Poplar for Bioenergy: The ENERGYPOPLAR PROJECT FP7

9 Partners, 3M (EU) Total 4.1M

Gail Taylor,
24 March, 2009
Madrid

energy poplar

Imperial College London

Porter Alliance
Innovating Bio-Energy Systems

UNIVERSITY OF Southampton
School of Biological Sciences

Policy Drivers for increased bioenergy

- 10% Renewable energy by 2010 and 20% by 2020. UK, European SET plan.

- 60% reduction in CO_2 emissions and first nation to have a climate change bill

- RTFO – 5% by volume liquid fuels from renewable source by 2010 and 10% by 2020

- Bioenergy currently contributes

    4.1 % to heat and electricity

    2.5 % to liquid transportation (April 2008, from 0.5%)

Taylor (2008), **Energy Policy** *In Press*
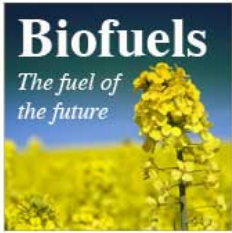
Bioenergy -concerns

- Greenhouse gas balance?
- Biodiversity? Loss of species?
- Other impacts?
- Food crop displacement and prices?
- Other indirect effects… tropical rain forests?
- Societal concerns? GM?
- Landscape-scale changes?
- Water use and management?

Bioenergy Research – what are the show stoppers?
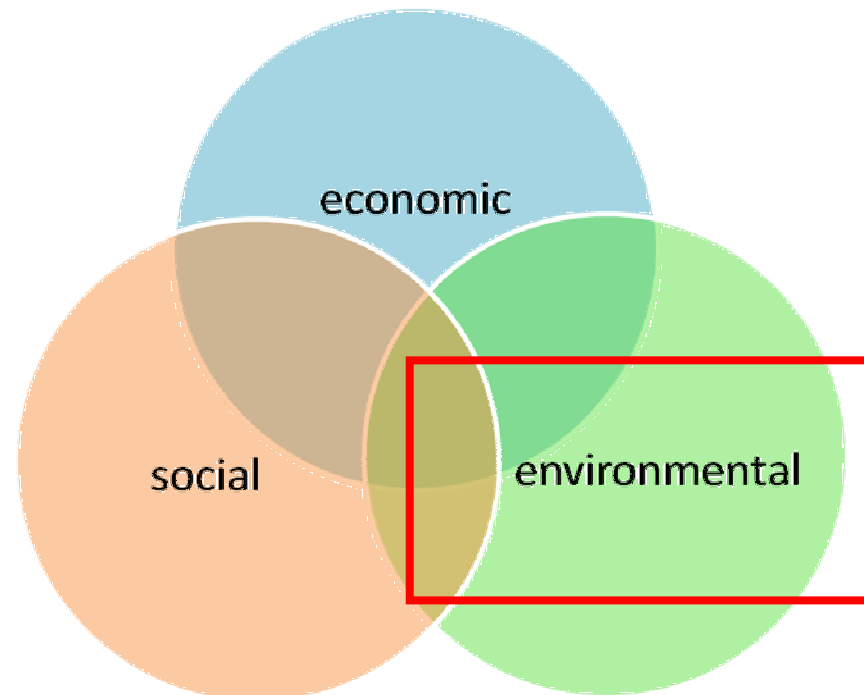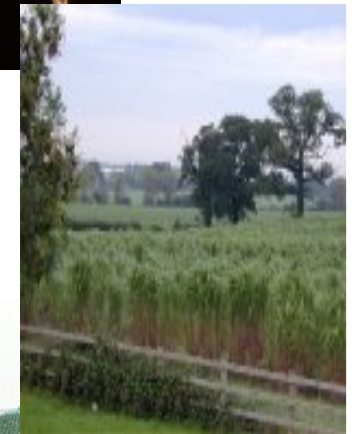
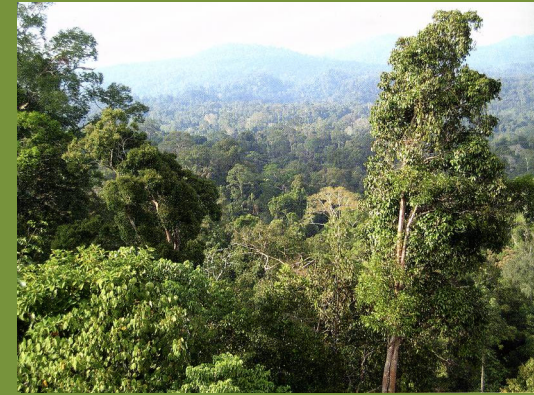# Feedstocks for bioenergy?

First generation crops
- Maize
- OSR
- Wheat grain
- Sugar beet
- Other oil crops from tropics -import
- Sugar cane (Brazil) - import

Second generation dedicated lignocellulose
- Trees – willow and poplar
- Grasses- miscanthus, switchgrass ,
- Others

Forest ecosystems – 50% global vegetation C

Estimated total amounts of C in soil & vegetation in different terrestrial systems (Royal Society 2001). Pg C or Gt C

croplands	131	boreal forests	559
wetlands	240	temperate forests	159
tundra	127	tropical forests	428
deserts & semides.	199		
temperate grasslands	304		
tropical savannas	330		

Total non forest   1,331   **Total forests   1,146**

Feedstock: Woody lignocellulosic biomass (2GC)

• Heat, power and liquid fuels (biological and thermochemical)

• Vast UK, EU and global resource

• Good GHG balance?

• Grown on marginal and abandoned land….. No food v fuel

• Biodiversity? Water use?

What feedstock traits need improving?
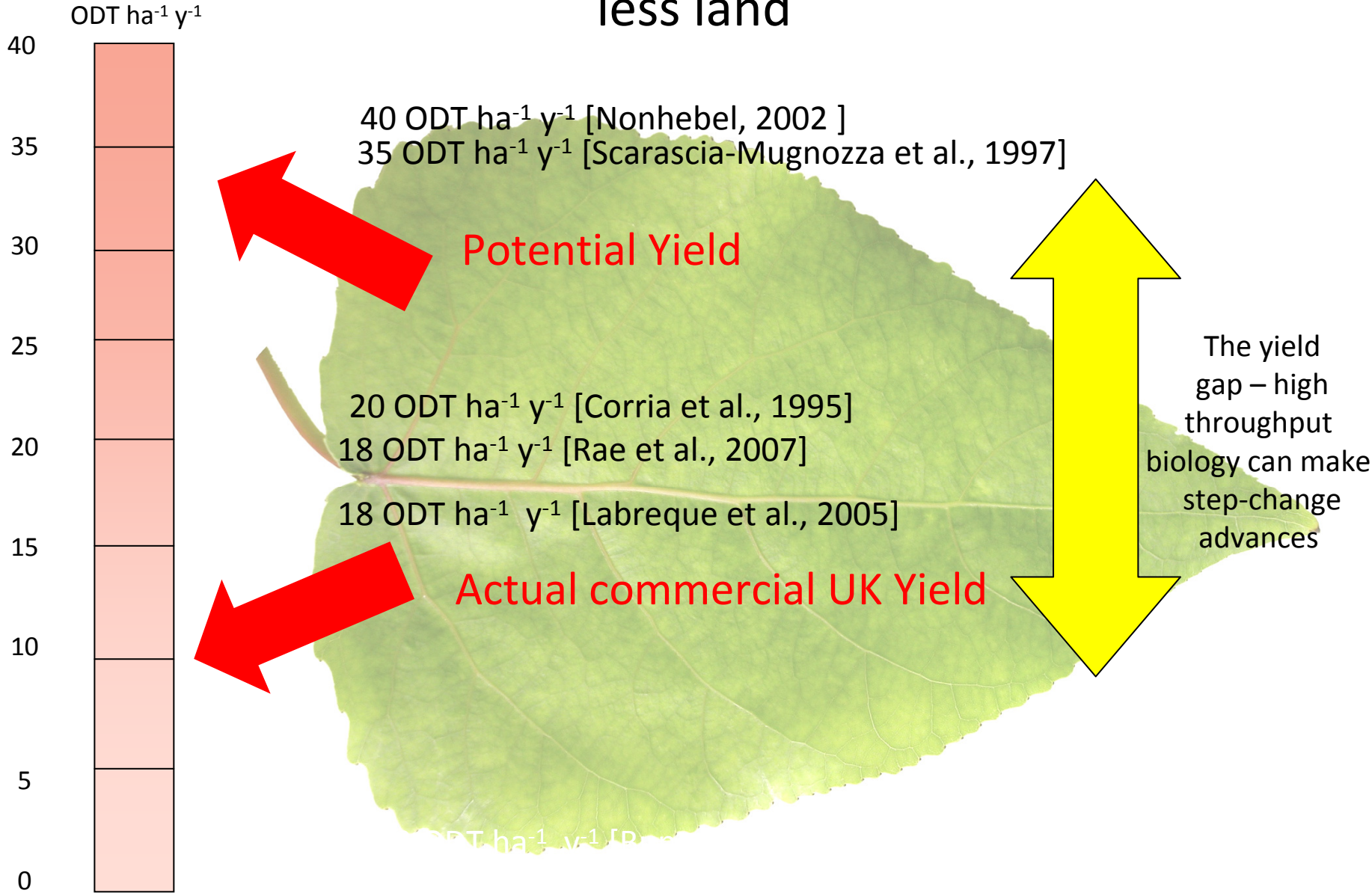# Ideotype breeding?

Biomass Quantity
-More biomass per hectare
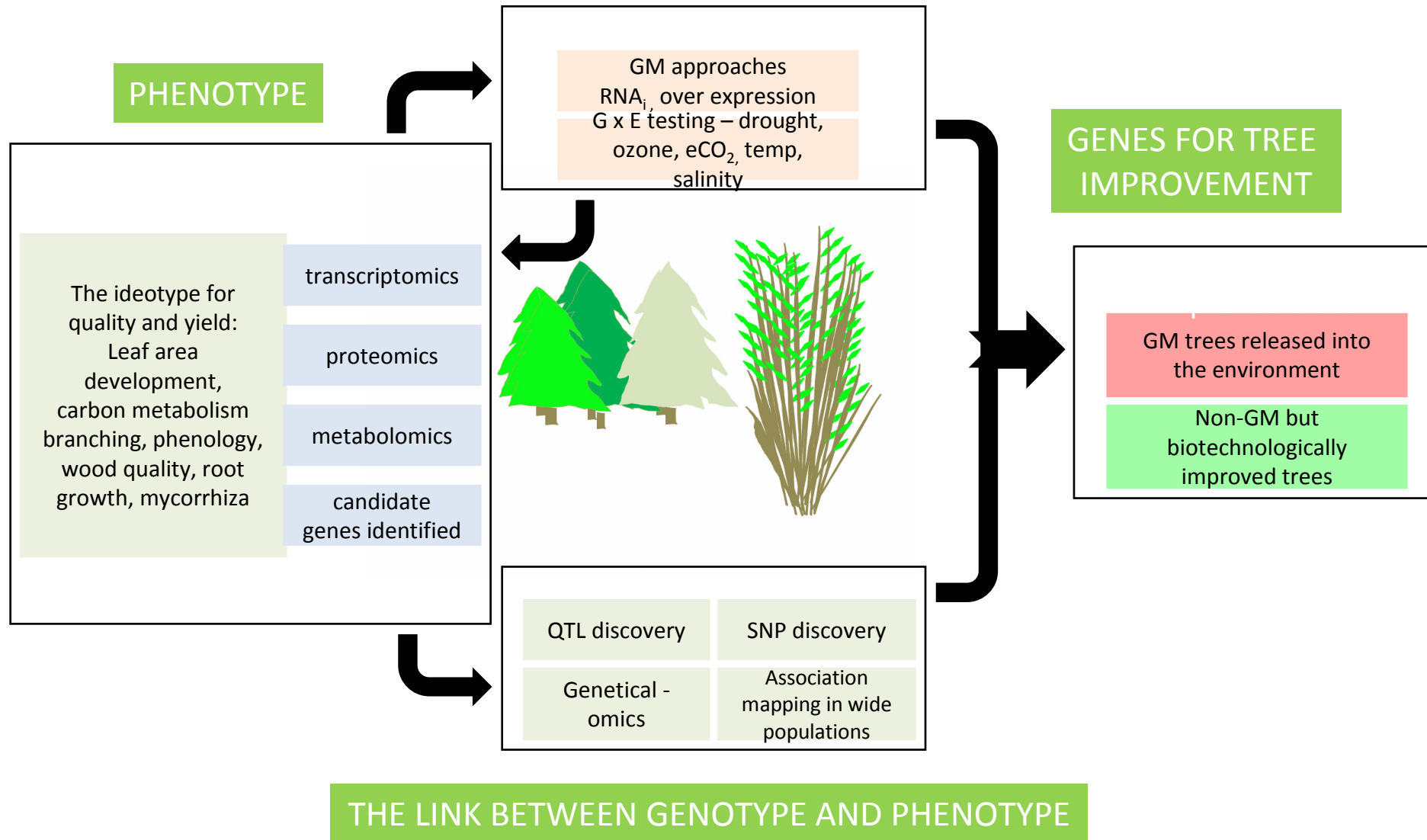-Limited N and water inputs

Biomass Quality
Improved quality
-lignin
--cellulose
-- hemicellulose
-saccharification
-calorific value

Sustainable – GHG balance, biodiversity, water use,

Addressing the yield gap in energy poplar – more biomass on less land

ODT ha^{-1} y^{-1}

40 ODT ha^{-1} y^{-1} [Nonhebel, 2002]
35 ODT ha^{-1} y^{-1} [Scarascia-Mugnozza et al., 1997]

Potential Yield

20 ODT ha^{-1} y^{-1} [Corria et al., 1995]
18 ODT ha^{-1} y^{-1} [Rae et al., 2007]

18 ODT ha^{-1} y^{-1} [Labreque et al., 2005]

Actual commercial UK Yield

The yield gap – high throughput biology can make step-change advances

Systems Biology for optimised yield and lignocellulosic quality in energy

PHENOTYPE

GM approaches
RNA$_i$, over expression
G x E testing – drought, ozone, eCO$_2$, temp, salinity

GENES FOR TREE IMPROVEMENT

The ideotype for quality and yield:
Leaf area development, carbon metabolism branching, phenology, wood quality, root growth, mycorrhiza

transcriptomics

proteomics

metabolomics

candidate genes identified

GM trees released into the environment

Non-GM but biotechnologically improved trees

QTL discovery

SNP discovery

Genetical - omics

Association mapping in wide populations

THE LINK BETWEEN GENOTYPE AND PHENOTYPE

Poplar for bioenergy – globally significant

More than 30 species, wide range of climates and soils

Large genetic diversity, large natural provenances (91%)

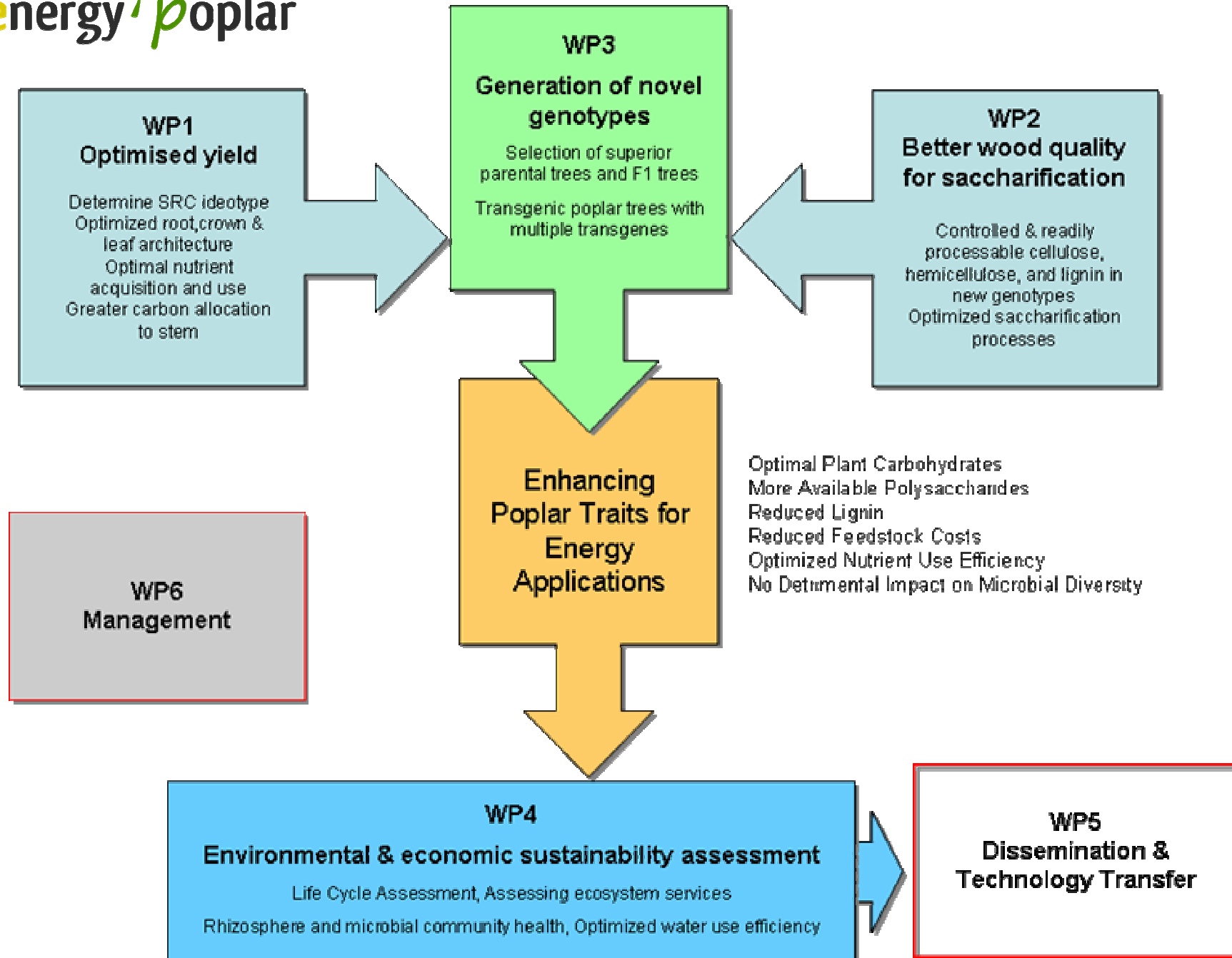Interspecific hybridisation

P. SIGAUD

FAO; Ball, Carle and Del Lungo   J. CARLE

Aims of ENERGYPOPLAR

- The aim of the project is to improve feedstock characteristics of poplar for bioethanol production

- Improved yield

- Improved saccharification

- Improved sustainability and water use efficiency

- Optimized LCA

energy poplar

- INRA, France- (F Martin) -mapping pop, association, mycorrhizal associations, genomics, ESTs, EVOLTREE, GM low lignin trees

- UPSC, Sweden (R Bhalerao) - GM lines, HT phenotyping cell walls, transcriptomics, metabolomics, gene discovery platform

- Southampton, UK (G Taylor)- mapping pop, association, Carbon isotopes, QTL elucidation, saccharification

- Udine, Italy (M Morgante) – Genotyping, HT SNPs discovery,

- Ghent, Belgium (W Boerjan) – GM low lignin trees, mapping pop

- Gottingen, Germany (A Polle) – GM trial, carbon isotopes, HT

- Imperial College, UK (R Murphy)- LCA , HT saccharification assay

- ALU, Germany (K Palme) - Gene discovery, Systems Biology

- SweeTreeTechnologies (M Hertzberg)- commercialisation

Engineering Perennial Feedstocks for Biofuel

energy poplar

WP3
Generation of novel genotypes

Selection of superior parental trees and F1 trees

Transgenic poplar trees with multiple transgenes

WP1
Optimised yield

Determine SRC ideotype
Optimized root,crown & leaf architecture
Optimal nutrient acquisition and use
Greater carbon allocation to stem

WP2
Better wood quality for saccharification

Controlled & readily processable cellulose, hemicellulose, and lignin in new genotypes
Optimized saccharification processes

Enhancing Poplar Traits for Energy Applications

Optimal Plant Carbohydrates
More Available Polysaccharides
Reduced Lignin
Reduced Feedstock Costs
Optimized Nutrient Use Efficiency
No Detrimental Impact on Microbial Diversity

WP6
Management

WP4
Environmental & economic sustainability assessment

Life Cycle Assessment, Assessing ecosystem services

Rhizosphere and microbial community health, Optimized water use efficiency

WP5
Dissemination & Technology Transfer

Workpackage 1

- Improve yield through genomics and genetical genomics

- Optimise shoot function using GM technologies

- Optimise root function using GM technologies

energy poplar

Five 'Poplar BIOMASS LOCI' identified in *Populus* following 10 years of research
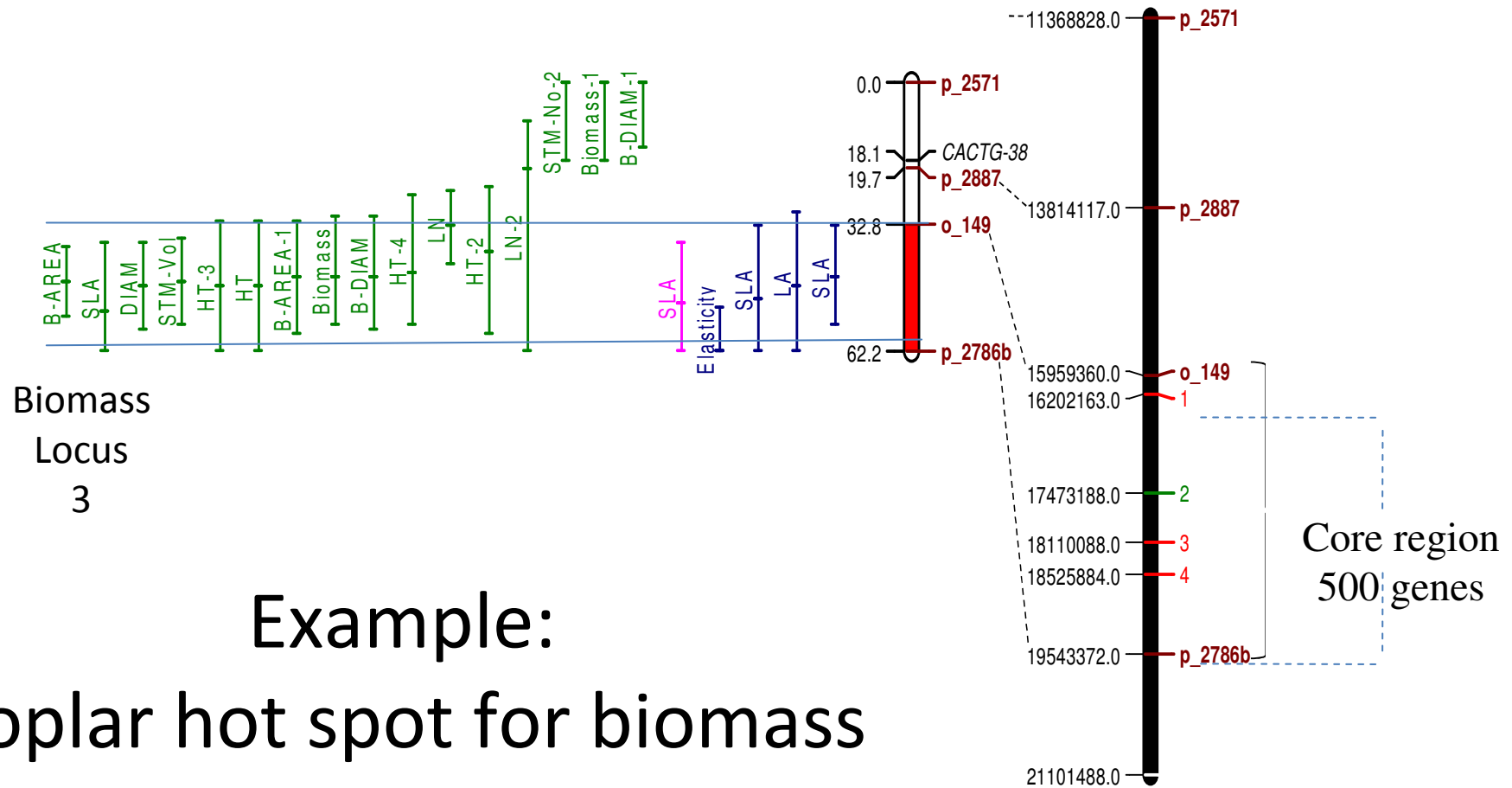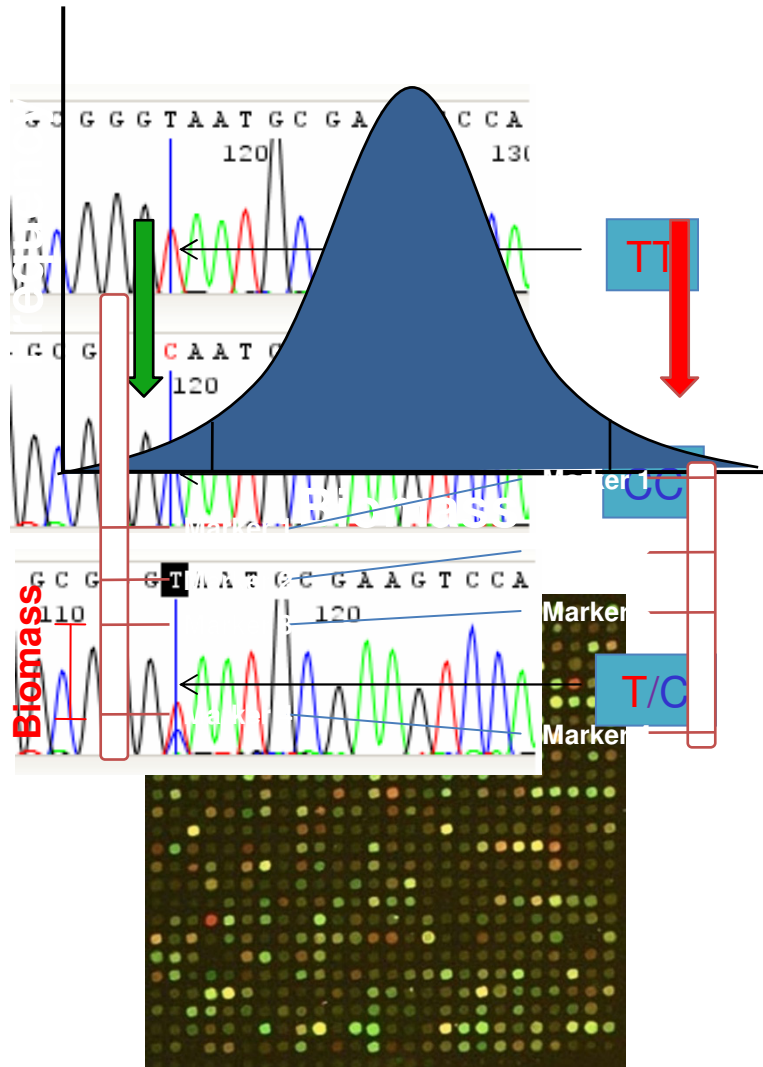

Biomass
Locus
3

Example:
Poplar hot spot for biomass traits
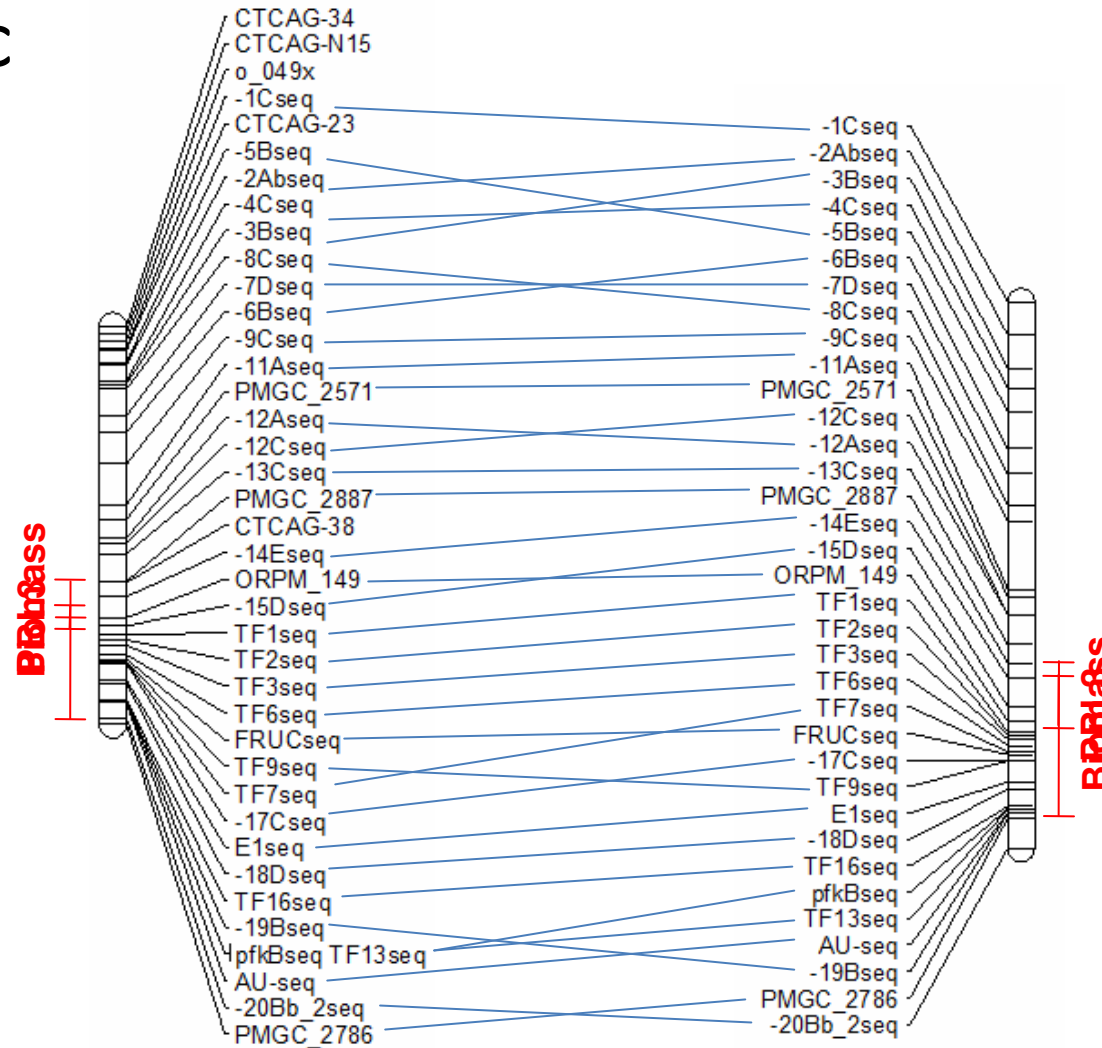
Core region
500 genes

Genetical genomics approach

- Improve density of markers on the key biomass LG and in PBL3 using SNPs.

- Conduct microarray experiment using 'biomass extremes'.

- Aim to identify key genes in the core regions of the QTLs:

  - Transcription factors potentially controlling biomass

  - Biomass related genes e.g. cell wall synthesis, sugar synthesis, cell cycle etc

Genetic

Physical

Workpackage 2

energy poplar

- Establish GM field trials of current and new material e.g. low lignin trees

- Establish high throughput phenotyping for lignin and cellulose traits

- Establish association genetics populations

- Undertake saccharification assay on 500 plus genotypes of *Populus* – SRC, GM, others

What is Saccharification?

- "The process of breaking down a complex carbohydrate into monosaccharide components"

- Breaking down ligno-cellulosic mass into glucose.

- This glucose can then be fermented to produce ethanol.

energy poplar

Saccharification potential of *Populus?*

- Identify natural genetic variation in glucose release across Family 331 genotypes (F2 mapping population) using a high throughput assay.
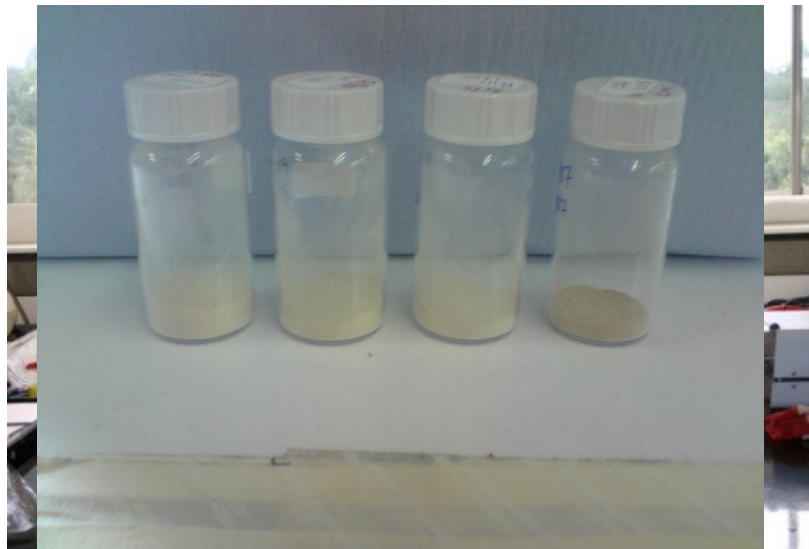
- Combine data with existing F331 markers to produce QTL and identify genes of interest.
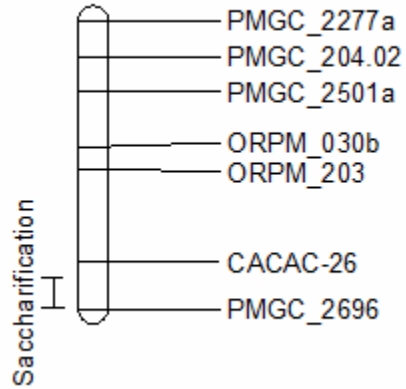
energy poplar

Overview of Process

1.Pre-treatment of dried wood

2.Hydrolysis of wood to glucose

3.Fermentation of glucose

Ethanol

energy poplar

UNIVERSITY OF
Southampton
School of Biological Sciences
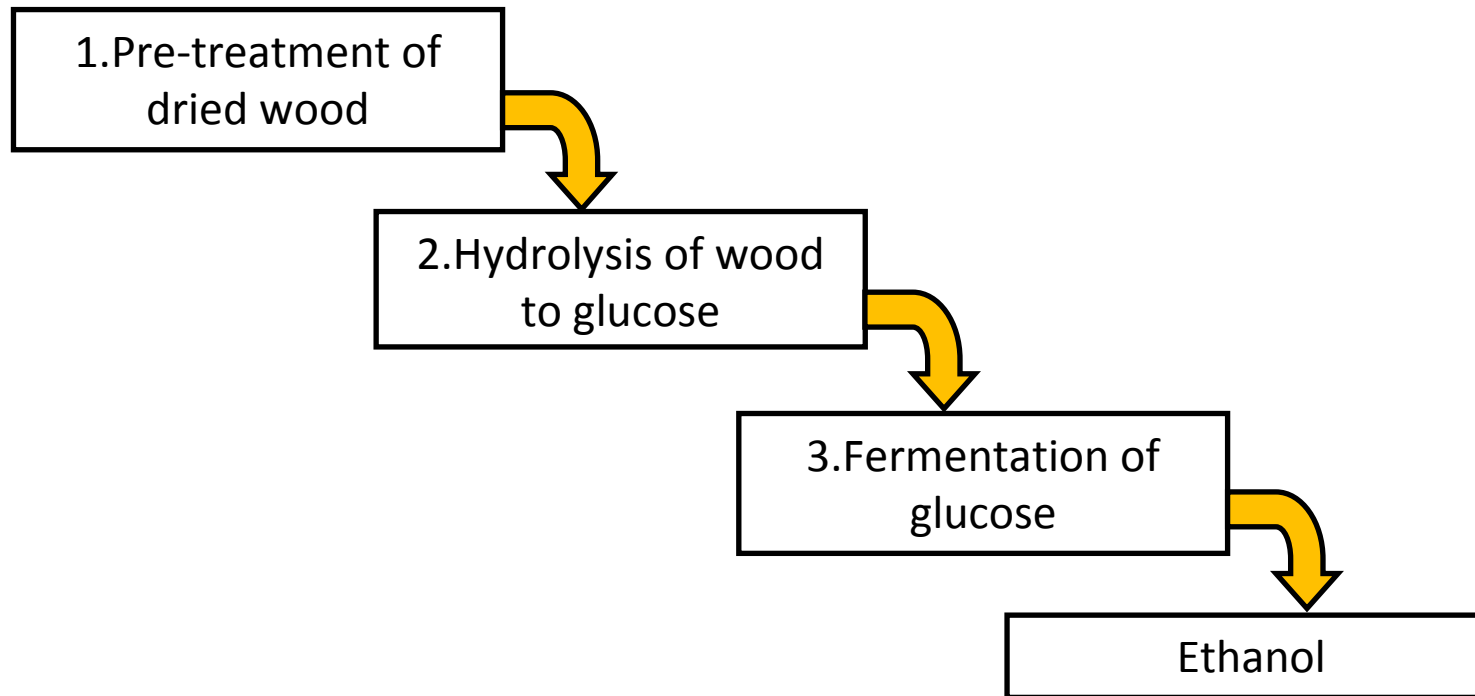
Wood Pre-treatment

- Wood ground to fine powder using 'Retsch 300MM Mixer miller'.

energy poplar

UNIVERSITY OF
Southampton
School of Biological Sciences
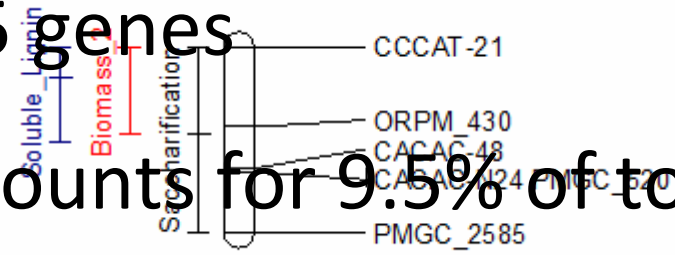
Results
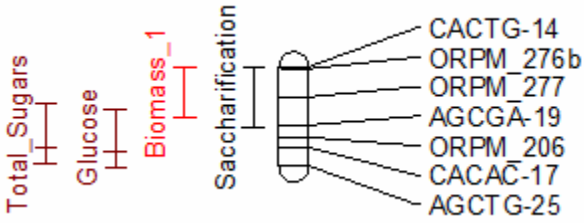
Glucose release across F331 genotypes after 48 hours
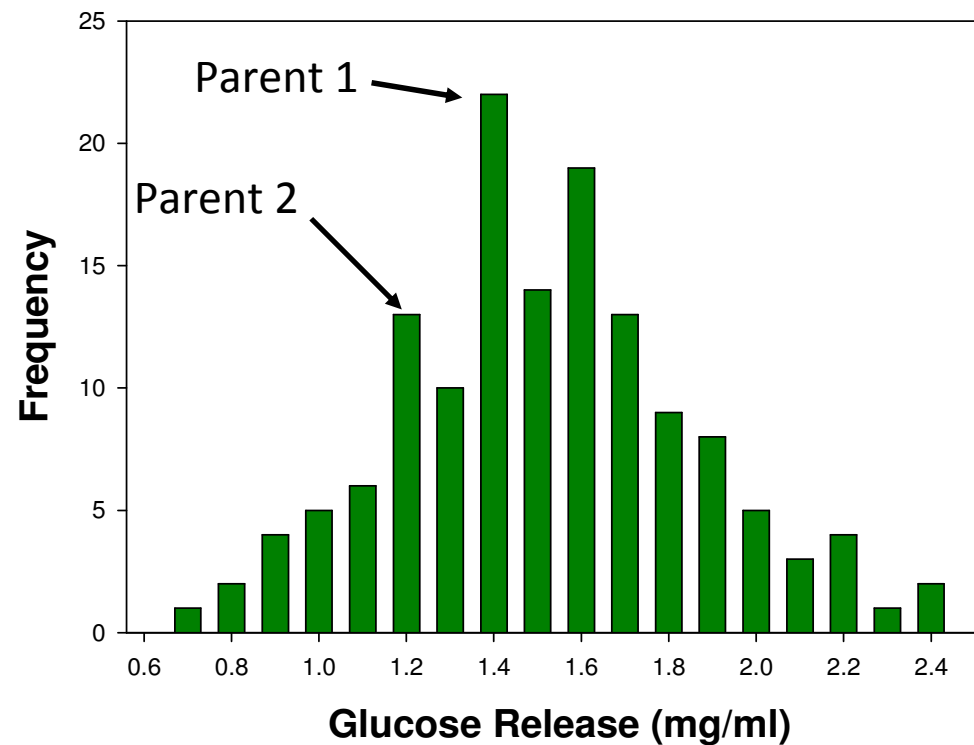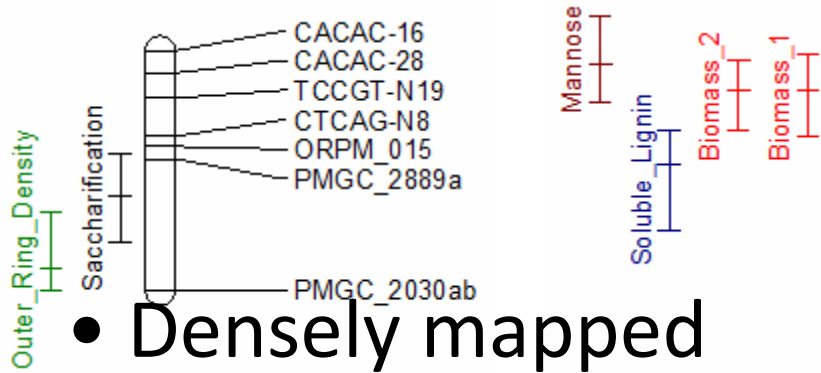
- Densely mapped

- Comparatively small - consists of 75 genes
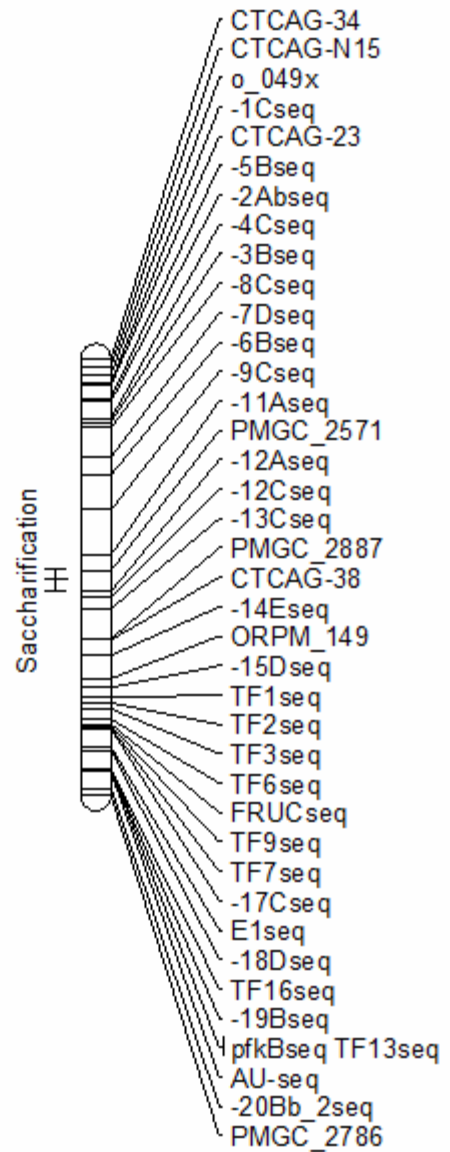
- Accounts for 9.5% of total variation

- In Total account for 35% of Variation

energy poplar Workpackage 3

- Genomics and breeding

- SNPs discovery and HT genotyping based on SNPs – areas of the genome and candidate genes of interest

- Select new trees for crossing with superior alleles

Workpackage 4

- Life Cycle Analysis

- Sustainability and ecosystem services

- Water use efficiency

energy poplar

Summary

- Poplar has potential, globally as a bioenergy feedstock crop

- Genomic approaches are beginning to unravel complex traits such as biomass, response to drought

- New Bioenergy Centres in the USA will invest massively in *Populus*. Europe should aim to remain competitive

energy poplar