camcore

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NC STATE UNIVERSITY

2012 Annual Report

2012 CAMCORE ANNUAL REPORT

International Tree Breeding and Conservation

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EXECUTIVE SUMMARY

1. In 2012, two new industrial members from Mozambique joined Camcore as active members: MozCarbon and Green Resources. Uumbal from Mexico joined Camcore as an associate member. The Camcore program now has 32 active, 5 associate, and 7 honorary members that represent 21 countries.

2. Great efforts were made to expand our eucalypt and *Corymbia* genetic bases. In 2012, we obtained seeds of *E. benthamii, E. badjensis E. brassiana, E. camaldulensis, E. globulus E. longirostrata, E. nitens, Corymbia citriodora, C. maculata,* and *C. torelliana.* The seeds were collected at the provenance/family level and came from a combination of wild stands in Australia, and seed stands and seed orchards from industrial and government breeding programs in various parts of the world. The genetic material is now being distributed to Camcore members for genetic testing.

3. Early results of last year's trials of *E. dorrigoensis* indicate that the species has much promise on sites in southern Latin America and South Africa, where it exhibits excellent growth and cold tolerance. However, on some sites it seems extremely sensitive to wind throw.

4. The pine breeding program continues to develop. Smurfit Colombia is the first company in Camcore to make selections in its 2nd-generation Camcore trials of *P. tecunumanii* and *P. maximinoi* for the 3rd cycle of improvement. Observations in plantations and Camcore field trials in northern Mozambique suggest that this region has the ideal climate and elevation for good flowering of both tropical species.

5. The first series of pine hybrid trials are now between 3 and 5 years of age. No single pine hybrid is best across environments in Latin America and southern Africa. However, in the cooler areas, *P. patula x P. tecunumanii* and *P. elliottii x P. caribaea* show much promise. Second-series trials also indicate that the *P. greggii x P. tecunumanii* hybrid is a very fast starter. On warmer sites, *P. caribaea x P. tecunumanii* and *P. caribaea x P. oocarpa* show much promise.

6. The fifth-year assessment of the *P. taeda* GxE trial series established in Brazil, Argentina and South Africa across 14 sites was completed. Selections that originated from Florida landraces performed the best in volume production across all locations and countries in the trial series. The minimal GxE effect found in *P. taeda* supports the value of the exchange of genetic material between companies in southern Latin America.

7. Progress was made in the Camcore Teak program with more trials being sent to members across a broader range of sites. Projects continue on initiating early flowering in teak and developing methodology to quantify percent heartwood in standing trees.

8. In 2012, Camcore members established 37 new pine trials and measured 74 existing ones. For eucalypts, 17 trials were established and data were received from 9 existing tests. In the next three years, Camcore members expect to establish 300 additional hectares of eucalypt/corymbia trials.

9. Conservation activities remain a strong component of the Camcore program. Conservation parks in South Africa for pines and eucalypts continue to be a high priority. Grafting of pines to fill missing cells in the parks and to maximize population diversity continue. In Colombia, Smurfit Colombia is developing conservation plans for its Camcore pines and Pizano has established a conservation park for *Gmelina arborea.* In the eastern USA, conservation seed collections continue of *Tsuga* sp. (hemlock) and *Pinus pungens* (Table Mountain Pine) and work has expanded to include *Chamaecyparis thyoides* (Atlantic White Cedar).

10. Much effort continues on developing ways to use near infrared spectroscopy (NIRS) as a tool for distinguishing among species, clones and hybrids. Ongoing research at Camcore indicates that we can use NIRS to distinguish among different eucalypt clones of the same species in the nursery and in the field using vegetative material, among closely related eucalypt species and hybrids by scanning woodmeal from mature trees, and to quantify the level of natural introgression in a pine species by assessing spectral signatures of the progeny.

11. Rudolf Rahn, Vice-President of Smurfit Kappa Cartón de Colombia, was elected as Chairman of the Camcore Advisory Board.

RESUMEN EJECUTIVO (Español)

1. En el 2012, dos nuevos miembros de Mozambique se afiliaron a Camcore como miembros activos: MozCarbon y Green Resources. Uumbal de México se afilió como miembro asociado. El programa Camcore tiene ahora 32 miembros activos, 5 asociados y 7 honorarios que representan 21 países.

2. Se hizo un gran esfuerzo para expandir nuestras bases genéticas de eucaliptos y *Corymbia.* En el 2012, nosotros obtuvimos semillas de *E. benthamii, E. badjensis E. brassiana, E. camaldulensis, E. globulus E. longirostrata, E. nitens, Corymbia citriodora, C. maculata,* and *C. torelliana.* Las semillas se colectaron a nivel de procedencia/familia y vinieron de una combinación de rodales silvestres en Australia y rodales y huertos semilleros de programas de mejoramiento genético de la industria y el gobierno de varias partes del mundo. El material genético está siendo distribuido a los miembros de Camcore para ensayos genéticos.

3. Resultados tempranos de los ensayos de *E. dorrigoensis* del año pasado indican que la especie es muy promisoria en sitios en el sur de Latinoamérica y Sur Africa, donde exhibe crecimiento y tolerancia al frío excelentes. Sin embargo, en algunos sitios parece que es extremadamente sensible al volcamiento generado por los vientos.

4. El programa de cruzamientos de pino se continúa desarrollando. Smurfit Colombia es la primera compañía en Camcore en hacer selecciones en los ensayos de Camcore de 2nda. generación de *P. tecunumanii* y *P. maximinoi* para el 3er. ciclo de mejoramiento. Observaciones en plantaciones y ensayos de campo de Camcore en el norte de Mozambique sugieren que esta región tiene el clima y elevación ideales para una buena floración de ambas especies tropicales.

5. La primera serie de ensayos de híbridos de pino tiene ahora entre 3 y 5 años de edad. Ninguno de los híbridos de pino es el mejor en todos los ambientes en Latinoamérica y el sur del Africa. Sin embargo, en las áreas más frías, *P. patula x P. tecunumanii* y *P. elliottii x P. caribaea* se muestran muy promisorios. La segunda serie de ensayos también indica que el híbrido de *P. greggii x P. tecunumanii* tiene un rápido crecimiento inicial. En sitios más cálidos, el *P. caribaea x P. tecunumanii* y el *P. caribaea x P. oocarpa* se ven muy promisorios.

6. Se completó la evaluación del quinto año de la serie de ensayos de genotipo por ambiente del *P. taeda* establecida en 14 sitios en Brasil, Argentina y Sur Africa. Selecciones que se originaron de razas locales de la Florida tuvieron el mejor desempeño en producción de volumen a través de todos los sitios y países en la serie de ensayos. El mínimo efecto de genotipo x ambiente encontrado en el *P. taeda* justifica el valor del intercambio de material entre compañías en el sur de Latinoamérica.

7. Se avanzó en el programa de Teca de Camcore, con más ensayos enviados a los miembros a través de un más amplio rango de sitios. Se continúa con proyectos para la iniciación de floración temprana en teca, así como también en el intento de desarrollar metodología para cuantificar el porcentaje de duramen de árboles en pie.

8. En el 2012, los miembros de Camcore establecieron 37 ensayos de pinos y midieron 74 ya existentes. En eucaliptos, 17 ensayos fueron establecidos y se recibieron datos de 9 ensayos existentes. En los próximos 3 años, los miembro de Camcore lo más probable es que tengan establecidas 300 hectáreas adicionales de ensayos de eucaliptos y *Corymbia.*

9. Las actividades de Conservación permanecen siendo un componente fuerte del programa Camcore. Los parques de conservación en Sur Africa para pinos y eucaliptos continúan siendo una alta prioridad. La ejecución de injertos de pino para llenar los espacios faltantes en los parques y para maximizar la diversidad de la población continúa. En Colombia, Smurfit Colombia está desarrollando planes de conservación para sus pinos con Camcore y Pizano (Colombia) ha establecido un parque de conservación de *Gmelina arborea.* En el sur de los Estados Unidos, se continúa con las colectas de semillas para conservación de *Tsuga* sp. (hemlock) y *Pinus pungens* (Table Mountain Pine) y el trabajo se ha expandido para incluir *Chamaecyparis thyoides* (Atlantic White Cedar).

10. Se continúa haciendo mucho esfuerzo en el desarrollo de formas de utilización de la técnica del infrarrojo cercano (NIRS por sus siglas en inglés) como una herramienta para distinguir especies, clones e híbridos. La investigación continua en Camcore indica que podemos usar NIRS para distinguir clones diferentes de eucaliptos de la misma especie en el vivero y en el campo usando material vegetativo, entre especies de eucaliptos e híbridos cercanamente relacionados mediante el escaneo de partículas de madera de árboles maduros, y para cuantificar el nivel de introgresión natural en una especie de pino mediante la evaluación de las huellas espectrales de la progenie.

11. Rudolf Rahn, Vice-Presidente de Smurfit Kappa Cartón de Colombia fue elegido como Chairman de la Junta Asesora de Camcore.

RESUMO EXECUTIVO (Português)

1. Em 2012, MozCarbon e Green Resources, ambas empresas de Moçambique se afiliaram à Camcore. A empresa Uumbal do México, também se tornou membro associada da Camcore. A Camcore, até o presente momento tem em seu programa32 empresas ativas, 5 associadas e 7 membros honorários que representam 21 países.

2. Durante o ano de 2012, grandes esforços foram empreendidos para expandir a base genética do gênero *Eucalyptus* e *Corymbia*. Neste período, obtivemos sementes de 10 espécies tais quais: *E. benthamii, E. badjensis, E. brassiana, E. camaldulensis, E. globulus, E. longirostrata, E. nitens, Corymbia citriodora, C. maculata,* e *C. torelliana.* Estas sementes foram coletadas a nível de procedência e famílias com origem na Austrália, pomares de empresas e também de programas de pesquisa governamentais em várias partes do mundo. Este material está sendo distribuído para os associados à Camcore para o estabelecimento de testes de pesquisa.

3. Resultados recentes com estudos de *E. dorrigoensis* indicam que esta espécie é demonstra potencial para crescimento e tolerância ao frio. Estes indicadores são provenientes de observações efetuadas em testes estabelecidos na América Latina e África do Sul. Entretanto, pode ser visto também que esta espécie, em alguns sítios foi altamente sensível ao dano por ventos fortes.

4. O programa de melhoramento com espécies de *Pinus* tropicais tem demonstrado desenvolvimento contínuo. A empresa Smurfit Colombia é a primeira empresa da Camcore a fazer seleções em seus testes de 2ª Geração de *P. tecunumanii* e *P. maximinoi* de forma a iniciar o 3º ciclo de melhoramento genético. Observações em plantações e testes da Camcore no Norte de Moçambique sugerem que esta região possui um clima e altitude ideal para um bom florescimento destas duas espécies tropicais.

5. A primeira série de testes de híbridos de *Pinus* está completando 3 e 5 anos de idade. Ainda não existe a definição do melhor híbrido neste testes na América Latina e dos países do Sudeste Africano, entretanto, nas regiões mais frias, híbridos de *P. patula x P. tecunumanii* e *P. elliottii x P. caribaea* são promissores. A segunda fase destes estudos, também indicam que os híbridos de *P. greggii x P. tecunumanii* apresentam ótimo crescimento inicial. Em sítios com temperaturas mais elevadas, os híbridos de *P. caribaea x P. tecunumanii* e *P. caribaea x P. oocarpa* apresentam potencial.

6. Foram analisados e sumarizados os resultados de cinco anos dos estudos de G X E com *Pinus taeda,* estabelecidos em 14 sítios no Brasil, Argentina e África do Sul. As seleções originárias da Flórida apresentaram uma melhor performance em crescimento volumétrico em todos os locais testados. A baixa interação genética X ambiente encontrada em *Pinus taeda* confirma opotencial valor em se executar trocas de material entre empresas do Sul da América Latina.

7. Com relação ao programa de melhoramento de Teka, a Camcore obteve progresso significativo através da dsitribuição de material aos respectivos associados e posterior estabelecimento destes estudos numa ampla gama de sítios florestais. Estamos dando continuídade aos projetos de florescimento precoce como também no desenvolvimento de metodologias para quantificar o percentual de madeira juvenil em árvores localizadas nos testes.

8. Em 2012, os associados da Camcore estabeleceram 38 novos testes com o gênero *Pinus* e 77 testes já estabelecidos foram mensurados. Para eucalyptus, 17 novos testes foram estabelecidos e forma enviados à Camcore dados de 8 testes já estabelecidos nas empresas. Nos próximos 3 anos, os associados à Camcore terão provavelmente estabelecido em suas áreas 300 ha com novos estudos dos gêneros eucalytp/corymbia.

9. As atividades relacionadas a conservação de espécies continuam a ter um grande peso dentro do programa da Camcore. Na África do Sul, áreas e parques de conservação para *Pinus* e *Eucalyptus* continuam a ter caráter prioritário. Objetivando maximizar a diversidade da população, o trabalho de enxertia de pinus para replantio nestas áreas de conservação tem sido contínuas. Na Colômbia, a empresa Smurfit Colombia está desenvolvendo planos de conservação para as espécies de *Pinus* da Camcore e a empresa Pizano, também da Colômbia já estabeleceu uma área de conservação para *Gmelina arborea.* No Sudeste dos EUA, continua o esforço para a coleta de sementes de *Tsuga* sp. (hemlock) e *Pinus pungens* (Table Mountain Pine) e agora incluímos esforços para a coleta de sementes de *Chamaecyparis thyoides* (Atlantic White Cedar).

10. Os esforços para desenvolver os uso de (near infrared spectroscopy-NIRS) continua, como ferramenta para distinguir espécies, clones e híbridos. Trabalhos de pesquisa contínuos na Camcore, NC State indicam que podemos fazer uso do NIRS para diferenciar distintos clones de eucalyptus da mesma espécie utilizando-se de material vegetativo no viveiro como também no campo. O NIRS também pode ser utilizado para diferenciar espécies de eucalyptus aparentadas e híbridos através de escaneamento de amostras de serragem da madeira de árvores adult

11. 11. Rudolf Rahn, Vice-Presidente da empresa Smurfit Kappa Cartón da Colômbia foi eleito Presidente do Comitê de Conselho da Camcore (Camcore Advisory Board).

MUHTASARI WA TAARIFA KUU (Kiswahili)

1. Mnamo mwaka 2012, mashirika mawili ambayo ni wanachama wa kiviwanda kutoka Msumbiji yalijiunga na shirika la Camcore kama wanachama halisi, mashirika hayo ni MozCarbon na Green Resources. Uumbal kutoka Mexico ilijiunga na Camcore kama mwanachama mshiriki. Kwa sasa, Shirika la Camcore lina wanachama 32 halisi, wanachama 5 washiriki, na wanachama 7 wateule, wote wakiwakilisha mataifa 21.

2. Jitihada kuu zilifanywa ili kupanua vituo vya kijenetiki vya mikalitusi na *Corymbia*. Katika mwaka wa 2012, tulipata mbegu za *E. benthamii, E. badjensis, E. brassiana, E. camaldulensis, E. globulus, E. longirostrata, E. nitens, Corymbia citriodora, C. maculata,* na *C. torelliana.* Mbegu hizi zilikusanywa kupitia kwa mfumo wa kijamii na kupatikana kutoka kwa vituo na maeneo ya mbuga tofauti tofauti huko nchini Australia na hali kadhalika kutoka kwa vituo vya mbegu na vitalu vya miradi ya kiviwanda na serikali vinavyoshughulikia ukuzaji wa mbegu kutoka kwa maeneo mbali mbali ulimwenguni. Bidhaa hizo za kijenetiki zinasambazwa kwa wanachama wote wa Camcore kwa lengo la kuzifanyia majaribio ya kijenetiki.

3. Matokeo ya awali ya majaribio yaliyofanyika mwaka jana ya mbegu za *E. dorrigoensis* yanaonyesha kwamba aina hii ya mbegu inaonyesha matumaini na uwezekano mzuri wa ukuaji na uthibiti wa majira ya kipindi cha kipupwe ama baridi kali hususan katika sehemu za upanzi huko Kusini mwa Marekani ya Walatino na taifa la Africa Kusini. Hata hivyo, baadhi ya maeneo mengine ya upanzi yanaelekea kuwa na upepo mkali sana.

4. Mradi wa kukuza misonobari bado unaendelea kuimarika. Smurfit Colombia ndio kampuni tanzu ya kwanza katika Camcore kufanya uteuzi katika mfumo wake wa 2 wa majaribio ya Camcore ya mbegu za *P. tecunumanii* na *P. maximinoi* hasa kwenye sehemu ya mzunguko wa 3 wa uboreshaji. Usimamizi wa mimea na majaribio ya nyanjani ya shirika la Camcore katika maeneo ya Msumbiji Kaskazini unaelekea kupendekeza kwamba eneo hilo lina hali safi ya hewa na ni bora katika utoaji maua hasa kwenye mbegu zinazofaa katika sehemu za kitropiki.

5. Kwa sasa, majaribio ya awali ya mbegu za katumani ya misonobari, yamefikia umri wa kati ya miaka 3 na 5. Hakuna mbegu yoyote ile ya katumani ya misonobari inayofaa na kuchukuana sambamba na mazingira yote ya sehemu za 'Marekani ya Walatino' na Afrika Kusini. Hata hivyo, katika sehemu zilizo na ubaridi, mbegu aina ya *P. patula x P. tecunumanii* na *P. elliottii x P. caribaea* zinaelekea kufaa zaidi. Majaribio ya miche midogo (majaribio ya pili) pia yanaonyesha matumaini kwamba mbegu za katumani za *P. greggii x P. tecunumanii* inafaa zaidi kwa kuanzia upanzi. Katika maeneo yaliyo na joto, mbegu za *P. caribaea x P. tecunumanii* na *P.caribaea x P. oocarpa* zimeonyesha matumaini yanayoridhisha.

6. Ukaguzi wa baada ya miaka mitano wa majaribio ya mbegu za *P. taeda* G x E uliofanyika kwenye sehemu 4 za upanzi huko Brazil, Argentina na Afrika Kusini umekamilika. Uteuzi ulioanzishwa kutoka kwenye mashamba ya huko Florida yalitoa mazao na mavuno mengi katika sehemu zote na mataifa yaliyofanyiwa majaribio. Athari ndogo ya G x E iliyopatikana kwa mbegu *P. taeda* inathibitisha thamani au ubadilishanaji wa bidhaa za kijenetiki kati ya kampuni zilizoko Kusini mwa Marekani ya Walatino.

7. Mradi wa Mivule wa Camcore (Camcore Teak Program) umefaulu kwa kiasi kikubwa huku majaribio zaidi yakitumiwa mashirika wanachama katika maeneo yao mbali mbali ya upanzi. Miradi ya kuendeleza utoaji wa maua ya mapema wa mivule pia unaimarika huku pakifanywa mbinu za kuandaa mifumo mahususi ya kuelezea asilimia ya mioyo (ngarange) ya miti ambayo haijakatwa.

8. Katika mwaka wa 2012, wanachama washirika wa Camcore walianzisha majaribio 37 mapya ya misonobari na kufanyia vipimo majaribio 74 yaliyopo kwa sasa. Kuhusu mikalitusi, majaribio 17 mapya yalianzishwa na data kupokelewa kutoka kwa majaribio 9 yaliyokuwa tayari yamefanyika. Kuna uwezekano mkubwa kwamba katika kipindi cha miaka mitatu ijayo, wanachama washirika wa Camcore watakuwa wameanzisha hekta 300 za majaribio ya mikalitusi/corymbia kwenye uanachama wao.

9. Shughuli za uhifadhi zinaendelea kuwa nguzo muhimu ya miradi ya Camcore. Mbuga za uhifadhi wa misonobari na mikalitusi huko Afrika Kusini zinaendelea kupewa kipaumbele. Umboji wa misonobari unaofanyika kwa lengo la kujaliza seli zilizopotea katika mbuga na kuzidisha uanuai wake bado unaendelea. Huko Colombia, Smurfit Colombia inaendeleza mipango ya uhifadhi wa misonobari na mi-pizano (Colombia) ya Camcore na imeanzisha kituo cha uhifadhi cha *Gmelina arborea.* Katika sehemu za Kusini mwa Marekani, ukusanyaji wa mbegu za uhifadhi za *Tsuga* sp. (hemlock) na *Pinus pungens* (Misonobari Inayomea Pembezoni mwa Milima) unaendelea na kazi hiyo imepanuka na imehusisha *Chamaecyparis thyoides* (Mikangazi Myeupe ya Atlantic).

10. Jitihada zinaendelea ili kukuza njia bora za utumiaji wa vifaa vya 'Near Infrared Spectroscopy (NIRS)' kama chombo cha kutofautisha kati ya mbegu aina mbali mbali, misimbo na katumani. Utafiti unaoendelea katika Camcore, NC State, unaonyesha kwamba wanaweza kutumia NIRS ili kutofautisha kati ya misimbo mbali mbali ya mikalitusi ya mbegu aina aina kwa kutumia bidhaa za kilimo kwenye vitalu na maeneo tambarare. Hali kadhalika, inatofautisha aina mbali mbali za mikalitusi na katumani kwa kupata vilaji vya mbao kutokana na miti iliyokomaa. Pia tunaweza kuelezea viwango vya uasili wa mbegu hizo kwa kupigia darubini ukomavu wa miti yenyewe katika majaribio ya misonobari.

11. Rudolf Rahn, Makamu wa Rais wa Smurfit Kappa Cartón de Colombia alichaguliwa kama Mwenyekiti wa Bodi Kuu ya Ushauri ya Camcore.

Message From the Director

I define a good year for the program as one when the membership stays stable or increases, and when the Annual Meeting brings participants together so that there is even more cooperation and good will than the year before. In 2012, our 32nd year of operation, we gained two new active members and one associate member representing Mozambique and Mexico, respectively. The annual meeting in Chile, hosted by CMPC Forestal and Arauco-BioForest, was a great success. We had the highest attendance ever at a Camcore annual meeting, and some very good cooperative research projects were outlined at the meeting. Congratulations to everyone.

We are embarking on several exciting research initiatives in 2013. We are developing a *P. patula x P. tecunumanii* breeding project where costs will be shared by all participating members. Companies with existing pine hybrid programs will be able to create even more hybrids for testing at a lower cost, and newer members will have the opportunity to obtain unique hybrid genetic material as long as they are willing contribute funds. Both the *P. patula* and *P. tecunumanii* parents will be Camcore material, so once a good cross is found, members can go back to the original parents in orchards or clone banks and make more crosses.

We are also going to study the degree of introgression of *P. patula* in our advanced-generation breeding programs of *P. tecunumanii.* Unfortunately, in most of southern Africa and in the highlands of Colombia, the two species flower at approximately the same time (along with *P. greggii, P. pringlei* and *P. oocarpa*), which produces quite a bit of pollen contamination. We want to quantify exactly what is the percentage of contamination in our *P. tecunumanii* trials using species-specific molecular makers and near infrared spectroscopy (NIRS).

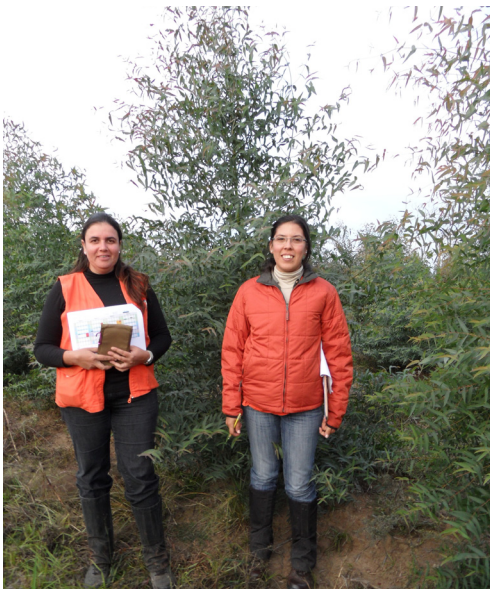
Great gains were made in our eucalypt program in 2012. A number of eucalypt and *Corymbia* species were sampled in Australia and other locations at the provenance and family level and these trials are now being distributed. For each major species distribution, Camcore members will be establishing special breeding orchards as well as progeny trials. We want to be in a position to have genetic material available from a wide selection of species in order to make hybrid crosses in the future. By 2015, the Camcore members will have an additional 300 ha of eucalypt trials.

We continue to make good use of NIRS as a tool to distinguish species and their hybrids using leaves, needles or wood meal. We believe that this technology can also provide an estimate on the amount of natural introgression in progeny trials that originate from seed collections in wild stands. To some extent, NIRS might be used as a surrogate to more expensive molecular marker analyses.

One of our main goals with pines, eucalypts, teak and *Gmelina* is to make sure that all of our species from wild collections are in at least the 2nd generation of breeding so that we can obtain a good estimate of their potential. *Pinus maximinoi* and *P. tecunumanii* entered their 3rd cycle of breeding in 2012. In just two years, we will be able to make selections in our most recent eucalypt trial series. Selections in teak provenance/progeny trials will follow shortly thereafter. This, along with the development of our pine and eucalypt hybrid programs, will make the next few years in Camcore very exciting.

Thank you again for all of your support.

Bill Dvorak, Director



Seven-month-old *Eucalyptus dorrigoensis* established by Weyerhaeuser in Uruguay. The species has not been widely tested, but exhibits fast growth and good cold tolerance in trials in southern Latin America and southern Africa.

2012 Camcore Membership

Active & Associate Members

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

Australia
- CSIRO (Associate)

Brazil
- Klabin, SA
- Rigesa, Celulose, Papel e Embalagens Ltda
- Suzano Pulp and Paper

Chile
- Arauco Bioforest
- CMPC Forestal Mininco

Colombia
- Cementos Argos, SA
- Pizano/Monterrey Forestal, SA
- Smurfit Kappa Cartón de Colombia, SA

Guatemala
- Grupo DeGuate (Associate)

Indonesia
- PT Sumalindo Lestari Jaya

East Africa
- Kenya, Uganda, Tanzania

Mexico
- Forestaciones Operativas de México, SA de CV (FOMEX)
- Proteak Uno SA de CV
- Grupo Agroforestal Uumbal SAPI de CV (Associate)

Mozambique
- Chikweti Forests
- Florestas de Niassa Limitada
- Green Resources AS - Mozambique
- MozCarbon

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

United States of America
- Mead Westvaco (Associate)
- USDA Forest Service (Associate)

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

Venezuela
- Maderas del Orinoco, CA
- Smurfit Kappa Cartón de Venezuela, SA
- Terranova de Venezuela, SA

Zimbabwe
- Border Timbers

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 2012 Annual Meeting in Chile

On October 29, Camcore gathered in Chile for the 32nd Camcore Annual Meeting hosted by CMPC Forestal Mininco and Arauco Bioforest. Verónica Emhart and Jean Pierre Lasserre (CMPC), and Cristian Montes and Claudio Balocchi (Arauco), and numerous other colleagues worked hard to organize ten days of informative field tours, technical meetings and wonderful meals enjoyed by 53 participants and seven spouses. The 2012 meeting marked Camcore's third visit to Chile with two previous annual meetings having been held there in 1993 and 2001.

The meeting began in Concepción where on the first evening we all enjoyed a welcome dinner that featured performances of tradition Chilean music and dance. The opening technical session included invited presentations on the Chilean forest sector by Corma President Jorge Serón, the conservation of native Chilean flora and fauna by Universidad de Concepción Professor Anibal Pauchard, and a very enthusiastic overview of the history of radiata pine in Chile by Daniel Contesse, former CMPC Vice President of Forestry, and long-time friend of Camcore. Field tours while in Concepción included a visit to Arauco-Bioforest's research center to learn about the company's efforts in hybrid eucalypt breeding, somatic embryogenesis, and the use of NIR for wood quality analysis. We also visited Bosque Arauco's La Posada nursery to see large-scale clonal production of pines and eucalypts, and we toured field trials of *P. patula, P. greggii, P. radiata,* and *E. globulus*.

The meeting then moved to the Los Ángeles area for two days of field tours hosted by CMPC, where participants visited the Carlos Douglas Nursery and various eucalypt field trials, including the Camcore *Eucalyptus* benchmark and species trials at Campanario. We also visited CPF, the national insect and disease control program, where efforts to manage pests and pathogens were reviewed. This portion of the meeting was capped off with a wonderful outdoor dinner at CMPC's Rucamanqui farm.

Valdivia was the final stop of the meeting for four days of tours and technical sessions. We visited Arauco's Valdivia Sawmill to see the production of structural lumber and remanufactured trims and mouldings, and had the opportunity to make cultural visits to the Spanish fort at Niebla and tour the native Valdivian rain forest at Parque Oncol. The stay in Valdivia also offered attendees free time to tour the city, the impressive riverside fish market (complete with resident sea lions), and the Universidad Austral de Chile campus and botanical garden.

Pepe Ordoñez (Bosques Arauco) speaks enthusiastically about the production of radiata pine cuttings.

The final day of the 2012 Annual Meeting began with a closing technical session that featured company descriptions by new Camcore members in Brazil, Mexico, and Mozambique and a presentation by Dr. Barry Goldfarb, Head of the NCSU Department of Forestry & Environmental Resources, on recent changes and developments in the College of Natural Resources. The day ended with the farewell dinner at the picturesque Isla Huapi, where a delicious meal of meat and seafood was cooked in the traditional Chilean style known as "Curanto en Hoyo". The evening ended with the Camcore staff presenting small gifts to our hosts to thank them for an excellent trip. We left Chile with renewed friendships, a better understanding of Chilean forestry, and an appreciation for the high quality research being done in the region by CMPC and Arauco.

Developments in Camcore

MozCarbon and **Green Resources** from Mozambique joined Camcore in 2012. MozCarbon is involved in the conservation of three high-value native species in the province of Zambezia, as well in the development of small-scale plantations of teak, pines and eucalypts. Green Resources is developing plantation forestry near Nampula and Lichinga in northern Mozambique, and is planting pines and eucalypts.

Uumbal in Mexico joined Camcore as an associate member in 2012. The company is interested in growing pines for resin production. Currently, Uumbal's planting areas are in Puebla and Veracruz. Uumbal has already decided to upgrade its membership from associate to active in 2013. We welcome these new members into the Camcore program. At the end of 2012, Camcore had 32 active members, 5 associate members, and 7 honorary members that represent 21 countries.

The Camcore staff made technical visits to most of its members in 2012. Below is a summary of our visits.

Carlos Gioia and Juan Schapovaloff (APSA) in front a 10-month-old *E. dunnii* tree in Argentina.

Argentina

Jesús Espinoza visited Argentina in August, and spent time with Alto Paraná and Bosques del Plata. **Alto Paraná** (APSA) has made good progress in the development of the tree improvement program and management of its plantations. This year in particular, several pine trials demonstrated the potential of a number of pure species and hybrids. In particular, *P. tecunumanii, P. greggii,* and the hybrids *P. greggii x P. tecunumanii* and *P. caribaea x P. tecunumanii* were growing well. The two series of Camcore eucalypt trials (South African Bench Mark and Temperate species) established in 2011 are also showing promise, especially *E. dunnii, E. grandis, E. benthamii, E. badjensis* and *E. occidentalis*.

On the same trip, Jesús visited **Bosques del Plata** (BDP). BDP has made great progress establishing new pine genetic trials including the pine hybrid trial series. In the most recent pine trial, at 11 months old, the *P. greggii x P. tecunumanii* hybrid showing very promising growth as it did at APSA. In older studies that are now five years of age, the *P. caribaea x P. tecunumanii* and *P. elliottii x P. caribaea* hybrids are competitive with improved *P. taeda.* BDP has begun to establish Camcore eucalypt trials to assess potential species. *Eucalyptus benthamii, E. macarthurii, E. smithii* and *E. dunnii* have shown high level of frost tolerance at an early age in Corrientes, Argentina and therefore, might play a role in plantation forestry as pure species or hybrid partners in the future.

Brazil

Bill Dvorak and Jesús Espinoza visited **Klabin** in January. Klabin has recently formed a partnership with Arauco and created the Vale do Carisco Company that includes some of the old Pisa Florestal lands. The land is well suited for eucalypts, tropical pines and *P. taeda.* Eventually, a new pulp mill with a 1.5 million ton capacity will be built that will use approximately 70% eucalypts and 30% pines. On this trip, Bill and Jesús reviewed breeding strategies and developed workplans for the major pine species *P. taeda* and *P. maximinoi.*

Gary Hodge and Juan López made a second visit to Klabin in September. Klabin made excellent progress in all areas in 2012. The company is using a Mass Control Pollination approach to produce operational quantities of *P. taeda* seed; it is a very cost-effective way to produce full-sib seed of high genetic quality. Klabin is also ramping up efforts to produce high-quality cuttings in the nursery; this is particularly important for *P. maximinoi* because seed production in this species is currently much more limited than for *P. taeda.*

In February, Bill Dvorak and Jesús Espinoza visited the **Suzano** eucalypt projects in the States of Piauí and Maranhão in northeastern Brazil. Up to 270,000 ha of eucalypts will eventually be established for pulp production and bio-energy. Suzano is well advanced in the testing and development of pure eucalypt species and hybrids for the region that is characterized by a five-month dry season and sandy soils. Camcore has provided Suzano with additional provenances and families of *E. urophylla* and *E. pellita* from natural stands in Indonesia. Suzano is also participating in the Camcore eucalypt hybrid program.

Jesús Espinoza also visited Suzano in April to collaborate on a project with CSIRO and Suzano researchers testing whether the hand-held NIR could distinguish among different eucalypt clones. The results of the project are described in another section of this report.

Chile

Bill Dvorak and Gary Hodge participated in the 4th Tree Improvement Shortcourse in Chile, hosted by the University of Concepción, **Arauco-BioForest,** and **CMPC Forestal Mininco**. This year there were 39 students from 7 countries, including 13 students from Camcore member companies. Bill and Gary each gave 3 lectures in Spanish. With the tree improvement course and the Annual Meeting both in Chile in 2012, there was not a technical visit to Arauco or CMPC. We will visit both companies early in 2013.

Colombia

Juan Lopez and Jesus Espinoza visited **Pizano/Monterrey Forestal** in March. Pizano continues to make progress in its tree improvement programs with *Gmelina arborea* and *Pachira quinata,* as well as its clonal program with *Gmelina.* The goal for 2012 was to plant 1,000 ha of commercial plantations using the 10 best clones of

2012 Annual Meeting participants at CMPC's Rucamanqui farm. The meeting was well attended with 53 representatives from southern and eastern Africa, Australia, Latin America, and the United States.

Gmelina arborea selected in its field trials. Camcore selections in progeny trials have now been established in a clonal seed orchard and will be eventually crossed with the clones from local company selections to produce the next generation of new progeny trials. Pizano started planting the *Gmelina arborea* conservation park this year that will eventually hold Camcore material from China, Thailand, Myanmar and India. A clonal seed orchard using Camcore selections of *Pachira quinata* was also established. Camcore has now initiated a program with Pizano to test eucalypts.

Juan López and Jesús Espinoza made a visit to **Cementos Argos** in March. They saw the two Camcore Teak progeny trials established by Argos that are part of a larger teak exchange among several of the members. The trials have been very well maintained, and the survival was high at the time of the visit. Camcore is helping Argos to establish a teak seed stand in Puerto Libertador that will produce a land race source of seeds that are well adapted to the local conditions while the seed orchard develops. With an idea to diversify and reduce risk, Camcore is offering Argos seed from a broad variety of eucalypt species for testing, in hopes to someday find alternatives to teak.

Gary Hodge and Bill Dvorak visited **Smurfit Kappa Cartón de Colombia** (SKCC) in March. SKCC has early results from a large pine hedge "recycling" study that indicate that there is no difference between seedling hedges and hedges produced by two cycles of cuttings from seedling hedges. These results are important because SKCC can easily increase cutting production 10 to 30 times using 1st cycle hedges, and even more using 2nd cycle hedges. SKCC has also done some very good work on airlayering and needle fascicle rooting of *P. maximinoi* (see article in this report). Camcore is working with SKCC on a project to evaluate genetic variation and genetic control of cellulose and lignin content in *P. tecunumanii* and *P. maximinoi.* These traits are economically important, and depending on their level of genetic control, could be included in SKCC selection indices in the future. SKCC continues to make good progress in their breeding programs with *P. tecunumanii* and *P. maximinoi:* in the latter species, they have made 37 3rd generation selections, the first 3rd generation selections in the Camcore program.

Carlos Mario Jimenez (SKCC, Colombia) in a 2-year-old *P. maximinoi* study comparing seedlings, cuttings from seedling hedges, and cuttings from hedges from one and two cycles of propagation.

East Africa

Gary Hodge visited **East Africa** in February. The trip this year was to Tanzania, and was well attended by representatives of the Tanzania Forest Research Institute (TAFORI) and the Kenya Forest Research Institute (KEFRI). In addition, we were accompanied by Abigail Brown of the Gatsby Foundation, and Rebecca Drinkwater, a Gatsby Foundation consultant working with the Tanzania Tree Biotechnology Project. This project is similar in structure and processes to the Tree Biotechnology Progamme Trust (TBPT) in Kenya. We visited Camcore trials of teak, *E. pellita*, and *E. urophylla*. The survival of the *E. pellita* at age one was excellent, and the survival and growth of the *E. urophylla* was very encouraging. The East African membership in Tanzania and Kenya will be establishing a large number of eucalypt and pine genetic trials in 2013. On this trip, we also visited the nursery and some plantations belonging to Green Resources, Tanzania, sister company to Green Resources Mozambique, which joined Camcore in 2012.

Guatemala

Juan López made the Camcore technical visit to **Grupo DeGuate** in Guatemala in June. Camcore continues giving assistance to Grupo DeGuate in the establishment of a clonal seed orchard of *Pinus maximinoi,* one of the most planted spe-

cies in Guatemala. Juan recommended the use of airlayers for the seed orchard to avoid problems with graft incompatibility. The Camcore teak progeny trial planted in Escuintla is growing well, and measurement data will be sent to Raleigh in the near future. Juan gave recommendations to Grupo DeGuate for the measurement of progeny trials of Palo Blanco *(Tabebuia donnell-smithii)* and a possible genetic thinning of these trials for phytosanitary purposes.

Mexico

Bill Dvorak and Juan Lopéz visited members in Mexico on separate trips. Juan visited **Proteak** in July. Camcore is providing assistance to the company to develop its teak tree breeding program. As part of this initiative, we have provided the company with teak seeds from Thailand, Laos, Indonesia, Bangladesh, Tanzania, Mozambique, Colombia, Costa Rica, Guatemala and Venezuela for the establishment of provenance/progeny tests. Camcore is also working with Proteak to help design their local clone-by-site interaction trials using genetic material from Malaysia, Costa Rica and Brazil. Camcore will also provide seeds of *Pinus caribaea* and *Gmelina arborea* for the establishment of second-generation progeny trials, as well as seeds of *E. urophylla* and *E. pellita* for provenance/progeny trials. The eucalypt and pine genetic base will provide a valuable option for sites where teak does not grow well.

Juan also visited **Fomex** in July. Camcore has been helping the company to identify new and better clones in their eucalypt clonal trials for commercial deployment. *Eucalyptus pellita*, a close relative of *E. urophylla*, is being tested in Camcore progeny trials in Tabasco and shows great potential as a pure species. *Eucalyptus pellita* should also be tested as a hybrid with *E. urophylla.* The good performance of *E. dorrigoensis* in the Camcore trial in Michoacán is encouraging; the species is growing similarly to *E. nitens,* so it may have potential on high-altitude sites with frost.

In early December, Bill visited **Grupo Agroforestal Uumbal**. The company is most interested in growing *P. elliottii* var. *elliottii* to produce high-quality resin for the local markets in Mexico. Camcore's expertise was used to determine if *P. elliottii* was the best choice of species for the fertile tropical landholdings of the company. Alternative species might include *P. caribaea* vars. *hondurensis* and *bahamensis.* Decisions on species choice will ultimately represent a balance between adaptability and productivity versus resin quality. Site preparation and weed control is excellent in the early stages of the project's development in Veracruz.

Ricardo Chacón and Evelyn Bosch de Chacón in a 1.5-year-old teak trial in Esquintla, Guatemala.

Mozambique

In July, Bill and Jesús visited all four companies in Mozambique: MozCarbon, Chikweti Forest, Green Resources and Florestas de Niassa.

Chikweti Forest has now successfully established a number of Camcore pine and eucalypt plantings on its landholding near Lichinga. The early growth of *P. maximinoi* and *P. tecunumanii* continues to be good. James Luckoff, the GM of Forestry, pointed out that the two species from Middle America continue to grow well into the dry season, while *P. elliottii* sets a resting bud when the rain ends. The end result is that the tropical pines are 2 to 3 times taller than the southern US pine by

the end of three years. Preliminary observations of the Chikweti pine plantings suggest it might be an ideal location for early seed production of *P. maximinoi* and *P. tecunumanii,* which are normally shy seed producers. On the eucalypt front, John Mudekwe and his research team have done a good job in the establishment of tropical benchmark trials and the drought hardy trials.

Florestas de Niassa (FDN) also made good progress in 2012, establishing Camcore trials of *P. maximinoi* and *P. tecunumanii.* The company has just built a new nursery that will produce high-quality seedlings, and fertilizer regimes have been better defined, which should also provide positive results. FDN will begin planting Camcore eucalypt trials at the end of 2012 when the rains begin.

MozCarbon, a new member in Camcore, is interested in *in situ* and *ex situ* conservation of native species *Khaya nyasica, Pterocarpus angolensis,* and *Dalbergia melanoxylon.* It also anticipates the development of pine plantations for resin production, teak plantations for the timber market, and eucalypt plantations for bio-energy and other products. Its first series of Camcore trials was dispatched in mid-2012 for planting early in 2013.

Green Resources has two plantation areas, Nampula (Nampula province) and Lichinga (Niassa province). The Nampula site is characterized by deep sandy (white) soils (altitude 40 m) and a well-defined dry season where *E. camaldulensis* will grow. Camcore is working with Green Resources to find other eucalypt species that might do well in the area or in hybrid combination with *E. camaldulensis.* The Lichinga plantations are at a 1000 m elevation and are adjacent to FDN and Chikweti Forest lands. *Pinus maximinoi, P. tecunumanii, P. caribaea* and the *E. urograndis* hybrid could all be grown on its landholding. Camcore has distributed seeds of *Corymbia* species to Green Resources for Nampula and *P. tecunumanii* for Lichinga.

South Africa

Visits to **Komatiland Forests (KLF)** and **York Timbers** were made in March. KLF is well along on its 2nd generation Camcore testing program of *P. tecunumanii* and *P. maximinoi,* but also has advanced-generation plantings of *P. chiapensis* and *P. greggii.* The company is commercially planting the *P. patula x P. tecunumanii* hybrid as well as cuttings of selected *P. maximinoi* on a small scale. The KLF Camcore conservation park is gradually being completed at Brooklands. One of the challenges of all forestry companies in the region is baboon damage in the pine plantations, which can account for 10% to 20% tree mortality on some forestry estates. KLF is also participating in the Camcore *Eucalyptus pellita* trial series to bring in more disease resistance into its *E. grandis* breeding program.

From the right, Irvine Kanyemba and Danie Gous with the Florestas de Niassa research team in a 1-year-old *P. caribaea* trial in Mozambique.

York Timbers is a relatively new organization in Camcore. However, it possesses a wealth of genetic material because of its past association with Mondi and Global Forest Products. The company is very much involved in developing pine hybrids, with both Camcore and its own local efforts, and is currently establishing a number of Camcore pine trials, including *P. maximinoi, P. tecunumanii, P. elliottii* and others. Glen Mitchell and his team are also working hard with other Camcore members to advance the genetic base of *P. pseudostrobus* and *P. leiophylla,* and are using the electrolyte leakage method promoted by Camcore to screen for cold hardiness in the greenhouse.

Gary Hodge and Bill Dvorak visited **Mondi Forests** in late May. The bulk of the visit was devoted to a company research review for foresters, scientists and upper-level managers, and focused on the progress made in the eucalypt and pine breeding programs over the last 5 years. Mondi is serving as Regional Coordinator for the third series of the Camcore pine hybrid project, and is using its new research nursery to grow the hedges and pro-

duce the cuttings. In the office, we had productive discussions about incorporating NIR models into the eucalypt selection criteria, and testing strategies for the Mondi *E. grandis x E. nitens* breeding program. We had field visits to Zululand, where we saw Camcore *P. elliottii, P. oocarpa,* and *E. pellita* trials.

On that same trip in early June, Bill and Gary visited **Sappi Forests.** We discussed Sappi's breeding programs for *E. dunnii, E. urophylla, E. grandis* and *E. grandis x E. nitens*. We visited Sappi's very impressive wood properties research facility, and discussed NIR modeling. We visited the new Sappi nursery at Clan, and the *P. taeda* GxE trial where the Argentina sources performed very well, just as they did in southern Latin America. We also visited some *E. pellita* trials in Zululand, where we observed a difference in leaf morphology between the Camcore populations from Indonesia, and the Sappi population, originally from Papua, New Guinea (see color photos in this report). Finally, we had a chance to visit the Sappi-Camcore conservation park in Zululand, and the conservation bank of *P. maximartinezii* at Tweedie (which is the largest planting of this species anywhere in world outside of Mexico).

Bill Dvorak visited **Cape Pine** in July. On the well-drained soils in the southern Cape, *P. tecunumanii* and *P. maximinoi* continue to grow well through age 5 years, competitive with *P. radiata.*

Regional Technical Meetings in Colombia, South Africa and Uruguay

Our regional technical meetings are held each year to discuss workplans, consider research opporutnities, and share results. The meetings are held at different times in northern Latin America, southern Latin America and southern Africa, and the hosts for the meeting rotate annually. The technical meetings are structured to include one day of indoor sessions and one day of field visits. In many ways, the discussions held at the regional technical session help formulate research ideas that are further discussed at the annual business meetings. In 2012, Pizano (Colombia) served as the host for the meeting in northern Latin America. Visits were made to *Gmelina* and *Pachira* plantations, orchards, and field trials on their land holding near Zambrano. The meeting for southern Latin America was hosted by Mead Westvaco Rigesa (Brazil). There, field visits were made to both pine and eucalypt trials. The regional meeting for southern Africa was hosted by Komatiland Forests (South Africa) with assistance from Glen Mitchell (York Timbers). Visits were made to pine trials in the colder regions of the high veldt in Mpumalanga. There was excellent attendance at all three meetings, and great collegiality and good will shown by all participants. We want to thank Pizano, Rigesa and KLF for hosting these important regional technical meetings.

Participants of the 2012 Camcore regional technical meeting for southern Africa hosted by KLF.

This is the southern-most planting area (34°S) for the two Mexican pines species in Africa. As one moves eastward along the Cape to the Tsitsikamma region, soils become more poorly drained and swampy. Species like *P. oocarpa, P. maximinoi,* and *P. herrerae* do progressively worse and pure *P. elliottii* and the *P. elliottii x P. caribaea* hybrid do proportionally better. Also, 2nd generation *P. taeda* from Marion Country, Florida, shows much promise. Interestingly, unimproved *P. greggii* var. *australis* shows good potential in the Eastern Cape (Longmore) if planted on the higher areas where drainage is not a problem. The challenge on the Cape is to find an alternative to pure *P. radiata* because of its susceptibility to *Fusarium* (Pitch canker). In addition to planting a number of Camcore progeny trials of Mexican pines, Cape Pine is also participating in the Camcore *P. elliottii* trial series, which will broaden its existing genetic base.

In August, Gary Hodge visited **Merensky** Weza, where we had some very interesting discussions about *P. patula x P. tecunmanii* hybrids, and the importance of straightness and form for sawtimber production. The 2nd generation trials of *P. maximinioi* and *P. tecunumanii* continue to show very good growth. As mentioned elsewhere in this report, a substantial proportion of the *P. tecunumanii* progeny in the trials appear to be *P. tecunumanii x P. patula* hybrids. The 4-year-old grafted *P. patula* seed orchard at Weza has already begun producing flowers. This is a welcome development, as it puts Merensky in the position of being able to produce its own *P. patula* and *P. patula x P. tecunumanii* for operational plantations. Merensky also has begun investigating protocols to vegetatively propagate *P. maximinoi*; this is important both so that the company can fulfil its commitment to conserve the species in its Camcore conservation park, and to more efficiently establish clonal seed orchards of *P. maximinoi*.

On this trip, Gary also visited **PG Bison** (PGB). PGB continues to make excellent progress at developing its own genetic resources of important species. PGB completed its first seed collection from the *P. patula* seedling seed orchards (converted from Camcore progeny trials), yielding a total of 8 kg of seed. The company also has plans to develop seedling seed orchards of *P. greggii,* with thinning planned for late-2012/early-2013. PGB has established a 2nd generation *P. patula* trial at Commonage containing 46 Camcore families collected in the Sappi clone bank at Lion's River. This test is replicated by other Camcore members on a number of sites across South Africa. Finally, in a wonderful example of collaborative spirit, PGB and Merensky have established jointly owned progeny trials at Langeni. The tests were planted on Merensky land by PGB research staff. This cooperation is a good way for PGB to have convenient access to *P. tecunumanii* and *P. maximinoi* resources, since these species will not likely do well on any PGB land at higher elevations.

Charles Kempthorne (Merensky) in the 2nd generation *P. tecunumanii* trial at Weza, South Africa. The tree is growing very well and has very nice form, but it may be a natural *P. tecunumanii x P. patula* hybrid.

Uruguay

Bill Dvorak visited **Weyerhaeuser** and **Montes del Plata (MDP)** in April. Both companies were very active in establishing Camcore eucalypt trials in 2011 and we had the opportunity to view the early development of a number of different species. Altogether, both companies planted 17 trials and 2 conservation banks across parts of Uruguay. Site preparation and weed control were excellent. Impressive early growth was seen for *E.*

benthamii, E. dorrigoensis, E. badgensis, and *E. dunnii,* and *E. longirostrata* also showed promise on some sites. Most trials had hobologgers on site for measuring temperatures. After the April visit, an unusually hard freeze of multiple-day duration occurred in southern Latin America. At some sites in Uruguay, temperatures were as low as -9.5°C for 8 hours and cold damage was severe for some species in many Camcore trials (results will be compiled and reported in 2013). The abnormal cold spell provided Camcore members in the region with an excellent opportunity for screening and future selections.

Robert Jetton made two visits to Weyerhaeuser this year, once in April and again in September. The March visit was focused on the selection of field sites for the *Thaumastocoris* impact study (discussed in detail in the Species Characterization section of this report), to visit and make management recommendations for a scolytid outbreak in a pine silviculture trial at Curticeiras, and to identify potential insect and disease problems in the nursery at Tacuarembo. During the September visit, Robert evaluated the scolytid management activities at Curticeiras and inspected the installation of treatment plots for the *Thaumastocoris* study. Weyerhaeuser has done an excellent job setting up this small pilot study and we look forward to learning what the results will tell us about the economic importance of this insect pest for eucalypt productivity in Uruguay.

Venezuela

Jesús Espinoza and Juan Luis López visited Smurfit Kappa Cartón de Venezuela and Terranova de Venezuela in March. **Smurfit Kappa Cartón de Venezuela** (SKCV) keeps working in the development of the tree breeding programs for eucalypts and pines, and also has some interest in *Gmelina arborea.* The objective of the company today is to improve genetic material of eucalypts and pines, and to develop material that is better adapted to the soil and environmental conditions of new plantation areas that they are developing. SKCV is also developing a new nursery site in Sarare in Lara state. The facility will have up-to-date greenhouses and irrigation systems.

After the SKCV visit, Jesus and Juan visited **Terranova de Venezuela**. The company is working diligently to develop its pine breeding program for *P. caribaea,* including a rooted cuttings program. The rooted cutting program is far enough advanced that Terranova has been selected by Camcore as regional coordinator for the Camcore pine hybrid program in Venezuela. New *P. caribaea* and pine hybrid trials using seeds and cuttings from Camcore were established in 2012, and four new trials will be established in 2013. Terranova has started to establish the first genetic trials of *E. urophylla* to assess the potential of eucalypts in the llanos region of the eastern part of the country. Camcore will send new genetic material from other eucalypt species to the company at the beginning of 2013.

Juan López (Camcore) and the technical staff of SKCV beside an 11-year-old selected *E. urophylla* tree at Tacamajaca Farm, Venezuela.

2nd Workshop on Genetic Improvement and Integrated Management of Forest Plantations in Venezuela.

In 2011, Camcore taught a tree improvement workshop for its members in Venezuela, with a focus on the tools that exist to maximize benefits of genetic improvement in forest plantations. This year, we again held a tree improvement workshop that was hosted by Maderas del Orinoco (Proforca) in facilities at Chaguaramas. We really appreciate the wonderful hospitality offered by the company. More than 30 technicians from the Venezuelan Camcore members participated in the course. Juan Lopez and Jesus Espinoza representing Camcore were the facilitators.

Progress in Pine Breeding and Testing

Camcore members made good progress in the areas of pine breeding, testing, and commercialization in 2012. Most of the activity dealt with 2nd generation testing. Some Camcore species, particularly *P. maximinoi* and *P. tecunumanii,* have demonstrated excellent growth in many regions, and some members are commercializing and deploying these species in plantations. Some species, like *P. greggii* or *P. chiapensis,* have demonstrated good potential, but have not yet displaced any current commercial species for any Camcore members. For these species, it is essential to go through one cycle of improvement to truly evaluate their place in our portfolio.

Paola Molina and Bob Purnell (Weyerhaeuser) in a 2-year-old 2nd generation *P. maximinoi* trial in Uruguay.

Test Distribution and Measurement

A total of 13 pine progeny tests were distributed to members in 2012. Four 1st generation tests were sent to Green Resources (two *P. maximinoi* tests) and MozCarbon (two *P. tecunumanii* tests), new Camcore members in Mozambique. We also sent out nine 2nd generation tests. Seven of these were part of the 2nd generation *P. tecunumanii* series in southern Africa. These tests were packed by York Timbers for distribution to Mondi, Merensky, Cape Pine, and York in South Africa, Border Timbers in Zimbabwe, Florestas de Niassa in Mozambique, and to East Africa for testing in Kenya and Tanzania.

Bill Dvorak (Camcore) and Nhora Isaza (SKCC) with a recent 1st generation selection of *P. tecunumanii* at La Quebrada farm in Colombia.

Camcore received measurement data for a total of 33 progeny tests in 2012. These were a mix of 1st generation, 2nd generation, and Reintroduction tests, which are progeny tests of Camcore material planted back into their native range.

Test Establishment

Camcore members established a total of 37 new pine progeny tests in 2012: *P. caribaea* (4), *P. elliottii* (7), *P. greggii* (4), *P. maximinoi* (15), *P. tecunumanii* (7). Most of these new tests were were 2nd generation tests (29), and most were in southern or eastern Africa (32).

As of the end of 2012, Camcore members have planted 104 2nd generation pine progeny tests. Over half of these are *P. maximinoi* and *P. tecunumanii*, but *P. patula, P. greggii,* and *P. caribaea* are represented by 11 or 12 tests each. There are also 3 tests of *P. chiapensis*, an extremely fast-growing white pine.

We currently have growth measurements (3-year, 5-year, and/or 8-year data) from 44 2nd

generation trials. This opens exciting opportunities to make 3rd generation selections in some trials, and in fact, Smurfit Kappa Cartón de Colombia (SKCC) has completed some 3rd selections of *P. tecunumanii* and *P. maximinoi*, the first in the program. At the same time, we need to ensure that we do a thorough job selecting from 1st generation trials (keeping a broad genetic base), and then conserving and testing all of the 2nd generation selections. We want to lay a good foundation for long-term breeding programs for these species.

Orchards and Plantations

SKCC continues to develop and expand its commercial cutting programs with *P. maximinoi* and *P. tecunumanii*. These two species currently account for about 80% of the company's annual pine planting. Klabin (Brazil) is expanding its *P. maximinoi* seed orchard and cutting capacity. Currently, *P. maximinoi* makes up about 15% of the annual pine planting, but the goal is to increase this to 50% in the future. In Africa, *P. maximinoi* and *P. tecunumanii* will likely play an important for both Komatiland Forests and York Timbers, and both species continue to grow very well at Cape Pine on the western Cape of South Africa, a region where *P. radiata* is the commercial species. In Mozambique, Chikweti and Florestas de Niassa are working to develop seed stands of *P. maximinoi* to provide seed in the near term. In Argentina, severe winter frosts in 2012 damaged 2nd generation trials of *P. maximinoi*, but *P. greggii* survived quite well. In Uruguay, both *P. maximinoi* and *P. greggii* are growing well in 2-year-old trials. It is critical that we better understand the limits of frost tolerance of these sub-tropical species. With proper site selection, and good management and planning, perhaps we can avoid damage to plantations at a young age and take advantage of the fast growth of these species. For this reason, members are increasingly using electronic temperature monitors (e.g., hobologgers or iButtons) in progeny tests and species trials to understand when, and under what conditions, frost damage occurs.

Below: Grant Olifant and Andre van der Hoef (Cape Pine) stand in a 3.5-year-old 2nd generation Camcore trial of *P. maximinoi* in Western Cape, South Africa. At this stage, the *P. maximinoi* (left) is outgrowing the *P. radiata* control (right).

Above: Thinned *P. maximinoi* seed stand at Lumbi, Mozambique. (Photo courtesy of J. Luckoff, Chikweti)

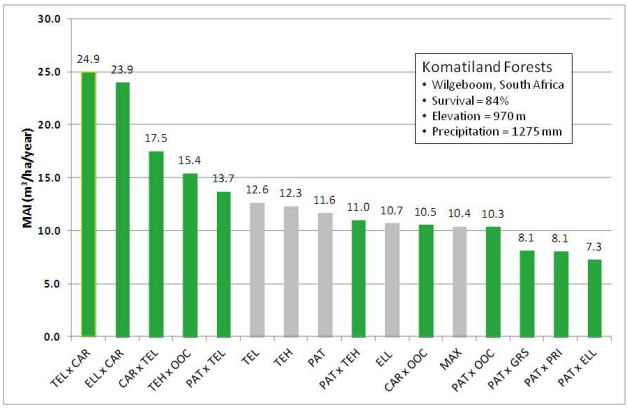
Progress in Pine Hybrid Testing

Three new pine hybrid trials were established by Camcore members in 2012, for a total of 64 tests planted in the program so far. The regional coordinators continue to manage hedges for the production of cuttings of pine hybrids from the third series of seeds shipped in 2011 and 2012. New hybrid trials will be established in 2013. An early assessment of 17 trials between 3 years and 5 years old was completed. For areas where *Pinus patula* is the main species in South Africa, some hybrids like *P. patula x P. tecunumanii* LE, *P. tecunumanii* LE x *P. caribaea* var. *hondurensis, P. patula x P. tecunumanii* HE, and *P. patula x P. oocarpa* show high potential in volume growth and survival (Figure 1). *Pinus patula* as a pure species has shown poor survival recently (perhaps due to *Fusarium*), below 60% in several of the tests. In comparison, survival of the pine hybrids has normally been above 80%. For the areas in Brazil and Argentina where *P. taeda* is the commercial species, the early assessment of the trials also indicates some hybrids with commercial potential. *Pinus elliottii x P. caribaea, P. caribaea x P. tecunumanii* LE, and *P. caribaea x P. oocarpa* all exhibit high survival and compete in growth with improved *P. taeda* material (Figure 1). Another exciting development in this region is the outstanding early growth of *P. greggii x P. tecunumanii* in two-year-old tests of the second series of hybrid trials (see photo).

New crosses of *P. taeda x P. jaliscana*, *P. taeda x P. pringlei*, *P. radiata x P. pringlei*, *P. radiata x P. herrerae, P. patula x P. leiophylla* and *P. tecunumanii* HE x *P. leiophylla* were made in 2012 by Camcore members. Additional crosses with pollen of *P. maximinoi, P. tecunumanii,* and *P. oocarpa* were made with mother trees of *P. taeda* and *P. radiata.* Seeds of *P. radiata x P. tecunumanii* LE and HE produced by Cape Pine, and *P. patula x P. oocarpa* and *P. greggii x P. radiata* produced by Mondi, will be sent to Camcore and verified using molecular markers.

Gary Hodge (Camcore) in a Klabin hybrid trial in Paraná, Brazil. On left is *P. taeda*, on the right is *P. greggii x P. tecunumanii.*

A new phase of the pine hybrid program will start in 2013 with the establishment of pine hybrid trials using families. Some of the hybrids that show high commercial potential will be planted in different regions to assess the variation among families within the hybrid. Part of the pollen to be used in this phase was collected in 2012.



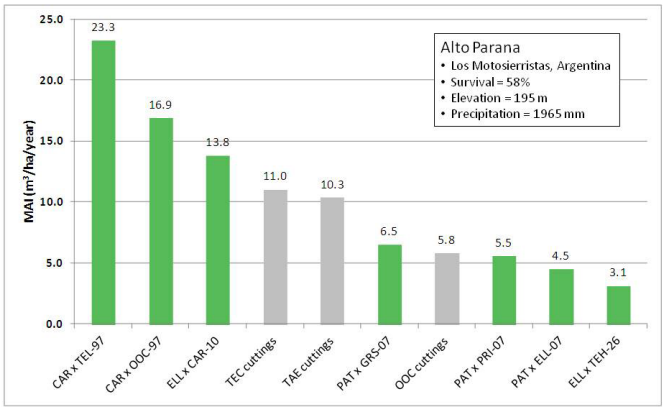


Figure 1. Mean Annual Increment (m^3/ha/year) for pure species (gray bars) and pine hybrids (green bars).
Left: Komatiland Forests, South Africa, age 3 years, commercial species is *P. patula.*
Right: Alto Parana, Argentina, age 4.8 years, commercial species is *P. taeda.*

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

Camcore began the Pine Hybrid Project in 2003. At that time, our goal was to make a wide variety of pine hybrids, and to test a number of crosses over a wide array of climatic conditions. The goal was to try to identify new hybrid combinations that had significant commercial potential. Our strategy was to make a bulk hybrid population in order to represent the average genetic potential of the hybrid. To date, Camcore members have made 23 verified hybrid crosses, and we currently have 64 hybrid tests established in the field (from two series of multiplications). A third test series is currently being multiplied by Regional Coordinators.

Although these field trials are still relatively young, some very promising trends have been observed. In South Africa, the *P. patula x P. tecunumanii* hybrid has performed very well in every environment where it has been tested: on warm sites in Sabie and KwaZulu-Natal in the north, on cold sites in the highlands in the northeastern Cape, and on *P. radiata* sites in the western Cape. 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*. A number of South African Camcore members (Sappi, York, Mondi, and Merensky) have been convinced of the potential of this hybrid, and have already begun their own *P. patula x P. tecunumanii* breeding efforts.

At the Regional Meeting of all African Camcore members in August 2012, we presented a proposal for a Joint Camcore Pine Hybrid Breeding Program, which is summarized here:

1. The current bulk hybrid testing will not identify any specific parents that will make outstanding hybrids for commercial propagation.
2. A hybrid breeding program will very likely require full-sib crossing and testing. This is a great deal of work, and it makes sense to work together and share the load and the costs.
3. The proposal called for large numbers of crosses using Camcore *P. patula* selections and Camcore *P. tecunumanii* selections. The companies that are already making hybrids are using their own proprietary *P. patula.* 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.
4. The proposal also called for all pollen collection and crossing be done by contractors, with the costs invoiced to all Camcore members in South Africa, as well as any interested members in Kenya, Mozambique, and Zimbabwe, and possibly other countries. This will allow equal contribution by "long-term" and "new" Camcore members toward the project.
5. Finally, it was suggested that the initial crosses be made in Sappi's Lions River seed orchard, where many of *P. patula* clones are already flowering.

There was general agreement on the proposal, and a committee was formed to develop a workplan and estimate timelines and costs. The committee consists of Gary Hodge, Bill Dvorak, André Nel, Kitt Payn, Glen Mitchell, and Johan de Graaf. We hope to make the first crosses in June-July of 2013.

Arnulf Kanzler of Sappi in a 3-year-old pruned progeny trial of *P. patula x P. tecunumanii* LE hybrid.

GxE in *Pinus taeda*: 5-year Results

In 2005, Camcore initiated a study to examine Genotype x Environment interaction (GxE) in *P. taeda* planted in the southern hemisphere. Objectives of the study were to understand the magnitude of GxE and the environmental factors contributing to GxE. If GxE is relatively low or well understood, it might be possible to develop cooperative breeding and testing of *P. taeda* across different geographic regions. The following is a update with 5-year growth results from the project.

Materials and Methods

Seven different Camcore members in Brazil, Argentina, and South Africa contributed 20 open-pollinated families from their operational breeding programs (from Brazil, Klabin Paraná, Klabin Santa Catarina, Rigesa, and Arauco Brazil, formerly International Paper; from Argentina, Alto Paraná and Bosques del Plata; and from South Africa, Sappi Forests). Seedlots were distributed among all seven organizations, and tests were established in 2006 and 2007. Masisa do Brazil also received some of the seedlots and established tests in 2008. Each member planted two tests, with a single-tree plot design and 20 replications. Most tests contained between 100 and 125 families, depending on seed availability and germination, and survival in all tests was quite good. There were typically between 80 to 110 families common between any given pair of tests, thus it is an excellent data set to examine GxE. Data were available for 15 trials with fairly significant variation in latitude, elevation, and precipitation (Table 1).

Results and Discussion

Across the 15 tests, mean 5-year height in the tests ranged from 6.2 m to 10.1 m. Single-site heritabilities (h^2_b) were calculated for all tests. Mean h^2_b was 0.21, and ranged between h^2_b = 0.07 to 0.35. A multi-site analysis was done using ASREML, with growth at all sites treated as independent traits. This was done to calculate site-site genetic correlations (i.e., Type B genetic correlations) between all possible pairs of sites. Two models were used, one to calculate Type B correlations at the seed source and family(source) levels, and one to calculate a correlation at the combined source-family level.

On average, there was relatively little GxE observed across all of the trials. At the source level, there was essentially zero GxE, with mean r_B(source) = 0.97. Overall, the rankings were remarkably consistent, with the sources ranked in essentially the same order at every site: APSA, BDP, Arauco, Sappi, KPR, Rigesa, KSC. One of the striking results was the superiority of the two Argentinian sources, APSA and BDP, which ranked first and second at almost every site. These two

Table 1. Site information for 15 trials in the *P. taeda* GxE study.

Test	Date Planted	Farm	Country	Lat	Long	Elev (m)	Precip (mm)
APSA 1	Sep-06	La Querencia	Argentina	26º 02' S	54º 37' W	195	1965
APSA 2	Oct-06	Monte Quemado	Argentina	26º 02' S	54º 37' W	195	1965
BDP 1	May-06	Timbauva	Argentina	27º 59' S	56º 00' W	127	1470
BDP 2	May-06	Jesus Cué	Argentina	27º 53' S	56º 09' W	127	1462
Arauco 1	Dec-06	Barra Mansa	Brazil	24º 01' S	49º 56' W	755	1167
Arauco 1	Feb-07	São Nicolau	Brazil	24º 18' S	49º 59' W	960	1167
Klabin PR1	Feb-07	Anta Brava	Brazil	24º 07' S	50º 29' W	740	1812
Klabin PR2	Feb-07	Cerradinho	Brazil	24º 18' S	50º 22' W	840	1813
Klabin SC1	Nov-06	Salto	Brazil	27º 29' S	50º 14' W	840	1394
Klabin SC2	Mar-07	Cervo	Brazil	27º 27’ S	50º 06’ W	850	1394
Masisa 1	Feb-08	Bituva Farm	Brazil	26º 27' S	49º 44' W	907	1722
Masisa 2	Mar-08	Kurashiki Farm	Brazil	24º 38' S	49º 31' W	926	1438
Rigesa 1	Nov-06	Taunay	Brazil	26º 04' S	50º 36' W	780	2172
Rigesa 2	Oct-06	Gugelmin	Brazil	25º 54' S	50º 37' W	790	2172
Sappi 1	Feb-07	Clan	S. Africa	26º 23' S	30º 24' E	746	1001
Sappi 2	May-07	Usustu	S. Africa	26º 29' S	30º 56' E	1381	1124

sources repectively averaged 31% and 12% more volume at 5 years than the mean of the 7 sources. In our opinion, the most likely explanation for this observation is that both the Argentinian sources had a substantial component of *P. taeda* from Florida provenances (APSA ≈ 100%, BDP ≈ 25%), while the other sources were composed mostly of material originally from Atlantic Coastal plain provenances. The Florida loblolly provenances exhibit very fast growth in the southern US. It appears that this fast-growth is consistent across the southern hemisphere as well.

At the family within source level, mean r_B(fam(source)) = 0.65, a moderate level of GxE. Using the model which combines source and family (or alternately, uses only family and ignores source), mean r_B(source-fam) = 0.87, a relatively low level of GxE. For both of the Type B correlation parameters, there were some sites that showed more GxE (or lower correlations) than the average. For example, KSC2 was clearly the most "unusual" site in that it had the lowest correlations with other sites. Across all pairs of trials that included KSC2, the mean r_B(source-fam) was 0.52, compared to 0.87 across all pairs of tests. Similarly for test SAP2, mean r_B(source-fam) was 0.78, compared to 0.87 across all pairs of tests.

Patterns of GxE

A set of 19 climatic variables for each of the 15 sites was obtained from the BIOCLIM database. The variables deal with temperature and precipitation, comparing means, minimums and maximums on monthly and quarterly bases. These variables were used in two different approaches to try to discern patterns of GxE.

First, SAS Proc Cluster was used to group the 15 tests into clusters based on the on the Type B genetic correlations (Figure 2). Tests that were assigned to the same cluster had higher correlations (less GxE) than with tests from different clusters. Next, stepwise discriminant analysis was used to try to identify BIOCLIM variables that could assign tests to the proper clusters. This approach identified a set of five variables (BIO9 = Mean Temperature of Driest Quarter, BIO13 = Precipitation of the Wettest Month, BIO16 = Precipitation of the Wettest Quarter, BIO15 = Precipitation Seasonality (CV), and BIO3 = Isothermality) which properly assigned 14 of the 15 trials.

A second approach used stepwise regression analysis to identify variables which could directly predict the 105 Type B correlation estimates in the data set. The independent variables associated with the Type B correlation for a particular pair of tests X and Y were the absolute values of the differences of the 19 BIOCLIM variables for that pair of tests. This approach identified nine variables that could predict the Type B correlations reasonably well (R^2 = 0.53). The six variables which seem most useful are BIO1 = Annual Mean Temperature, BIO8 = Mean Temperature of the Warmest Quarter, BIO12 = Annual Precipitation, BIO14 = Precipitation of the Driest Month, BIO15 = Precipitation Seasonality, and BIO19 = Precipitation of the Coldest Quarter.

Summary and Conclusions

Further analyses to examine patterns of GxE will be done in early 2013, and data for important soil characteristics will be added to the climatic data. Some refinement of these models will be possible, and we will be able to classify potential *P. taeda* sites in the southern hemisphere with some accuracy. Nevertheless, one of the primary conclusions from this study is that GxE in *P. taeda* in the southern hemisphere is rather low. This is very good news for *P. taeda* breeders in Brazil, Argentina and Uruguay, as it means there is opportunity for exchange of genetic material across geographic regions, joint testing and breeding programs, and perhaps region-wide clonal testing.

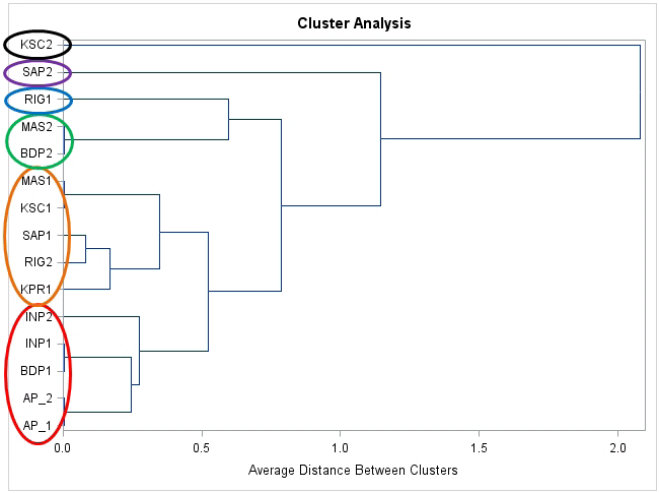


Figure 2. Cluster analysis of 15 sites in the *P. taeda* GxE study based on Type B genetic correlation estimates among all pairs of sites.

Progress in *Eucalyptus* Breeding and Testing

Roughly 2/3 of the Camcore membership plants some species of eucalypts, and collectively they manage 1.2 million ha of eucalypt plantations. Camcore has been working hard over the past 15 years to expand its portfolio of eucalypt genetic resources, as we wish to make a significant contribution toward our members' *Eucalyptus* breeding efforts. From 1996 to 2003, we worked with member organization P.T. Sumalindo Lestari Jaya to collect *E. urophylla* in all seven island where it occurs in Indonesia. Currently Camcore has the world's largest genetic base of *E. urophylla,* with over 1100 families and 180 tests established in the field. In recent years, we have expanded our eucalypt work into a number of areas:

Camcore has made a strategic decision to acquire seedlots of a large number of *Eucalpytus* (and *Corymbia)* species...

... to ensure that every Camcore member has access to genetic resources of these important commercial species at any time in the future.

- We completed provenance/progeny collections of *E. dorrigoensis* and *E. pellita.*
- We collaborated with CSIRO to establish numerous field trials of "obscure" eucalypt species on cold and droughty sites.
- We acquired seedlots of a number of putatively drought-hardy species for testing across a wide range of sites.
- We coordinated a series of Benchmark field trials with commercial populations of important temperate and tropical eucalypts,
- Finally, in 2012, Camcore acquired genetic resources of 14 commercial species to ensure that all members will have access to these different species.

E. dorrigoensis and *E. pellita*

In 2010, Camcore collaborated with CSIRO Australia to obtain 40 open-pollinated families of *E. dorrigoensis* from four provenances with the objective of expanding the genetic base of this important cool temperate eucalypt species for members in Chile, southern Brazil, Uruguay and South Africa. The species has very good growth and very good cold tolerance, and is closely related to *E. benthamii,* another species which has demonstrated very good growth in cool temperate climates. As of the end of 2012, *E. dorrigoensis* seed was sent to 10 members, and a total of 13 field trials were planted in 2011 and 2012.

In 2009, Camcore worked again with P.T. Sumalindo Lestari Jaya to collect 99 open-pollinated families of *E. pellita* from 6 provenances in Papua Indonesia. This species is fast-growing, produces high-density wood, and appears to be generally disease and pest resistant. As of the end of 2012, seed was sent to 13 members, and a total of 14 field trials were established in 2011 and 2012. We hope for another 9 trials to be planted in the first half of 2013.

Gert van den Berg of Mondi with a 7-month-old *E. pellita* in the Camcore provenance / progeny trial.

Species Trials

Camcore has collaborated with CSIRO Australia to test an array of "obscure" eucalypt species with the idea to try to identify species with cold hardiness and drought resistance. These have gone out in two series of trials, a temperate series with 10 species, and a subtropical / tropical series with 11 species (Table 2). In addition, Camcore acquired genetic material of six species that are thought to be very drought tolerant (Table 2), which has gone out in a third series of trials. To date, a total of 49 tests (18 temperate, 24 subtropical, and 7 drought-hardy) from these three series have been sent out to members, and a total of 34 tests (15 temperate, 16 subtropical, and 3 drought-hardy) were planted in the field in 2011 and 2012. Although these trials are still very young, we have already seen some encouraging results. In the APSA trials in Misiones, Argentina, *E. occidentalis, Corymbia maculata, E. benthamii, E. badjensis,* and *E. cladocalyx* from the temperate species trial are growing very well.

Benchmark Trials

Camcore has a temperate and sub-tropical series of Benchmark trials, which have the objective of comparing an array of improved seedlots of commercial species on sites around the world. The genetic entries in all of these trials that are serving as "benchmarks" are genetically improved bulk seedlots, mostly from our members in South Africa. For the temperate series, the entries are improved material of *Eucalyptus nitens, E. smithii, E. macarthurii, E. dunnii,* and *E. benthamii* from Sappi and *E. saligna* from Merensky. For the tropical series, there are 17 entries from 9 species or hybrids from 9 different organizations (Table 3). Each company in Africa and South America that establishes one or more of these trials will also include its own material of various species to compare with the benchmark seedlots. To date, 25 of these Benchmark trials have been sent to members, and a total of 18 tests were planted in 2011 and 2012.

Table 2. Species of *Corymbia* and *Eucalyptus* included in the Camcore species trials. There are three different series of trials: a temperate series, a subtropical series, and a drought tolerant series.

Temperate	SubTropical	Drought Tolerant
E. argophloia	*E. badjensis*	*E. cladocalyx*
E. benthamii	*E. benthamii*	*E. diversicolor*
E. crebra	*E. cladocalyx*	*E. gomphocephala*
E. drepanophylla	*E. dunnii*	*E. marginata*
E. longirostrata	*E. microcarpa*	*E. wandoo*
E. major	*E. occidentalis*	*C. calophylla*
E. molucana	*E. sideroxylon*	
E. raveretiana	*E. tricarpa*	
E. siderophloia	*E. globulus* ssp. *bicostata*	
E. thozetiana		
C. citriodora ssp. *variegata*	*C. maculata*	

Table 3. Species and sources to be included in the Tropical *Eucalyptus* Benchmark trial series.

Species	Country	Source
E. longirostrata	South Africa	Sappi
Corymbia henryi	South Africa	Mondi
E. brassiana	Indonesia	Sumalindo
E. camaldulensis	East Africa	East Africa
E. grandis	Brazil	IPEF
E. grandis	Colombia	SKCC
E. grandis	East Africa	East Africa
E. grandis	Mozambique	Chikweti
E. grandis	South Africa	Merensky
E. pellita	Colombia	Refocosta
E. pellita	South Africa	Sappi
E. urophylla	Brazil	IPEF
E. urophylla	Colombia	SKCC
E. urophylla	Venezuela	SKCV
E. urophylla x E. grandis	Venezuela	SKCV
E. urophylla x E. grandis	Brazil	IPEF
E. grandis x E. camaldulensis	Brazil	IPEF

Acquisitions of Commercial Species

Although some Camcore members have been working with eucalypts for many years, other organizations have only recently begun to plant and breed eucalypts. In addition, there is an increasing interest around the world in the potential of hybrid eucalpyts, with organizations thinking about trying to incorporate complementary traits (e.g., cold or drought tolerance, disease resistance, or wood properties) into their current commercial species. Camcore has made a strategic decision to acquire genetic material of a large number of *Eucalpytus* (and *Corymbia)* species (Table 4). Some of these species are currently-important commercial species *(E. grandis, E. globulus,* or *E. nitens)*, some have potential as commercial species (such as *E. benthamii* and *E. longiostrata)*, and some are species which are known to be useful as hybrid partners (such as *E. pellita)*. Of course, for a given organization, a species might fit into different categories, depending on climate and product objective. What is important is that these collections are Camcore genetic material; in other words, every Camcore member has access to at least some genetic resources of this broad array of *Eucalyptus* and *Corymbia* species. As we work together to test this material and establish breeding orchards, Camcore members will be well-positioned to respond rapidly to changes in the climate or the economy in the future.

Pablo Fontes of Montes del Plata in a block of one-year-old *Eucalyptus badjensis* in a Camcore trial in Uruguay.

Table 4. Summary of *Eucalcyptus* and *Corymbia* seed aquisitions by Camcore in 2012.

Species	Climate	Origin	Level of Improvement	Complementary Traits
E. urophylla	Tropical	Indonesia	2nd generation	Good hybrid partner
E. pellita	Tropical	Indonesia	unimproved	Disease resistance
E. brassiana	Tropical	Australia	unimproved	Drought tolerance
E. camaldulensis	Tropical	Australia	unimproved	Drought tolerance
E. grandis	Subtropical	Various	unimproved to 3rd gen.	Good growth
E. dunnii	Subtropical	Australia	unimproved	Cold tolerance
E. longirostrata	Subtropical	Australia	unimproved	Drought tolerance
C. torelliana	Subtropical	Australia	unimproved	Rooting ability
C. citriodora	Subtropical	Brazil	Seed Stand	Drought tolerance
C. maculata	Subtropical	Brazil	Seed Stand	Drought tolerance
E. benthamii	Temperate	Brazil, Chile	Seed orchard, progeny trial	Cold tolerance
E. dorrigoensis	Temperate	Australia	unimproved	Cold tolerance
E. badjensis	Temperate	Australia	unimproved	Cold / Drought tolerance
E. globulus	Temperate	Australia	2nd generation orchard	Wood quality
E. nitens	Temperate	Australia	unimproved	Growth, Cold tolerance

Update: Cooperative Eucalypt Hybrid Breeding

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.

Currently the workplan calls for a total of 16 hybrids to be produced (Table 5). 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. We made good progress, and all the required pollens were shipped by the end of 2012. In 2013, we hope to complete all of the necessary crossing. We are already on the way: two of the crosses, *E. grandis x E. pellita*, and *E. urophylla x E. pellita* have been completed by Smurfit Kappa Cartón de Colombia.

Carlos Contardo Dunn of Arauco Bioforest demonstrates control pollination technique on very small *E. nitens* flowers. CMPC Forestal Mininco will make a *E. nitens x E. pellita* cross for the Camcore Hybrid Project.

Table 5. Status of planned crosses for the Camcore Eucalypt Hybrid Breeding Project.

Female	Male	Fem Crossing	Male Supplier	Status
grandis	*dunnii*	Mondi	Rigesa	pollen shipped
dunnii	*grandis x cam*	Rigesa	Weyco	pollen shipped
grandis	*pellita*	SKCC	SKCC	Cross Completed
grandis	*tereticornis*	Pizano	Pizano	in process
grandis	*saligna*	Weyco	Merensky	pollen shipped
grandis	*nitens*	KLF	CMPC	pollen shipped
grandis	*benthamii*	Merensky	Mondi	pollen shipped
grandis	*globulus*	Sappi	Arauco	pollen shipped
grandis	*smithii*	York	Sappi	pollen shipped
urophylla	*pellita*	SKCC	SKCC	Cross Completed
urophylla	*brassiana*	SKCV	Suzano	pollen shipped
pellita	*grandis*	Suzano	SKCC	pollen shipped
globulus	*grandis x cam*	Arauco	Weyco	pollen collected
dunnii	*urophylla*	MDP	KLF	pollen coll'n Jan 2013
nitens	*pellita*	CMPC	Sappi	pollen shipped
urophylla	*maidenii / globulus*	York / Merensky	MDP	in process

Jesús Espinoza (Camcore) and James Luckoff (Chikweti) beside a 2-year-old *P. tecunumanii* in a 2nd generation trial in Mozambique.

Sappi research staff in a Camcore *E. urophylla* trial in Zululand, South Africa. The group is standing next to a natural *E. urophylla x E. alba* hybrid.

Nhora Isaza and other members of the Smurfit Kappa Cartón de Colombia research staff. The tree in the foreground is a propagule of *P. maximinoi* produced by airlayering. This approach is useful to avoid the problem of graft incompatibility with this species (e.g., see the yellow dying tree in the background).

Eloy Sanchez (Uumbal) in an agroforestry planting of *P. elliottii*, coffee, and an overstory crop, in Puebla, Mexico.

Andy Whittier (Camcore) collects seed cones from the Atlantic White Cedar population at Jones Lake, North Carolina, USA.

Left: Nico Olivier of Komatiland Forests in a 9-year-old stand of *P. patula x P. tecunumanii* hybrid.
Above: Kitt Payn of Mondi and Gary Hodge of Camcore inspect hedges for the third series of the Camcore pine hybrid project.

Bill Dvorak (Camcore) compares leaf morphology of *E. pellita* from Indonesia (top) and a South African landrace (bottom).

The Camcore Teak provenance trial established by Argos Cementos at Carmen de Bolivar, Colombia.

Monica Heberling (Montes del Plata, Uruguay) in a one-year-old trial of eucalypts (on the left is *E. benthamii*, on the right is *E. dunnii*).

Jesús Espinoza (Camcore) and the Smurfit Kappa Cartón de Venezuela research team check seedlings of 2nd generation *P. caribaea* at the new nursery in Sarare, Venezuela.

Teak and *Gmelina* Update

In 2012, Proteak in Mexico provided seeds of teak from six different provenances in India to Camcore. These seeds, together with seeds received from Argos in Colombia and the University of Chittagong in Bangladesh, have been divided into lots for trials that are ready to be shipped (pending import permits) to Argos, Proteak, and East Africa in Tanzania for the establishment of at least six progeny trials. In 2012, Camcore sent seeds of teak to MozCarbon in Mozambique for the establishment of two Camcore progeny trials in 2013. MozCarbon also will contribute seeds from 20 more trees in Mozambique to the program.

So far, five teak trials have been planted by current Camcore members in Colombia, Guatemala and Mozambique. The field tests in Guatemala are 2.3 years old and the trees are beginning compete with one another. One measurement will be made in 2013, and a genetic thinning will take place after this measurement.

The use of hormones to promote flowering in teak continues to be an important topic for Camcore. A study is being done in a commercial plantation in Mexico to count the number of flowers per tree after the application of paclobutrazol. Counts are being done monthly. No significant differences among treatments have been found yet, but observations will continue for one more year. A second study on flowering promotion in grafts grown in a greenhouse will be established in Guatemala in 2013. The objective of this test will be to determine the optimal month of hormone application for flower induction. For the study, teak scions were collected from adult clones and grafted onto rootstocks using the patch method. Survival of the grafts has been 70% , and hormone applications will begin in the first half of 2013 when the grafts develop large crowns.

In December 2012, a trial was established by Argos on land on the Atlantic coast of Colombia to study the sprouting response to girdling treatments in different seasons and at different stem heights. The purpose of this test is to learn the capacity of sprout production, and the rooting percentage and growth in the field of rooted cuttings under several treatments. Evaluations will begin in February 2013.

Elmer Gutiérrez (Camcore) showing a succesful patch graft of teak. Using this approach, survival of 70% has been achieved in teak grafts produced in Guatemala for a flowering promotion study.

Other research includes the development of a non-destructive method to assess heartwood proportion in teak trees. The field work for this study will be done in February 2013. Three tools will be tested: the hand-held microPhazir NIR, the TreeSonic and the Resistograph. The objective is to determine whether it is possible to assess heartwood proportion in standing trees in order to use this trait as a selection criterion at an early age.

Results of the teak genetic diversity study conducted at the University of Copenhagen in Denmark, in which Camcore is participating, are under review and a formal presentation will be made at the Teak Conference in Thailand in March 2013 by Ole Kim Hanssen.

Pizano received genetic material of *Gmelina arborea* originally from China, but donated from Camcore trials in Venezuela. The materal will be planted in tests in Zambrano, Colombia. Pizano is also involved in developing a Conservation Park for *Gmelina* to protect the original material obtained from Southeast Asia. The goal is to hold the genetic material in a protected area so that if new diseases or problems develop with the current *Gmelina* population, the company has a genetic reserve of new *Gmelina* genes. The first part of the park was planted during the regional meeting held in Zambrano in May 2012. Pizano will follow the Camcore protocols for the establishment of the park that will include material from India, Myanmar, Thailand and China.

2012 Seed Collections in Central America

In 2012, Camcore made pine seed collections in three natural stands in Central America, two in Honduras and one in Nicaragua (Table 6). Our seed collection efforts focus on populations that are poorly represented in the Camcore members' trials and conservation banks, and also in seed storage in Raleigh. In some of the natural stands, where we made seed collections in Central America, the trees are competing with cattle and agricultural crops which, together with fires and insect attacks, are contribute to decrease the life-expectancy of the forest. The *Pinus caribaea* stands in Limón, Honduras, for example, are classified as an endangered population because chances are that they will decrease in area by 50% in the next 10 years. On the other hand, the *P. tecunumanii* stands in Yucul, Nicaragua are considered as low-risk populations because the natural forest has been declared a genetic reserve, where only minimal harvesting activity will take place, supervised by the National Institute of Forest (INAFOR). In our Camcore collections, the best phenotypes are selected and the seeds are sent to Camcore members in different countries where they are used for the establishment of additional progeny tests and *ex situ* conservation banks. Seed collections were not possible in some of the areas that were scheduled for 2012, because of the lack of cone production and difficulties with access due to community issues. In sites like Chiul and San Miguel in Guatemala where access was not possible, *P. tecunumanii* seeds are scheduled for collection in 2013.

Table 6. Summary of seed collections completed in Central America and Mexico in 2012.

Country	Species	Provenance	Conservation Status	Latitude	Longitude	Trees
Honduras	*P. caribaea*	Limón	Endangered	15° 51' N	85° 23' W	20
Honduras	*P. tecunumanii*	San Esteban	Endangered	15° 17' N	85° 40' W	16
Nicaragua	*P. tecunumanii*	Yucul	Low Risk	12° 55' N	85° 44' W	20

Flowering in Pine Hybrids

In 2011, we visited a 4-year-old Merensky 2nd generation *P. tecunumanii* trial at Weza, South Africa. The trees in the test that looked like natural *P. tecunumanii x P. patula* hybrids were flowering in late October, and the trees that looked like "pure" *P. tecunumanii* were not. André van der Hoef, Cape Pine, observed in a different Camcore 2nd generation test established at Kruisfontein that natural hybrids *(P. tecunumanii x P. patula)* were flowering in late August and the pure HE *P. tecunumanii* was generally not, nor were trees in the LE *P. tecunumanii.* Weza and Kruisfontein are located at 30° and 34° S latitude, respectively.

Heavy flowering on a natural *P. tecunumanii x P. patula* hybrid in a 5-year-old trial at Kruisfontein (photo by Andre van der Hoef, Cape Pine).

Similarly, André Nel, Sappi (South Africa), observed some natural *P. jaliscana x P. oocarpa* hybrids in a *P. jaliscana* progeny trial (see *P. jaliscana* article on the next page). The hybrids were producing flowers (in late April / May), while the pure *P. jaliscana* generally were not.

We still need more observations to determine if the flowing times of pine hybrids shy towards one parent, or are generally intermediate between both pure species.

Gene Exchange between *P. jaliscana* and *P. oocarpa*

In the 2011 Camcore Annual Report, we presented preliminary results of a study to determine if there was *P. oocarpa* introgression in natural stands of *P. jaliscana* in western Mexico. A number of putative hybrid trees were observed in a Sappi Camcore OP progeny trial at De Rust, South Africa that were thought to be *P. jaliscana x P. oocarpa.* We used botanical analysis to verify hybridity in the progeny test, confirmed that near infrared spectroscopy (NIRS) could distinguish differences between "pure" and "hybrid" trees (Figure 3), and then developed models using NIRS to scan a larger subsample of trees in the trial to estimate provenance and species-wide introgression rates. The final results are summarized here:

1. Only low levels of natural introgression (1.2%) occur between the two species in natural stands in Mexico based on botanical samples collected in native populations.
2. NIRS analysis gave a more conservative estimate of the degree of hybridity in the verification population than did subjective grading of the crowns in the field. Introgression rate as determined by quick visual assessment of a subsamples of 260 trees in *P. jaliscana* trial in South Africa was 7.7%, versus 2.3% using estimates from the NIRS models.
3. In the progeny trial, 88% of the hybrid trees were producing male pollen cones in April versus only 30% for the pure *P. jaliscana* at 10 years of age. The general trend is that the hybrids produce male catkins earlier than the pure species in this exotic environment. More precocious flowering in hybrid trees than in pure species has also been found for other pines native to Middle America (see box on previous page).
4. We also noted that the 24 *P. jaliscana* parents from natural stands in Jalisco that produced the 37 hybrids in the progeny test had significantly higher numbers of resin canals in the internal and medial position and a lower number in the external position than did parent trees that did not contribute hybrid progeny.

The NIRS approach appears to have much value in providing a quick and inexpensive way to obtain a reasonable estimate of species admixture in cases when samples from field progeny trials include only one of the pure species and putative hybrids. We want to thank André Nel and the Sappi Research team for making multiple trips to the De Rust trial to score hybridity and to collect needle samples. Results of the study will be published in Forest Ecology & Management in 2013.

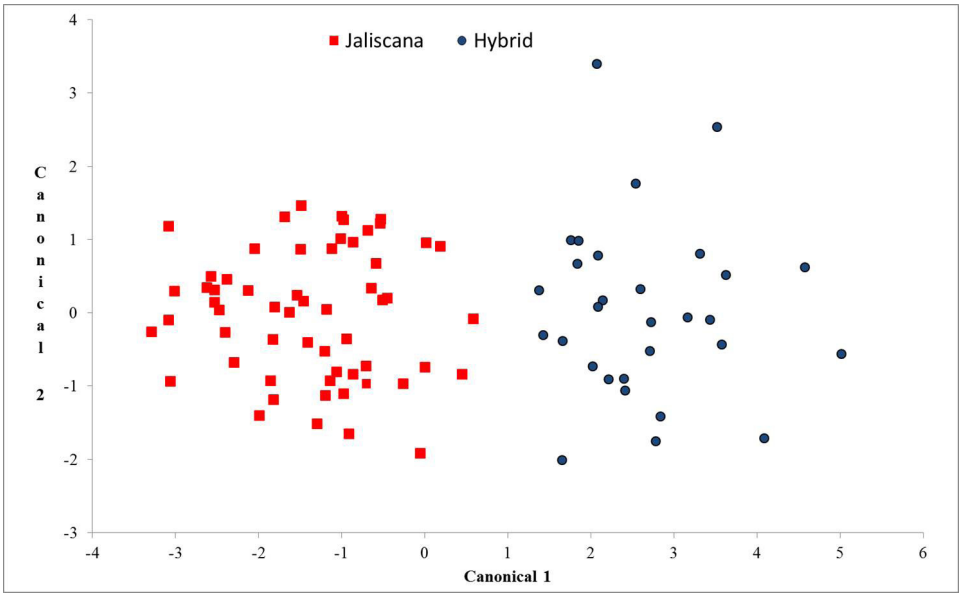


Figure 3. Separation of *P. jaliscana* and *P. jaliscana x P. oocarpa* hybrids with canonical multivariate analysis using NIRS spectral results.

Responses of *Pinus tecunumanii* populations across climatic gradients

Camcore's *Pinus tecunumanii* trial network has produced data that has allowed members to identify superior populations and individuals within these populations for the development of seed production orchards and subsequent establishment of forests with increased productivity. These field trials of replicated progeny within provenance trials have primarily been established in three regions, and breeding values for individuals within these three regions have been used to identify material that is broadly adapted to these regions. These trials have been established across environmental gradients, which provided an opportunity to evaluate methodologies developed by CSIRO's Climate Adaptation Flagship designed to quantify how populations respond to changes in climatic variables in addition to identifying populations with different patterns of adaptation. A clear interpretation of changes in populations' performance along these climatic gradients can help with immediate deployment decisions as well as longer-term decisions about where plantation estates may be expanded or where consideration should be given to the use of alternative species. An alternative analysis methodology was developed to provide this information using the data from the PTEC trial network.

A selection of well-tested populations from the Camcore trial network of *P. tecunumannii* was analyzed so that patterns of genotypic response to changes in environmental variables (genotype by environment interactions) could be visualised. The analysis was based upon clustering and ordination of correlation coefficients generated using simple linear regressions of genetic values on environmental values. Genetic values (deviations in a populations' volume production relative to all populations evaluated in each trial) were regressed against 20 climatic variables from the United Nations' Bioclim database, which is commonly used to classify environments and model species distributions. These regression coefficients were interpreted as a population's response to higher or lower levels of each environmental variable. For example, populations like Chanal and Villa Santa were relatively productive when precipitation was low and relatively unproductive when precipitation was high so that a negative correlation between genetic values and precipitation would be found. Alternatively, the Juquila population had large genetic values in trials where precipitation is high, and low genetic values when precipitation is low, and therefore had a positive correlation of genetic values and precipitation. Juquila is an interesting population, in that it was originally classified and tested as *P. tecunumanii*, but later molecular marker work confirmed that it is more closely related to *P. herrerae.*

The two-way table of correlations, which indicate positive or negative changes in genetic value across environmental gradients, were then used for subsequent analysis. Cluster analyses were first used to aggregate and separate the various populations studied in terms of their response to climatic variables. In addition, climatic variables were classified in terms of their ability to elicit responses in the selected PTEC populations. These clusters were subsequently summarised within a single principal components based biplot

The biplot presented in Figure 4 ordinates all populations and climatic variables to highlight various aspects of the populations and climatic variables: similarities in population responses to climatic variables, similarities in climatic variables impact on population performance, how reactive populations are relative to one another and the importance of each climatic variable in eliciting responses in each population. Interpretations of the influence of climatic variable on the relative productivity of PTEC populations should be visually apparent in the biplot as it spatially represents similarities in climatic variables and population responses to these climatic variables. For example, the climatic variables associated with precipitation were tightly clustered to the left of the biplot indicating they have similar effects on the populations' performance. Conversely, the Mountain Pine Ridge population is spatially separated or relatively isolated from other populations indicating MPR is distinct in its response to the environmen-

tal variables. As well as displaying similarities or differences in populations or environmental variables, the location of populations with respect to the environmental variables provides an indication of how these two factors are related. As mentioned above, the Juquila population performed relatively well in trials that experienced high precipitation and relatively poorly in trials established in areas that experience low rainfall. Further information can be gained by inspecting the distance of populations or climatic variables from the origin with relatively responsive populations positioned far from the origin and relatively unresponsive populations such as San Esteban located near the origin.

The principal strength of presenting genotype by environment interactions as they are displayed Figure 4 is the abstraction of individual trial information to the underlying climatic variables that lead to changes in performance. However, this methodology does not provide any information about the genetic value of the populations evaluated and this information must be retrieved from genetic analyses focused on breeding value predictions. Nevertheless, a greater understanding of the suitability of genetic material for certain environments may be provided when predictions of genetic value are combined with an understanding of genotypes' responses to environmental variables. This combination of genetic analyses would be particularly useful in distinct environments where no field trials are available, as well as for the development of different breeds with adaptive patterns tailored to distinct environments or for future climates. Subsequent to final publication of this work, further analyses of alternative Camcore species, as well as among-species comparisons, are planned.

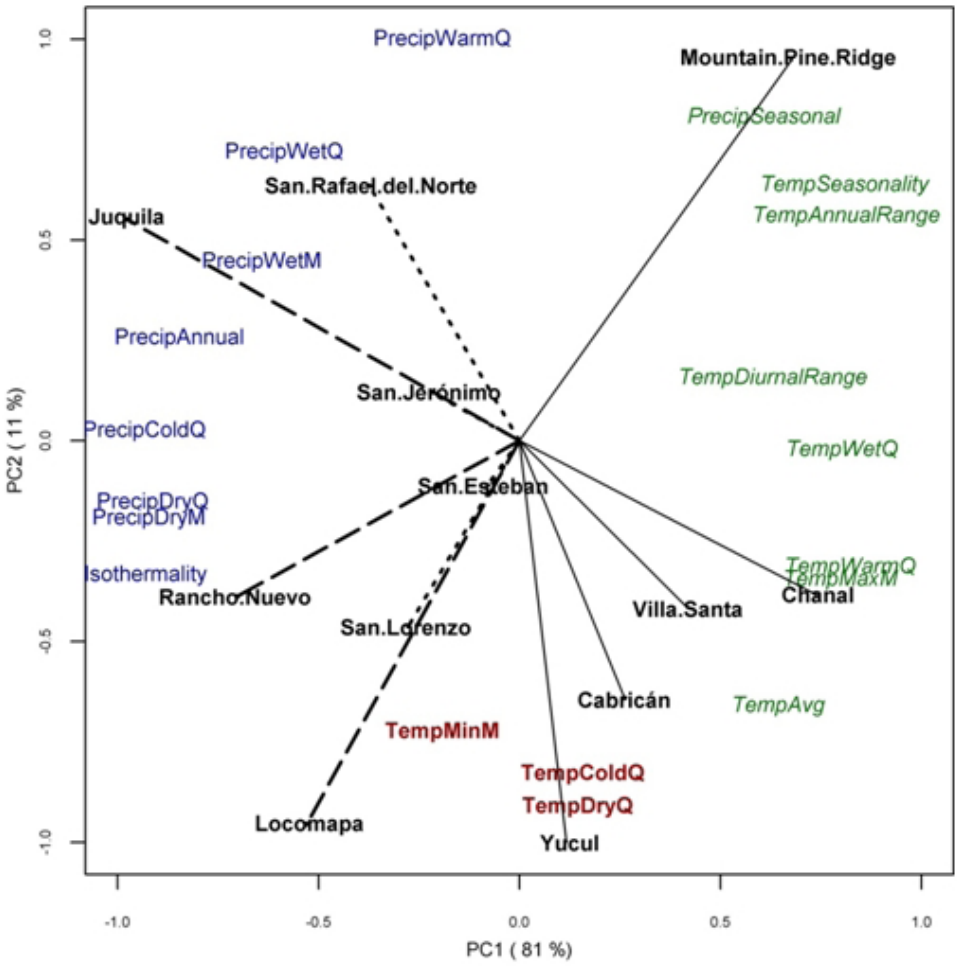


Figure 4. Principal component based ordination of changes in productivity across environmental gradients experienced by 12 well tested *Pinus tecunumanii* populations evaluated in the Camcore trial network.

Conservation of Hemlock Species Native to the USA

In 2012, Camcore continued its collaboration with the USDA Forest Service (USFS) Forest Health Protection on hemlock *(Tsuga)* genetic resource conservation in the eastern United States. This project involves two ecologically important species, Eastern hemlock *(T. canadensis)* and Carolina hemlock *(T. caroliniana)*. Both species face a significant threat from the invasive insect pest hemlock woolly adelgid (HWA, *Adelges tsugae*) which has caused widespread decline and mortality in natural stands of both species. Camcore and the USFS began this project in 2003 and over the last 10 years has succeeded in securing seed from 407 families across 59 populations of Eastern hemlock and 134 families across 19 populations of Carolina hemlock. Hemlock conservation banks have been successfully established in Brazil (Rigesa), Chile (Arauco-Bioforest), and the US (Camcore), and seedlings are currently being cultivated for conservation plantings in the Ozark Mountains of Arkansas (Weyerhaeuser). This work has been accomplished with $757,704 in funding awarded to Camcore in a series of four grants from the USFS. James "Rusty" Rhea, Forest Entomologist with Forest Health Protection, has been instrumental in ensuring the continued funding of this effort.

After a very successful seed collection in 2011, hemlock seed crops were low across the range in 2012 and little progress was made by Camcore and our federal and state cooperators. We were fortunate, however, to be contacted by Russell Fulcher, a Boy Scout from Tennessee who was conducting eastern hemlock seed collections on the Cumberland Plateau for his Eagle Scout project. Andy Whittier, Camcore Research Forester, worked with Russell, providing advice on field protocols and helping with some of the field work. Russell and his father Bob visited Camcore in December 2012 to work with Andy on seed processing and were kind enough to donate a portion of their seed to Camcore. This donation yielded seed from an additional 32 families and 3 populations of Eastern hemlock for the Camcore/USFS hemlock seed stocks. In addition to seeds donated to Camcore, Russell will be submitting seeds to the Seeding the Cumberlands Project and the Kew Millennium Bank for long-term preservation.

We also made progress on hemlock-related research projects in 2012. M.S. Graduate Research Assistant Zaidee Powers completed data collection for her project studying mass artificial infestation techniques in hemlock. The protocols she is developing will be important for screening large numbers of hemlock genotypes for resistance/susceptibility to HWA as part of future breeding and restoration programs. Zaidee plans to complete her research and have her final degree defense in the fall. This project has been conducted in cooperation with USFS Research Entomologist Dr. Albert E. "Bud" Mayfield and was funded by a $45,040 grant to Camcore from the USFS.

Camcore welcomed new M.S. Graduate Research Assistant Lia Campbell in the fall of 2012. Lia will be studying population genetic structure and diversity in Carolina hemlock using microsatellite molecular markers with $83,316 in funding, also from the USFS. This project is being conducted in cooperation with USFS Research Geneticist Dr. Dana Nelson and the Southern Institute of Forest Genetics in Saucier, MS.

We also reported on the progress of the hemlock project at professional meetings and workshops in 2012. Robert Jetton gave invited presentations and posters at the Entomological Society of America Annual Meeting, the Southern Forest Insect Work Conference, the Virginia Tech Department of Forest Resources and Environmental Conservation, and the NCSU Department of Forestry and Environmental Resources. Zaidee Powers discussed the progress of her project in oral presentations and posters at the Southern Forest Insect Work Conference and the Southern Appalachian Forest Entomology and Pathology Seminar.

Finally, we are pleased to announce that in late 2012, Camcore received a new two-year $156,492 grant from the USFS to continue work on this conservation effort through 2014. While continued population explorations and seed collections will be a part of our work, the primary focus of this new grant is the establishment of additional hemlock conservation banks, both inside and outside of the US. We look forward to continuing our work on this project with our USFS partners and Camcore members.

Conservation of Atlantic White Cedar

Camcore began work on a new US based gene conservation program in 2012 focused on Atlantic White Cedar (AWC, *Chamaecyparis thyoides)*. Following successful conservation efforts with the Hemlocks and Table Mountain Pine, this new project marks the fourth domestic genetic resource conservation program in which Camcore has partnered with the USDA Forest Service (USFS). As with the previous projects, this new program is being carried out with grant funding in the amount of $249,240 provided to Camcore by the USFS, and with our primary USFS collaborators Don Duerr (Forest Health Protection) and Barbara Crane (Southern Regional Geneticist).

AWC is a cypress species (family Cupressaceae) endemic to the freshwater swamps and bogs of the Atlantic coast of the eastern US. Historically it occupied more than 200,000 ha, growing in a narrow coastal belt 80 to 210 km wide that extended from southern Maine to northern Florida and west to southern Mississippi (Figure 5). In areas where it was most abundant, such as eastern North Carolina, southeastern New Jersey, and the western Florida panhandle, AWC was an important commercial species where it was harvested for its light-weight decay-resistant wood. Annual harvests yielded up to 19 million board feet sold for a variety of uses including house siding, fencing, decking, lawn furniture, boat planking, and small specialty products such as roofing shingles and duck decoys.

AWC swamps and bogs are also of great ecological significance, particularly with respect to their role in hydrological processes. Cedar swamps stabilize stream flows, store flood waters, help to mitigate the effects of drought, and filter and purify water as it flows through them. They are also home to a great diversity of plant, mammal, amphibian, and bird species, many of them rare and/or threatened and some that are obligates to AWC habitats. Unfortunately, AWC is now restricted to less than 40,000 ha of its original distribution, and with growing public awareness of the importance of these unique wetland ecosystems, efforts to regenerate or restore cedar swamps have increased in the last 20 years. The primary cause of this reduction was the draining of wetlands for agriculture and timber harvesting. Subsequent regeneration has been hampered by altered hydrologic regimes and severe wildfires. Given AWC's decline, patchiness across its distribution, exacting site requirements, and ecological and economic importance, the species is a good candidate for seed collection and genetic resource conservation efforts to support ongoing restoration efforts.

The specific objectives of this project are to (1) identify seed zones for the species using existing population data and the FloraMap™ climatic model, (2) secure seeds from 400 mother trees in 40 remnant populations distributed across the historical range of the species, and (3) retain portions of the seed in repositories in Raleigh, NC (Camcore-NCSU) and Fort Collins, CO (USDA-ARS) for long-term preservation. Seed will also be used to establish seed orchards for conservation and reforestation. Since beginning work on the project

Table 7. Population information for Atlantic White Cedar seed cone collections conducted by Camcore in 2012.

Population Name	County	State	Latitude (Dm.m)	Longitude (Dm.m)	Elevation (m)	Mother Trees
Singletary Lake	Bladen	NC	34 35.185	-78 26.988	10	8
Jones Lake	Bladen	NC	34 41.055	-78 35.779	25	8
Catfish Lake	Craven	NC	34 56.659	-77 06.768	12	10
Cheraw State Park	Chesterfield	SC	34 38.456	-79 53.876	41	10
Alligator River	Dare	NC	35 46.782	-75 51.764	1	10
Pettigrew State Park	Tyrrell	NC	35 52.094	-76 20.892	11	5
Gravatt Center	Aiken	SC	33 44.324	-81 34.909	136	10
Kalmia Gardens	Darlington	SC	34 22.075	-80 06.787	56	1
Sandhills Gameland	Richmond	NC	35 02.116	-79 36.845	99	10
Great Dismal NC	Camden	NC	36 30.193	-76 29.225	5	5
Great Dismal VA	Suffolk	VA	36 42.086	-76 31.720	7	6

in early 2012 significant progress has been made. A list of project accomplishments to date follows:

- Utilizing the FloraMap™ climate model, Camcore identified four seed zones for AWC across its geographic range (Figure 5). Seeds collections in each seed zone will target 10 mother trees in each of 10 populations.
- Camcore explored 16 AWC populations in the southern Atlantic seed zone (Figure 6), to determine if the populations were suitable for the project and whether they were producing cone crops for collection during the fall of 2012.
- Camcore prepared a set of seed collection guidelines specifically for the AWC project.
- Camcore returned to 11 AWC populations and completed seed cone collections from a total of 83 mother trees (Figure 6, Table 7). Seed cones are currently being dried and prepared for seed extraction, cleaning, and cataloguing.

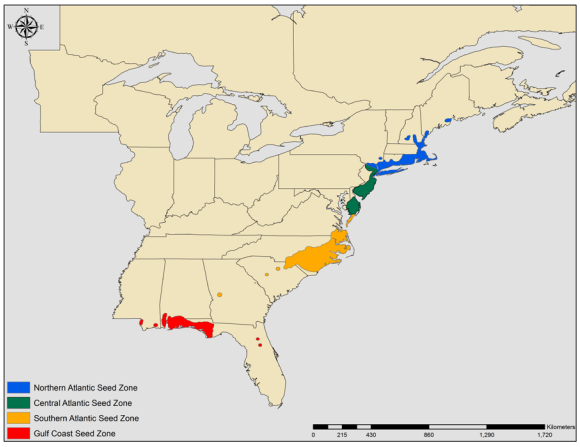


Figure 5. Atlantic White Cedar seed zones defined by the FloraMap™ climate model.

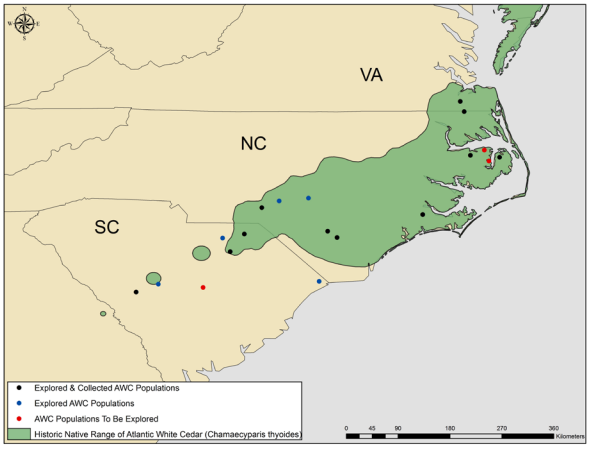


Figure 6. Atlantic White Cedar populations where explorations and/or seed collections were completed in 2012.

Conservation of Table Mountain Pine

For the last several years, Camcore has been working on a project with the USDA Forest Service (USFS) to conserve the genetic resources of Table Mountain pine (TMP, *Pinus pungens*) in the southern Appalachian Mountain region of the United States. This project was originally funded as a three-year $48,563 grant to Camcore. and in 2012, it was extended by one year with an additional $17,472 to be utilized for expanded seed collections and for researching TMP population genetic structure and diversity. Barbara Crane, USFS Southern Regional Geneticist, is Camcore's primary USFS collaborator on this project.

TMP is a member of the pine subsection Australes and its closest genetic relatives are *P. rigida, P. taeda,* and *P. serotina.* The species is sometimes used commercially for pulpwood, low-grade sawtimber, and firewood, but no references to selection and breeding for plantation silviculture are found in the literature. Its most valuable assets are the ecosystem services provided by natural stands such as food and shelter for wildlife and soil stabilization. Across its native range, spanning the Appalachian Mountains from central Pennsylvania south to northern Georgia, TMP is threatened by wildfire suppression activities and periodic outbreaks of the bark beetle *Dendroctonus frontalis.* As part of ongoing TMP restoration activities across the region, Camcore and the USFS are working together to collect representative seed samples for reforestation efforts, seed orchard establishment, and long-term seed preservation.

Since beginning work on the project in 2009 significant progress has been made. The list of project accomplishments includes:

- Seed collections from 214 mother trees in 31 populations (Table 8, Figure 7), and seed viability testing for collected seed lots at the provenance level.

- Placement of 250 seeds from each mother tree into long-term preservation at the USDA ARS National Center for Genetic Resources Preservation in Fort Collins, CO.
- Submission of 200,000 seeds to the USFS for seed orchard establishment and reforestation efforts. An additional 200,000 seeds are stored at Camcore-NCSU and will be used for the establishment of conservation seed orchards.

Plans for 2013, the final year of this project, include additional seed collections from under-represented areas (southwestern Virginia and Pennsylvania), and a population genetics study to be conducted in the second half of the year. Project Leader Robert Jetton will also make a presentation on this important conservation effort at the IUFRO Conference to be held February 2013 in Jacksonville, FL.

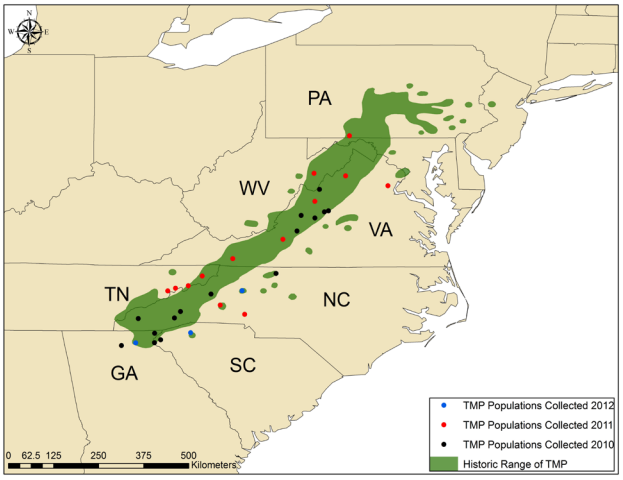


Figure 7. Locations of provenance seed collections of Table Mountain Pine made by Camcore 2010–2012.

Table 8. Provenance location for Table Mountain Pine seed collections made by Camcore 2010-2012.

Provenance Name	County	State	Elev. (m)	Latitude (DM.m)	Longitude (DM.m)	Year	Mother Trees	Germ. (%)
Briery Branch	Rockingham	VA	727	38 27.506	-79 10.703	2010	10	67
Hanging Rock	Stokes	NC	616	36 23.046	-80 16.403	2010	8	36
Walnut Fork	Rabun	GA	768	34 55.742	-83 17.453	2010	10	86
Poor Mountain	Oconee	SC	509	34 45.976	-83 08.615	2010	6	22
Pine Mountain SC	Oconee	SC	472	34 42.239	-83 18.010	2010	7	41
Looking Glass Rock	Transylvania	NC	1065	35 17.876	-82 47.254	2010	8	56
Bent Creek	Buncombe	NC	876	35 27.672	-82 38.837	2010	2	31
Table Rock Mtn NC	Burke	NC	551	35 52.988	-81 50.400	2010	10	56
North Mountain	Rockbridge	VA	944	37 49.547	-79 37.793	2010	10	58
Ravens Roost BRP	Augusta	VA	982	37 55.988	-78 57.160	2010	2	49
Bald Mountain BRP	Nelson	VA	1000	37 54.821	-79 04.392	2010	10	72
Buena Vista BRP	Rockbridge	VA	726	37 44.555	-79 18.109	2010	10	32
Iron Mine Hollow BRP	Botetourt	VA	703	37 24.502	-79 48.213	2010	3	49
Nolton Ridge	Graham	NC	1125	35 17.443	-83 41.799	2010	6	66
Camp Merrill	Lumpkin	GA	583	34 37.823	-84 07.217	2010	4	39
Greene Mountain	Greene	TN	766	36 01.460	-82 46.601	2011	10	53
Meadow Creek	Cocke	TN	843	35 58.285	-82 57.940	2011	7	70
Cliff Ridge	Unicoi	TN	709	36 06.044	-82 27.032	2011	9	63
Iron Mountain	Johnson	TN	743	36 19.858	-82 06.472	2011	5	33
Elliott Knob	Augusta	VA	1203	38 09.898	-79 18.368	2011	10	50
Snake Den Mountain	Smyth	VA	963	36 45.829	-81 18.964	2011	10	54
Edinburg Gap	Shenandoah	VA	525	38 47.369	-78 31.513	2011	1	
Quantico	Stafford	VA	76	38 32.803	-77 28.049	2011	3	18
Smoke Hole	Pendelton	WV	793	38 51.192	-78 18.470	2011	7	51
Poor Mountain VA	Roanoke	VA	652	37 14.255	-77 28.418	2011	10	66
Stone Mountain	Wilkes	NC	641	35 36.923	-81 38.157	2011	10	51
South Mountains	Burke	NC	671	35 23.635	-81 02.789	2011	10	59
Buchanan State Forest	Bedford	PA	432	39 46.179	-78 26.722	2011	6	56
Paris Mountain	Greenville	SC	478	34 56.613	-82 23.539	2012	4	53
Smithgall Woods	Habersham	GA	535	34 41.696	-82 45.746	2012	1	51
Rocky Face	Alexander	NC	538	35 58.345	-81 06.562	2012	5	24

Pine Hybrid Wood Properties

As part of his Ph.D. dissertation on "Economics of Pine Hybrids", Juan López is investigating the wood properties of a number of pine hybrids. He made very good progress on this work in 2012, finishing up lab work on micro-pulping and X-ray densitometry.

For the pulping study, chips of wood were obtained from the wood samples (wedges) taken from 13-year-old trees of three hybrids (*P. patula x P. tecunumanii, P. greggii x P. tecunumanii, P. taeda x P. tecunumanii)* and the pure parental species. Cooking conditions were set to produce pulp with a kappa number of 26 ± 1.5 for production of Bleached Softwood Kraft Pulp (BSKP). An H factor of 2100 was used for the cooking of the three hybrids Each variety was cooked three times and mean pulp yields were calculated. Results show that the pulp yield of a pine hybrid is intermediate between those of the two parent species. Values of pulp yield without rejects varied between 42.1% for *P. taeda* and 44.6% for *P. patula.* *Pinus taeda* had the highest lignin content (30%) as well as the second lowest cellulose content (40.2%) after the hybrid *P. taeda x P. tecunumanii* with 39.5% of cellulose. The highest pulp yield of the hybrids was 43.6% for *P. patula x P. tecunumanii,* and the lowest was 42.5% for *P. taeda x P. tecunumanii.* Bleached Kraft Market Pulp has been produced in the lab using the bleaching sequence ODPD and Brightness (ISO) values above 88 have been obtained for all varieties.

Preliminary results of X-ray densitometry measurements show that for some hybrids like *P. taeda x P. tecunumanii,* the percentage of latewood is greater in the hybrid than that in the pure species, making the wood density of the hybrid greater than the pure species (Figure 8). This would seem to be an advantage both for pulpwood or sawtimber production.

Market pulp handsheet properties, fiber analysis, and the economic assessment of pine hybrids is under evaluation and results will be presented at the end of 2013.

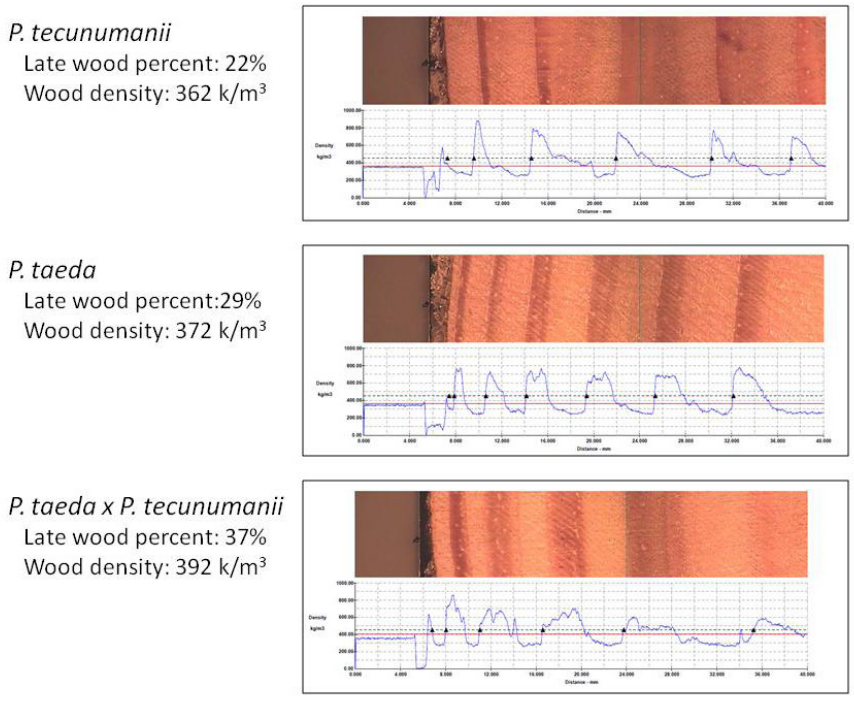


Figure 8. Wood density and late wood percentage for *P. tecunumanii, P. taeda* and the *P. taeda x P. tecunumanii* hybrid, based on X-ray densitometry analysis.

Measuring Growth Rhythms in *Pinus maximinoi*

Camcore members have established *Pinus maximinoi* trials from 14° to 34° S latitude in southern and eastern Africa. We have noticed that the species is producing some female and male strobili at an early age at both latitude extremes. We have begun a preliminary experiment to examine the growth dynamics of *P. maximinoi* across environments. Specifically, we hope to do the following:

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

A dendrometer band is simply a metal or plastic band that goes around a tree at breast height. The band is connected with a spring, and when the tree circumference expands, the spring allows the band to expand. Seven companies are involved in this project, and we will take bi-monthly measurements for a year. Our hypothesis is that *P. maximinoi* begins growth earlier and ends growth later than any of the commercial controls. We are unsure whether *P. maximinoi* sets a resting bud in all tropical climates, and if so, for how long. Growth patterns will be correlated to flowering patterns.

The dendrometer band placed around the tree is held tightly in place with the spring.

Pinus tecunumanii Breeding Populations Contaminated with *P. patula* Pollen

Camcore members are well along in the establishment of 2nd generation progeny trials of *Pinus tecunumanii.* In the Colombian highlands and in many areas of southern Africa, *P. tecunumanii* and *P. patula* flower at the same time. Because of these similar flowering patterns, many of our *P. tecunumanii* trials in these regions appear to contain some natural *P. tecunumanii x P. patula* hybrids. This contamination may cause problems if the percentage of natural hybrids is high. First, the natural hybrid is generally not as *Fusarium* resistant as pure *P. tecunumanii.* Second, estimation of breeding values becomes complex when some of the trees in a family are “pure” and others are “natural hybrids”. Third, in the future, when we make advanced-generation selections in the *P. tecunumanii* progeny tests, mating strategy will be difficult since some selections will be progeny of pure crosses *(P. tecunumanii x P. tecunumanii)*, and some will be from hybrid crosses *(P. tecunumanii x P. patula).*

Camcore has initiated a project to determine the severity of the problem. The specific objective is to quantify the degree of natural hybridity in 2nd generation *P. tecunumanii* breeding trials in Colombia and South Africa. It has three broad phases:

1. Develop markers to distinguish between *P. tecunumanii* and *P. patula* using 1st generation populations (progeny from wild stands). The genotyping part of the project is in collaboration with Dr. Zander Myburg at the University of Pretoria.
2. Develop NIRS models for *P. tecunumanii* and the *P. tecunumanii x patula* hybrid in 2nd generation trials. Needles will be collected from a small number of trees in both groups, (their identity confirmed by genotyping) and oven-dried needles will be used to develop an NIR model.
3. Use the NIR models to quantify the percentage of *P. tecunumanii x P. patula* hybrids present in entire trials of Camcore 2nd generation *P. tecunumanii* in Colombia and South Africa.

We believe the approach will provide some interesting information on pollen contamination in the breeding programs of *P. tecunumanii* as well as improve our knowledge on how to more effectively use NIRS to address pine hybridity questions.

Eucalyptus urophylla Wood Properties: Variation Among Islands and Provenances

In the 2011 Annual Report, we reported on preliminary results of a project to study variation in wood properties among *Eucalyptus urophylla* provenances. At that time, the project was about 2/3 complete. In 2012, we processed additional samples from Argentina, and did some additional work to look at wood chemical properties. The project is now complete and here we report final results.

Background

Camcore began collecting *E. urophylla* in 1996, and has made seed collections from 62 provenances and 1196 mother trees covering all seven island where the species occurs naturally. Camcore members have established a total of 187 field tests in Argentina, Brazil, Colombia, Venezuela, Mexico, South Africa, Mozambique and Tanzania. In 2010, Camcore initiated a project to study variation in wood properties among *E. urophylla* provenances.

Materials and Methods

Wood samples were taken in four distinct geographic regions: Argentina, Colombia, Venezuela, and South Africa. In each region, two to four provenance/progeny tests were sampled. A provenance was represented by at least 20 trees, from as many different families as possible. A total of 1743 trees from 46 provenances were sampled at breast height. Wood samples were also taken at various heights from 45 trees to study the relationship between breast-height and whole-tree wood properties.

Gravimetric density measurements were taken on 10% of all samples. Samples were then ground into woodmeal and scanned with near-infrared spectroscopy (NIR). An NIR prediction model was then built for density. The NIR density model and existing NIR models for pulp yield were then used to predict density and pulp yield for all samples. For pulp yield, three separate and independent models (developed for *E. urophylla, E. grandis,* and *E. nitens*) were each used to predict pulp yield. Each of the models was based on approximately 100 data points, and had an $R^2 \approx 0.67$ with and SECV ranging from ±0.84% to 2.20%.

In 2012, we developed NIR models to predict sugar (glucose, xylose, arabinose, galactose, and manose) and lignin composition (i.e., soluble and insoluble lignin, and syringyl/guaiacyl ratio (S/G)). A group of 50 samples was selected for wetlab chemical assessment. The selection criteria was to cover the full range of spectral variation, lignin and cellulose content, and also to represent all four sampling regions and a wide assortment of provenances. The wetlab chemical assessments were done by Shawn Mansfield at the University of British Columbia, Canada. NIR prediction models were developed and used to predict chemical components for all 1743 samples.

Results and Discussion

The NIR model for density had a reasonably good fit. For density, there were 349 data points with a mean of 590 kg/m^3, and a range of 442 to 713 kg/m^3. The NIR model had an $R^2 = 0.75$ with a standard error of cross-validation (SECV) of ±33 kg/m^3.

The predictions from the three pulp yield models were all highly correlated, with R ranging from 0.83 to 0.86. It seems that regardless of species, the NIR spectra are detecting similar chemical properties of the wood related to pulp yield.

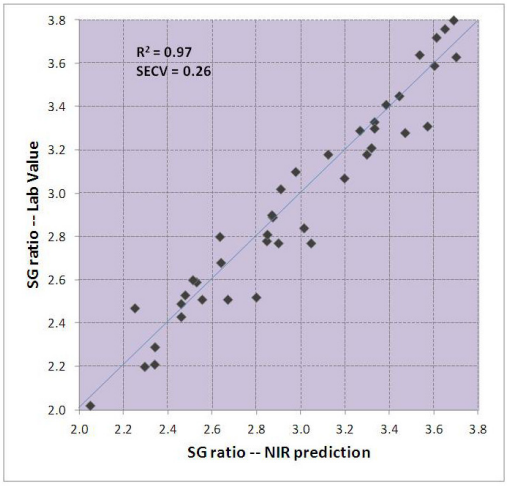


Figure 9. Comparison of laboratory measurement and NIR prediction of S/G ratio (syringyl / guaiacyl) in lignin of *E. urophylla*.

This gives us confidence that any of the predictive models, or some average of the three values, will give similar, and presumably reliable, rankings for pulp yield. For this analysis, we used the average prediction from all three models.

Very good NIR models were developed for all of the chemical traits assessed for the 50 samples, with R^2 values ranging from 0.81 to 0.98. The model for S/G ratio was particularly good, with $R^2 = 0.97$ (Figure 9). Syringyl lignin is much easier to cook and remove than guaiacyl lignin, so trees with high S/G ratios have higher pulp yields, higher rates of delignification, and lower chemical consumption. Thus, S/G ratio is potentially a very important trait for pulp producers.

For all traits, breast-height wood samples give a very good indication of whole-tree wood properties, with breast-height and whole-tree correlations ranging from R = 0.90 to 0.95.

NIR models were used to predict density and chemical wood property traits for all 1743 trees. Subsequently, provenance-level BLUPs were calculated.

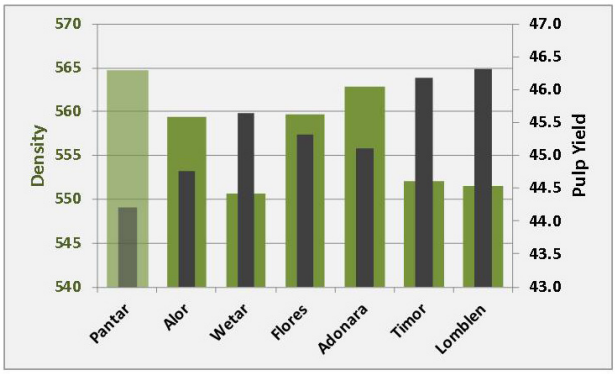
As was seen in the preliminary analyses which were reported in 2011, there was a strong negative relationship between density and pulp yield at the island level (Figure 10). Clearly, this is an unfavorable relationship, as pulp producers want both high density and high pulp yield. This unfavorable correlation between density and pulp yield was also found at the provenance level (R = -0.65). Based on these results, one might expect that much of the advantage in density of some provenances would be due more to an increase in lignin rather than cellulose. In fact, there was a positive relationship between density and lignin at the provenance level (R = 0.55). Again, this is unfavorable: higher density means higher lignin. Finally, another unfavorable relationship was observed, between lignin and S/G ratio. At both the island level (Figure 10), and the provenance level (R = -0.83), there was a tendency for higher insoluble lignin to be associated with low S/G ratios, i.e., higher levels of the less desirable guaiacyl lignin.

Summary

High-density *E. urophylla* wood will tend to be high in lignin, have higher amounts of "bad" lignin, and have lower pulp yields. This relationship holds at the island and provenance levels.

We cannot confirm that these unfavorable relationships will also apply at the family and clonal levels, but it seems like a strong possibility, and one that should be investigated further. in *E. urophylla*.

On a positive note, we now have some very good NIR models which can be used to screen our populations for "correlation-breakers", i.e., families and clones that have both high density and high pulp yield.



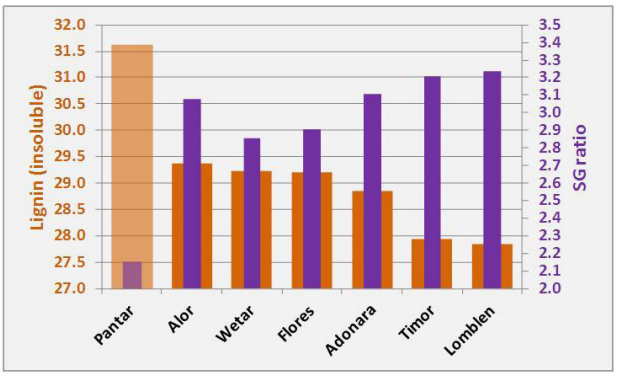


Figure 10. Means of *E. urophylla* provenance BLUPs for imporant wood property traits for the seven islands where the species occurs naturally. *The island of Pantar (shaded bars) was represented by only one provenance.*

Left: Density (left axis, green bars) and pulp yield (right axis, grey bars)

Right: Lignin (left axis, orange bars) and S/G (syringyl / guaiacyl ratio, right axis, purple bars)

Evaluating the Impact of *Thaumastocoris peregrinus* on Eucalyptus Plantations in Uruguay

Thaumastocoris peregrinus (Hemiptera: Thaumastocoridae), commonly referred to as the bronze bug, is a significant world-wide pest of Eucalyptus. It has caused severe defoliation in *Eucalyptus camaldulensis* and *E. grandis x camaldulensis* plantations in South Africa, and has been found to feed, reproduce, and complete development on approximately 30 Eucalyptus species. Since its first detection in Australia in 2001, *T. peregrinus* infestations have been observed in plantations in Africa (Kenya, Malawi, Mozambique, South Africa) and South America (Argentina, Brazil, Chile, Paraguay, Uruguay). While the severe defoliation observed in South Africa was alarming, subsequent monitoring in South Africa and South America has revealed that *T. peregrinus* population density and impacts vary greatly in space and time, and that even highly susceptible species will remain non-symptomatic in certain regions. Thus, proper population monitoring surveys and evaluations of the potential impacts of the bronze bug on specific eucalypt species in specific regions are key to determining if, when, and where investment in pest management strategies are warranted.

In 2012, Camcore and Weyerhaeuser initiated a study in Uruguay to determine the impact of *T. peregrinus* infestation on the productivity of *E. grandis, E. grandis x camaldulensis,* and *E. benthamii* plantations in the northern region of the country. Bronze bug infestations occur in plantations of all three species in the region, but it is not certain what, if any, impact the insect has on the trees. Both *E. grandis* and *E. grandis x camaldulensis* are highly preferred hosts in laboratory tests, and in plantations in other regions of the world, but in Uruguay these species support relatively low density *T. peregrinus* populations and do not present severe visual symptoms of infestation. In contrast, *E. benthamii* appears highly symptomatic (high levels of foliar bronzing), but still shows excellent growth performance in species trials. Thus, in northern Uruguay, it remains unclear if this pest is having a significant economic impact on the productivity of these eucalypts, and if investment in *T. peregrinus* management is necessary.

The study consists two small field trials per species (six total). For each species, one trial was 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 insecticides and two untreated control plots where insect populations were left intact. Insect exclusion was achieved through the use of systemic stem injections of the insecticide imidacloprid, applied individually to each tree in the exclusion plots. To compare productivity between exclusion plots and control plots, growth data were measured once pre-treatment and will be measured every three months post-treatment for two years. Two measures of crown health are also being monitored: (1) crown rating on an individual tree basis to evaluate degree of foliar bronzing, branch dieback, and defoliation and (2) plot level leaf area index using a light meter. Sticky traps were placed at the center of each treatment plot, and will be checked monthly to monitor the activity of *T. peregrinus* and other insects. Climate conditions in each trial are also being monitored with iButton® data loggers (three per trial). Final data from this pilot study will be available in October 2014. Robert Jetton (Camcore) and Jorge Martínez Haedo (Weyerhaeuser) are coordinating this study. Please contact them if you want additional information or are interested in becoming involved in the trial.

Jorge Martínez Haedo (Weyerhaeuser) standing in the *E. grandis x camaldulensis* high-quality site trial at Los Ranchos in Rivera, Uruguay

Pine Hybrid Verification with NIR

Camcore works with more than 25 pure pine species, and has been investigating the commercial potential of many different hybrid combinations for use in the tropics, subtropics and temperate regions. We have used a number of different molecular marker techniques such as RAPDs, isozymes, and SNPs to confirm hybridity. For organization s using hybrids on an operational scale, a more cost-effective method to confirm hybridity would be very useful.

In 2009, Camcore began to investigate the use of Near Infrared Spectroscopy (NIRS) as a potential tool to verify hybridity. Foliage was collected from seedlings of 16 different tropical, subtropical and temperate pine species. The samples were dried and ground and scanned with a desktop NIRS machine. The results from this study showed that the technique distinguished among pure pine species with 94% accuracy. A subsample of 6 species was then selected from the previous study and used to create three "simulated synthetic hybrids" by manually mixing needles from 3 sets of parental pure species. The samples and data were analyzed using the same procedure, and the results obtained were very similar; the technique identified the simulated hybrids with 90% accuracy (see Espinoza et al. 2012, JNIRS 18:437-447).

In 2012, we completed a study using needles from hybrid seedlings that were verified as true hybrids using SNP markers. Ground dried needles of verified hybrids *P. patula x P. tecunumanii, P. patula x P. greggii, P. patula x P. taeda* and their pure species were collected in Colombia and South Africa and sent to Camcore for the processing and data analysis. The spectral data were processed using multivariate analyses (SAS PROC Candisc and PROC Discrim) to determine if we could build models to disinguish hybrids from the pure species parents. Models were built with 15 samples from hybrids and 10 to 15 samples from each parent species. The independent validation data sets were comprised of 10 samples from hybrid trees, and 10 samples from each parent species.

For all four hybrid types, it was possible to develop an NIR model to discriminate among the hybrid and the parents with 100% accuracy (Table 9). The results demonstrate that NIRS can be a useful tool to distinguish pure pine species from their hybrids in an operational program.

Table 9. Accuracy of discriminant analysis models using NIR spectra to classify foliage samples as hybrid or pure parental species for four different pine hybrid combinations.

Actual Taxon	Samples	Percentage Classified by NIR Model		
		P. patula	***P. tecunumanii***	***P. pat x P. tec***
P. patula	10	100	0	0
P. tecunumanii	10	0	100	0
P. patula x P. tecunumanii	10	0	0	100
		P. patula	***P. elliottii***	***P. pat x P. ell***
P. patula	10	100	0	0
P. elliottii	10	0	100	0
P. patula x P. elliottii	10	0	0	100
		P. greggii	***P. patula***	***P. greg x P. pat***
P. greggii	10	100	0	0
P. patula	10	0	100	0
P. greggii x P. patula	10	0	0	100
		P. patula	***P. taeda***	***P. pat x P. tae***
P. patula	10	100	0	0
P. taeda	10	0	100	0
P. patula x P. taeda	10	0	0	100

The Use of NIR to Identify Eucalypt Clones

Over the past two years, Camcore has had very encouraging results with the use of Near Infrared Spectroscopy (NIRS) as a fast, cheap, and effective way to distinguish between pure and hybrid pines (see previous article). In 2012, Camcore worked on a project to determine if NIRS could distinguish among 13 different *Eucalyptus grandis* clones, and to examine whether results obtained from a portable handheld NIR and a laboratory desktop NIR machine are comparable. This project was done in collaboration with Roger Meder (CSIRO, Australia), and Suzano Pulp and Paper (Brazil). In 2013, we will finalize this project and prepare a manuscript for publication in a scientific journal. Here we present a summary of the methods and results.

Materials and Methods

Leaf samples were scanned, collected, and processed as described below from two distinct locations: from the nursery using 3-month-old seedlings, and from the field uing 2-year-old trees. At each location, live green foliage samples from 10 ramets of each of the 13 different eucalypt clones were scanned using a handheld portable NIR (microPhazir) from CSIRO. Foliage was then collected, partially dried, and sent to Camcore for further scanning in the lab. There the partially dried leaves (referred to as "fresh" in this report) were scanned again with an identical microPhazir handheld NIR. Following this, the foliage samples were then oven dried, ground in a Wiley mill, and scanned using both the handheld microPhazier and a laboratory desktop NIR machine (Foss 6500). In addition to these measurements, on the large field trees we also took NIR spectra of the cambium using the CSIRO microPhazir.

Roger Meder of CSIRO analyzed the spectral data taken on the live green seedlings and trees. Jesús Espinoza and Gary Hodge of Camcore analyzed the spectral data from the "fresh" leaves and dried ground leaf meal. The idea was to use various data transformations and discriminant analysis models to see if we could successfully use the NIR spectra to distinguish among clones.

Results and Discussion

Desktop NIR: Foss 6500

Figure 11 presents a canonical discriminant analysis of the entire dataset of foliage-meal scans using the Foss 6500. It is clear from this figure that it is possible to distinguish many clones from one another, as there is very distinct separation in the two-dimensional space defined by the canonical axes. There are a few clones that appear to have rather similar spectra: for example, clones 1280 (green circle) and 1387 (grey triangle) are quite close together, as are clones 1375 (open square) and 1291 (black triangle). From this illustration, one might conclude that those pairs of clones could not be distinguished from one another based on NIR spectra. As it turns out, this is not the case.

In the graph, the data points appear to be a single observation, but in fact, the visible points are 15 samples of each clone (both from the nursery and the field) that are almost exactly on top of one another. In other words, although the relative distance between clone 1280 and 1387 is quite small, all samples for 1280 are in precisely one spot, and all samples from 1387 in precisely another spot. This suggests that a discriminant classification analysis might be able to distinguish among the clones.

Using dried foliage meal scans from the Foss 6500, an NIR discriminant analysis model was built using 12 samples from each clone (mixing nursery and field samples). This model was then used on an independent validation data set of 6 samples of each of the 13 clones (again, with a mix of field and nursery samples). The goal was to classify each sample as one of the 13 clones. The results were 100% correct classification: every sample was assigned the correct clonal identity.

Handheld NIR: microPhazir

A great advantage of the handheld NIR is its portability. This allows the user to take measurements in the field on live trees, and get rapid results without the need for sample preparation. But this advantage comes at a cost: the handheld ma-

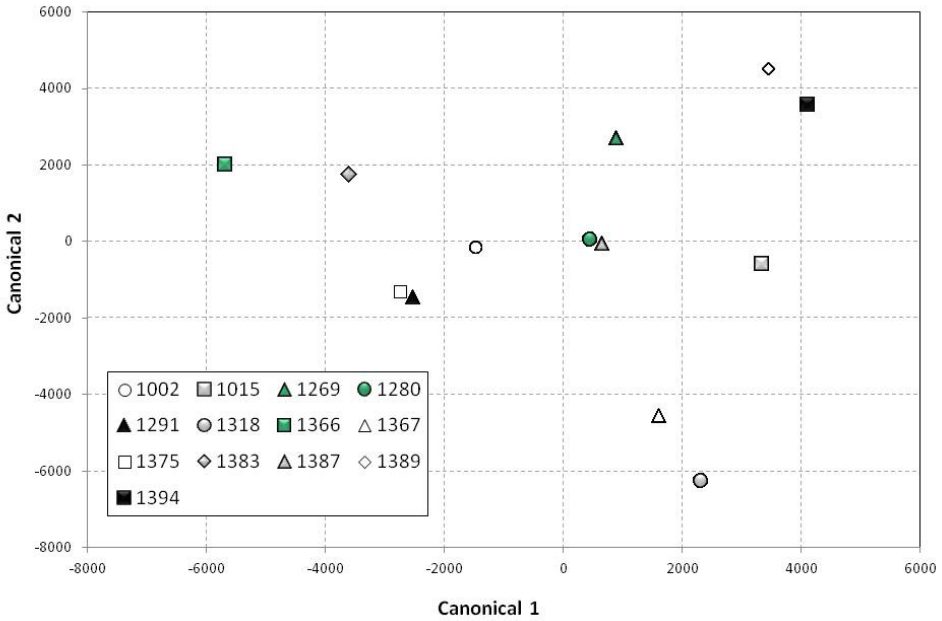


Figure 11. Canonical discriminant analysis of 13 eucalypt clones using NIR scans of foliage samples from the nursery and from 2-year-old field trials.

chine is less precise than a desktop machine. Specifically, the handheld microPhazir measures NIR spectra over the range of 1600 to 2400 nm, with an interval of 8 nm. This means that the resulting data set has 100 independent variables (which are reflectance at a particular wavelength). In comparison, the Foss 6500 measures over the range of 1100 to 2500 nm, with an interval of 2 nm, for a total of 700 variables in the near-infrared range.

As with the data from the desktop NIR, we attempted to build discriminant models using the handheld NIR spectra. When all 13 clones were included in a single dataset, we were unable to obtain satisfactory models. This is likely due to the fact that there were fewer wavelengths, thus fewer independent variables for the discriminant model to use. However, when the same approach was tested with a subset of only 5 clones (as might be the situation in many operational eucalypt nurseries), we were able to obtain models which gave 100% correct classification of the independent data set.

Roger Meder (CSIRO) used somewhat different statistical approaches, but the end result was similar. His analyses were all based on handheld microPhazir scans of live green foliage. He found that a single NIR model could not discriminate among all 13 clones. However, using a cascading hierarchy of discriminant analysis models, almost all clones could eventually be distinguished from one another. Essentially, this approach uses a sequence of NIR models to categorize the samples, in a manner reminiscent of a taxonomic identification key one might use in dendrology class. For example, a first-level model might assign the sample to group A or B. A different, second-level model could then be used on group A samples to further assign the sample to groups A1, A2 or A3, and a third-level model might then be used on group A1 to identify particular clones. This approach was able to correctly separate almost all 13 clones.

Summary

NIRS can be used to distinguish among eucalypt clones using either a desktop or handheld NIR. Using a desktop NIR on dried ground foliage, classification models with very high accuracy should be possible. Using a handheld NIR scanning intact leaves, very accurate classification models should be possible for a limited population of around five clones. For larger numbers of clones, a series of NIR discriminant models can probably distinguish most clones. The results suggest that NIR can be used to provide quality control and clonal identification in operational nurseries and plantations, similar to molecular fingerprinting, but with advantages in cost and time.

Distinguishing *Eucalyptus* Wood Samples with NIR

Eucalyptus globulus is a well-known hardwood species used for commercial plantations in many subtropical and temperate regions due to its fast growth and excellent pulpwood properties. *Eucalyptus nitens* is another important eucalypt species for those regions due to its high frost tolerance compared to *E. globulus.* However, *E. nitens* has lower pulpwood quality than *E. globulus.* Therefore, in countries such as Chile, where the two species are planted, there is a trend where local farmers who produce and sell wood to the pulp and paper companies to try to sell *E. nitens* labeled as *E. globulus* in order to get a higher price. The companies are trying to find tools that will allow them to determine quickly and inexpensively what species of logs are arriving at the mill gate.

NIR spectroscopy is a rapid analytical technique that offers a unique combination of speed, ease of sample preparation, and reduced laboratory time compared to other conventional methods. In the last 4 years, Camcore has been using this technique to predict, with very high level of accuracy, chemical and physical properties of pine and eucalypt wood. In 2012, by request of Forestal Mininco in Chile, Camcore developed a project to determine whether NIRS can be used to identify the species in samples of wood of *E. globulus* and *E. nitens* and their hybrid.

Wood samples of *E. globulus, E. nitens* and the hybrid *E. nitens x E. globulus* of different ages and places were collected. The wood samples were dried, ground and scanned in the NIR in the Camcore lab at NC State University. A total of 108 samples were processed and the raw data was transformed using Standard Normal Variation (SNV) and De-trend using Unscrambler software. The transformed data was processed using SAS PROC Discrim.

The calibration data set was built using 72 samples, 24 samples per species. The validation data set consisted of 36 samples, 12 from each species. The average spectra for the three types of wood meal were visibly different (Figure 12), and the discrimination model was able to classify wood samples of the hybrid and the two pure species with 100% accuracy (Table 10).

The results of this study demonstrate that multivariate analyses of NIRS spectra of ground wood is an effective statistical method for discriminating between wood of *E. globulus, E. nitens* and their hybrid. The next step in this project is to use the portable NIR to scan the logs at the mill gate and run the data in the models built to validate the technique on an operational scale.

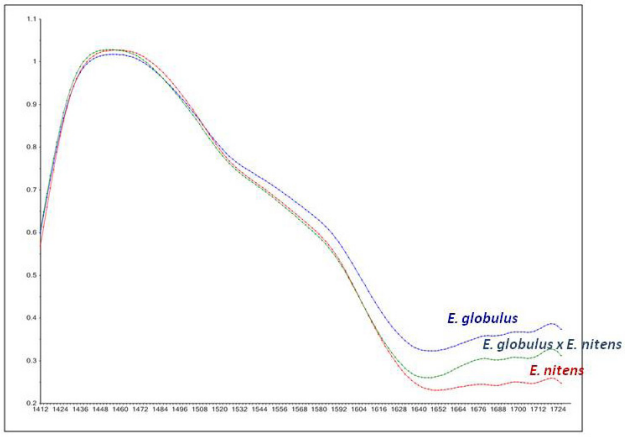


Figure 12. Average NIR spectra for woodmeal of *E. globulus, E. nitens,* and the hybrid *E. globulus x E. nitens* using NIR.

Table 10. Percentage of *E. globulus, E. nitens,* and *E. globulus x E. nitens* classified correctly using NIR data from wood scans and discriminant analysis

Actual Taxon	Samples	Percentage Classified by NIR Model		
		E. globulus	*E. nitens*	*E. glob x E. nit*
E. globulus	12	100	0	0
E. nitens	12	0	100	0
E. globulus x E. nitens	12	0	0	100

Airlayering and Fascicle Rooting of *Pinus maximinoi*

In the 2011 Annual Report, we briefly reported on some work being done by Smurfit Kappa Cartón de Colombia (SKCC) investigating alternative vegetative propagation techniques for *P. maximinoi.* The idea is to overcome a problem of severe graft incompatibility in the species. Following is a summary of the SKCC methodology and results.

Airlayering is a technique by which a tree branch is girdled or wounded to promote the formation of roots. The branch is girdled by removing a 20 to 25 mm strip of bark with a sharp knife, exposing the cambium, but leaving all the xylem intact. Rooting hormone is applied on the exposed cambium, which is then covered by peat moss or other moisture-holding medium. The medium is held around the branch by a piece of clear plastic that is tied below and above the girdle, and covered with aluminum foil (Photo 1). Experiments focused on determining the optimum hormone concentration to apply on the cambium. The treatments were: control (no hormone), powder Indolebutyric acid (6000 ppm), and liquid Indolebutyric acid (1000 ppm). Across all treatments, the airlayering process produced roots 72% of the time on branches of *P. maximinoi* in a seed orchard established on May 2007 (the ramets in the orchard had a physiological age of 26 years). The best treatment was the liquid hormone at 1000 ppm, with a mean of 87.0% of rooting (see Photo 2).

Photo 1. Example of the plastic bag used for airlayering (note the outer layer of aluminum foil has been removed).

Photo 2. Typical root development of *P. maximinoi* with the airlayering technique.

Photo 3. Rooting of needle fascicles. Protocols are similar to normal rooted cuttings from hedges.

Needle fascicle propagation consists of stimulating the fascicle with commercial rooting hormones to form roots and a long shoot. Needle fascicles are collected and stuck into trays of rooting medium in a manner very similar to that used for cuttings collected from hedges (Photo 3). Experiments were conducted to determine the effect of the hormone concentration and application method (liquid or powder) on rooting success. The treatments were: control (no hormone), liquid Indolebutyric acid (1000 & 2000 ppm), and powder Indolebutytic acid (3000 & 6000 ppm). Across all treatments, there was 36% rooting success using fascicles collected from 26-year-old ramets. The best treatment was the hormone powder at 6000 ppm, with a mean of 46% of rooting.

Both airlayering and needle fascicle propagation techniques appear to be very promising as alternative methods to propagate *P. maximinoi* for seed orchards or clone banks, but more research is needed on the physiological factors that influence plant development subsequent to root production by the needle fascicle.

CNR Welcomes New Dean

In October 2012, the College of Natural Resources at NCSU welcomed a new dean, Dr. Mary Watzin. The CNR dean oversees the departments of Forestry and Environmental Resources, Forest Biomaterials, and Parks, Recreation, and Tourism Management.

An expert in marine sciences, aquatic ecology and management, Dean Watzin previously served as dean of the Rubenstein School of Environment and Natural Resources at the University of Vermont (UVM) since 2009. Before becoming dean, she served as the associate dean for Graduate Education and School Planning, and also founded and directed the UVM's lakefront ecosystem science laboratory.

Dean Watzin has received numerous awards for her work, including the Teddy Roosevelt Conservation Award, the SUNY College of Environmental Science and Forestry Partner of the Year Award in 2006, and the Ibakari-Kasumigaura Prize for her work in Macedonia and Albania on transboundary water management. This project culminated in a treaty between the two countries for the joint management of Lake Ohrid. Other international experience includes the World Lake Basin Management Initiative. This project with the UN-sponsored organization Global Environment Facility helped develop management plans for 28 major lakes in Africa, Asia, Europe and North and South America. She received her bachelor's degree in marine science from the University of South Carolina in 1978 and her Ph.D. in marine sciences from the University of North Carolina at Chapel Hill in 1984.

Dean Watzin has only recently been introduced to Camcore. She found the international work in her own field very rewarding, and looks forward to learning more about Camcore. She hopes that her schedule will allow her to participate in the 2013 Annual Meeting in South Africa.

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

Camcore and North Carolina State University are the lead organizers and sponsors of the next IUFRO meeting for Working Group 2.02.20 "Breeding and Genetic Resources of the Southern US and Mexican Pines (including *Pinus radiata*) to be held in Jacksonville, Florida, February 4-7, 2013. The keynote speaker for the conference will be Dr. Tim White, Director of the School of Forest Resources and Conservation, University of Florida. Invited speakers come from all over the world and include Luis Apiolaza, Claudio Balocchi, John Davis, Danilo Fernando, Fikret Isik, Washington Gapare, Arnulf Kanzler, Steve McNulty, Dana Nelson, Jerry Pullman and Laurie Schimleck. Invited and volunteer papers will cover traditional breeding, genomic selection and pedigree reconstruction, wood quality, gene conservation, somatic embryogenesis, clonal forestry, and other areas of interest. The keynote and invited papers will be published in New Forests.

A number of sponsors of the IUFRO meeting come from the Camcore membership, which we greatly appreciate. These include: Arauco, (Chile) and the USDA Forest Service (sponsors), Klabin (Brazil) (patron), and CMPC (Chile), Masisa (Mexico), Terranova (Venezuela), Smurfit Kappa Cartón de Colombia, Sappi (South Africa), and Weyerhaeuser (contributors). Bill Dvorak (Camcore) is Deputy of this working group and Gary Hodge (Camcore) is Chair of the Technical Planning Committee for the conference. The internal arrangements for the international conference are being made by the NC State Forestry and Environmental Outreach Program (FEOP), that is led by Susan Moore (Director) and Kelley McCarter (Program Coordinator).

Data Management Shortcourse in Uruguay

The 2012 Data Management short course took place in Uruguay at Weyerhaeuser's Tacuarembó facility. The group was comprised of Weyerhaeuser staff and a few guests from affiliated forestry companies. This annual course is offered by Camcore to member companies to train staff in data handling techniques. The objective was to improve the efficiency and accuracy of the participants' manipulation of data coming from genetic trials. Much of the work is learning and practicing advanced spreadsheet management. Tools such as filtering, logical formulas, pivot tables, and macro recording are useful for cleaning and verifying data and for creating relational databases. Other topics include: trial design, data coding and organization, and the use of electronic data recorders.

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

Thanks are due to Juan Pedro Posse and the Weyerhaeuser staff for organizing and hosting the workshop. The participants were: Javier Barboza, Jorge Martínez Haedo, Juan Pedro Posse, Juliana Ivanchenko, Luciana Ingaramo, Paola Molina, Sergio da Luz, all from Weyerhaeuser, Diego Rubbo and Fernanda Romero from Terrasys, and Milton Cabrera Gallo from FOSA. Next year's course will be held in Brazil.

Participants at the 2012 Camcore Data Management Shortcourse in Uruguay.

Grants

This was another successful year for Camcore's partnership with the USDA Forest Service (USFS) on gene conservation and genetic diversity projects in the United States. We utilized USFS funding allocations totaling $302,724 to conduct projects related to gene conservation seed collections with Eastern and Carolina hemlock *(Tsuga canadensis* and *T. caroliniana)*, Table Mountain pine *(Pinus pungens)*, and Atlantic white-cedar *(Chamaecyparis thyoides)*, genetic structure and diversity analysis of Carolina hemlock, and the development of host resistance screening methods for both hemlock species. Additionally, we received a new $156,492 grant from the USFS that is funding a three-year project focused on the establishment of hemlock conservation banks both inside and outside of the United States.

Camcore and the Forestry and Agricultural Biotechnology Institute (South Africa) collaborated on its second project in Guatemala entitled, "Anticipating risk to outplanted pine forests: unraveling complex relationships between beetles, fungi and trees". Funding of $10,000 was obtained for the project through a joint grant program sponsored by NC State Univeristy and the University of Pretoria.

Executive Committee Members

Rudolf Rahn, Vice-president of Forestry for Smurfit Kappa Cartón de Colombia, was named Chairman of the Camcore Advisory Board. Congratulations, and thanks, to Rudolf. The Chairman position was left vacant in 2012 after Andrew Morris (Sappi Research, South Africa) stepped down after nearly a decade of service. The accompanying table lists all of the past Camcore Chairmen; many thanks to these gentlemen for their outstanding service to the program.

Glen Mitchell (York Timbers) was selected to serve on the Camcore Executive Committee beginning in 2013. Congratulations to Glen.

Date	Chair	*Company*	*Country*
1980-1982	Carl Gallegos	International Paper Company	USA
1983-1986	Flavio Pereira	Jari Florestal	Brazil
1987-1988	Ricardo Umaña	Pizano-Monterrey Forestal	Colombia
1988-1992	Roger Fairest	Smurfit Venezuela	Venezuela
1993-1997	Edgar Londoño	Smurfit Colombia	Colombia
1998-1999	Neville Denison	Mondi	South Africa
2000-2002	Juan Jurado Blanco	Smurfit Venezuela	Venezuela
2003-2011	Andrew Morris	Sappi	South Africa
2012	*OPEN*		
2013	Rudolf Rahn	Smurfit Colombia	Colombia

Graduate Programs and Training

Lia Campbell began her Master of Science program with Camcore during the fall semester of 2012. Her research with Camcore will focus on population genetic structure and diversity in Carolina hemlock. The results of Lia's thesis research will be utilized by Camcore to properly manage diversity and adaptability in conserved seed resources and conservation banks of the species.

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) visited NCSU and Camcore during the 2012 Fall semester to sit in on a class on Forest Quantitative Genetics in preparation to begin his Ph.D. program at the University of Pretoria. Mmoledi will study with Prof. Zander Myburg, and work closely with Gary Hodge (Camcore) and Fikret Isik (NCSU-TIP).

Oscar Nilsson, a student from Sweden, is working on his M.S. with Camcore. His thesis project is still to be defined but it probably will involve a growth and soil assessment of the species/site interaction studies established by several Camcore members in South Africa.

Zaidee Powers began work on her Master's degree in Forestry and Entomology in fall 2011. She will be testing artificial infestation techniques of hemlock woolly adelgid on eastern, Carolina, and western hemlock species for use in resistance screening methods.

Braden Ramage finished his Masters of Forestry entitled, "The Socioeconomic Impacts of Plantation Forestry in Rural Communities in Northern Mozambique".

Andy Whittier (Camcore) continues to take classes toward his MS degree, and has initiated his work on his thesis project entitled "Genetic/nutrient interactions and deficiency symptoms in teak raised in growth chambers".

Changes in Camcore

Arno Brune (Green Resources, Mozambique) left the company in September for a forestry position in Ghana. We wish Arno much success in his new position.

Julian Chan has left PG Bison and taken a position with the Institute of Commercial Forestry Research in South Africa. Julian will continue work in tree breeding with the ICFR, and we wish him the best in his new postion.

Enver Mapanda (BTL, Zimbabwe) was hired as the company's new technical manager. She also will be in charge of research including the Camcore studies.

Botha Maree (Merensky, South Africa) retired from the company after a number of years of service. Botha was Merensky's representative on the Camcore Advisory Board and was an active supporter of our program. We wish him and his wife Edith a long and fruitful retirement.

Glen Mitchell (Research Manager, York Timbers, South Africa) was awarded his Ph.D. degree in the faculty of Natural and Agricultural Sciences, University of Pretoria, South Africa. The title of Glen's thesis was, "Reducing the Risks of Pitch Canker Disease (Caused by *Fusarium circinatum*) to *Pinus patula* in South Africa.

Etsuro Murakami (Mead-Westvaco Rigesa, Brazil) retired from his position as Forestry Director after more than three decades of service to the company. Etsuro was a great champion for Camcore in Brazil. He often provided us with useful insights on trends of the forest industry in Latin America. We wish him a long and happy retirement.

Jan van der Sijde (KLF, South Africa) left the company for a forestry assignment in Laos. Jan was one of our strongest supporters and served on the Camcore Executive committee. He had been interacting with Camcore in various capacities since the early 1980s. We all want to wish Jan the best in his new position.

Marius du Plessis (Tree Improvement Manager, Mondi, South Africa) received his Ph. D. in the Department of Wood Sciences and Forestry, Stellenbosch University. The title of his thesis was, "A fibre optimization index developed from a material investigation of *Eucalyptus grandis* for the Kraft pulping process".

Mike Wingfield (Director of the Forestry and Agricultural Biotechnology Institute (FABI) at the University of Pretoria, South Africa) has been awarded an Honorary Doctorate by North Carolina State University. Mike has been a great supporter of Camcore activities over the years, and we are all very proud that he is being given this prestigious award.

Passing of Friends

Doug Dell, CEO of Border Timbers Ltd. (BTL), Zimbabwe died suddenly in March. Doug was in the process of re-vitalizing the BTL program, which included improving output at the sawmills as well as making needed changes in silvicultural practices at the four different timber estates. His passing was a big loss to the forestry community in the region.

Louis van Zyl (Merensky) passed away in July after a one-year battle with cancer. He had worked 17 years for the company and had attended local Camcore technical visits and annual meetings. He was a long distance runner and loved rugby. He had great knowledge of forestry in South Africa and will be missed by all.

Publications and Papers

Publications

Cerda Granados, D.A. 2012. Geographical variation of cold hardiness in Pinus patula provenances and genetic inheritance of cold hardiness in *Pinus patula x Pinus tecunumanii* hybrids. NCSU Master of Science Forestry Thesis. http://repository.lib.ncsu.edu/ir/bitstream/1840.16/7688/1/etd.pdf.

Dvorak, W.S. 2012. The strategic importance of applied tree conservation programs to the forest industry in South Africa. Southern Forests. 74(1): 1-6.

Dvorak, W.S. 2012. Water use in plantations of eucalyptus and pines: a discussion paper from a tree breeding perspective. International Forestry Review. Vol. 14: 110-119.

Espinoza, J.A., Allen, H.L., McKeand, S.E., Dougherty, P.M. 2012. Stem Sinuosity in Loblolly Pine with Nitrogen and Calcium Additions. Forest Ecology and Management. 261:1. 55-61.

Espinoza, J.A., Hodge, G.R., Dvorak, W.S. 2012. The potential use of near infrared spectroscopy to discriminate between different pine species and their hybrids. Journal of Near Infrared Spectroscopy. 18, 437-447.

Hodge, G.R., Dvorak, W.S., Tighe, M.E. 2012. Comparisons between laboratory and field results of frost tolerance of pines from the southern USA and Mesoamerica planted as exotics. Southern Forests. 2012. 74(1): 7-17.

Hodge, G.R., Dvorak, W.S. 2012. Growth potential and genetic parameters of four Mesoamerican pines planted in the Southern Hemisphere. Southern Forests. 74(1): 27-49.

Mitchell, R.G., Wingfield, M.J., Hodge, G.R., Dvorak, W.S., Coutinho, T.A. 2013. Susceptibility of provenances and families of *Pinus maximinoi* and *Pinus tecunumanii* to frost in South Africa. New Forests. 44(1): 135-146.

Mitchell, R.G., Wingfield, M.J., Hodge, G. R., Steenkamp, E. T., and Coutinho, T. A. 2012. Selection of *Pinus* spp. in South Africa for tolerance to infection by the pitch canker fungus. New Forests 43(4): 473-489.

Mitchell, R.G., Wingfield, M.J., Hodge, G. R., Steenkamp, E. T., and Coutinho, T. A. 2012. The tolerance of *Pinus patula x Pinus tecunumanii,* and other pine hybrids, to *Fusarium circinatum* in greenhouse trials. New Forests, In Press (published online July 2012).

Potter, K.M, Jetton, R.M., Dvorak, W.S., Hipkins, V.D., Rhea, J.R., Whittier, W.A 2012. Widespread inbreeding and unexpected geographic patterns of genetic variation in eastern hemlock *(Tsuga canadensis)*, an imperiled North American conifer. Conservation Genetics. 13:475-498.

Publications In Press

Dvorak, W.S., Nel, A., and Espinoza, J.A. 2013. Evidence of low-levels of natural introgression between *Pinus jaliscana* and *Pinus oocarpa* in an open-pollinated progeny tril using near-infrared spectroscopy. For. Ecol. & Mgment.

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

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

Posters

Dvorak, W.S. and Espinoza, J. A. 2012. The Camcore Worldwide Eucalypt Program. Symposium on the Assessment and Management of Environmental Issues Related to Eucalyptus Culture in the Southern United States. Feb. 22-24. Charleston, SC, USA.

Jetton, R.M., Crane, B.S., Dvorak, W.S., Hodge, G.R., Whittier, W.A., Duerr, D. Gene Conservation of Atlantic White Cedar *(Chamaecyparis thyoides)* in the Eastern United States. Poster presented at The Ecology and Management of Atlantic White Cedar *(Chamaecyparis thyoides)*. Suffolk, VA. June 12-14, 2012.

Jetton, R.M., Dvorak, W.S., Whittier, W.A., Rhea, J.R., Crane, B.S. Genetic Resource Conservation for Threatened & Endangered Tree Species in the Eastern United States. Poster presented at The Southern Forest Insect Work Conference. Charlottesville, VA. July 24-27, 2012.

Powers, Z.L., Jetton, R.M., Mayfied III, A.E., Powers, Hain, F.P. Comparing artificial infestation techniques on hemlock species (*Tsuga* spp.) for use in Hemlock Woolly Adelgid *(Adelges tsugae)* resistance testing. Poster presented at The Southern Forest Insect Work Conference. Charlottesville, VA. July 24-27, 2012.

Jetton, R.M., Mayfied III, A.E., Powers, Z.L., Hain, F.P. Operation Adelgification: Evaluating Rain Down Technique to Artificially Infest Seedlings with the Hemlock Woolly Adelgid. Poster presented at 23rd USDA Interagency Research Forum on Invasive Species. Annapolis, MD. January 10-13, 2012.

Presentations

Jetton, R., Potter, K., Dvorak, B, Hipkins, V., and Rhea, R. Population genetic structure and diversity in eastern hemlock: implications for gene conservation. Oral presentation at the 60th Annual Meeting of the Entomological Society of America, November 11-14, 2012, Knoxville, TN.

Jetton, R.M. Dynamic gene conservation and threats to forest sustainability: efforts to conserve the genetic resources of hemlocks and other threatened tree species by the NCSU Camcore Cooperative. Oral presentation in the Va. Tech Department of Forest Resources & Environmental Conservation Seminar Series, April 30, 2012, Blacksburg, VA.

Jetton, R.M. Current domestic gene conservation programs at Camcore. Oral presentation in the NCSU Department of Forestry & Environmental Resources Seminar Series, April 9, 2012, Raleigh, NC.

Other Publications of Interest

Bredenkamp, B. and. Upfold, S.J. (eds). 2012. South African Forestry Handbook. 5th Edition. South African Institute of Forestry. Menlo Park, South Africa. 742 p.

du Plessis, M. 2012. A fibre optimization index developed from a material investigation of *Eucalyptus grandis* for the Kraft pulping process. Ph.D. dissertation, University of Stellenbosch, South Africa. 280 pp.

Mitchell, R. G. Reducing the risk of pitch canker disease (caused by *Fusarium circinatum)* to *Pinus patula* in South Africa. Ph.D. dissertation, University of Pretoria, South Africa. 161 pp.

Mitchell, R.G., Coutinho, T.A., Steenkamp, E., Herbert, M., Wingfield, M.J. 2012. Future outlook for *Pinus patula* in South Africa in the presence of the pitch canker fungus *(Fusarium circinatum)*. Southern Forests 74(4): 203–210.

Mitchell, R.G., Wingfield, M.J., Steenkamp, E. T., and Coutinho, T. A. 2012. Tolerance of *Pinus patula* full-sib families to *Fusarium circinatum* in a greenhouse study. Southern Forests: a Journal of Forest Science; 74 (4): 247-252.

Plomion, C., Bousquet, J., and Kole, C. (eds.) 2011. Genetics, Genomics and Breeding of Conifers. CRC Press. 447 p.

Rojas, A., Moreno, L., Melgarejo, L.M., and Rodriguez, M.A. 2012. Physiological response of gmelina (*Gmelina arborea* Roxb.) to hydric conditions of the Colombian Caribbean. Agronomia Colombiana. Vol. 30:52-58.

University Committees and Service

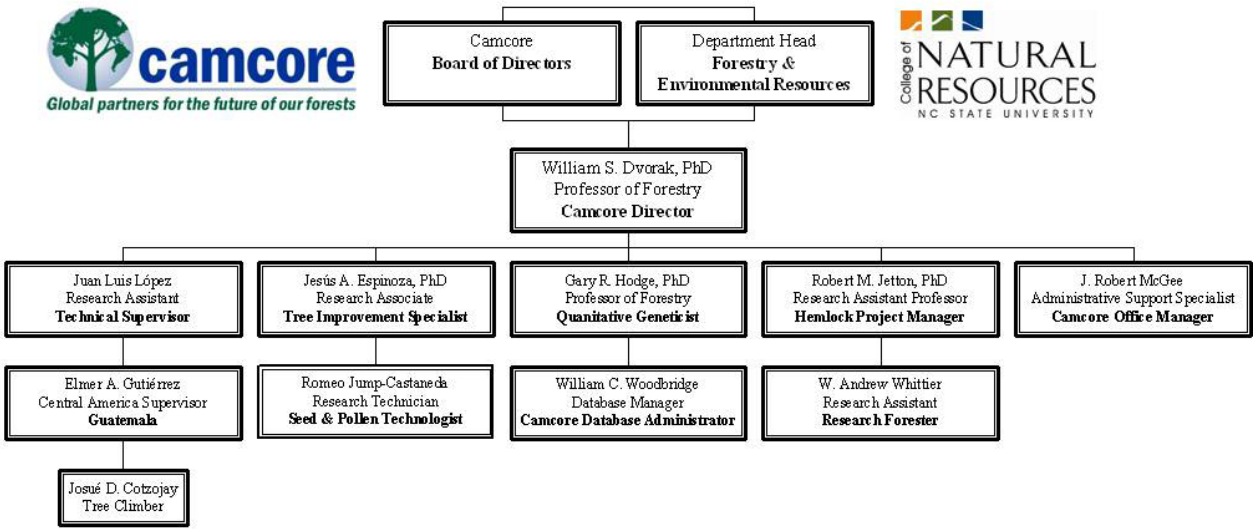
Bill Dvorak, Professor of Forestry and Camcore Director, NC State University, continues to serve as an adjunct professor in the Department of Forest and Wood Science, Stellenbosch University, South Africa. Bill gave one-week of lectures on tree improvement to 3rd year forestry students (juniors) at Stellenbosch University in July. He continues to serve as an officer for the IUFRO Working Group on the Breeding and Genetics Resources of Southern US and Mexican Pines (see IUFRO, p. 47). He is an Associate Editor of Southern Forests (South Africa) and is a member of the International Committee in the Department of Forestry and Environmental Resources (FER), NC State University.

Gary Hodge, Professor of Forestry and Camcore Quantitative Geneticist, continued to serve as Associate Editor for the *Canadian Journal of Forest Research.* He also served as a reviewer for *Silvae Genetica,* and an external PhD reviewer for the Stellenbosch University, South Africa. Gary also served on the FER Adjunct Faculty Committee.

Robert Jetton, Research Assistant Professor & Camcore Hemlock Project Leader, continues to serve as an Associate Editor for the *Journal of Insect Science,* and was a peer reviewer for *Canadian Journal of Forest Research, Environmental Entomology,* and *Forest Ecology and Management.* He 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 was also elected to a three-year term as Councilor on the Southern Forest Insect Work Conference Executive Committee.

Robert McGee, Camcore Office Manager, continues to serve on the University's Group Insurance and Benefits Committee. The responsibility of the committee is to make policy recommendations to the Benefits office relative to maintaining and strengthening programs. Robert also continues to serve on the University's Transportation Appeals Hearing Board.

Camcore Personnel



CAMCORE BOARDS AND COMMITTEES

The 2012 Camcore Advisory Board

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Miguel Rodríguez, Pizano Monterrey Forestal, Colombia

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

Arnulf Kanzler, Sappi Forests, South Africa

Byron Urrego, Smurfit Kappa Cartón de Colombia

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Glen Mitchell, York Timbers Pty Ltd, South Africa

Asa Tham, MozCarbon, Mozambique

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Osmany Salas, Ministry of Natural Resources, Belize

College of Natural Resources, North Carolina State University

Mary Watzin, Dean, College of Natural Resources

Barry Goldfarb, Professor and Head, Department of Forestry and Environmental Resources

The President of Mozambique, Mr. Armando Guebuza (on the left, in a white shirt) visits a Camcore progeny test site in northern Mozambique. Jose Manteiga of Florestas de Niassa (on the left, in a gray vest) explains Camcore's role in the FDN research program. FDN is an important contributor to the economic development of Mozambique. *(photo by Irvine Kanyemba)*

Front Cover: Lizette De Waal (York Timbers) kneels by a hybrid of *P. greggii* x *P. tecunumanii* in a 3-month-old trial in Mpumalanga, South Africa. A number of hybrids produced for the Camcore Pine Hybrid Project are showing great potential in southern Africa and South America.