badjensis* and *E. marcarthurii.*

There will be multiple assessments of these trials over time. The ultimate value of these Camcore eucalypt introductions (both wild and improved) will be dependent not only on growth, but also on survival and tolerance of severe frost, heat and increasing disease and pest problems.

Veronica Emhart, CMPC with the *E. globulus x E. nitens* hybrid on the left and *E. benthamii* on the right at two years of age in a benchmark trial in Chile *(photo courtesy of Veronica Emhart).*

Gmelina Breeding and Testing

Pizano / Monterrey Forestal continues to make good progress in its *Gmelina* breeding program. The company planted four clonal trials on distinct site types in 2007, with a group of 33 clones selected from commercial plantations. Camcore helped Pizano with the data analyses of these trials over the last several years. Based on the results of the analyses, Camcore made recommendations about which clones should be planted operationally on different sites.

In 2010, Pizano established four additional clonal trials, but with a new set of 50 selections from Camcore progeny trials. In 2013, we analyzed 2.6-year data from these trials. The results show a relatively low broad-sense heritability (across-site $H^2 = 0.10$), but still with economically important clonal variation, and low levels of genotype x environment interaction ($r_{Bg} = 0.80$). A subset of 10 clones was recommended for bulking up in the nursery in preparation for further testing and pilot plantation establishment.

Two-and-a-half-year-old clonal trial of *Gmelina arborea* planted by Pizano with 50 selections in Camcore progeny trials.

Genetics of *Eucalyptus urophylla*

Eucalyptus urophylla is one of the most important species in tropical plantation forestry. Although it is sometimes used as a pure species, it is best known as an important hybrid partner with *E. grandis, E. pellita,* and *E. brassiana.* Crosses between *E. urophylla* and cold-tolerant species like *E. benthamii* and *E. dunnii* are also now being tested for temperate regions in Latin America.

Camcore has been working with *E. urophylla* for many years, and has what is probably the largest genetic base of this species in the world. From 1996 to 2003, Camcore collected seed from 61 populations and 1104 mother trees on the seven islands where *E. urophylla* naturally occurs. The seed was distributed to Camcore members, and tests were established in Brazil, Colombia, Mexico, South Africa, and Venezuela, as well as in some other countries. In 2013, a comprehensive genetic analysis was done of 127 provenance/progeny tests with 3-year growth data. The results of this genetic analysis will be submitted for publication in early 2014, and are briefly summarized here.

Materials and Methods

Most of the progeny/provenance tests were measured for height and DBH at age 3 years. For a small number of tests, data were not available for age 3 years, and data from age 2 or 5 years were used as proxies. In South Africa, a large number of trials were measured only for DBH.

Analyses were done on standardized growth data. Phenotypic observations in each rep and tests were standardized to a mean = 100, and standard deviation = 100 CVy where CVy = coefficient of variation on the raw scale. As a result of standardization, any predicted genetic value can be directly interpreted in terms of percent gain (above or below 100%).

Variance components and genetic parameter estimates were calculated for each country, and then across-country analyses were done to estimate genetic and provenance correlations across countries.

Results and Discussion

Mean survival at age 3 years ranged from 68.6% in Mexico to 90.4% in Colombia. Growth rates were quite good in all countries. Even in Venezuela, which had the slowest growth, average height growth exceeded 3 meters per year, with mean height of 9.8 m and mean DBH of 9.8 cm. In the other four countries, mean heights were generally 12 m and mean DBH from 11 to 12 cm.

As is often the case for forest trees, age-age genetic correlations were very high ($r_g > 0.94$ for all combinations), and correlations among height, DBH, and volume were also very high ($r_g = 0.81$, 0.90, and 0.98 for ht-DBH, ht-volume, and DBH-volume, respectively).

Across all country pairs, the average of both provenance and genetic correlations was $r_g = 0.72$. The between-country provenance correlations range from $r_{prov} = 0.54$ for Mexico-Colombia, to $r_{prov} = 1.00$ for Mexico-Venezuela. The between-country genetic correlations range from $r_g = 0.34$ for Brazil–South Africa, to $r_g = 0.92$ for Colombia–Venezuela. The pair of countries that are the most "alike" is Mexico and Venezuela, with $r_{prov} = 1.00$ and $r_g = 0.90$. These parameters indicate that provenance and family rankings for Mexico and Venezuela will be almost identical.

Best linear unbiased predictions (BLUPs) were made for Gprov (provenance effect for volume or DBH, expressed in units of % gain above the unimproved population mean). There was very large provenance variation for growth in all countries. The largest variation was in Mexico, where the best provenance had a predicted Gprov of +32.7% (Kilawair, Flores), and the worst provenance had a predicted Gprov of -50.0% (A'esrael, Timor), a range of 82.7%. Less, but still quite important, provenance variation was observed in Colombia, where the best provenance had a predicted Gprov of +25.6% (Palueh, Flores), and the worst provenance had a predicted Gprov of -26.2% (Watololong, Adonara), a range of 51.8%. Provenance differences for DBH3 in South Africa ranged from Gprov = +7.5% (Palueh, Flores) to -7.4% (Naususu, Timor). Converting these DBH gains to approximate volume gains, the range would be roughly +24.2% to -20.6%. It is clear that there is tremendous opportunity for genetic gain from selection of the best provenances. As was seen in earlier analyses of these *E. urophylla* provenance /

progeny trials, there is a clear pattern where high-elevation provenances from Timor island grow substantially more slowly than low-elevation provenances from the other islands. Although this general pattern was clear, there was also much variation among provenances very close to one another, even from on the same volcano. For example, there are seven provenances collected from the Boleng volcano on Adonara island that are all within a 7 km radius. Two of the seven provenances (Muda and Lamahela) have Gprov > +17%, while the remaining five provenances have a Gprov ranging from -21% to +0.8%, with a mean Gprov = -7.1%.

It is also clear that there is much opportunity for genetic gain from family and within-family selection within provenances. Heritability for volume was above $h^2 = 0.15$ in all countries except Venezuela, where $h^2 = 0.09$. The genetic coefficient of variation ranged from 21 to 26%. Substantial genetic gains can be made with selection and breeding.

Nora Barrios (Terranova, Venezuela) in a one-year-old Camcore *E. urophylla* trial

Summary and Implications

There is tremendous provenance and genetic variation for growth in *E. urophylla.* It seems likely that the best *E. urophylla* provenances, families, and clones within families will tend to also make the best hybrid partners with other species. We have also found substantial provenance variation with *E. urophylla* for important wood property traits, such as density, pulp yield, and lignin / cellulose content (see 2012 Annual Report). Camcore members should evaluate provenance and genetic values for growth and wood properties as they move forward with pure-species or hybrid breeding with *E. urophylla.* There may be opportunities for collaborative breeding and testing among regions, for example between Mexican and Venezuelan members.

Pedigree Reconstruction and GBLUP

At the 2013 Annual Meeting, the Camcore Advisory Board approved a research project in the area of Pedigree Reconstruction / Genomic BLUP. Specifically, the project will investigate an application of what is sometimes called “Breeding Without Breeding”. We hope that this approach will allow companies working with a new plantation species to make a rapid jump forward in their tree improvement program. If an organization has plantations established with bulk orchard improved seed purchased externally, it might be possible to use molecular markers and Pedigree Reconstruction to extract “progeny test data” from its plantations, improving selection efficiency.

This project will be done in collaboration with Milan Lstiburek of the Czech Agricultural University. Milan has received a grant from the Czech government to work with Camcore on this topic, as the idea has potential application in a number of European countries as well as for Camcore members. Milan received his Ph.D. from NC State, and will be working closely with Gary Hodge on this project.

Status of the Eucalypt Hybrid Project

In 2011, Camcore initiated a cooperative Eucalypt Hybrid Breeding Project to further support the efforts of our eucalypt-growing members. The objective of this project is to produce full-sib families of a wide array of eucalypt hybrids, sharing the workload and the genetic material. A total of 14 Camcore members have agreed to participate: Arauco Bioforest, CMPC Forestal Mininco, Komatiland, Montes del Plata, Merensky, Mondi, Pizano, Rigesa, Sappi, Smurfit Kappa Cartón de Colombia, Smurfit Kappa Cartón de Venezuela, Suzano, Weyerhaeuser, and York Timbers.

The workplan calls for a total of 15 hybrids to be produced. All of the hybrids include at least one parent from a group of commercially important species: *E. grandis, E. urophylla, E. dunnii, E. globulus,* and *E. nitens.* The idea is that we will produce some hybrids with potential in any geographic region or climate. We hope that each participant will end up with 20 full-sib families of four to six different hybrids that can go into field tests. For hybrids which show commercial potential, the best clones and families from this project can serve as the initial population of a plantation and breeding program.

In 2012, most of our effort was focused on pollen collection. In 2013, we made some progress on completing the crosses, but we also ran into difficulties. Six of the 15 crosses are completely done. Three of the crosses are partially or mostly complete, although some additional breeding will be done in 2014 to try to increase the amount of seed. Two of the crosses were scheduled to be made in late 2013. With four of the crosses, we had challenges with flower or pollen production, or phytosanitary and import problems. In one case, a pollen shipment was delayed in customs and was eventually destroyed. Overall, everyone is still encouraged about what has been completed, and we are excited about this project. A strong push in 2014 should complete the crossing work, and we hope to distribute seed in 2015.

Pinus taeda Wood Properties Study

In the 2012 Annual Report, we presented 5-year growth results of the *P. taeda* GxE Study in southern Latin America. There were a number of important conclusions that came from that study, but two important ones were:

1. There is relatively little GxE interaction among sites either at the provenance or family-within-provenance level across 14 sites in Brazil, Argentina, Uruguay, and two sites in South Africa. This opens the door for cooperative breeding and testing of *P. taeda* among Camcore members.
2. It appears that Florida-source *P. taeda* is superior for growth rate across all regions. Many breeding programs had very little of this material in their internal *P. taeda* breeding programs.

At the Southern Latin America Regional Meeting in 2013, the participating organizations discussed using these trials for various breeding opportunities, including thinning to develop seed production areas, doing some wood properties testing, and making selections. From other forest tree species, we know that 5-year and 8-year data are very highly correlated, and that the patterns of genetic parameters (h^2, GxE) observed at age 5 will probably change very little. We agreed to maintain one test per company to age 8 years, and measure the other test at age 7 years in 2014. The test could then be thinned or used for selections. In addition, we agreed to use this material for a collaborative study on the genetic control of wood properties, and to rank the top half of the populatons (based on growth) for important wood traits. The workplan calls for wood property assessment in two trials, probably one in Brazil and one in Argentina. We plan to assess cellulose and lignin content (with NIR), MOE (with the TreeSonic acoustic tool), and density (with the Resistograph).

Genetic Control of Wood Properties of *Pinus patula* in Southern Africa

André Nel (Sappi Forests) recently completed his Ph.D. at the University of the Free State, in Bloemfontein, South Africa. Below is a brief summary of André's research on the genetics of wood and fiber properties in Pinus patula.

This study utilized half-rotation (8-year-old) *P. patula* progeny material from a 5×5 full diallel mating design and additional factorial crosses from the Zimbabwe Forest Commission tree improvement programme. Radial wood samples at 1.3 m above ground level from 300 trees were used to study a range of wood density, tracheid cross-sectional and dimension characteristics. A large range of family variation was found for all wood properties. The combining ability analysis indicated that general combining ability was the most predominant effect and that specific combining ability effects were absent for nearly all the investigated wood density and tracheid traits. Reciprocal, maternal and non-maternal effects were also not significant for all but a few traits. Some of the wood properties were influenced by the specific site where trees were grown.

Heritability estimates for many of the important wood density and tracheid traits were moderate to high, indicating strong additive genetic control of these properties. Wood density traits were under strong genetic control (h^2 of 0.90 to 0.20), with a pith-to-bark increase. Latewood proportion and earlywood density had a strong effect on weighted mean wood density. There were also strong positive correlations for density traits between growth rings, indicating that early selection would be possible. Tracheid cross-sectional properties were also strongly inherited (h^2 of 1.04 to 0.38), and strong correlations were found between the cross-sectional traits and calculated pulp and paper traits. Use of the MorFi® fiber analyzer enabled rapid and comprehensive assessment of tracheid dimension traits (e.g., see Table 2). Tracheid dimension traits such as length, width and cellwall thickness had lower heritability estimates (h^2 of 0.64 to 0.13) than those found for wood density and tracheid cross-sectional traits. Some of these properties such as tracheid length, width and cell wall thickness were, however, still higher than normally found for growth trait heritabilities.

Several strong positive and negative correlations were found between growth, wood density and tracheid property traits. Negative correlations would make multi-trait selections very problematic. Predicted gains for some of the wood properties were substantial, but correlated responses between primary and secondary selection traits were often negative. This study has provided novel information on the genetic inheritance of physical wood properties of *P. patula* grown in southern Africa, and will allow tree breeders to include some of these properties in breeding programmes. This study has shown that important physical wood properties such as wood density, tracheid diameter and tracheid length and cell wall thickness are under moderate to strong, additive genetic control.

Table 2. Summary statistics of tracheid dimension traits of *P. patula* in two Zimbabwe Forest Commission progeny trials.

Variable	Mean	SD	Min	Max	Range	CV
Arithmetic tracheid length (μm)	1415.2	94.6	1164	1731	567	6.7
Tracheid weighted length (μm)	2222.4	160.6	1749	2670	921	7.2
Tracheid width (μm)	40.5	1.0	36.3	43.5	7.2	2.5
Tracheid wall thickness (μm)	5.0	0.3	4.1	6.2	2.0	6.0
Number of tracheids per gram (No/g)	3.2	0.5	1.2	4.5	3.3	14.8
Coarseness of tracheids (mg/m)	0.2	0.04	0.16	0.61	0.44	17.7
Percentage kinked tracheids (%)	13.0	2.0	7.2	18.4	11.2	15.6
Percentage curl (%)	5.5	0.6	4.0	7.3	3.2	10.4
Percentage break ends (%)	36.3	1.8	31.3	42.9	11.6	5.1
Percentage area of fines (%)	1.800	0.386	1.118	4.2	3.082	21.4

2013 Seed Collections

Conservation of forest species continues to be one of the main objectives of Camcore. Natural stands of pine species in Central America are dwindling due to competition with other land uses like agriculture and grazing. In addition to these factors, forest fires and pests contribute to the decrease of natural forests, increasing their fragmentation and extinction. In some cases, excessive extraction of resin ends up killing trees.

In 2013, Camcore made collections of *P. tecunumanii* in five stands, three in Guatemala (San Marcos, San Jerónimo, and Chiul) and two in Honduras (Villa Santa and San Esteban). *Pinus caribaea* var. *hondurensis* was also collected in two different populations in Honduras, Limón and La Brea (Table 3). Elmer and Josué, the two Camcore workers in Central America, attempted seed collections in the small stands of *P. tecunumanii* at Chiul, Guatemala, but they only could collect from 3 trees because access was restricted by the land owners in the area.

Camcore members continue planting conservation parks in South Africa and Colombia, using some of the seed collected in Central America.

Josué Cotsojay and Elmer Gutiérrez, making seed collections of *P. tecunumanii* in Guatemala.

New Camcore members receive seeds from natural populations to start building a broad genetic base in their tree breeding programs with different species. The distribution of these seedlots to Camcore members around the world, and their efforts to establish genetic tests and conservation banks are means to conserve the threatened species and populations of Belize, Guatemala, Honduras, Mexico, and Nicaragua.

Table 3. Summary of seed collections completed in Central America and Mexico in 2013.

Country	Species	Provenance	Conservation Status	Latitude	Longitude	Trees
Guatemala	*P. tecunumanii*	San Jerónimo	Vulnerable	15° 00’	90° 16’	15
Guatemala	*P. tecunumanii*	San Miguel	Vulnerable	15° 17'	91° 40'	11
Guatemala	*P. tecunumanii*	Chiul	Endangered	15° 20'	91° 04'	3
Honduras	*P. tecunumanii*	Villa Santa	Vulnerable	14° 11'	86° 16'	20
Honduras	*P. tecunumanii*	San Esteban	Endangered	15° 17'	85° 40'	16
Honduras	*P. caribaea*	Limón	Endangered	15° 51'	85° 23'	20
Honduras	*P. caribaea*	La Brea	Vulnerable	15° 45´	86° 00	12

Genetic Conservation of Eastern and Carolina Hemlock

This year marked Camcore's 10th year of collaboration with the USDA Forest Service (USFS) on the genetic resource conservation of Eastern hemlock *(Tsuga canadensis)* and Carolina hemlock *(T. caroliniana)*. This ongoing project has been possible thanks to more than $700,000 in grant funding provided to Camcore by the USFS through the forest health program coordinated by USFS Entomologist Rusty Rhea. Both hemlock species are native to the eastern United States and face a significant risk of local population extinction and range-wide population decline due to the invasive insect hemlock woolly adeglid *(Adelges tsugae)*. Over the last 10 years, more than 2 million hemlock seeds, representing 70 populations and 500 mother trees of Eastern hemlock and 19 populations and 134 mother trees of Carolina hemlock, have been placed into conservation (Figure 5). Many of these collections have been made by Camcore, but a number of federal, state, and local government collaborators and private citizens have participated in the seed collection effort as well. The seeds collected have been utilized to meet a number of research and conservation objectives with the hemlocks, including studies on population genetic structure and diversity, seed stratification requirements for germination, long-term seed preservation at the USDA Center for Genetic Resource Preservation in Fort Collins, Colorado, and the planting of conservation banks in Chile (Arauco-Bioforest), Brazil (Rigesa), and the United States (Camcore). A manuscript detailing progress made in hemlock gene conservation during the past 10 years was recently published by Camcore in the USFS journal Tree Planters' Notes (see citation in the Publications section of this annual report).

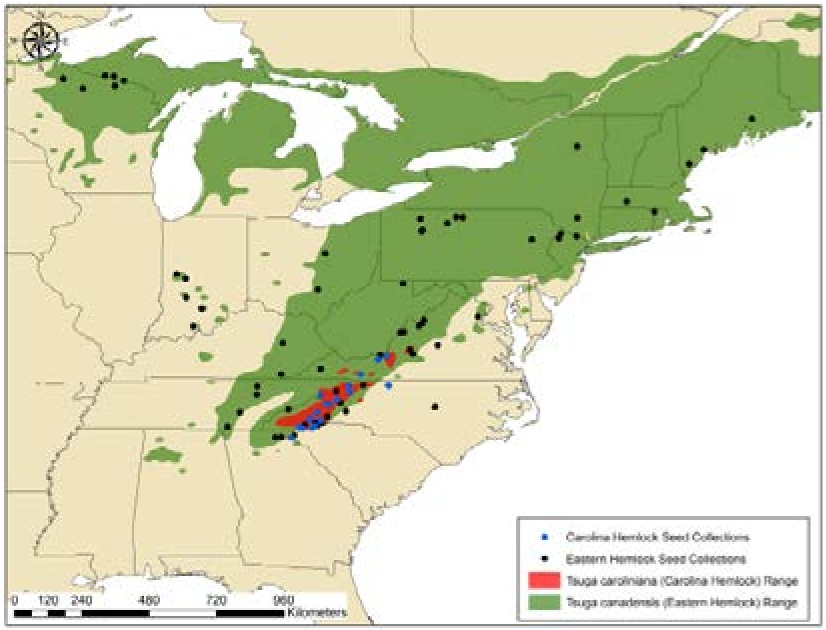


Figure 5. Locations of provenance seed collections of Eastern hemlock *(Tsuga canadensis)* and Carolina hemlock *(Tsuga caroliniana)* made by Camcore 2003-2013.

It was a busy year for the hemlock project as we traveled extensively throughout the eastern United States for research, population explorations, field collections, and presentations. Andy Whittier assisted Camcore graduate student Lia Campbell with foliage collections from 29 populations and 459 trees for her thesis research on the population genetics of Carolina hemlock. Robert Jetton travelled to Pennsylvania in October to distribute collection kits and teach a one-day short course in seed collection techniques organized by the Pennsylvania Chapter of The Nature Conservancy, an effort that so far has yielded seed collections from 6 populations and 46 mother trees of Eastern hemlock. We also had opportunities to report on the progress of the hemlock project through invited presentations given by Robert Jetton at the University of Tulsa and the Entomological Society of America Annual Meeting, and Andy Whittier at the Alliance for Saving Threatened Forests Symposium. Finally, Camcore graduate student Zaidee Powers completed and successfully defended her thesis research on mass artificial infestation techniques for screening hemlock genotypes for resistance to the hemlock woolly adelgid.

Genetic Conservation of Table Mountain Pine

This marked the final year of seed collections for Camcore's genetic resource conservation program for Table Mountain Pine (TMP, *Pinus pungens)*. TMP is endemic to the central and southern Appalachian Mountain regions of the eastern United States. Natural populations are threatened due to climate change, wildfire suppression, and periodic outbreaks of the southern pine beetle. These seed collection efforts were accomplished with $76,300 in grant funding from the USDA Forest Service (USFS) and in partnership with USFS geneticist Barbara Crane.

Snow-covered cones of Table Mountain Pine *(Pinus pungens)* at a northern Virginia population on Bull Run Mountain where seed collections were made in 2013.

Seed collections in 2010, 2011, and 2012 covered the majority of TMP's natural distribution (Figure 6), and represented 213 mother trees in 31 populations. Our 2013 collections were targeted to portions of the range in Maryland, central Pennsylvania, and northern and southwestern Virginia that were underrepresented in previous collections (Figure 6). These collections yielded seed from an additional 41 mother trees in 6 populations, bringing total seed collections for the project to 254 mother trees in 37 populations. Portions of seed from the 2010 and 2011 collections have been submitted to the USDA Center for Genetic Resource Preservation in Fort Collins, CO for long-term preservation and to the USFS for seed orchard and reforestation efforts. Similar submissions will be made for the 2012 and 2013 seed in early 2014.

Although the seed collection phase of this project has ended, Camcore and the USFS will continue to partner on a population genetics study of TMP in 2014. The objective of this study is to understand the recent evolutionary history of the species by describing patterns of genetic structure and diversity in natural stands, comparing this to the genetic variation present in the seed sample, and assessing levels of introgression between TMP and sympatric pine species such as Virginia and pitch pine. This study will be accomplished with approximately $50,000 from the USFS to cover laboratory and data analysis costs and $5,000 provided by Camcore for the collection of field samples and greenhouse production of seedlings.

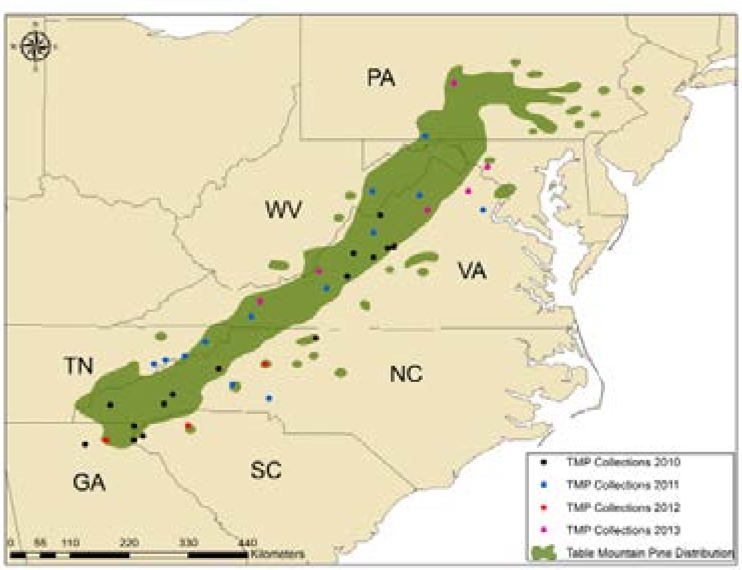


Figure 6. Locations of provenance seed collections of Table Mountain Pine *(Pinus pungens)* made by Camcore 2010-2013.

Genetic Conservation of Atlantic White Cedar

We first reported on Camcore's genetic resource conservation program with Atlantic White Cedar (AWC, *Chamaecyparis thyoides)* in the 2012 Annual Report. AWC is endemic to the freshwater swamps and bogs of the eastern United States where populations once covering more than 200,000 ha have been reduced to less than 40,000 ha in recent decades due to over harvesting, wetland conversion for agriculture and development, and severe wildfires. In late 2011, Camcore received $250,000 in grant funding from the USDA Forest Service (USFS) to secure representative seed samples from the remaining distribution of AWC to support long-term seed preservation and reforestation efforts for the species.

The objective of the project is to collect seeds from 400 mother trees in 40 remnant populations distributed across four seed zones that Camcore identified using FloraMap™ software (Figure 7). Portions of the seed will be submitted to the USDA Center for Genetic Resource Preservation in Fort Collins, CO for long-term preservation and to the USFS for seed orchard and reforestation efforts. During the first two seed collection seasons (2012 and 2013), Camcore explored 24 reported AWC populations in the Southern Atlantic and Gulf Coast seed zones and collected seed from a subset of 15, yielding seed from a total of 120 mother trees (Figure 7, Table 4). Collections in 2013 were coordinated by Andy Whittier, and he was assisted in the field by USFS Geneticist Barbara Crane, our primary Forest Service collaborator on the project. Explorations and collections in 2014 will focus on the Northern and Central Atlantic Seed Zones (Figure 3).

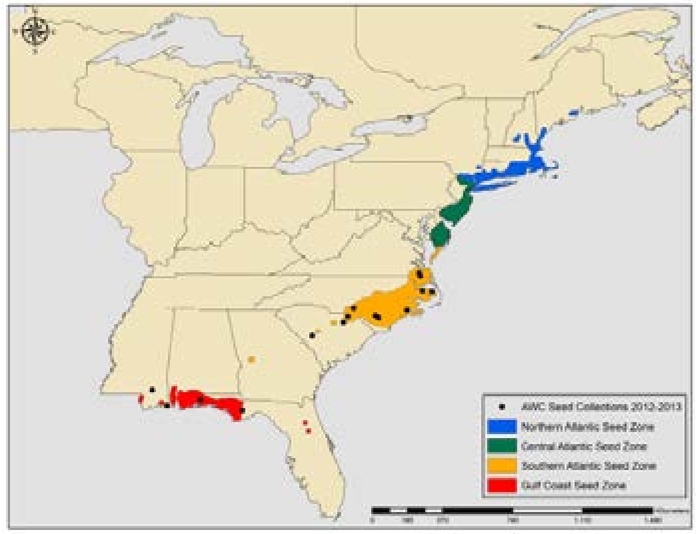


Figure 7. Locations of provenance seed collections of Atlantic White Cedar *(Chamaecyparis thyoides)* made by Camcore 2012-2013.

Table 4. Population and seed yield information for Atlantic White Cedar *(Chamaecyparis thyoides)* collections made by Camcore 2012-2013 (n/a = seed yield information not yet available).

Population	County	State	Latitude (D m.m)	Longitude (D m.m)	Elev. (m)	Seed Year	Trees	Seed (#)
Singletary Lake	Bladen	NC	34 35.185	-78 26.988	10	2012	8	21,793
Jones Lake	Bladen	NC	34 41.055	-78 35.779	25	2012	8	9,972
Catfish Lake	Craven	NC	34 56.659	-77 06.768	12	2012	10	51,708
Cheraw State Park	Chesterfield	SC	34 38.456	-79 53.876	41	2012	10	10,920
Alligator River	Dare	NC	35 46.782	-75 51.764	1	2012	10	18,276
Pettigrew State Park	Tyrrell	NC	35 52.094	-76 20.892	11	2012	5	5,286
Gravatt Center	Aiken	SC	33 44.324	-81 34.909	136	2012	10	25,393
Kalmia Gardens	Darlington	SC	34 22.075	-80 06.787	56	2012	1	1,272
Sandhills Gameland	Richmond	NC	35 02.116	-79 36.845	99	2012	10	6,960
Great Dismal NC	Camden	NC	36 30.193	-76 29.225	5	2012	5	17,169
Great Dismal VA	Suffolk	VA	36 42.086	-76 31.720	7	2012	6	13,668
Apalachicola	Liberty	FL	30 13.191	-84 53.433	21	2013	12	n/a
Blackwater River	Santa Rosa	FL	30 42.471	-86 52.515	3	2013	10	n/a
Escatawpa	Jackson	MS	30 26.320	-88 28.377	0	2013	10	n/a
Camp Shelby	Forrest	MS	31 09.905	-89 10.352	54	2013	5	n/a

Indirect Selection for Teak Heartwood Percentage

In February 2013, Camcore and Cementos Argos/Tekia, initiated a study in a 16-year-old commercial stand of teak in Sucre department, northern Colombia. The purpose of the study was to develop a non-destructive method to assess the heartwood proportion of standing trees. The appealing dark color of teak wood is from the heartwood, and its proportion in logs and lumber affects the price in the market. If the method works, the heartwood percentage could be used as a criterion in the provenance/progeny trials to make family and individual tree selections at early ages.

Camcore and Tekia staff spent 5 days in the field selecting, cutting and measuring trees with three tools to examine if they had potential as methods of indirect selection for heartwood content. The three tools were 1) the Fakopp TreeSonic, that measures sound wave velocity in standing trees, 2) the hand held NIR to assess cambial chemistry, and 3) the IML resistograph, which measures wood density profile in the tree. The plan was to use the three tools to take readings in four logs per tree from 50 trees. After the first 10 trees, the resistograph stopped working because of a malfunction in its electronic system. The other two tools were used to measure the 200 logs of the study. All the logs were also assessed with a ruler on the cut end of each log, measuring the diameters of heartwood and the entire log in two directions. Correlations between the tool readings and the overall percentage of heartwood in the log were calculated. Wood samples were also taken from the logs and will be used to look for correlations between desktop NIR scans of the sapwood and of the measured heartwood proportion.

The results obtained with the TreeSonic showed a correlation of $r = 0.50$ between the mean heartwood percentage and the velocity of the sound wave. The value of the heartwood proportion varied between 60% and 90% for the logs sampled. The correlation coefficient obtained with the NIR scans was $r = 0.47$, slightly lower than that obtained with the TreeSonic.

Juan López using the TreeSonic in Colombia to measure the velocity of sound waves in a standing teak tree.

Even though the results obtained are only moderately encouraging, the study will continue in March 2014 when a second visit to the site will be made by Camcore and Tekia employees. Fifty more trees will be cut and measurements with the resistograph and the TreeSonic will be recorded. Some changes in the method of measurement with the TreeSonic will be implemented in an attempt get more precise measurements and improve the correlation. Additional wood samples will be taken and correlations between wood density measured with the gravimetric method and readings with the resistograph will be calculated.

Teak Seedling Nutrient Disorder Study

Andy Whittier continues to make progress on his research for his M.S. on teak *(Tectona grandis)* seedling nutrient disorders. During the summer of 2013, seedlings were germinated and grown at NC State in both a greenhouse and an environmentally controlled chamber. In the greenhouse, seedlings were subjected to three different levels of a standard nutrient solution in a sand-culture hydroponic system. In the environmentally controlled chamber, seedlings were grown in a liquid-culture hydroponic system and subjected to the same three levels of the nutrient solution. Results from this study indicate that the full strength solution resulted in superior growth in the teak seedlings.

Building on the nutrient strength studies conducted during the summer of 2013, additional research looking at three different pH levels (5.5, 6.0, and 6.5) of the nutrient solution in the liquid-culture system was completed during the fall of 2013. While we experienced some technical difficulties with the pH 5.5 treatment dropping below the target level, results indicated that the pH 6.0 treatment resulted in the best seedling growth.

A final study in late 2013 used newly germinated teak seedlings to compare sodium hydroxide to calcium hydroxide for use as a base in maintaining the nutrient solution at the target pH. Previous Camcore hydroponic teak studies used sodium hydroxide to control pH, but questions arose concerning sodium toxicity in the seedlings. The use of calcium hydroxide (slaked lime) would avoid sodium toxicity issues while providing additional calcium to calcium-dependent teak seedlings. Preliminary results from this study indicate that the use of sodium hydroxide as a base results in better growth in teak seedlings.

These initial studies were done in order to evaluate the feasibility of growing teak seedlings hydroponically in North Carolina and in preparation for larger studies to be completed during the summer of 2014. Results from these preliminary studies will be used to determine the correct nutrient solution strength, solution pH, and buffer to use in hydroponics. During the summer of 2014, seedlings will be grown in both a greenhouse and environmental chamber where they will be subjected to 12 different nutrient deficiencies. Each treatment will consist of the standard nutrient solution minus one of the macro or micro nutrients. Individual treatments will be followed with regular growth measurements and photographs. Throughout the research, foliage samples will be taken and analyzed for nutrient concentrations in order to determine foliar nutrient levels in healthy and unhealthy seedlings. At the conclusion of the research, a high quality photographic guide will be developed and distributed to teak growers for use in their nurseries for diagnosing seedling issues.

In addition to the nutrient disorder studies, we will subject potted teak seedlings to nutrient solutions with differing levels of nitrogen, phosphorous, and potassium. Foliage of these seedlings will be regularly scanned with both a handheld and desktop NIR module. Results from this study will be used in the creation of NIR models depicting N, P, and K levels in healthy and deficient teak seedlings. NIR models combined with diagnostic photograph guides and foliar nutrient concentration levels will provide teak growers with several different methods to evaluate the health of their teak seedlings in the nursery.

Teak seedlings grown in the greenhouse sand-culture hydroponic system using a ten percent strength nutrient solution.

Pine Species-Site Trials in South Africa: Three-year Results of Growth and Modulus of Elasticity

Oscar Nilsson completed his M.S. thesis titled "Growth and Modulus of Elasticity of some Pine Species and Hybrids Three Years After Planting in South Africa". The full thesis will be available online from Camcore or the NCSU library.

Introduction

In South Africa, *Pinus patula* has been planted for over 100 years, and it is currently the most widely planted pine species in the country. Over the past 30 years, Camcore members in South Africa have tested many "new" pine species with unimproved genetic material from native stands, and some of these shown good potential, including *P. tecunumanii, P. maximinoi, P. greggii* var. *australis* (greggii South) and var. *greggii* (greggii North), and others. In 2008, Camcore initiated a series of species-site trials with the objective of comparing a number of these "new" pine species with the commercial species *P. patula* and *P. radiata.* There were three factors contributing to the need for these trials: 1) not all of the species were tested thoroughly across the entire forestry region, e.g., in southern Kwazulu-Natal, or in the southern Cape; 2) an increase in mortality due to *Fusarium* was being being observed in nurseries and young plantations of *P. patula* and *P. radiata,* suggesting increased value of *Fusarium*-tolerant species like *P. tecunumanii*; and 3) the availability of genetically improved seed (at least somewhat improved) of species like *P. tecunumanii* or *P. greggii* from seed orchards or thinned progeny tests.

A series of six trials were planted (Table 5), and in each trial, commercial species and an array of "new" species were planted. In addition to the Camcore species, the trials included *P. taeda, P. elliottii, P. elliottii x P. caribaea* hybrids, and other varieties. The objective of this study was to examine survival and growth after three years, and also to examine wood stiffness, specifically, Modulus of Elasticity (MOE) as measured with an acoustic time-of-flight tool.

Materials and Methods

All tests were planted using four replications and a RCB design with 6x6 tree block plots. Spacing was between 3 x 2.5 m (1333 stems per ha) to 3 x 3 m (1111 stems per ha). At age 3, survival, height and DBH were measured, and a volume index calculated. For species which had greater than 50% survival, MOE measurements were made using the Fakopp TreeSonic tool. For the TreeSonic measurements, eight trees per rep were sampled, using the largest trees in the plot (minimum DBH of 4 cm). The probes of the TreeSonic were driven into the stem at 1.5 and 0.5 m. The tool was used to measure the time of flight of an acoustic wave. MOE was calculated as MOE = ρV2 * 100000 where ρ is the green density of the material (kg/m^3), V is the longitudinal wave velocity (m/s) and MOE is the modulus of elasticity (GPa). It is typical in the literature to assume a constant green density of 1000 kg/m^3, but often the goal is for within-species selection. Since this study involved different species, increment core samples were taken from four trees per replication in order to estimate green density. As a result, this study estimated green density, dry density, moisture content, and three different

Table 5. Site information for six pine species-site trials in South Africa.

TestID	99-18-03C	99-49-03D	99-55-03E1	99-55-03E2	99-55-03E3	99-55-03E4
Region	KwaZulu-Natal	KwaZulu-Natal	Eastern Cape	Eastern Cape	Western Cape	Western Cape
Site	Ncalu	Weza	Wildebeest	Glen Cullen	Ruigtevlei	Brackenhill
Company	Mondi	Merensky	PG Bison	PG Bison	PG Bison	PG Bison
Date planted	3-Dec-09	18-Feb-10	18-Feb-10	16-Feb-10	25-Mar-10	25-Jun-10
Spacing (m)	3 x 2.5	3 x 3	3 x 3	3 x 3	2.7 x 2.7	2.7 x 2.7
Latitude	30° 12' S	30° 34´ S	31° 12´ S	31° 07´ S	34° 01' S	34° 01´ S
Altitude (m)	1130	1100	1421	1406	110	299
Rainfall (mm)	809	996	989	989	698	945
Mean Ann. Temp. (°C)	16.0	14.4	14.0	14.0	16.7	16.7

MOE estimates: MOE, calculated using observed green density, MOE2 using the species average green density, and MOE3 using an assumed constant density of 1000 kg/m^3.

Results and Discussion

Average survival across all species and all sites was 61.8%. All of the tests had some species with greater than 75% survival, with the exception of 99-55-03E1, Wildebeest. Some of the low survival was due to trying some subtropical species on colder sites (e.g., *P. tecunumanii* at Wildebeest, where it had 0% survival). Some of the low survival was due to extended drought events that occurred shortly after planting. Growth analysis was limited to species with greater than 50% survival.

Height, DBH, and volume growth were strongly correlated, and only height results will be summarized here (Table 6). The best growth was observed on Ncalu (KZN), the warmest site, where the best species had 3-year mean heights around 5 to 6 m. On all other sites, mean height growth was closer to 2.5 to 3 m for the best species. At Ncalu, the top performers for growth were *P. patula x P. tecunumanii* (6.2 m), *P. patula x P. oocarpa* (5.6 m), *P. maximinoi* (5.6 m), followed by the commercial species *P. patula* (5.5 m). At Weza (KZN), the best growth was seen in a *P. elliottii x P. caribaea* hybrid (3.7 m), followed by *P. elliottii* (3.4 m) and then a *P. patula* seedlot (3.2 m). On the Eastern Cape at the Glen Cullen site, *P. greggii* South and *P. patula* both had mean heights of 3.4 m. And on the Western Cape, the *P. radiata* seedlots had the best height (2.9 to 3.3 m), but a *P. elliottii x P. caribaea* hybrid (2.8 m) and *P. maximinoi* (2.6 m) showed some potential.

For wood properties, there was significant species variation in density, green density, and MOE (Table 7). There was substantial variation among species for green density, ranging from 927 kg/m^3 to 1060 kg/m^3. Compared to the normal practice of assuming a constant green density of 1000 kg/m^3, species with higher green density will have their MOE underestimated, and species with lower green density will have their MOE overestimated. For example, in this study, under an assumption of constant green density of 1000 kg/m^3, *P. patula* was estimated to have an MOE3 of 5.28 GPa. In comparison, using the observed mean green density for *P. patula* (926.7 kg/m^3), the

Table 6. Three-year survival and height for four of the six pine species-site trials in South Africa.

Ncalu, KwaZulu-Natal					
Species	**Surv.**	**Height**	**Tukey**		
PatxTecL KLF	90	6.23		A	
PatxOoc KLF	86	5.61		B	
Max	83	5.56		B	
Pat	96	5.53		B	
Rad	90	5.29		B	
GregS	89	4.87		C	
TecH	81	4.84	D	C	
Tae	92	4.53	D	C	E
TecL	77	4.45	D		E
Ell	90	4.44			E
ECC SAPPIN	85	4.31			E
Pseu	92	4.29			E
GregN	90	3.56		F	
Weza, KwaZulu-Natal					
Species	**Surv.**	**Height**	**Tukey**		
ECC SAPPIX	93	3.67		A	
Ell	92	3.42	B	A	
Pat KLFE	79	3.17	B	C	
Tae	75	3.08	D	C	
MaxOXF	67	3.01	D	C	
Tae MONDIB	79	3.01	D	C	
PatxTecL Y	90	2.98	D	C	
Max	51	2.98	D	C	
Pat KLFGF	77	2.86	D		
GregN	53	2.04		E	
Pseu	70	1.83		E	
Glen Cullen, Eastern Cape					
Species	**Surv.**	**Height**	**Tukey**		
GregS	91	3.39	A		
Pat	71	3.38	A		
PatPGB	71	3.36	A		
GregN	83	2.99	B		
Ell	83	2.64	C		
Ruigtevlei, Western Cape					
Species	**Surv.**	**Height**	**Tukey**		
RadS MTO	59	3.26		A	
RadC MTO	53	3.09	B	A	
Rad	88	2.88	B	C	
ECC SAPPI	90	2.81	D	C	
Max	85	2.61	D	E	
Ell	88	2.55		E	
TecH	90	2.46	F	E	
ECC MTO	92	2.43	F	E	
Tae	69	2.41	F	E	
GregS	97	2.37	F	E	
TecL	83	2.23	F	G	
Pat	88	2.12		G	
Pseu	88	1.55		H	
GregN	79	1.51		H	

MOE2 was estimated to be 4.93 GPa. If MOE2 is considered more accurate, then MOE3 is an overestimate of 7.1%. The opposite effect was observed for *P. maximinoi*, which had a very high green density of 1059.8 kg/m^3. For this species, MOE3 was calculated as 6.00 GPa, while MOE2 (using the observed green density of 1059.8 kg/m3) was calculated as 6.36 GPa. In this case, MOE3 underestimates wood stiffness by 5.75% compared to MOE2. Nevertheless, this effect, though real, seems to generally have little impact on species ranks for MOE, as the ranks for all three MOE variables are very similar.

Some species have very good MOE even at age 3 years, e.g., *P. maximinoi*, with MOE2 = 6.4 GPa. Other species are much lower, e.g., *P. radiata* at 4.4 GPa and *P. elliottii x P. caribaea* at 3.45 GPa. One must take some caution in the interpretation of these MOE values, measured in green stems, when comparing them to values for dried sawtimber in the marketplace. Nevertheless, it seems reasonable to expect that a much higher proportion of the juvenile wood of *P. maximinoi* would meet minimum strength standards for sawtimber than one would find with *P. radiata.*

Summary and Implications

These are early results, but at every site, some species have comparable growth to the commercial species, and possibly better juvenile wood properties. All of these species will have mature wood that will produce acceptable sawtimber, but improving the juvenile portion of the stem should have an important economic impact.

Table 7. Across-site mean for wood property traits from four pine species-site trials in South Africa.

Species	Green Den (kg/m^3)	Tukey						Species	Dry Den. (kg/m^3)	Tukey			
Max	1059.8				A			PatxTecL YOR	396.3			A	
Pseu	1026.9		B		A			TecL	395.5	B		A	
GregN	999.7		B		C			Max	394.1	B		A	
Rad	998.0		B		C			GregS	383.7	B		A	C
PatxOoc KLF	997.6		B		C			Pat KLFE	377.7	B	D	A	C
ECC SAPPIN	994.7		B		C	D		GregN	377.7	B	D	A	C
PatxTecL KLF	987.3		B		C	D		Tae	369.7	B	D		C
TecH	978.3		E		C	D		PatxOoc KLF	369.3	B	D		C
GregS	975.1		E	F	C	D		ECC SAPPIX	364.7		D		C
ECC MTO	974.5		E	F	C	D		Pseu	363.8		D		C
PatxTecL YOR	965.9	G	E	F	C	D		ECC SAPPIN	362.6		D		C
TecL	965.0	G	E	F	C	D		TecH	361.7		D		C
ECC SAPPIX	962.7	G	E	F	C	D		Ell	360.9		D		C
Ell	951.0	G	E	F		D		ECC MTO	359.3		D		C
Pat KLFE	937.3	G	E	F				PatxTecL KLF	358.4		D		C
Tae	929.9	G		F				Pat	353.4		D		
Pat	926.7	G						Rad	353.0		D		
Species	**MOE2 (GPa)**	**Tukey**						**Species**	**MOE3 (GPa)**	**Tukey**			
Max	6.36			A				PatxTecL KLF	6.31		A		
PatxTecL KLF	6.23			A				Max	6.00	B	A		
TecL	5.50			B				TecL	5.70	B	C		
Pat KLFE	5.19	C		B				Pat KLFE	5.54	B	C		
PatxTecL YOR	5.04	C		B				Pat	5.28	D	C		
Pat	4.96	C		B				PatxTecL YOR	5.22	D	C		
PatxOoc KLF	4.85	C		D				TecH	4.95	D	E		
TecH	4.84	C		D				PatxOoc KLF	4.87	D	E		
GregS	4.37	E		D				GregS	4.48	F	E		
Pseu	4.23	E		F				Pseu	4.11	F	G		
GregN	3.99	E		F	G			GregN	3.99	F	G	H	
Tae	3.68	H		F	G			Tae	3.96	F	G	H	
Rad	3.61	H		I	G			Rad	3.62	I	G	H	
ECC SAPPIN	3.45	H	J	I	G			ECC SAPPIN	3.46	I		H	

Growth Rhythms in *Pinus maximinoi*

Pinus maximinoi is becoming one of Camcore's most important commercial species in tropical and subtropical regions. In 2012, Camcore members in Africa initiated a study to do the following:

1. To determine if dendrometer bands are a useful tool for discerning growth rhythms and timing of flower production in *Pinus maximinoi.*
2. To better understand the growth development patterns of *P. maximinoi* relative to local and commercial controls of *P. patula, P. elliottii* and *P. radiata.*

Our hypothesis was that *P. maximinoi* growth begins earlier and ends later than any of the commercial control species. In some cases in the tropics, it appears that *P. maximinoi* grows all year.

As stated in last year's report, a dendrometer band is a ring of metal or plastic that measures circumference increment over time. The band is placed around the tree at breast height (1.3m) and is connected to a spring. When the tree circumference expands, the spring allows for the band to expand and the amount of expansion can be recorded.

To test our hypothesis over a wide range of climates and environments, seven Camcore members participated in the study, from northern Mozambique (13°S) to the Cape of South Africa (34°S) or a distance of 2,250 km.

Each member was given dendrometer bands for 20 trees, 10 for *P. maximinoi* or an alternate species and 10 for the control. The bands were placed at 1.3 m height on the stem. Increments were recorded on all trees every 15 days for one year from October 1, 2012 to September 30, 2013. Height and DBH were measured on each tree at the beginning and end dates of the study. At each assessment of circumference, researchers were asked to score the degree of shoot elongation on the branches as: *0 = Resting*: most or all of the shoots are not actively growing, *1 = Mix:* some of the shoots are elongating, but many are not, *2 = Growing:* most or all of the shoots are actively growing.

Our observations suggest that the flowering periods for *P. maximinoi* on sites between latitudes 13° and 34° in southern and eastern Africa are very similar and occur between the months of (late) June to September with cone crops becoming ready between October and December.

Results from the dendrometer study indicated that in terms of cumulative circumference increment in the most tropical latitudes in Mozambique (13°S), *P. maximinoi* grew more rapidly than *P. tecunumanii* during the wet season and maintained this advantage during the dry season (Figure 8). In terms of shoot elongation, both species were actively growing during the wet season as expected, but *P. tecunumanii* branch shoots exhibited a semi-resting stage (elongation of some branches but not others on an individual tree) while *P. maximinoi* continued to actively grow during the dry season of 2013 (Figure 9).

At more subtropical latitudes at Mondi (25°S) and Merensky (30°S), *P. maximinoi* exhibited a well-defined shoot resting stage with the onset of the dry season in May, as did the control species *P. patula* and *P. taeda* (Figure 10). Shoot elongation for *P. maximinoi* resumed in the middle of the dry season (July) as did strobili production.

At Cape Pine (34°S), which is located predominantly in a winter rainfall climate, monthly circumference growth increment of *P. maximinoi* and *P. radiata* mirrored each other except in periods of drought. During periods of low rainfall, the circumference increment of *P. maximinoi* was greater than that of *P. radiata.*

Our preliminary results indicate that *P. maximinoi* does have a shoot resting stage in some environments but not in others (at least in some years). Assessing patterns of rainfall is important to quantify growth rhythms in *P. maximinoi*, but high soil moisture holding capacity serves as a surrogate for precipitation during the "dry season" in some environments, similar to a trickle irrigation system. Early and heavy flowering of *P. maximinoi* in northern Mozambique might be the result of a nearly perfect match of latitude and altitude with Central America, but also might be because trees have year-round access to moisture in the heavy clay soils.

More detailed studies conducted over several years are needed to better understand what triggers flowering in the tropical pines when planted in exotic environments. Refinements of the dendrometer band study include a larger sample size (banding more trees), stronger bands that can accommodate a larger circumference range, more precise measurements of shoot elongation and more rigorous observation of flowering patterns. At present, we know that in *P. maximinoi* there is a 12 to 14-month time period between pollination and cone production in many countries, which is about 8 months shorter than for most other commercial pine species. What we do not know is when flower bud initiation occurs in *P. maximinoi* and how this varies across latitudes. Understanding this would give us more precise information on the length of the species' reproductive cycle and allow us to better time fertilizer applications in seed orchards to maximize strobili production.

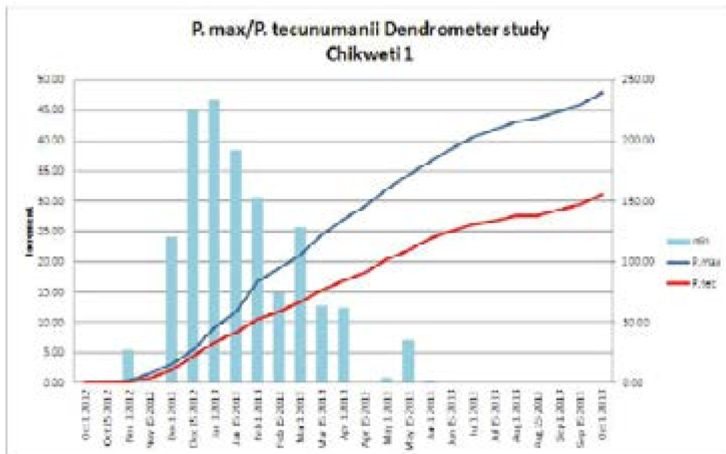


Figure 8. Cumulative circumference increment of *P. maximinoi* and *P. tecunumanii* in northern Mozambique from Oct. 1, 2012 to Oct. 1, 2013. Blue bars show bi-monthly rainfall amounts for the study period.

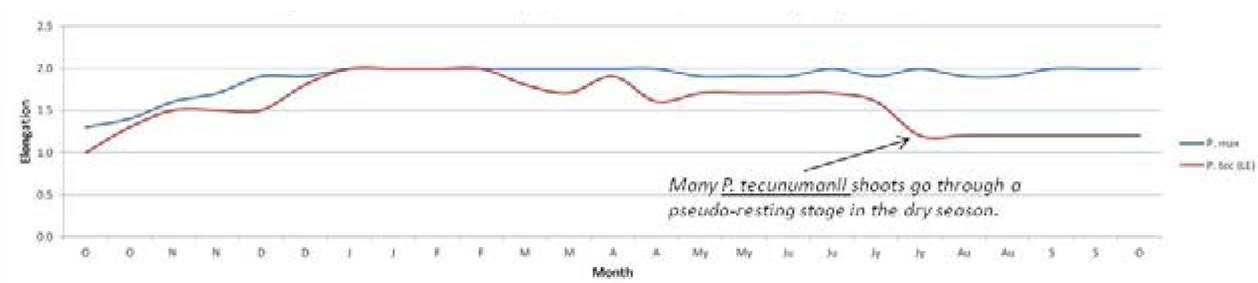


Figure 9. Stages of shoot elongation of *P. maximinoi* and *P. tecunumanii* in northern Mozambique from October 2012 to October 2013. Elongation scores are 0=resting, 1=mix, 2=actively growing

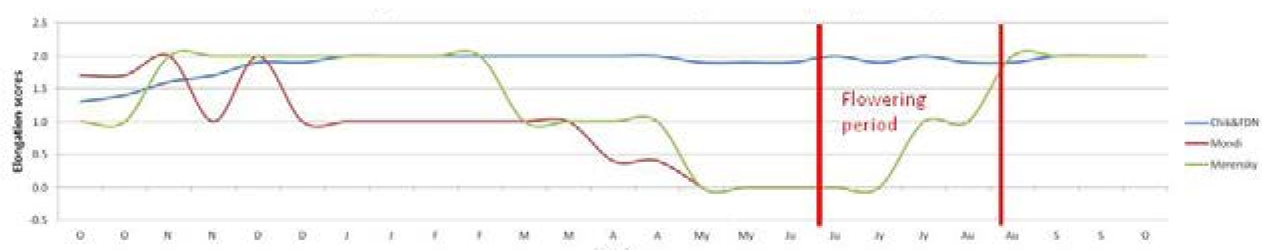


Figure 10. Stages of shoot elongation of *P. maximinoi* in northern Mozambique (Chikweti and FDN), the eastern Cape province (Merensky Forestry) and Mpumalanga province (Mondi) from October 2012 to October 2013. Elongation scores are 0=resting, 1=mix, 2=actively growing.

Evaluating *Thaumastocoris* Impacts on *Eucalyptus* Plantations in Uruguay

In the 2012 Annual Report, Camcore introduced a pilot study we are conducting with Weyerhaeuser to evaluate the impacts of *Thaumastocoris peregrinus* on eucalypt plantations in Uruguay. *Thaumastocoris peregrinus* 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 it has been noted to cause severe defoliation in plantations of *E. camaldulensis* and *E. grandis x camaldulensis* in South Africa. The insect was first reported in Uruguay in 2008 where it has caused significant dieback of *E. camaldulensis* and other species planted on cattle farms and along roadsides, but severe defoliation and decline has not been widely noted in plantations. The lack of readily apparent impacts in plantations may result from the fact that *T. peregrinus* population density and feeding vary greatly in space and time and even highly susceptible species can remain non-symptomatic in some regions. Thus, thorough evaluations of the potential impacts of this insect on specific species or genotypes in specific regions are necessary to determine if, when, and where investment in pest management is needed. The purpose of this study is to determine if stem injections of the insecticide imidacloprid can be utilized as a reliable technique for evaluating the potential economic impacts of this pest through insect exclusion.

The study is focused on three eucalypt taxa: *E. benthamii, E. grandis,* and an *E. grandis x camaldulensis* clone. The field design consists of two field trials per taxon. For each species, one trial is established on a high-quality site and a second on a low-quality site. Each trial is sub-divided into four 25-tree treatment plots; two exclusion plots where *T. peregrinus* populations were removed using stem injections of imidacloprid and two untreated control plots where insect populations were left intact. To compare productivity between imidacloprid treated and control plots, tree heights (m) and dbh (cm) were measured once pre-treatment and are being measured every three months post-treatment for two years. Yellow sticky traps were placed at 6 and 10 m on a tree at the center of each plot and are checked monthly to monitor the activity levels of *T. peregrinus.* Pre-treatment measurements were made in August 2012 and initial insecticide injections were done in October 2012.

This study is ongoing and a final report is anticipated for the 2014 Camcore Annual Report. At this point, only preliminary data are available and firm conclusions cannot be drawn, but analysis of the data through the June 2013 collection period is encouraging. The following trends are apparent at this point:

1. *Thaumastocoris peregrinus* densities are much higher in the *E. benthamii* plots compared to *E. grandis* or the *E. grandis x camaldulensis* clone (Figure 11).
2. For all three taxa, there is a trend for higher insect density in control plots compared to imidacloprid treated plots, a difference that is statistically significant for *E. benthamii* (Figure 4). This indicates that the insecticide treatments are excluding some but not all *T. peregrinus* from the treated plots, and, perhaps, additional insecticide treatments may be necessary.
3. Height and diameter growth of *E. benthamii* has increased significantly in the imidacloprid treated plots with lower *T. peregrinus* densities compared to the untreated control plots with higher densities of the pest (Figure 12).
4. The growth trends are the opposite for *E. grandis* and the *E. grandis x camaldulensis* clone with lower height and diameter growth in the treated compared to untreated plots, although these difference are not significant (Figure 5). This suggests that stem injections of insecticide may actually cause more damage to trees than insect feeding in areas where *T. peregrinus* densities are low. The cost/benefit of using stem injection for pest evaluation should be weighed carefully.

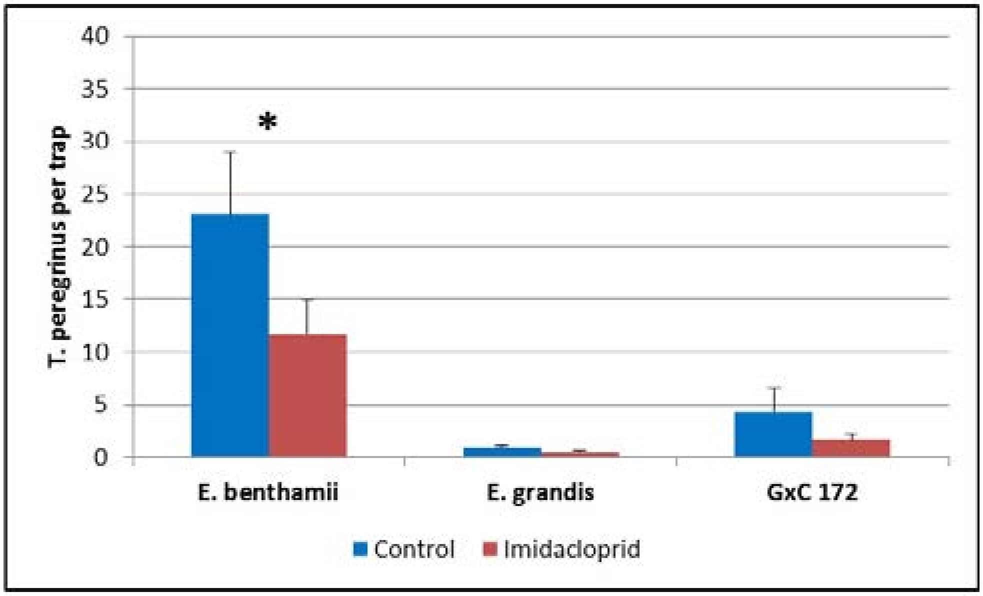


Figure 11. Mean *T. peregrinus* abundance in yellow sticky traps during the summer (December 2012 to March 2013) trapping period. Bars with * are significantly different at α = 0.05.

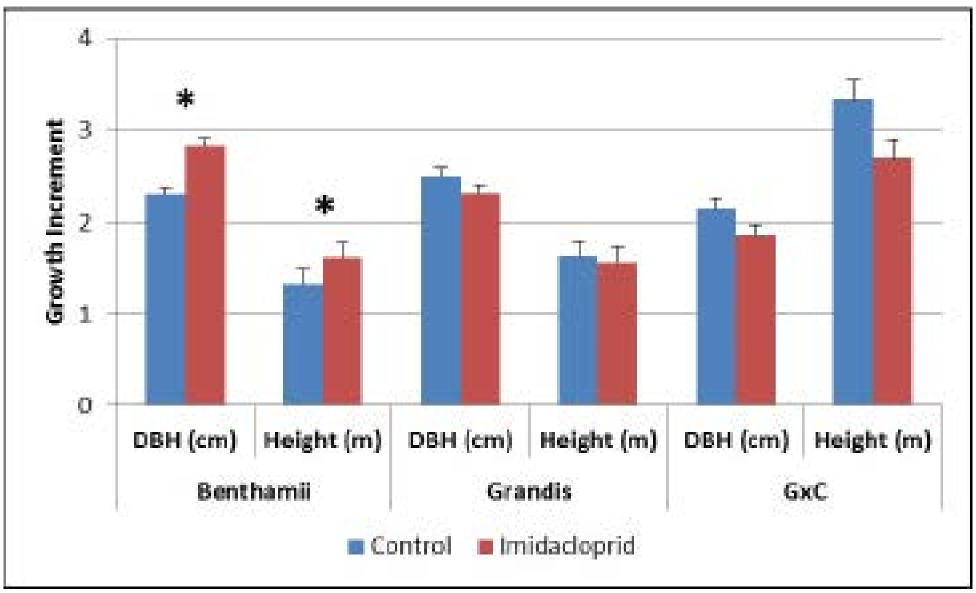


Figure 12. Growth increments of *E. benthamii, E. grandis,* and the *E. grandis x camaldulensis* clone in treated and untreated plots. Bars with * are significantly different at α = 0.05.

Lab Protocols for Eucalypt Frost Tolerance Screening

There is increasing interest in developing cold-tolerant eucalypts for plantation forestry in southern Latin America, South Africa, and even in the southern United States. This raises the need to select and screen for frost tolerance among and within eucalypt species. Generally, this is done simply by observing the damage and mortality that occurs in the field under natural conditions. The problem with this approach is that it depends on receiving an appropriate frost event, one which is of the right intensity and duration to discriminate among the genotypes of interest. These "ideal" frost events will probably occur sporadically, at best. It would be of great benefit to breeding programs if there were laboratory freezing protocols that could identify frost-tolerant genotypes. Camcore has some experience with laboratory freeze screening of pines, and has had good results discriminating among species, provenances and families (see 2009 and 2011 Annual Reports). In 2013, we conducted a preliminary study on laboratory freeze screening of eucalypts.

Materials and Methods

A total of 10 seedlots were sown in the NC State Phytotron, including 6 *E. dunnii* families contributed by Sappi Forests (South Africa). Three of the six *E. dunnii* families were putatively frost tolerant and three were frost susceptible based on results from a field studies. In addition, four species bulks were included in the study: tropical, frost-susceptible *E. grandis* and *E. urophylla*, and temperate, frost tolerant *E. benthamii* and *E. badejensis*. Briefly, the experimental approach was to grow seedlings in the phytotron (under controlled conditions), then to excise leaf tissue and freeze the leaves in a laboratory freezer, and to determine damage with electrical conductivity.

For each seedlot, 24 seedlings were grown and divided into three replications. The seedlings were grown in environmentally-controlled chambers under conditions similar to summer and autumn conditions that might occur in southern Brazil or subtropical South Africa (e.g., Sabie). Specifically, there were three phases:

1. Phase 1: 90 days with a 14-hour daylength, and day/night temperatures of 24° / 14°C.
2. Phase 2: 21 days, with a 12-hour daylength, and day/night temperatures of 16° / 10°C.
3. Phase 3: 21 days, with a 10-hour daylength, and day/night temperatures of 10° / 4°C.

There were three freezing treatments to target temperatures of -5, -9, and -13°C. Leaves of each seedling were excised and placed into tubes, with two treatment and two control tubes per replication. Care was taken to ensure that all tubes inluded leaves sampled from similar positions on the stem. The open tubes were then placed into the laboratory freezer and chilled for 8 hours using the following regime: two hours cooling from 0°C to the target temperature, six hours at the target temperature, and two hours warming from the target to 0°C. Following the freezing treatment, the tubes rested in a cold room at 4°C for three hours. The tubes were then filled with water to allow electrolytes from the freeze-damaged tissue to leak into solution. After 16 hours, the electrical conductivity of the solutions was assessed. The tubes were then heated to a temperature of 85°C in an oven to completely kill the tissue and release all electrolytes into solution. Electrical conductivity was then measured again, and a relative conductivity and injury index were determined.

An additional experiment was done using whole trees, i.e., live, intact seedlings. These seedlings were not grown in the phytotron, rather they were grown in a normal greenhouse. At the time the freezing experiment was initiated, the seedlings were 25 to 30 cm tall, and daytime temperatures in the greenhouse were around 27°C. The seedlings were given only a very brief "acclimation" treatment, consisting of three 14-hours nights at 4°C. Seedling roots were insulated to concentrate damage on the stem and limit damage to the root systems, and the whole seedlings frozen to a target temperature of -3°C using the same 2 hour chill, 6 hours at target, 2 hours warm protocol as described above. One week after the freezing treatment, damage was scored using a five-point scale: 4 = top 5% of the crown damaged, 3 = top 25% of the crown damaged, 2 = top 50% of the crown damaged, 1 = top 75% of the crown damaged, 0 = entire seedling damaged.

Results and Discussion

Excised Foliage - Electrolyte Leakage

For the -5°C treatment, there were no statistical differences among the *E. dunnii* families, however the -9°C and -13°C treatments showed good separation. Very similar results were obtained with the -9° and -13°C treatments, so a combined injury index was calculated. All three injury indices gave similar results. There were two distinct groups among the *E. dunnii* families, with three families that were "frost susceptible" and three that were "frost tolerant" at least under the lab conditions. These families were independently identified in the lab without prior information about specific families. Subsequently, Sappi Research confirmed that the lab and the field rankings showed very good agreement (Table 8, Figure 13). The frost-tolerant families identified in the lab ranked 5th, 6th and 10th out of 108 families in the field test, while the frost-susceptible families identified in the lab ranked 99th, 100th, and 108th out of 108 families. In the lab, the mean Injury Index of the tolerant families was Injury = 0.53, while the susceptible families had a mean Injury = 0.65. Overall, these results were very encouraging.

Less encouraging were the results with the species-bulk seedlots. Rankings of the electrolyte leakage injury index for species were not at all correlated with field frost tolerance. Frost-susceptible *E. urophylla* and frost-tolerant *E. badjensis* had very similar injury indices, the lowest in the experiment. Next was frost-tolerant *E. benthamii,* followed by frost-susceptible *E. grandis*. The species which was expected to have intermediate frost tolerance, *E. dunnii*, had the highest levels of injury. We do not have a good explanation for this result, but one possibility is that differences in leaf morphology could impact electrolyte leakage.

Table 8. Results of laboratory screening of six families of *E. dunnii* for frost tolerance using electrolyte leakage.

Fam	Injury Index			Field Frost	Field Rank
	-9° C	-13° C	-9,-13° C		
D5	0.49	0.43	0.46	1.6	5
D4	0.56	0.55	0.56	1.6	6
D1	0.59	0.55	0.57	1.7	10
D3	0.65	0.62	0.63	2.7	99
D6	0.59	0.68	0.63	2.5	100
D2	0.67	0.72	0.69	2.5	108

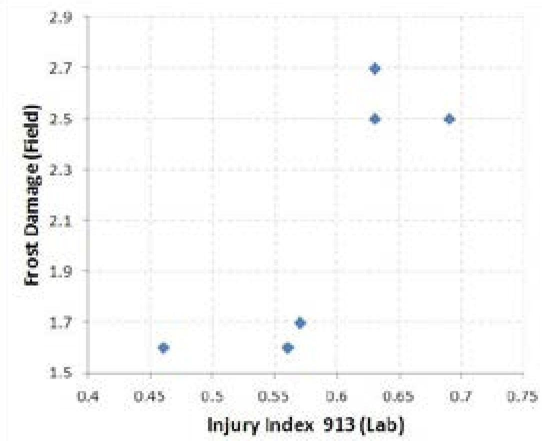


Figure 13. Relationship between lab frost tolerance and field frost damage of six *E. dunnii* families.

Whole Tree Freezing

Whole tree freezing gave very good results at the species level. Frost-tolerant species *E. badjensis* and *E. benthamii* showed the least damage, with damage scores of 3.3 and 2.7, respectively. Frost-susceptible species *E. urophylla* and *E. grandis* showed the most damage, with scores of 0.3 and 0.0, respectively. And the intermediate species, *E. dunnii*, had an intermediate mean damage score of 1.6. In addition, the frost-susceptible and frost-tolerant *E. dunnii* families were correctly identified with the whole tree freezing.

Conclusions and Implications

It appears that both the electrolyte leakage technique and the whole-tree freezing technique could be used to identify the most frost-tolerant and least frost-tolerant genotypes within a species. In the lab, mean injury index of these two groups was distinct, but the magnitude of the difference (Injury = 0.53 vs 0.65) suggested that it might be difficult to accurately rank genotypes of intermediate frost tolerance. Whole-tree freezing gave good results at the species level and the within-species level, but the disadvantage of this technique is that many fewer trees can be screened at a time. In a single experiment, the electrolyte leakage technique could screen many more genotypes and/or use more replications and should produce more precise rankings. The next step is to decide whether to try to refine these techniques, or to use them to evaluate genetic variation in frost tolerance within a species like *E. dunnii*, or within a hybrid of a frost-tolerant and frost-susceptible species, for example, *E. grandis x E. benthamii.*

Discriminating Logs of *E. globulus* and *E. nitens* Using the microPHAZIR Handheld NIR

In the 2012 Annual Report, Camcore reported on the first phase of a project with Forestal Mininco (Chile) to use NIR spectroscopy to distinguish among wood samples of *E. globulus, E. nitens,* and the *E. globulus x E. nitens* hybrid. The objective was to determine if NIR could be used as a diagnostic tool to distinguish the higher quality/ higher value wood of *E. globulus* from that of lower quality, lower value *E. nitens.* This first phase utilized wood samples collected from each species that were dried, ground, and scanned on the laboratory FOSS NIRSystems™ 6500 NIR scanner. The results indicated that NIR could distinguish wood samples of the two pure species and the hybrid with 100% accuracy. Here we report on the second phase of the project, using the handheld microPHAZIR™ NIR scanner to distinguish between whole logs of *E. globulus* and *E. nitens* on trucks arriving at the mill gate.

NIR scanning data for the second phase was collected during Camcore's March 2013 technical visit to Forestal Mininco. The original plan was to collect data from logs of *E. globulus* and *E. nitens* on trucks arriving at the mill, but due to safety concerns this was not possible. Therefore, the scan data for this study was collected from logs that had been stacked in the field and at the nursery for more than six months. In total, 72 logs (36 per species) were scanned four times each (two scans on each cut end of the log) with the handheld NIR. The raw data was transformed using Multiplicative Scatter Correction (MSC) and Second Derivative methods in Polychromix MG software, log means calculated, and analyzed with multivariate discriminant analysis is SAS.

The calibration data set was built using 48 samples, 24 samples per species, and the validation data set consisted of 24 samples, 12 per species. The discrimination model was able to correctly classify logs of *E. globulus* and *E. nitens* with 94% and 90% accuracy, respectively. This result is encouraging and indicates that the handheld NIR might be an effective diagnostic method for distinguishing between logs of these two eucalypt species. However, the sample sizes utilized here are small and the logs were not fresh when scanned. Therefore, before we can be certain of the utility of the handheld NIR for this application, additional evaluations with larger numbers of fresh logs as they arrive at the mill are necessary.

Types of logs sampled for the *E. globulus - E. nitens* NIR study:
Left: log stacks in the field; Right: log stack at the nursery.

Discrimination of Teak Provenances with NIR

In our teak program in Camcore, we have tried to form a very broad genetic base by acquiring seeds from many provenances and sources in Asia, Africa and Latin America. In 2013, we conducted a small research study to see if it would possible to distinguish among eight different sources of teak seedlings using the handheld microPHAZIR NIR. The idea was to examine if this could be a quick and practical tool to differentiate teak seedlings from different provenances or sources in operational nurseries.

Seeds of eight teak sources (Table 9) were sown in greenhouses at NC State University with a target of 20 seedlings per source. At three months of age, the upper surface of the top 4 leaves larger than 15 cm in length were scanned with the hand held microPHAZIR™ NIR. The scanned leaves were then collected, oven dried at 45° C for 48 hours, and ground into a powder. The dried leaf meal was scanned with a desktop NIR machine, a FOSS NIRSystems™ 6500. Canonical analyses to discriminate sources were done using spectral data both from the handheld and the desktop NIR.

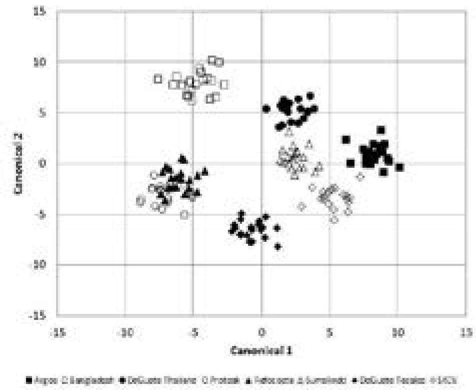


Figure 14. Canonical analysis of teak provenances using handheld NIR scans of fresh foliage.

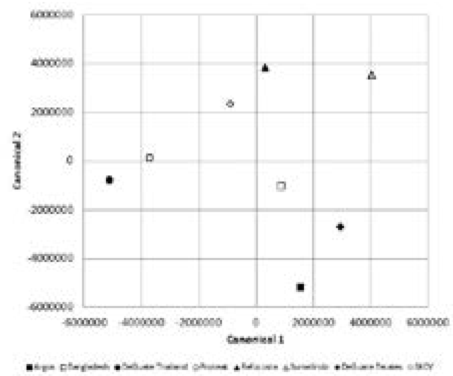


Figure 15. Canonical analysis of teak provenances using desktop NIR scans of dried ground foliage

Results

Canonical discriminant analyses indicate that NIR scans from both machines can be used to distinguish teak sources (Figures 14, 15). As expected, the scans of ground leaf meal using the FOSS 6500 desktop machine provide a more clear separation of sources, with the 20 different samples from a given source tending to lie almost exactly on top of one another in the canonical analysis (Figure 15). While the handheld NIR generally gave good results, in some cases there was overlap of sources. For example, as shown in Figure 14, the Refocosta and Proteak sources overlap significantly. Nevertheless, the average percentage of seedlings classified correctly by source with the handheld NIR was 80%, with a minimum of 73% and a maximum of 88%. The desktop machine gave even better results. Across all sources, the mean percentage of seedlings classified correctly was 90%, with a minimum of 81% and a maximum of 95%. Overall, this is another piece of evidence supporting the utility of NIR technology for taxon identification and quality control in breeding progams.

Table 9. Different sources of teak seedlings sampled for canonical analysis using NIR.

Country	Seed provider	Source	Possible origin	Seedlings
Bangladesh	University of Chittagong	Seed orchard	Myanmar	20
Indonesia	Sumalindo	Plantations	Indonesia (naturalized)	20
Colombia	Argos (Tekia)	Plantations	Unknown	20
Colombia	Refocosta	Seed stand	Unknown	20
Costa Rica	Grupo DeGuate	Plantations	Thailand	20
Guatemala	Grupo DeGuate	Plantations	Unknown	20
Mexico	Proteak	Provenance trials	India	20
Venezuela	Smurfit Kappa	Plantations	Unknown	20

NIR Model Transfer

Over the past ten years, Camcore has done a tremendous amount of work with NIR models, looking for opportunities to use this technology to improve efficiencies in tree breeding programs. Most of our work has been in the development of NIR models for cheap and rapid indirect selection for wood properties. We have a global NIR models 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. Both of these models were developed for multiple temperate and tropical pine species across an array of geographic regions and sites. Recently, we have developed models to predict pulp yield, lignin and sugar content and composition for *E. urophylla*, and in 2014 will be expanding those models to include *E. dunnii*. In addition, we have begun to use NIR for classification models, for example, to classify foliage samples as either pure species or hybrid, or to distinguish among a small subset of clones. All of these applications have immediate practical use in tree improvement and or nursery operations.

Once an NIR model is developed, application of the model in the real world is fast and easy. The challenge is developing the model. This requires processing many samples, preferably numbering in the hundreds, in order to end up with robust models that can be "extrapolated" with confidence to all future samples coming from a broad array of sampling environments or conditions. Often the sample processing includes associated costs of money or time to do wet chemistry work (as in the case of most wood property traits). 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. NIR model transfer, however, is not as easy it sounds.

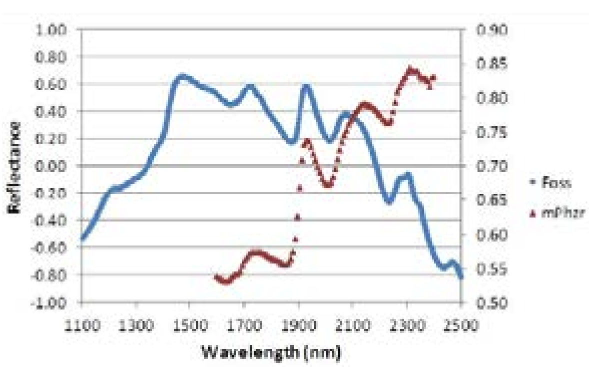


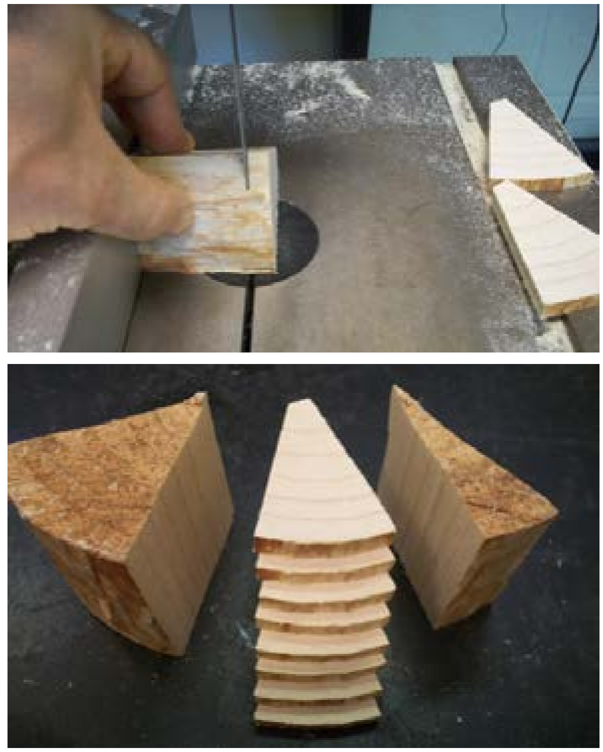
Figure 16. Comparison of NIR reflectance spectra from a FOSS NIR Systems™ 6500 desktop machine and the microPHAZIR™ handheld NIR. Note different wavelengths, different reflectance scales, and different patterns from the two machines. Sample was eucalypt foliage meal.

Camcore does NIR model development using a specific machine following specific protocols in our lab. Other organizations have different protocols, but more importantly, different NIR machines. Briefly, NIR machines all generate near-infrared light at specific wavelengths (typically hundreds of wavelengths across the region of 1100 to 2500 nm), beam the light onto a sample, and measure the amount light that is reflected by (or transmitted through) the sample. An NIR model uses partial least squares, similar to a multiple linear regression, to use the reflectance values to calculate the independent trait of interest. The problem with transferring NIR models from one machine to another is that different machines will measure different wavelengths, and even if measuring the same wavelengths, will generate different intensities of light, producing different reflectance values (e.g., see Figure 16). In addition to these concerns, different sample processing protocols and lab conditions can also affect reflectance values.

Model transfer is an active area of research among NIR scientists. Essentially, to do model transfer one must begin by scanning the same wood samples on the "Original" and "Secondary" machines. Then one seeks to find mathematical functions (in other words, the matrix equations) to convert the Original spectra to the Secondary spectra. If we can systematically convert spectra, then the appropriate linear regression weights for the "Secondary NIR model" are easy to derive.

Our first effort in the area of model transfer is focused on the Global Pine models for lignin and cellulose. Currently, there are six Camcore members participating in this project: Klabin (Brazil), Weyerhaeuser (Uruguay), Mondi and Sappi (South

Africa), and CMPC Forestal Mininco and Arauco Bioforest (Chile). Wood samples in the form of thick wedges have been received for 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 then sawn into thin slices in order to try to have "identical" samples to process in the different labs and scanned on different machines. An "identical" set of 200 wedges was sent to each participant for processing and scanning on their "Secondary" machine. Spectra from all machines will be sent to Camcore for spectral comparison, data analysis, and model building. Some participants have the same NIR machine as in the Camcore lab (i.e, a FOSS NIRSystems™ 6500), while other participants have lab machines from different manufacturers. We will also compare the spectra and attempt to transfer models to a handheld microPHAZIR™ NIR. At the end of this project, we hope to have a good understanding of how to transfer models from one machine to another, and the numbers of spectral samples needed to be able to complete a satisfactory transfer.



Preparation of wood wedges, and a typical set of "identical" wood wedges being used in the NIR Model Transfer project.

Somatic Embryogenesis of *Pinus maximinoi*

Background

Camcore members are still interested in the potential of using Somatic Embyrogenesis (SE) as a technology to permit clonal forestry of some of our subtropical pines, such as *P. maximinoi*. In 2007, we had some encouraging results from work done by Yil Sung Park (Natural Resources Canada) using immature embyros (i.e., green cones) for SE initiation. In 2009, we had more encouraging results on SE initiation from work done by Jerry Pullman (Institute of Paper Science and Technology) using mature embyros (i.e., from harvested seed).

Based on these results, Camcore began another SE project in 2012. The specific objectives were to: 1) confirm prior initiation success with the same or different seed lots of *P. maximinoi*, and 2) attempt to take somatic embryos through several rounds of an embryo development protocol, cryopreservation, retrieval, and germination.

Results

In this experiment, we again had good success initiating somatic embyros, with an average of 27% initiation across five different families. However, most of the 201 lines failed on the maintainance media, and only 11 cultures were taken into cryopreservation. None of the tissue retrieved from cryo survived. These were disappointing results, and it seems likely that the culture maintenance medium is probably at fault. To overcome this, it will be necessary to research optimum medium formulations for *P. maximinoi*. In addition, it would probably be wise to return to the use of immature embyros for further study.

Camcore members know that the development of this technology for subtropical pines will likely be a long process. But the payoff would be substantial, so we will continue to look for ways to collaborate on this topic and do cost-effective research.

Reproductive Barriers in *Pinus radiata*

Hannél Ham, lecturer in the Department of Forestry and Wood Sciences, Stellenbosch University, South Africa is working on a Ph.D. project, partially funded by Camcore members, to understand what causes reproductive barriers in P. radiata and how to overcome them. Below is an update of Hannél's progress on her work.

It has always been difficult to make successful inter-specific hybrid crosses between *Pinus radiata* and pine species in the Mexican closed pines (Oocarpae) subsection and the US southern pines (Australes). However, it is not clear exactly what are the barriers to hybridisation, whether they are pre-or post-fertilisation, and whether this varies depending on pollen species. This research seeks to provide some knowledge in this area.

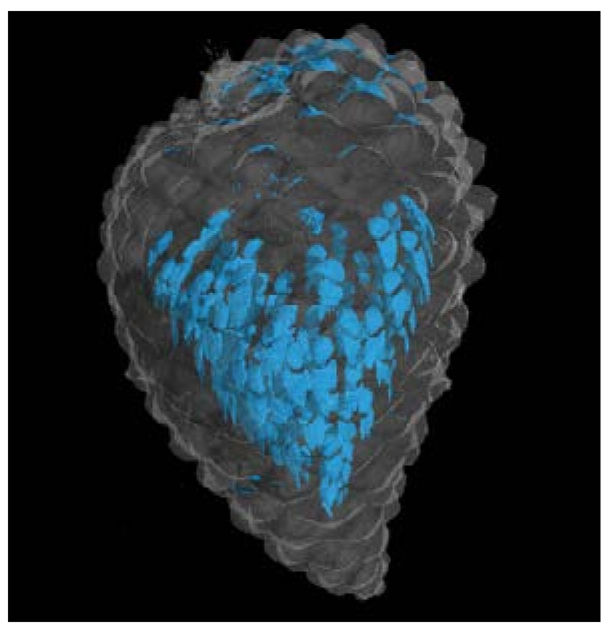
The seed from two interspecific hybrid crosses (*P. radiata x P. tecunumanii* LE and *P. radiata x P. oocarpa)* that were made in 2011 were harvested, photographed, measured, weighed and counted. Seedlings will be verified for hybridisation success and tested after one year for *Fusarium circinatum* susceptibility.

Climatic data (temperature and relative humidity) taken during the making of interspecific hybrid crosses (*P. radiata x P. tecunumanii* LE, *P. radiata x P. oocarpa,* and *P. radiata x P. maximinoi*) in 2011 to 2013 were analysed. These data were used to compile temperature ranges for the pollen tube growth rate studies. Pollen tube growth rate and pollen germination studies were done at 4, 10, 15, 20, 24, 28, 32, 36, 40 and 42°C. Data are currently being analysed, but temperature seems to have a large effect on pollen tube growth and development. The next phase will be to simulate a 24-hour cycle based on the three-year climate field data.

Computer Tomography (CT scanning) was tested as an alternative to wax embedding of female flowers used to determine pollination and fertilisation success. CT scanning produced three-dimensional "life-like" images of female cones. The aim was to look through layers of images to find a possible problem or solution as different tissues have different contrasts. However, CT scanning cannot be used as an alternative to wax embedding in this study as younger material tends to be more herbaceous (low contrast), but seed formation was clearly visible in mature cones (see image below).

Three interspecific hybrids *(P. radiata x P. oocarpa, P. radiata x P. maximinoi* and *P. radiata x P. tecunumanii* LE), and one intraspecific hybrid *(P. radiata x P. radiata)* controlled crosses were made in 2013. Flower cones were harvested at weekly intervals from one to seven weeks after pollination to monitor pollination success. Intraspecific hybrid flower cones were harvested from week 20 to 68 to determine fertilisation success. Female cones were embedded into wax for further analysis.

This project will be concluded during 2014 and final results will be available soon afterwards. Hannél thanks all the partners involved for their valuable support and contribution to the success of this project.



A Computer Tomography (CT) scan of a *P. radiata* cone showing developed seeds and seed wings (blue color) (photo courtesy Hannél Ham).

IUFRO 2013 - Breeding and Genetic Resources of the Southern US & Mexican Pines

Camcore and NC State University were the lead organizers and sponsors of an IUFRO meeting for Working Group 2.02.20 “Breeding and Genetic Resources of the Southern US and Mexican Pines (including *Pinus radiata*) held in Jacksonville, Florida, February 4-7, 2013. A total of 90 participants from 14 countries attended the conference (Australia, Brazil, Canada, Chile, Colombia, France, Germany, Kenya, Liberia, New Zealand, South Africa, Thailand, Venezuela, and the United States).

The keynote speaker for the conference was Dr. Tim White, Director of the School of Forest Resources and Conservation, University of Florida. Invited speakers included Luis Apiolaza (New Zealand), Claudio Balocchi (Chile), Washington Gapare (Australia), Arnulf Kanzler (South Africa), and John Davis, Danilo Fernando, Fikret Isik, Steve McNulty, Dana Nelson, Jerry Pullman and Laurie Schimleck from the USA.

Bill Dvorak was Deputy of the IUFRO Working Group and Gary Hodge was Chair of the Technical Planning Committee for the conference. Greg Powell and Gary Peter of the University of Florida, and Ben Cazell, Early McCall, and Josh Sherrill of Rayonier organized an interesting field day where we saw different aspects of *P. elliottii* breeding, testing, orchard management, and genetics research, and enjoyed some good barbecue.

There were two awards given for Outstanding Presentation by a student. First prize was awarded to Jared Westbrook of the University of Florida for his talk *"Integrating association and expression analyses to discover genes regulating oleoresin production in loblolly pine"*, and second place to Christoph Leibing of the University of Hamburg for his talk *"Selection of provenances to adapt tropical pine forestry to climate change on the basis of climate analogues"*.

Many thanks to all of the sponsors of the confernce, which included Camcore, the NC State University Tree Improvement Program, and a number of Camcore member organizations: Arauco, (Chile) and the USDA Forest Service (sponsors), Klabin (Brazil) (patron), and ArborGen (USA), CMPC (Chile), Masisa (Mexico), Terranova (Venezuela), Smurfit Kappa Cartón de Colombia, Sappi (South Africa), and Weyerhaeuser (contributors). Thanks also to Susan Moore and Kelley McCarter of the NC State Forestry and Environmental Outreach Program (FEOP) for all their work in organizing the logistical details of the conference.

Early McCall of Rayonier talks about *P. elliottii* seed orchard management during the IUFRO 2013 Field Day.

Graduate Programs and Training

Lia Campbell is an M.S. student with Camcore working on a USDA Forest Service funded project with Carolina hemlock under the direction of Robert Jetton. Her thesis project is to describe patterns of genetic structure and diversity among 30 natural populations of Carolina hemlock.

Zaidee Powers completed her M.S. thesis project with Camcore under the direction of Robert Jetton entitled, “Evaluating Techniques for Artificially Infesting Hemlocks (*Tsuga* spp.) with the Hemlock Woolly Adelgid *(Adelges tsugae)* for Genotype Resistance Screening.”

Oscar Nilsson completed his M.S. degree at NC State University. His thesis was titled “Growth and Modulus of Elasticity of some Pine Species and Hybrids Three Years after Planting in South Africa”. Oscar’s studies at NC State were funded by the Atlantis program, part of the EU-US Transatlantic Masters degree in Forest Resources at North Carolina State University, in 2012.

Andy Whittier (Camcore) made good progress on his M.S. degree and his thesis project entitled “Genetic/nutrient interactions and deficiency symptoms in teak raised in growth chambers”. In 2013, he refined the protocols for growing teak seedlings hydroponically in the NC State University phytotron and the Horticulture greenhouses.

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.

Juan López (Camcore) continues to make progress on his Ph.D. research entitled, “The economic value of pine hybrids”.

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

Grants

Camcore continued its successful collaboration with the USDA Forest Service in 2013 on conservation and research projects related to tree species native to the United States. In total, we utilized $242,256 of grant funding to conduct population explorations and seed collections for Eastern and Carolina hemlock, Table Mountain Pine, and Atlantic White Cedar and carry out research projects on Carolina hemlock and Table Mountain Pine population genetics and the development of mass artificial infestation strategies for genotype resistance screening in hemlock against the hemlock woolly adelgid.

Milan Lstiburek, Associate Professor of Forest Genetics at the Czech Agricultural University, and in collaboration with Gary Hodge, Camcore, has received a three-year $34,000 grant from the Czech government to work on a project titled "Theoretical Background to the Incorporation and Optimization of Novel “Breeding-Without-Breeding” Schemes into Operational Forest-Tree Breeding Programs".

Changes in Camcore

Andrew Morris left his position as General Manager of Research at Sappi to become the Research Manager of the Institute for Commercial Forestry Research (ICFR), Pietermaritzburg, South Africa. Andrew is one of Camcore's strongest supporters and was Chairman of the Camcore Executive Committee for nine years. During his tenure, Camcore industrial membership increased by 30%. We wish Andrew the best of success in his new assignment at the ICFR.

Ali Ayoub was named the Forest Business Director at MWV Rigesa (Brazil). Ali has worked with the company for a number of years on the mill side and replaces Etsuro Murakami.

Benson Kanyi, the Camcore Advisory Board representative for East Africa, was elected to the Camcore Executive Committee. Congratulations Benson!

Edgar Londoño retired from his position as CEO of Smurfit Kappa The Americas. He had almost 42 years of dedicated service to the Smurfit Kappa Group. He was a very strong supporter of the Camcore program and Chairman of the Camcore Advisory Board from 1993-1997, during which time he was Vice-president of Forestry for Smurfit Colombia. Edgar had a positive, easy-going management style, which was very conducive to successful team building. We wish Edgar the best in his retirement.

Deon Malherbe, Nursery Manager at Cape Pine, left his position early in the year. Deon served as the Camcore Advisory Board Representative for MTO in past years, and was always very supportive of the Camcore efforts.

Jesús Espinoza, Tree Improvement Specialist at Camcore left to join a private consulting company in the southern US. Jesús worked with Camcore for four years and made a big impact in guiding research in the transition areas between tree genetics and silviculture for the members. We wish Jesús much success in his new job.

Irvine Kanyemba left his position as CEO of Florestas de Niassa (Mozambique) and was replaced by **Tonderai Kechale**. Irvine is now in charge of Forestry Operations at Cape Pine (South Africa). We want to wish both Irvine and Tonderai much success in their new positions.

Gabriel Algorta joined Green Resources, Mozambique as their Tree Breeding Manager. Gabriel is originally from Uruguay and brings good tree improvement experience to the company.

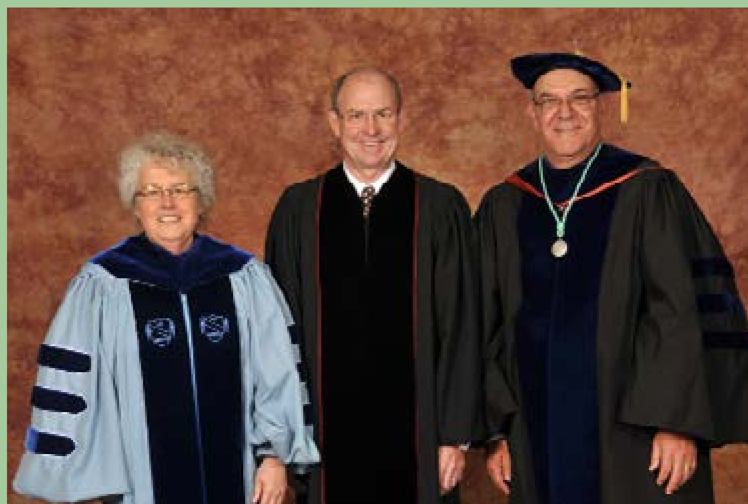
Mario Cesar Gomes Ladeira was named the new Research Coordinator at Klabin (Brazil).

Jeremy Brawner, Research Scientist, CSIRO, was awarded his Ph. D. degree from the School of Agriculture and Food Science, University of Queensland, Australia. The title of Jeremy's thesis was, "Genetic Improvement of *Corymbia citriodora:* Mixed model applications".

André Nel, Principal Research Officer: Pine Breeding, Sappi, was awarded his Ph. D. degree from the Faculty of Natural and Agricultural Sciences, Department of Genetics, University of the Free State, Bloemfontein, South Africa. The title of André's thesis was, "A Quantitative Genetics Study of the Physical Wood Properties of *Pinus patula*".

Mike Wingfield, Director of the Forestry and Agriculture Biotechnology Institute (FABI) at the University of Pretoria, South Africa, received an Honorary Doctor of Science degree at NC State University in a ceremony at the May graduation ceremony in Raleigh, NC (see box). Mike was also named as the next president of the International Union of Forestry Research Organizations (IUFRO). Mike is the first ever African to be elected to this prestigious position, which has a five-year term running from October 2014 to 2019.

Mike Wingfield Awarded Honorary Ph.D. by NC State University



Mary Watzin, Dean, College of Natural Resources (left), Mike Wingfield (center) & Barry Goldfarb, Head of the Department of Forest and Environmental Resources, NC State University.

(photo courtesy of Roger Winstead, NC State University)

Mike Wingfield, a good friend of Camcore and founding Director of the Forestry and Agriculture Biotechnology Institute (FABI) at the University of Pretoria, South Africa, officially received an Honorary Doctor of Science degree from NC State University in May. Mike has always been a strong supporter of Camcore conservation and testing initiatives in the tropics and subtropics as a means of finding genetic material that might grow well and is also tolerant to new disease and insect problems that are constantly being found in plantation forests.

Mike has a long history of outstanding academic and scientific achievements in the area of plant health over the last 30 years. He has served as an advisor to more than 60 doctoral students and an equal number of master's students, many of whom now hold senior positions globally. He has published widely on the topic of tree health in more than 700 research papers, seven books, and in numerous prestigious invited presentations globally. He consults in forest pathology for many Camcore industrial members. Despite his busy schedule, he has attended several of our Camcore annual meetings and field trips, and is always eager and willing to address our questions on tree pathology and entomology. We all want to congratulate Mike for being selected for this distinguished honor; it could not have happened to a more deserving person.

Publications and Papers

Publications

Dvorak, W.S., Nel, A., Espinoza, J.A., 2013. Evidence of low-levels of natural introgression between *Pinus jaliscana* and *P. oocarpa* in an open-pollinated progeny trial using near-infrared spectroscopy. Forest Ecology and Managment. 2013. 295: 20-27.

Jetton, R.M., 2013. Saving hemlocks, one seed at a time. Chinquapin 21: 21-23.

Jetton, R.M., Whittier, W.A., Dvorak, W.S., Rhea, J., 2013. Conserved *Ex Situ* Genetic Resources of Eastern and Carolina Hemlock: Eastern North American Conifers Threatened by the Hemlock Woolly Adelgid. Tree Planters' Notes. 56: 59-71.

Leibing, C., Singer, J., van Zonneveld, M., Jarvis, A., Dvorak, W.S., 2013. Selection of Provenances to Adapt Tropical Pine Forestry to Climate Change on the Basis of Climate Analogs. Forests. 2013. 4: 155-178.

Mitchell, R.G., Wingfield, M.J., Hodge, G.R., Dvorak, W.S., Coutinho, T.A., 2013. The tolerance of *Pinus patula x Pinus tecunumanii*, and other pine hybrids, to *Fusarium circinatum* in greenhouse trials. New Forests. 2013. 44: 443-456.

Powers, Z.L., 2013. Evaluating techniques for artificially infesting hemlocks (*Tsuga* spp.) with the hemlock woolly adelgid *(Adelges tsugae)* for genotype resistance screening. NCSU Master of Science Forestry Thesis.

Papers in Press

Jetton, R.M., Crane, B.S., Whittier, W.A., Dvorak, W.S., 2013. Genetic Resource Conservation of Table Mountain Pine *(Pinus pungens)* in the Southern Appalachian Mountains. Manuscript in Press. Proceedings of IUFRO 2013 Breeding for Value in a Changing World.

Jetton, R.M., Mayfied III, A.E., Powers, Z.L., 2013. Development of a Rain Down Technique to Artificially Infest Hemlocks with the Hemlock Woolly Adelgid (Hemiptera: Adelgidae). Manuscript in Press. Journal of Insect Science.

Jetton, R.M., Robison, D.J., 2013. Effects of Artificial Defoliation on Growth and Biomass Accumulation in Short-Rotation Sweetgum *(Liquidambar styraciflua* L.) in North Carolina, USA. Manuscript in Press. Journal of Insect Science.

Oten, K.L.F., Merkle, S.A., Jetton, R.M., Smith, B.C., Talley, M.E., Hain, F.P. 2013. Understanding and developing resistance in hemlocks to the hemlock woolly adelgid. Manuscript In press. Southeastern Naturalist.

Papers Submitted

Brawner, J.T., Hodge, G.R., Dvorak, W.S., Meder, R. Visualising the environmental responses of forest tree populations. (Submitted to Tree Genetics & Genomes)

Koskela, J, Vinceti, B, Dvorak, W.S., Bush, D, Dawson, I.K., Loo, J, Kjaer, E.D., Navarro, C, Padolina, C, Bordács, S, Jamnadass, R, Graudal, L, Ramamonjisoa, L. 2013. Utilization and transfer of forest genetic resources: a global review. (Submitted to Forest Ecology and Management)

Posters

López, J.L. International Efforts for Tree Breeding Research of Teak. Poster presented at the World Teak Conference. 2013. Bangkok, Thailand. March 25-30, 2013.

Mayfield III, A.E., Jetton, R.M. 2013. A Shady Situation: Evaluating the effect of shade on hemlock woolly adelgid densities on potted hemlock seedlings. Poster presented at the Southern Forest Inesct Work Conference. New Orleans, LA. June 23-26, 2013.

Potter, K.M., Jetton, R.M., Dvorak, W.S., Hipkins, V.D., Rhea, J.R., Whittier, W.A.. 2013. Rangewide assessment of genetic variation and structure in eastern hemlock, an imperiled conifer, using microsatellites. Poster presented at the Alliance for Saving Threatened Forests Symposium, October 29-30, Asheville, NC.

Presentations

Brawner, J., Hodge, G.R., Meder, R., Dvorak, W.S., 2013. Visualizing pine populations' response across climatic gradients. In: Breeding for Value in a Changing World. IUFRO. Jacksonville, FL., USA. February, 4-7, 2013.

Dvorak, W.S., 2013. What have we learned about the Mexican and Central American pines in the last 30 years? In: Breeding for Value in a Changing World. IUFRO. Jacksonville, FL., USA. February, 4-7, 2013.

Dvorak, W.S., Nel, A., Espinoza, J.A., Hodge, G.R., 2013. Using botanical analysis and near infrared spectroscopy to confirm natural introgression between *P. jaliscana* and *P. oocarpa* in a progeny trial in South Africa. In: Breeding for Value in a Changing World. IUFRO. Jacksonville, FL, USA. February, 4-7, 2013.

Espinoza, J. A., Hodge, G.R., Dvorak, W.S., 2013. The potential use of near-infrared spectroscopy of foliage samples to distinguish among pine species and verify hybridity. In: Breeding for Value in a Changing World. IUFRO. Jacksonville, FL, USA. February, 4-7, 2013.

Ham, H., Dvorak, W.S., Kanzler, A., 2013. Pinus radiata hybridization: The quest for success. In: Breeding for Value in a Changing World. IUFRO. Jacksonville, FL, USA. February, 4-7, 2013.

Hodge, G.R., Dvorak, W.S., Woodbridge, W.C., 2013. Genotype x environment interaction of P. taeda planted as an exotic in the southern hemisphere. In: Breeding for Value in a Changing World. IUFRO. Jacksonville, FL, USA. February, 4-7, 2013.

Hodge, G.R., Woodbridge, W.C., Dvorak, W.S., 2013. Wood properties of tropical and subtropical pine species planted as exotics in the southern hemisphere. In: Breeding for Value in a Changing World. IUFRO. Jacksonville, FL, USA. February, 4-7, 2013.

Isaza, N., Espinoza, J.A., Dvorak, W.S., Hodge, G.R., 2013. Circumventing graft incompatibility in *Pinus maximinoi* by air-layering and needle fascicle propagation. In: Breeding for Value in a Changing World. IUFRO. Jacksonville, FL, USA. February, 4-7, 2013.

Jetton, R.M., 2013. Population genetics and climate adaptability in eastern hemlock (*Tsuga canadensis*): implications for gene conservation. Presentation to the Department of Biological Science, University of Tulsa, March 1, 2013, Tulsa, OK.

Jetton, R.M., Crane, B.S., Dvorak, W.S., Whittier, W.A., 2013. Genetic resources conservation of Table Mountain Pine *(Pinus pungens)* in the southern Appalachian mountains. In: Breeding for Value in a Changing World. IUFRO. Jacksonville, FL, USA. February, 4-7, 2013.

Jetton, R.M., Mayfield III, A.E., Salom, S.M., 2013. Integrating insecticides, biological control, host resistance, genetic resource conservation, and silviculture to combat the hemlock woolly adelgid. 61st Annual Meeting of the Entomological Society of America, November 10-13, Austin, TX.

López, J.L., Hodge, G.R., Dvorak, W.S., 2013. Production and testing of a large assortment of pine hybrids in the southern hemisphere. In: Breeding for Value in a Changing World. IUFRO. Jacksonville, FL, USA. February, 4-7, 2013.

Mayfield, A.E., Jetton, R.M., Reyonlds, B.F., 2013. Exploring tools for use in hemlock restoration. Alliance for Saving Threatened Forests Symposium, October 29-30, Asheville, NC

Powers, Z.L., Jetton, R.M., Mayfield III, A.E., Hain, F.P., Frampton, J., 2013. Evaluating techniques for artificially infesting hemlocks (*Tsuga* spp.) with the hemlock woolly adelgid *(Adelges tsugae).* 55th Southern Forest Insect Work Conference, July 23-26, New Orleans, LA.

Whittier, W.A., R.M. Jetton, W.S. Dvorak, Rhea, J.R., 2013. Genetic resource conservation of Eastern and Carolina Hemlock: North American conifers imperiled by Hemlock Woolly Adelgid. The Alliance for Saving Threatened Forests 2013 Symposium. October 29, 2013, Asheville, NC.

University Committees and Service

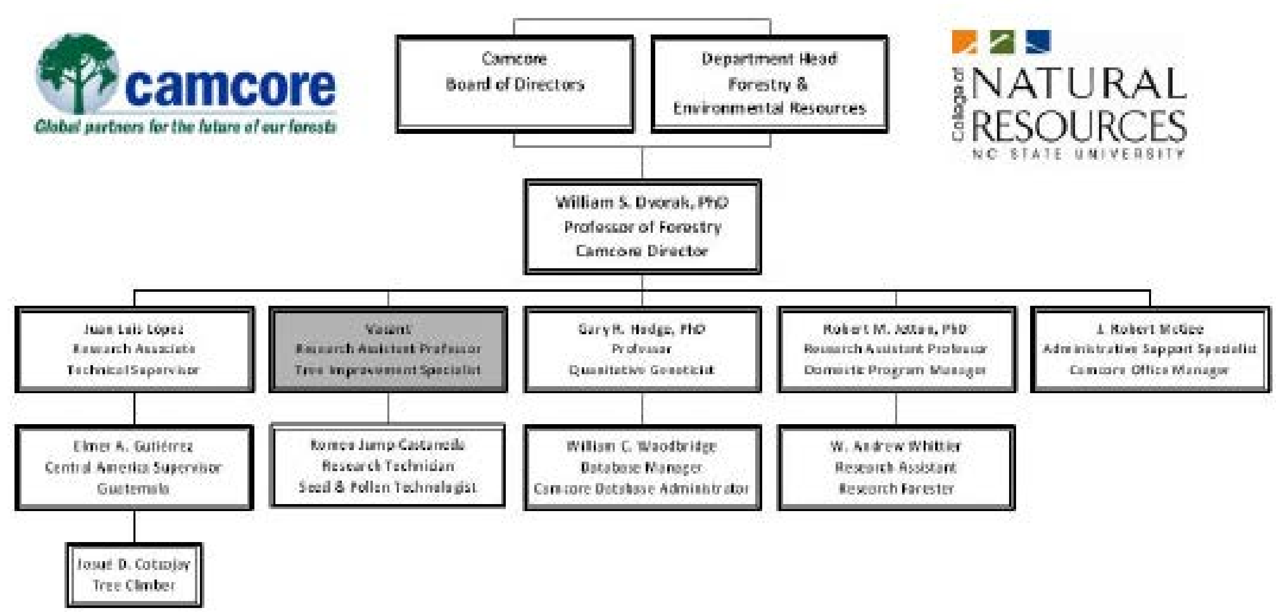
Bill Dvorak, Professor of Forestry and Director of Camcore, NC State University, continues to serve as an Extraordinary Professor in the Department of Forest and Wood Sciences, Stellenbosch University, South Africa. As Deputy of IUFRO Working Group 2.02.20, "Breeding and Genetic Resources of the Southern US & Mexican Pines", he and Gary Hodge at Camcore organized a successful meeting of 90 tree breeders and researchers from around the world in Jacksonville, Florida, USA in February (see IUFRO, page 47). Bill also served as an external Ph. D. reviewer for the University of Queensland, Australia. He continued his work as an Associate Editor for *Southern Forests* (South Africa) and reviewed a number of manuscripts for other international journals.

Gary Hodge, Professor of Forestry and Camcore Quantitative Geneticist, continued to serve as Associate Editor for the *Canadian Journal of Forest Research.* He served as an external PhD reviewer for the University of the Free State and the University of KwaZulu-Natal, South Africa. Gary also conducted a review of the BLUP protocols used by the Ontario Ministry of Forests.

Robert Jetton, Research Assistant Professor & Camcore Domestic Project Leader, continues to serve as an Associate Editor for the *Journal of Insect Science,* and was a peer reviewer for the *Journal of Insect Science, Forest Ecology and Management,* and *Southeastern Naturalist.* He is currently serving a three-year term as Councilor on the Southern Forest Insect Work Conference Executive Committee. He also serves as a Steering Committee member for both the USDA Forest Service Working Group on Genetics and Host Resistance in Hemlock and the Alliance for Saving Threatened Forests.

Robert McGee, Camcore Office Manager, continues to serve on the University's Group Insurance and Benefits Committee, Transportation Appeals Hearing Board, and on the State Employee's Combined Campaign which coordinates donations from NCSU employees to a host of local, regional and national charities. In addition to his university service, Robert was a host parent for the EF Foundation for Foreign Study, and received a 'President's Volunteer Service Award' from President Obama for his efforts in community service.

Camcore Personnel



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Ben Pienaar, Mondi South Africa

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Laercio Duda / Ricardo Paím, Rigesa, Celulose, Papel e Embalagens, Brazil

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Pedro Brajcich Gallegos, INIFAP, México

Patricia Negreros Castillo, Instituto de Investigaciones Forestales, México

Osmany Salas, Ministry of Natural Resources, Belize

Arnulf Kanzler and André Nel (Sappi, South Africa) in the thinned *Pinus maximartinezii* conservation bank at the Shaw Research Centre in Tweedie, KwaZulu-Natal, South Africa. The species is rare and endangered, and occurs in only one location in north-central Mexico. We hope that the trees in this genetically diverse planting will produce mature cones and viable seeds in another three to four years.

Front Cover: Carlos Gioia of Alto Paraná holding a Camcore eucalyptus seedling that is ready to be planted.