If Vegetative Propagation and/or Clonal Forestry is so great… why are we not using more of it in Europe?

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World Rooted Cutting Production 1989 and 2004

Region	1989	2004
Japan	31.4m	No data available
Australia	8.3	6.0+m
New Zealand	1.85	28.5
Scandinavia	8.45	0.1
United States	1.0	1.0 to 2.0
Canada	5.85	5.0+
UK and Ireland	6.15	7.3
Western Europe	2.14	0.1
Eastern Europe	0.11	No data available
Soviet Union	0.05	No data available
South Africa	Not surveyed	2.0
TOTAL	65.3m	51.0m

Points to be Addressed

- Why should we be interested in it?
- Where has it been tried?
- Where is it working?
- What will it take to make it work in Europe?

Why Vegetative Propagation?

- Originally seen as a way to bulk up small amounts of rare and valuable material.
- Also seen as a way of improving testing and selection accuracy.
- Later seen as a way to establish genetically uniform plantations (Clonal Forestry).

Advantages and Disadvantages of Vegetative Propagation

- Advantages
  - Fastest way to get improved material into production.
  - Reproduces genetic make up of the original individual.
  - Flexible
  - Avoids flowering/seed problems
- Disadvantages
  - Higher production costs than seed.
  - Possible “C”-effects

Types of Vegetative Propagation

- Macropropagation
  - root cuttings
  - Air layering
  - Grafting
  - Rooted cuttings
- Micropropagation
  - Organogenesis
  - Somatic embryogenesis

Ideal Veg Propagation System

- Works with all genotypes.
- No or limited somaclonal variation.
- Moderate “c-effects”.
- Broad donor plant age spectrum.
- Preserves donor plant age.
- High multiplication rate.
- Uniform multiplication rate across genotypes.
- Low cost.
- Produces plants with normal growth rate and habit.

Martin Werner 1995

Advantages and Disadvantages of Clonal Forestry?

- Advantages
  - Captures advantage of the best individuals from the best families.
  - Increased uniformity
  - Increased predictability and repeatability
  - Ability to utilise correlation breakers
- Disadvantages
  - Higher costs than veg prop
  - Could result in reduced genetic diversity
  - Clone X Environment interactions
  - Requires clonal storage system

Some Definitions

- Mass or Bulk Propagation- half- or full-sib material propagated vegetatively with identities not kept during propagation and deployment.
- Clonal Forestry- half- or full-sib material of tested clones with identities maintained during both vegetative propagation and deployment.
  - Clonal mixtures
  - Monoclonal blocks
  - Mosaics of monoclonal blocks

Other “Definitions”

- Family Forestry- planting of half- or full-sib families from parents selected on the basis of breeding values, as single-family blocks, either as seedlings or vegetatively multiplied, without maintenance of clonal identities.
- Full-sib forestry- untested clones of full-sib crosses planted in mixtures.
- Multi-Varietal Forestry- deployment of tested tree varieties in plantation forestry.

Where did the Idea for the Veg Prop of Forest Trees Originate?

- 2009- Veg Prop and Deployment of Varieties (UK)
- 2008- Veg Prop of Conifers (SF)
- 2002- “Clonal Forestry- Who do you think you are kidding?” (UK)
- 1999- Arborgen founded (US)
- 1997- IUFRO Radiata pine Symp. (NZ)
- 1992- “Clonal Forestry” the book
- 1992- IUFRO/AFOCEL Symp. (F)
- 1991- Clonal Forestry Workshop (NZ)

Where did the Idea of the Veg Prop of Forest Trees Originate? (continued)

- 1989- B.C. Research founded (1996 Silvagen, 1999 CellFor) (Can.)
- 1986- Workshop on growing radiata pine from cuttings (NZ)
- 1984- First published report of SE in conifers.
- 1983 CTIA meeting in Ontario (Can.)
- 1982- “Imp. Veg Prop Crops” book (UK)
- 1982- IUFRO Multi-clonal Varieties (D)
- 1981- IUFRO In Vitro Propagation (F)
- 1981- Symp. On Clonal Forestry (S)

Where did the Idea of the Veg Prop of Forest Trees Originate? (continued)

- 1977- Veg Prop of Forest Trees (S)
- 1973- IUFRO meeting of Veg Prop (NZ)
- 1968- Fielding- use of veg prop in plantations (AU).
- 1939- Schreiner “The possibility of the clone in forestry” (US)
- 1830s rooting of cuttings of *Picea abies* (D)
- 1400s- Rooted cuttings of *Cryptomeria japonica* (JN)
- 1100/1200s- Rooted cuttings of *Cunninghamia lanceolata* (C)

Worldwide Use of Clonal Forestry as of 2004

(Weir, 2004)

- Populus 1.5 million ha.
- Eucalyptus 1.2 million ha.
- Conifers 5.1 million ha.
- Hardwoods 0.02 million ha.
- TOTAL 7.82 million ha.

Model for Vegetative Propagation and Clonal Forestry

- Hardwood species- *Eucalyptus*, *Populus*, *Salix*
- Short rotation crops.
- Some species no previous breeding programme.
- Hybrid vigour important.
- Maturation not a big problem.
- Pulp or biomass species.

Clonal Forestry in Eucalyptus, Poplar and Willows

- The number of clones employed is small. A few clones account for more than 50% of the material in plantations.
- Monoclonal blocks are most common.
- Multi-clonal mixes require testing for clonal compatibility.
- Monoclonal blocks are better than mixtures of 2 to 3 clones.
- “Clonal forestry is only as reliable as the clones in it.”

Level of Improvement Possible

(conifers)

Source of Material	Percent Improvement
Unimproved Seed	0
Seed orchard	10 to 15
Best Family	20 to 25
Clones	25 to 35
Best Clone	40 to 60

“The rule of thumb for clonal improvement seems to be that clonal gains for most traits are **double** that expected from family forestry; e.g. for DBH growth (Dean et al., 2006; Baltunis et al. 2008).

Cown and Sorensson, 2008

Uniformity

- Consequence of using tested clones.
- May be greatly underestimated
  - An increase in wood quality and uniformity may be more important than an increase in volume.
- Eucalyptus wood density
  - Seedlings 300 to 900 Kg/m^3
  - Clones 500 to 600 Kg/m^3
- Monoclonal plots provide greatest uniformity.

“Clonal forestry represents an end-point of an evolving series of tree-improvement practices ranging from seed stands and seed-tree selection, through open-pollinated and then control-pollinated orchards (“family forestry”) and finally, to clonal forestry.”

Aimers-Halliday, Shelbourne and Hong 1997

“Clonal propagation of softwoods is arguably the most important forest technology currently emerging from the R&D pipeline. Deployment of the technology is now needed.”

“The question is no longer will clonal forestry provide at least some of the future forests, but rather when will it become prevalent?”

Thompson, 1984

Concerns about Clonal Forestry

- Biological/Technical concerns
  - Maturation
  - Testing
  - Deployment
- Economic/Marketing concerns
  - Costs
  - Future market demands
  - Crop failure
- Environmental Concerns
  - Certification
  - Regulation
  - Public acceptance

Maturation

- Much time and effort spent on “maturation” and “rejuvenation”- with only limited success.
- Avoid maturation by multiplying juvenile material.
- Cryogenic storage has also avoided the problem of maturation, but is most successful in storing embryogenic cell lines.
- Several recent studies report Somatic Embryogenesis from mature tissues.

Clonal Testing
(Libby, 1987)

- Level 1- Initial Screening
  - Survival, growth, form, resistance
- Level 2- Candidacy Testing
  - Testing as clones, G X E interactions
- Level 3- Clonal Performance Testing
  - Predictability, stability
- Level 4- Compatibility Testing
  - Mixture composition trials

Deployment

- Ways to manage risk.
  - Different clones in different years
  - Different clones in different locations
  - Number of clones depends on area to be planted with clones
- Start with multi-clonal mixtures and move towards monoclonal blocks.
- Develop clones for specific sites and end uses.

Costs

- Veg Prop by either rooted cuttings or SE cost more than seedling planting stock.
- Should not focus only on the costs without considering the benefits.
  - Reduction in time to get improved material into production
  - Decrease in rotation lengths
  - Decrease in establishment costs
  - Increase in productivity
  - Increase in uniformity

“Assumptions affecting genetic gain are clearly the most critical: **one could clearly afford to pay five or six times more per year in order to double the genetic gain** (in this example).”

Timmis, 1985

Environmental Concerns

- Veg prop is seen as part of “Intensive Forest Management”- manipulation of nature.
- Possible narrowing of genetic diversity is greatest concern.
- Regulations
  - Forest Reproductive Material (FRM)
  - Certification
  - National Regulations

How to Address Environmental Concerns

(Seltzer and Goldfarb, 1997)

- Must gain confidence of stakeholders.
- To do this must act together as equal partners
  - Scientists do not have all the answers
- Need to separate actual from perceived risks.
- Must have mutual ownership and involvement
  - At the planning stage
  - Identification and addressing of stakeholder concerns
  - What to monitor during trials
- Continuous communication!
- If this is not possible, National Regulations may be the only way to resolve the problem.

Where Has Vegetative Propagation and Clonal Forestry Been Tried?

Promise of Clonal Forestry

Those working with conifer species may have been seduced by the concept and promise of Clonal Forestry without fully appreciating:

- Maturation problems
- Propagation technologies
- Costs
- Time required to implement
- Market size (and whether there is a market)
- Environmental concerns

Clonal Forestry- Past Attempts New Zealand 1960s and 1970s

- Cuttings from 5 to 10 year-old trees.
- Maturation effects- poor rooting, slow growth rates.
- Loss of material in hedge orchards.
- Large number of hedges needed to produce the number of cuttings required.
- Hedge management costs high.

Veg Propagation- Past Attempts Ontario, Canada 1980s

- Bulk propagation of selected crosses.
- No maturation problems.
- No production problems.
- Production costs high.
- Foresters not convinced to benefits.
- Programme “too far ahead of its time”.

“Clonal” Forestry- Past Attempts Sweden 1970s to 1990s

- Used nursery bed selected individuals.
- Weak demand for rooted cuttings.
- High production costs.
- Government regulations on number of clones permitted.
- General tendency towards a more “natural” forestry at the time.

Why did the previous programmes fail?

- Maturation (aging) of plant material.
- High production costs.
- Limited market.
- “Idea too far ahead of its time!”
- Environmental concerns.
- Government regulations.

Is Vegetative Propagation and/or Clonal Forestry being used successfully today?

Current Production of Vegetatively Propagated Forest Trees

Country	Species	No./yr	Method	Deployed
Aust.	Pine hybrids	6m	FS SP-RC	Mass Prop.
Aust.	Pinus radiata	?	FS SP-RC	Mass Prop.
Brazil	Eucalyptus	400m	RC	Clonal blocks
Brazil	P. taeda	?	FS SE-RC	?
Canada	Picea, Pinus	1.2m	SE direct	?
Canada	Picea glauca	2m	SE-SP-RC	Mass Prop.
Chile	Pinus radiata	70-100m	FS/SE-SP-RC	?

Current Production of Vegetatively Propagated Forest Trees

Country	Species	No./yr	Method	Deploy
China	Cunninghamia lanceolata	65m	RC	Clonal Blocks
China	Eucalyptus	?	RC	Clonal Blocks
Ireland	Picea sitchensis	3m	FS SE-SP-RC	Mass Prop.
Japan	Cryptomeria japonica	17m	RC	Clonal Blocks
NZ	Pinus radiata	17.5-20m	FS SP-RC	Family Forestry
NZ	Pinus radiata	2m	FS SE-SP-RC	Clonal Blocks
Portugal	Eucalyptus	3m	RC	Clonal Blocks

Current Production of Vegetatively Propagated Forest Trees

Country	Species	No./yr	Method	Deployed
S. Africa	Eucalyptus	30m	RC	Clonal Blocks
S. Africa	Pine hybrids	5m	RC	Mass Prop
UK	Picea sitchensis	7 m	RC	Mass Prop
US	Pinus taeda	10-30m	SE direct	Clonal Forestry
	Total	691.2m		

Comparison of Propagation/Deployment Options

	Seed orchard	Mass Prop.	Clonal Prop.
Improvement	10-15%	20-25%	40+%
Flexibility	Low	High	High
Uniformity	Low	Some	High
Predictability	Low	Some	High
Corr.Breakrs	No	No	Yes
Match to site	No	Some	Yes
Match to use	No	Some	Yes
Env. Concrn	No	Low	High
Cost	Low	Medium	High
G X E	No	Some	Yes

Why has Veg Prop and/or Clonal Forestry not taken off in Europe?

- Forestry is a conservative profession.
- European forests are owned and managed by a large number of public and private landowners.
- Few R&D organisations ready or willing to “sell the idea”.
- Few forest owners willing to try a new idea.
- Perceived concerns about veg prop/clonal forestry:
    - Biological concerns
    - Economic/marketing concerns
    - Environmental concerns

Vegetative Propagation/Clonal Forestry Checklist

- Species with a large “critical mass”.
- Improved material available.
- Reasons why veg prop makes sense.
- Efficient veg prop (and germplasm storage methods).
- Field demonstrations.
- Economic analysis.
- No major opposition.
- Appreciation of environmental concerns.
- Customers for the product.
- Gradual scale-up (Mass Prop-Family For-Clonal Forestry).
- Robust self-regulation.
- Project “champion” and a team committed to making the project a success.

Potential Applications of Veg Prop/Clonal Forestry in Europe

- Shy flowering species
  - Spruces
- Small amounts of valuable material
  - Hybrid aspen
- Hybrids
  - Hydrid larch
- Highly uniform products
  - Noble and Nordman fir Christmas trees
- High quality timber species
  - Wild cherry

Conclusions

- Most of the main technical problems have now been overcome.
- Examples from other parts of the world show that it can be made to work.
- Need to have examples in Europe where it can be demonstrated to work.
- Must recognise environmental concerns.
- It is now up to us to either make it work or decide to continue to watch others use it.

“The question is no longer will vegetative propagation and/or clonal forestry provide at least some of the future forests in Europe, but rather when and how will it become prevalent?”

Thompson, 2009