3rd International Congress on Planted Forests
Satellite Workshop, Dublin, 16-18 May 2013

Root growth potential in seedlings of three coniferous tree species of contrasting root branching characteristics

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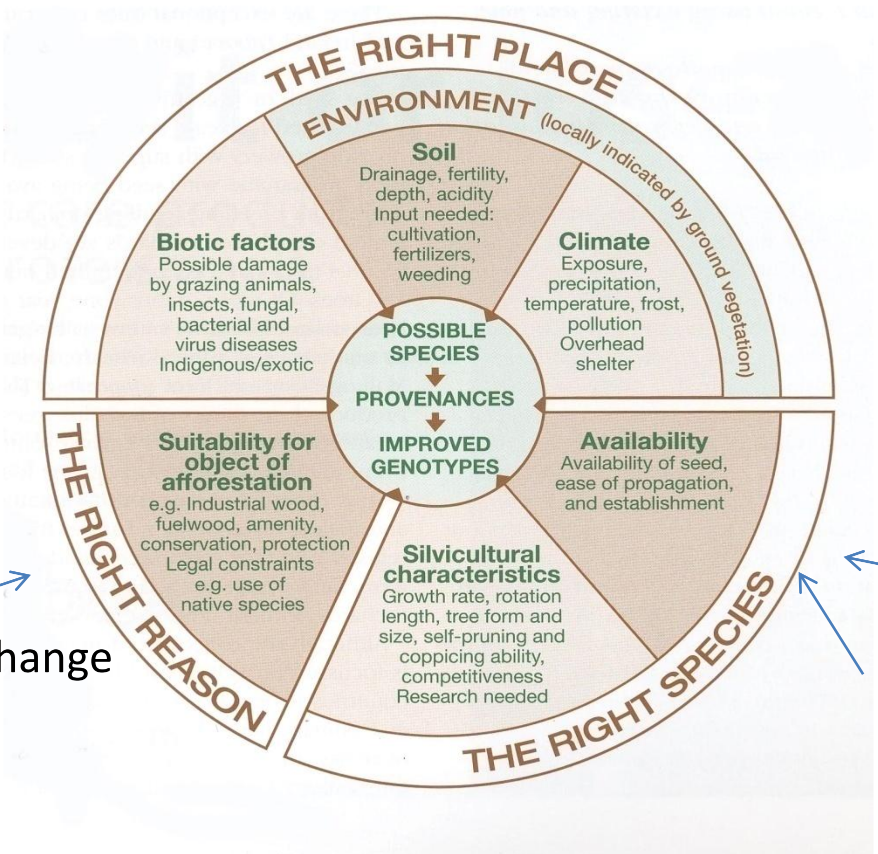
Outline of Presentation

- **From global priorities to seedling roots …**
- **Background** to role and importance of roots characteristics in planted seedlings
- Defining a **classification system** for root architecture
- Explore relationships between root architecture, **root growth potential and carbohydrate allocation** following transplanting/release from dormancy
- Briefly consider **implications** for future seedling establishment research
- Recognize the need to **sustain "core" technical skills and applied research** to address emerging and new forestry priorities.

Successful Establishment:

The Right Species, Place and Reason



"New" priorities:

Adaptation to climate change

Landscape restoration

Ecosystem services

The right **genotype**

The right **seedling**

(quality and source)

Seedling quality and the physiological basis of transplanting stress

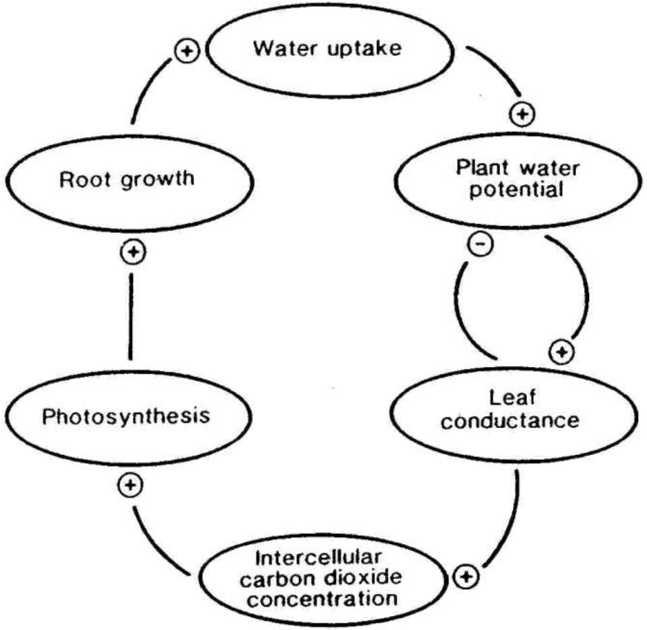


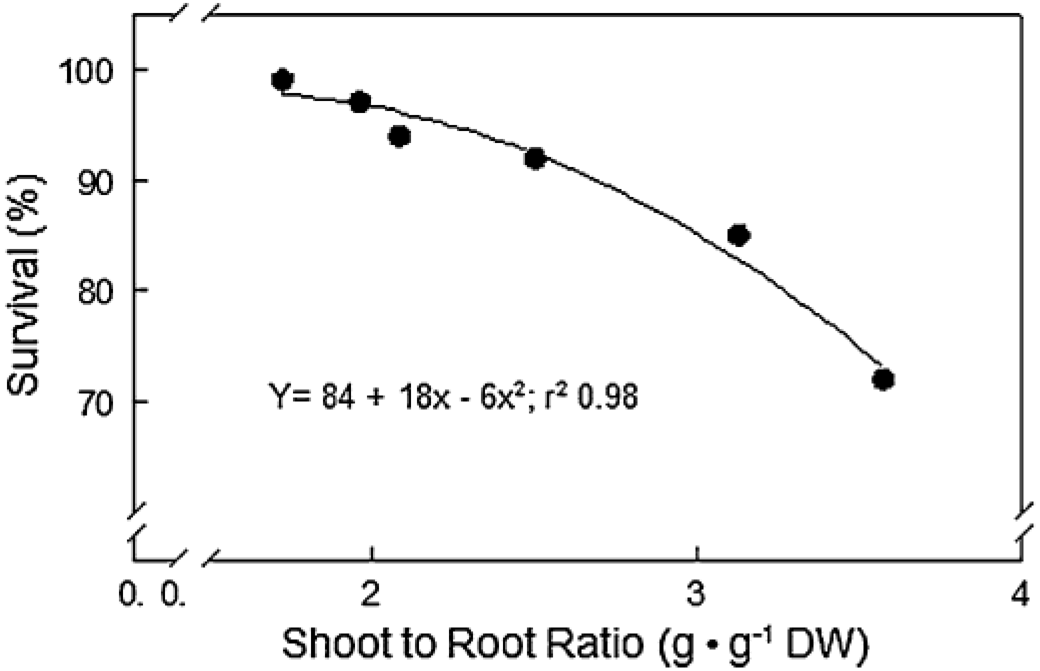
FIG. 3. The feedback relationship between root growth and photosynthesis in newly planted trees. +, enhancement effects; −, negative effects.

(Burdett 1990)

Attributes of *successful* planted seedlings

Characteristic	Advantage
Well-developed terminal bud	Dormant stock; greater shoot growth
Large root-collar diameter	Greater survival and volume growth; resistant to animal and heat damage
Tall	Better competitor with weeds and brush
Low height:diameter ratio	Better resistance to wind desiccation; greater survival and growth on droughty sites
Numerous secondary needles	Greater regulation of water loss; better light interception and utilization in photosynthesis
Fibrous root system	Greater exploitation of soil; more root-initiation points
High root-growth potential	More rapid proliferation of roots; greater survival
Cold hardy	Better resistance to cold damage and other environmental stresses

Seedling performance attributes
Shoot: Root ratio versus Survival



Performance of loblolly pine under simulated drought (Mexal and Dougherty 1983)

Root system form and function

Sitka spruce
(Natural Regeneration)

Equilibrium between root and shoot systems

Extensive network of structural roots (First order)

High density of fine roots (Higher order)

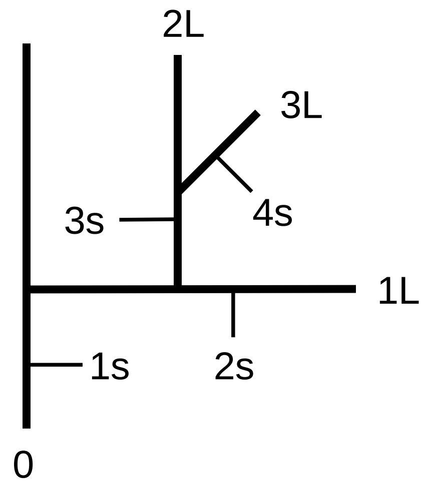
Root Architecture

- 2 major components:
- **Structural root system**
  - support, storage, transport
- **Fine root system**
  - uptake of water, mineral nutrients
  primary site for mycorrhizal associations

- *Pattern and distribution of roots reflects evolutionary adaptations to variable resource priorities (e.g., water, mineral nutrients)*
- *Plasticity in response to nursery cultural practices*

Root Architecture Classification

Lateral long roots and short roots



Root Orders

0 – Primary root axis, tap root
1 – First-order lateral root
2 – Second-order lateral root
3 – Third-order lateral root
4 – Fourth-order lateral root

Root Type

L – Lateral long root
s – Lateral short root (fine roots)

Root architecture, Root regeneration and Carbohydrates

- **"If the root system did not increase in size at a fairly rapid rate…the seedling would die of drought…."** (Stone 1955)

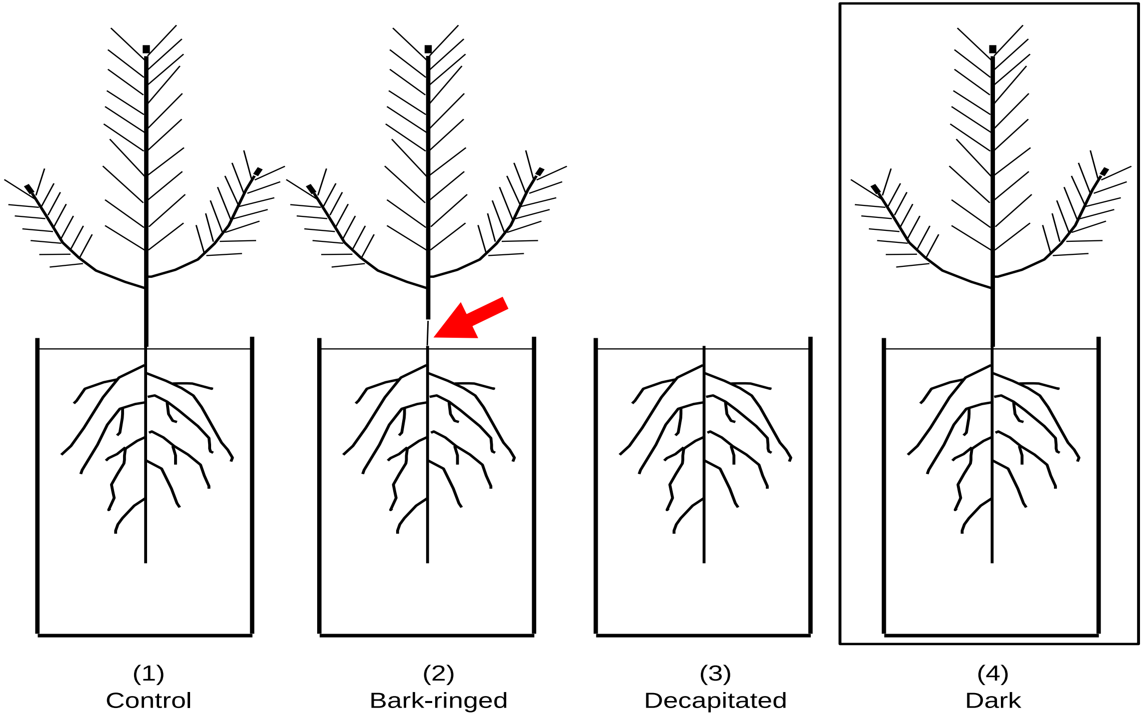
Objectives of study:

- Assess root form and architecture for a range of species: Corsican pine, Scots pine, Sitka spruce
- Is there a link between initial fibrosity and root growth potential ?
- What might be the importance of current photosynthate in new root regeneration?

Methods

- Dormant container seedlings (1.5 yrs)
- 10 seedlings per treatment (50 per species)
- Initial sample measured to give baseline values, remainder transplanted to root observation boxes
- 4 treatments – Control (C), Bark-ringed (B), Excised (E) and Dark (D)
- Controlled environment
- Parameters:
  - biomass, shoot and root growth, non-structural carbohydrates
  - **Root characteristics**: counts of roots by branch order
  - **Index of fibrosity** – (1L x (2L + 3L))/g (root dry wt)
  - **Root growth potential** – number new roots>10 mm in 16 days
- **Statistics**: ANOVA, LSD

Experimental treatments



Variable effect on transpiration, translocation and photosynthesis

Controlled Environment

16 h day/8 h night. 20 ° C. 65% humidity. Cool white/incandescent light at 300 mol $m^{-2}s^{-1}$

Results - Initial seedling characteristics:

root and shoot relationships

Seedling characteristic	Corsican pine	Scots pine	Sitka spruce	P-value
Root biomass (g)	1.2a	1.1b	0.6c	<0.001
Shoot:root biomass ratio ($g \cdot g^{-1}$)	2.2b	1.8c	2.6a	<0.001
First order lateral long roots (1L)	9.1c	12.6b	15.3a	<0.001
Root fibrosity index (RFI)[1]	6.6c	39.7b	115.5a	<0.001
Short root: long root ratio[1]	4.9b	5.0b	8.7a	<0.001

[1] Based on mean of three 50 mm segments of 1L root on each of 10 seedlings per species.

Results - Initial seedling characteristics:

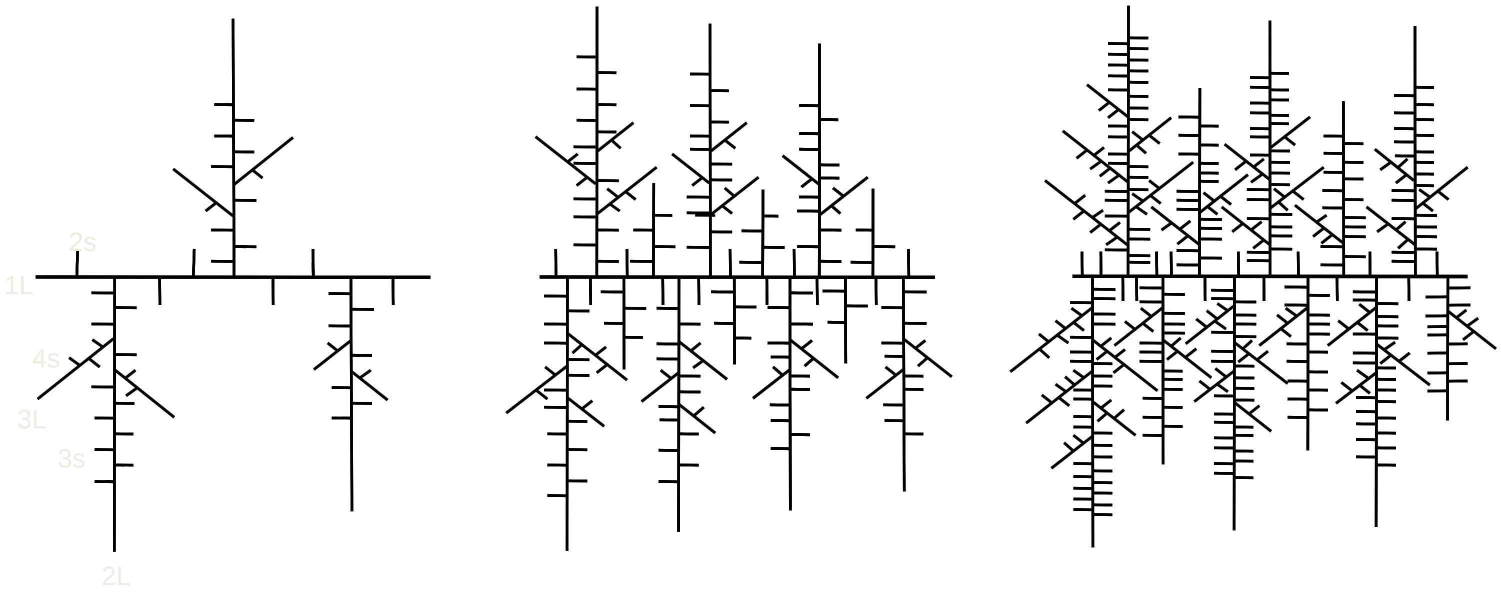
root system architecture

Root type (order)	Corsican pine	Scots pine	Sitka spruce	P-value
Long roots (L)				
2L	3.3c	13.0a	10.4b	<0.001
3L	5.7c	17.3b	31.3a	<0.001
Total L	9.0c	30.2b	41.7a	<0.001
Short roots (s)				
2s	5.6b	11.2a	13.8a	<0.001
3s	27.0c	102.6b	235.5a	<0.001
4s	9.2c	26.6b	100.7a	<0.001
Total s	41.8c	140.5b	350.0a	<0.001
Total L and s	50.8c	170.8b	391.7a	<0.001

Contrasting root architectures

based on 50 mm sections of 1L root

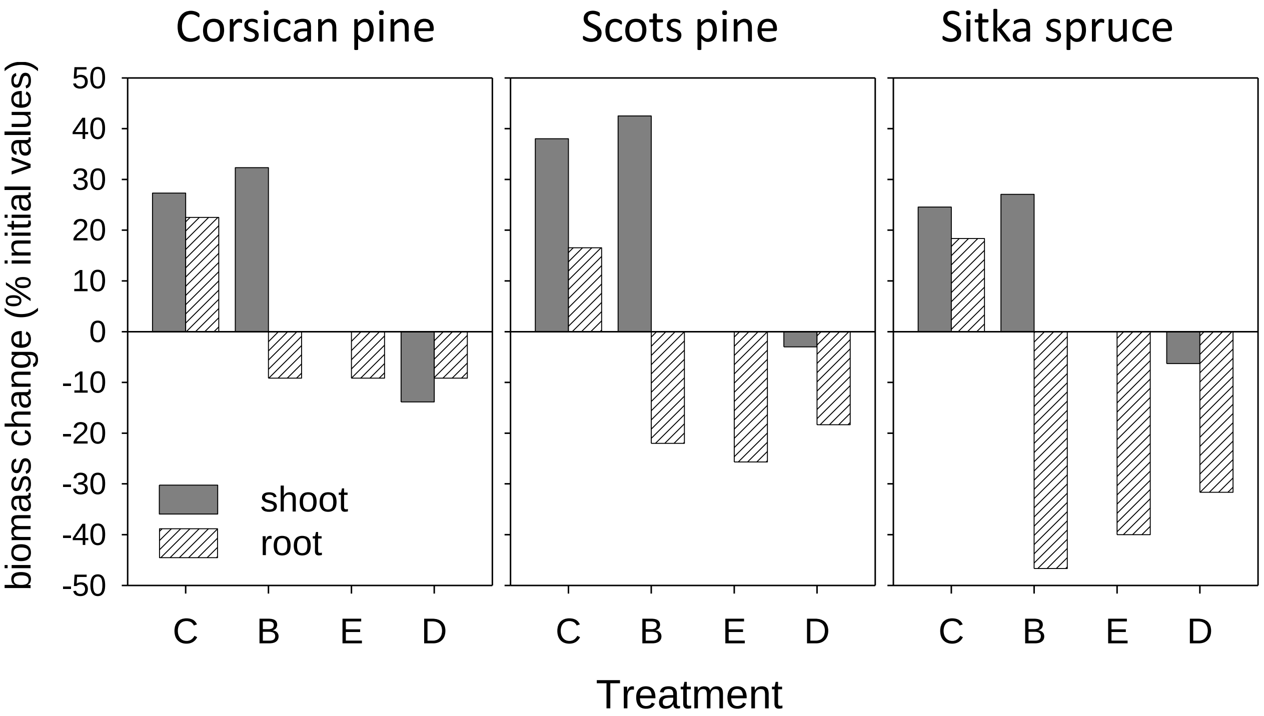
a. Corsican pine b. Scots pine c. Sitka spruce



Analysis based on 3 x 50 mm segments of 1L on each of 10 seedlings per species

Treatment Effects

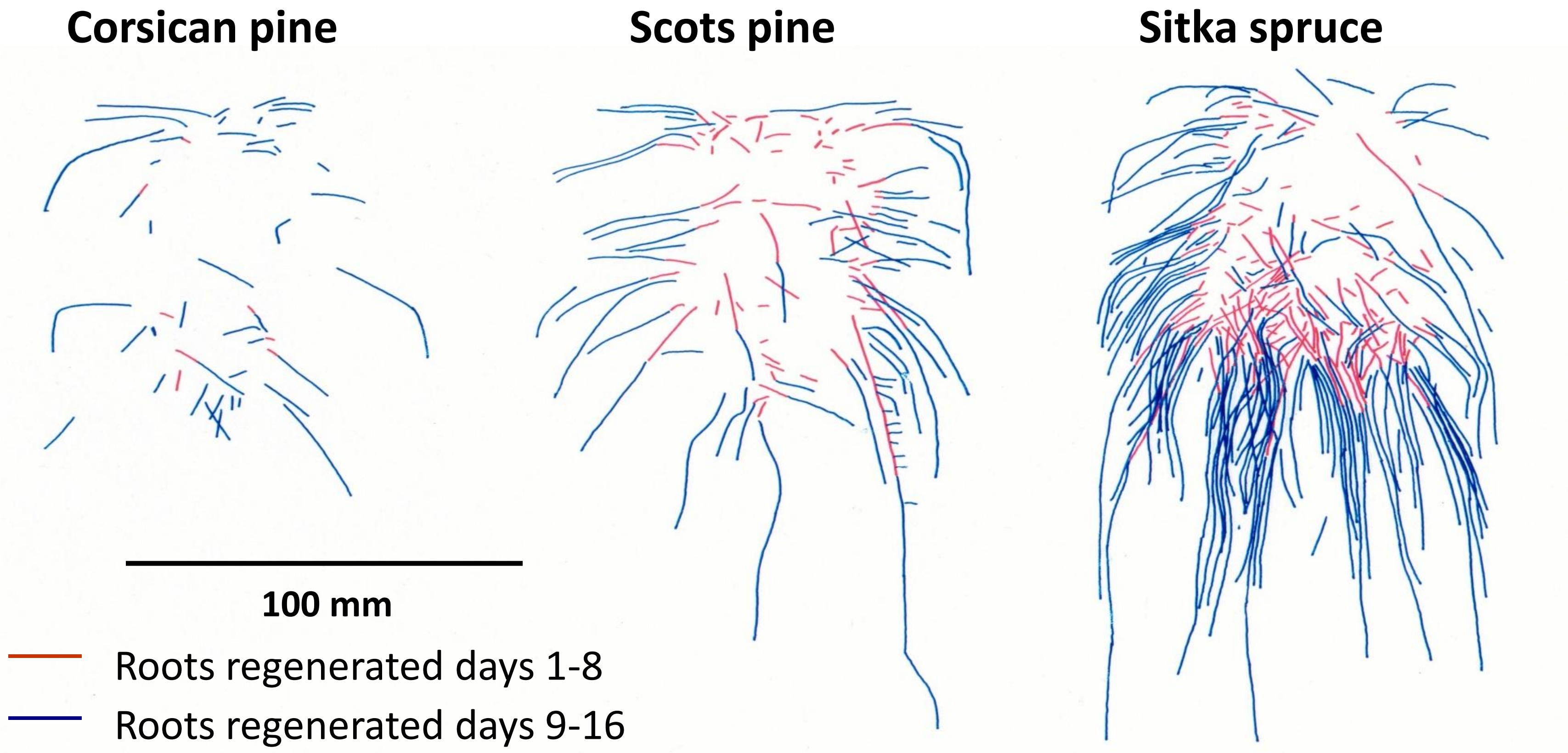
Percentage change in biomass relative to initial condition



C = Control B = Bark-ringed E = Excised D = Dark

Root regeneration patterns after 16 days

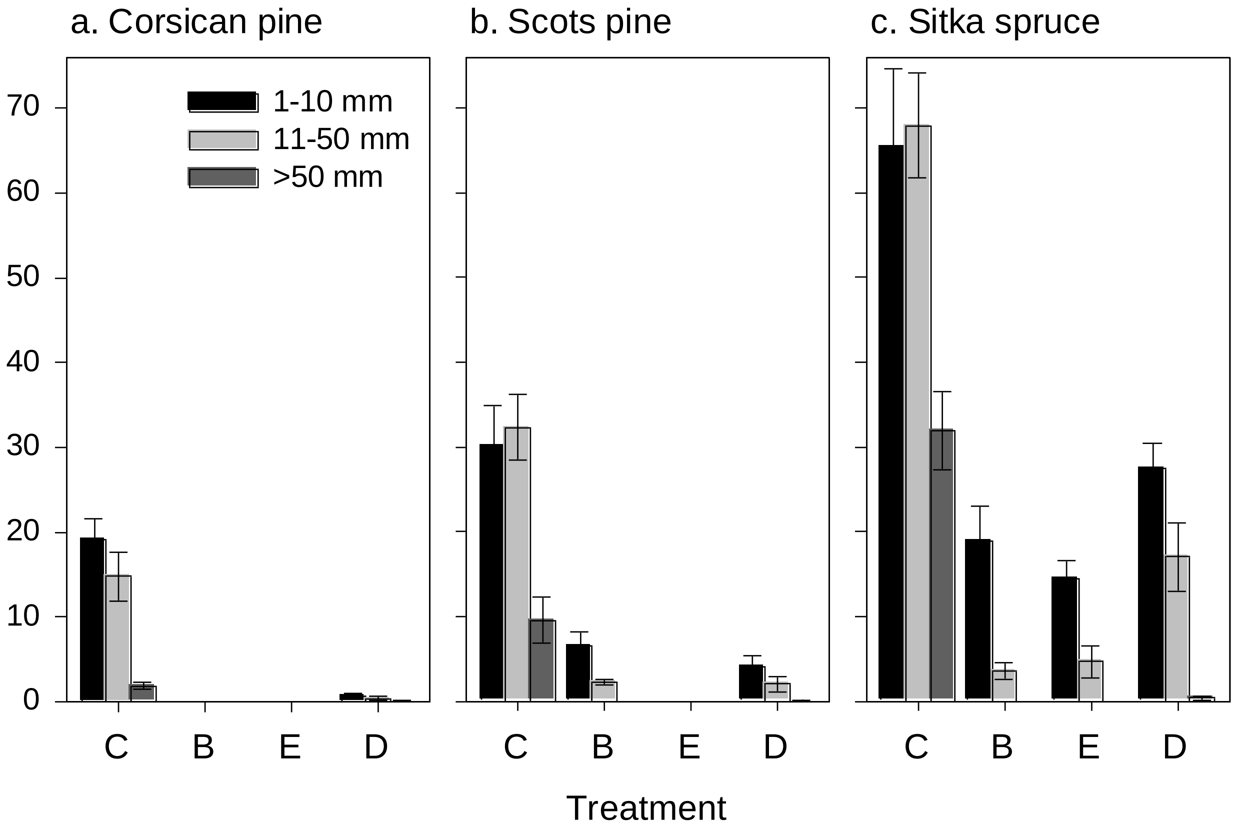
(Control seedlings)



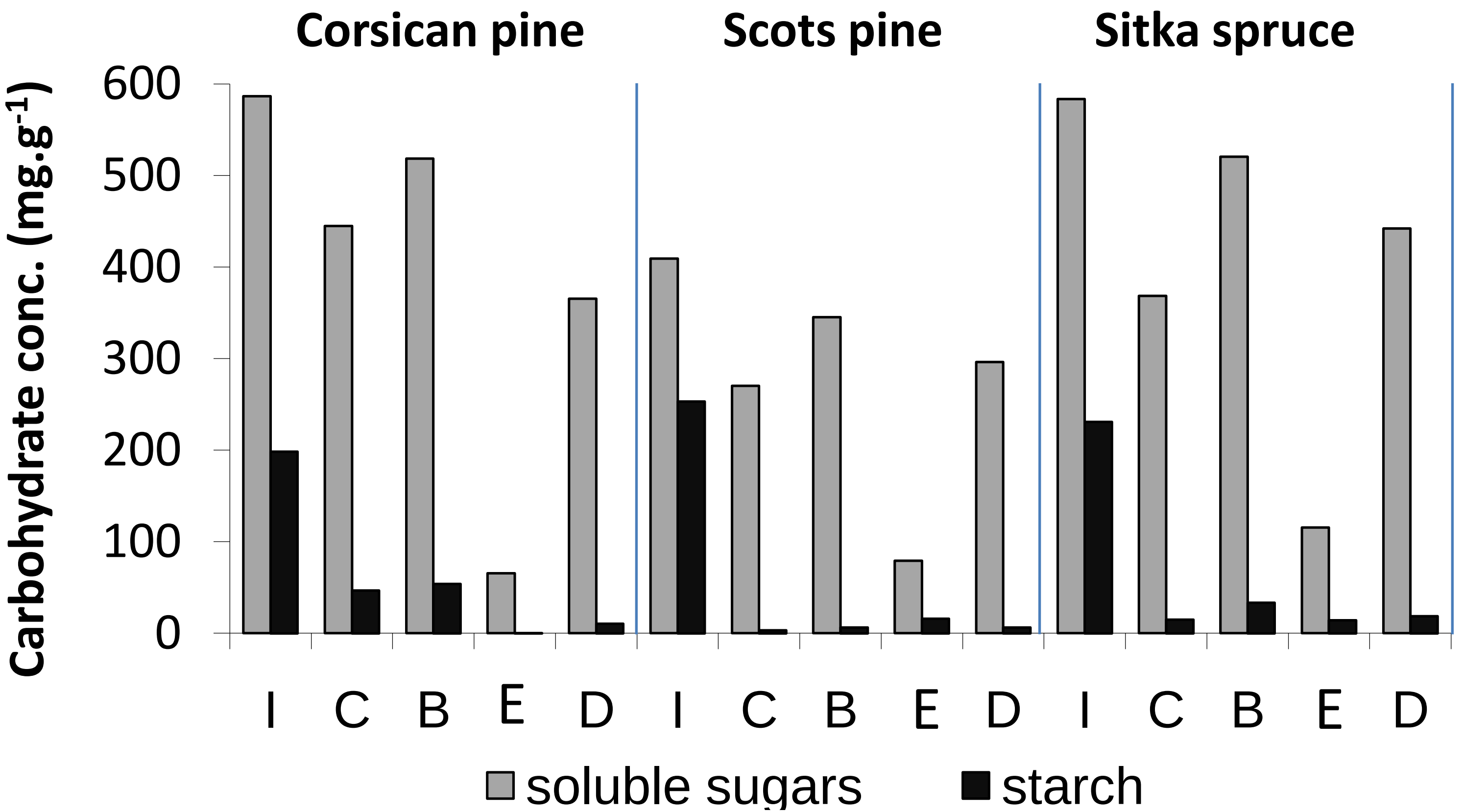
Total length (mm) of regenerated roots, by treatment (day 16)

	Control (C)	Bark-ringed (B)	Excised (E)	Dark (D)
Corsican pine	570	0	0	20
Scots pine	1750	40	0	50
Sitka spruce	4580	150	140	510

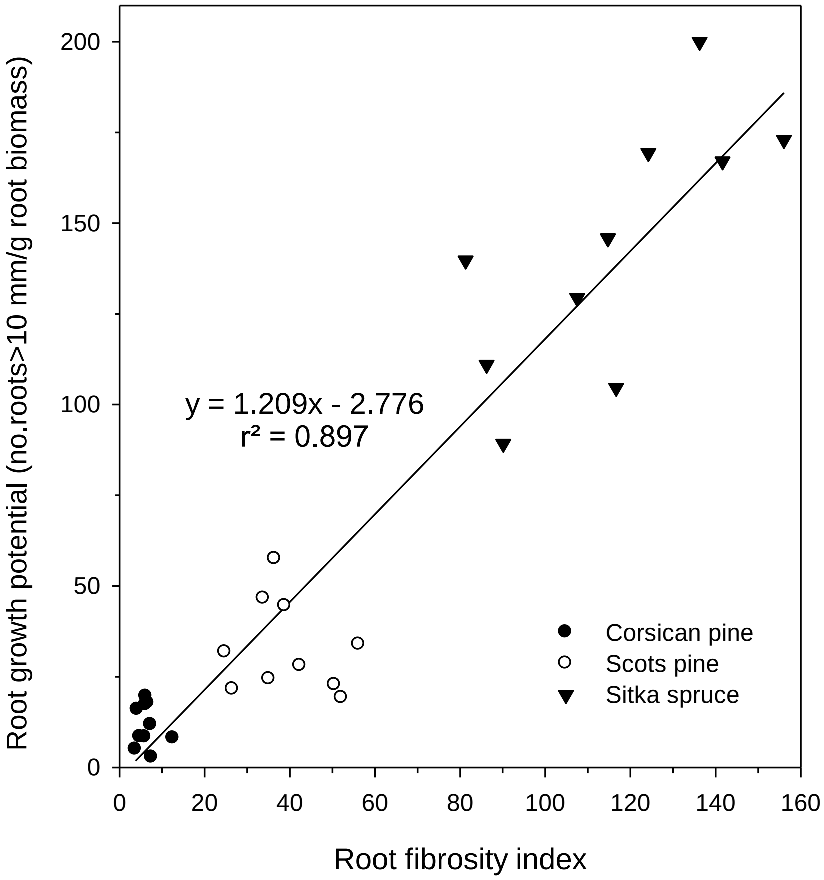
Number of roots by length class and treatment (day 16)



Carbohydrate dynamics



Initial root fibrosity and root growth potential (RGP)



Conclusions

- **Significant differences are evident among species** in structural and fine root systems, cultivated in same production regime
- **Corsican pine and Scots pine** are entirely **dependent** on current photosynthate for new root development; **Sitka spruce** appears **able to metabolise stored photosynthate** for new root development
- **Contrasting patterns of root architecture and carbohydrate metabolism may help explain species differences in sensitivity to transplanting stress** – implications for cultural practices
- **Ecosystem Services and Plantations … Back to the future**
  - Species diversification is an important adaptation to climate change and future risk management - **likely to stimulate renewed interest in seedling cultural practices and a renewed focus on elements such as root system parameters**.