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EUROPEAN UNION FUNDING FOR RESEARCH & INNOVATION

SERBIA FOR EXCELL

Climate impact on xylem tissue in woody plants

Practical and breeding aspects

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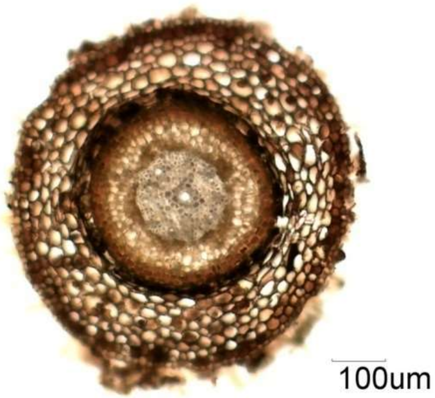
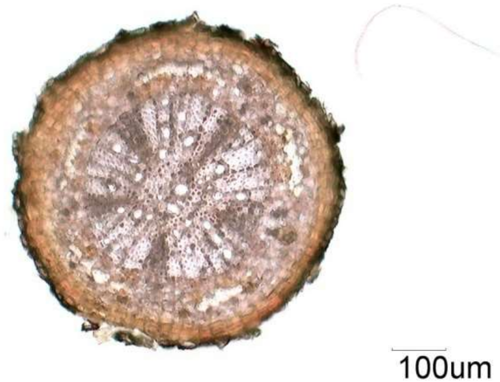
Secondary growth in woody plants

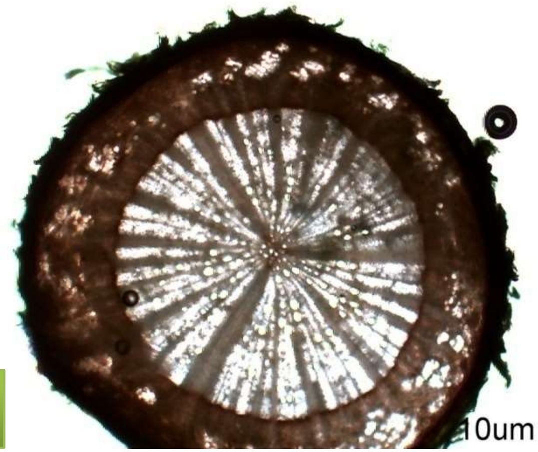
All in a function off water conductance/lower resistance, as the vegetation proceeds ...



Primary structure, short period of time



Differentiation of secondary wood/cortex – xylem and phloem



Scarce traces of the primary structure

How important are the trunk characteristics?

- Communication – bridge between root system and the scion.
- Water and nutrient conductance upwards, ascending.
- Photoasimillates conductance downwards, descending.
- Mechanical support.
- The importance of wood as a renewable natural resource

If so important, should both axial and radial growth be constant, higly heritable?

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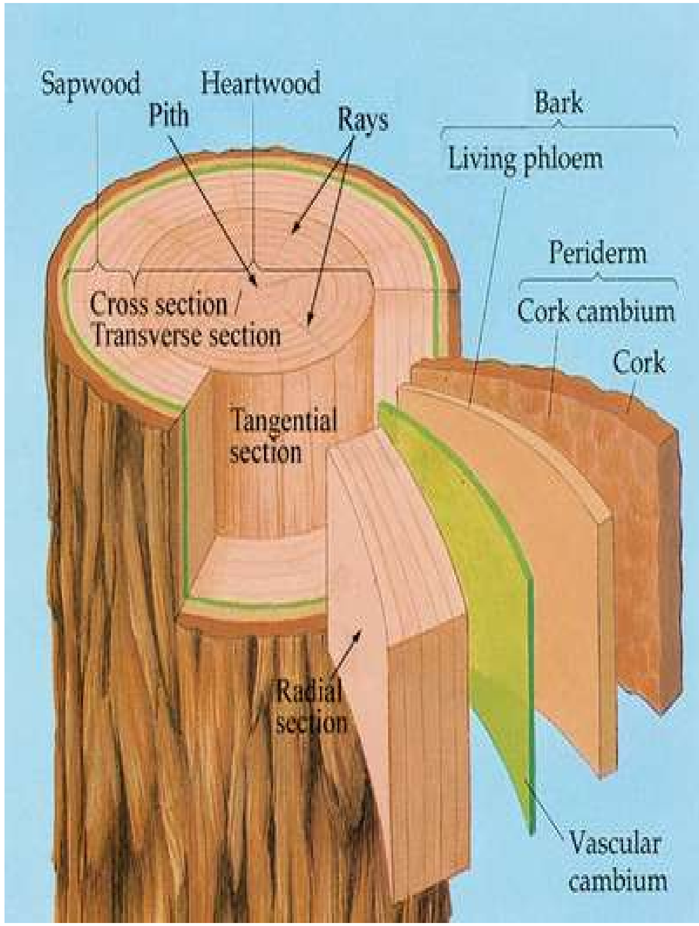
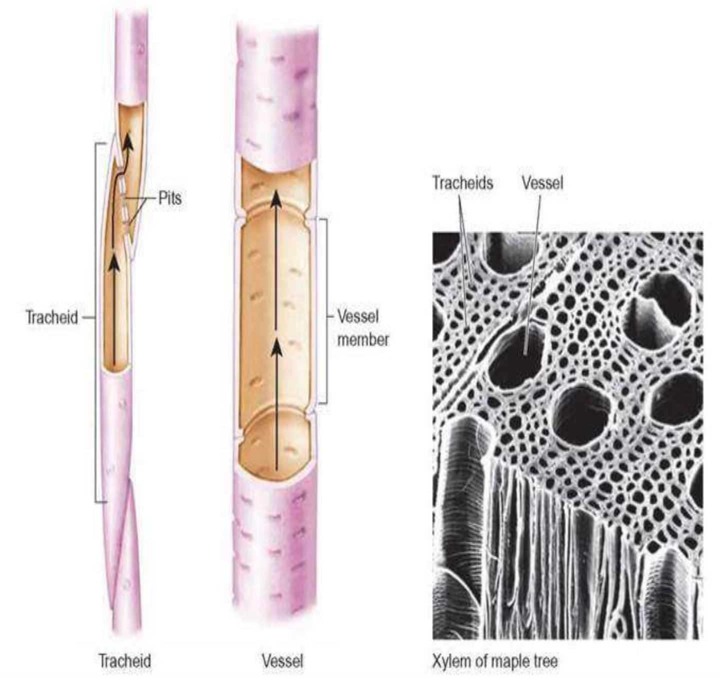
No! And it isn't...

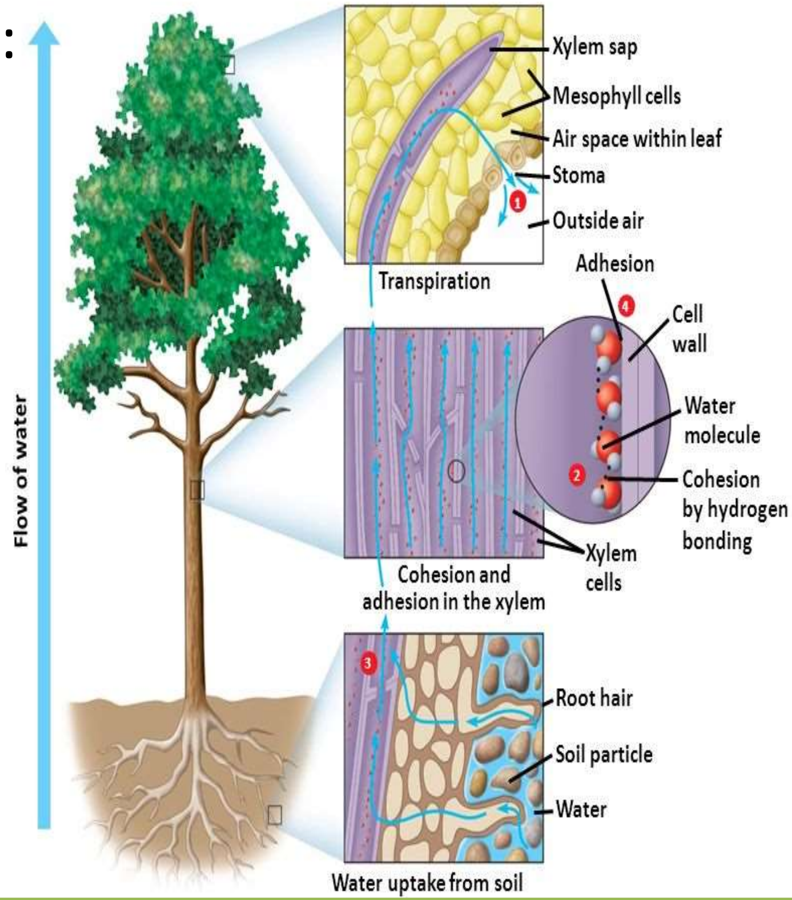
- **Cambial activity and formation of wood and cortex are genetically and environmentally driven!**
- Dendrochronology and variability of tree-ring characteristics
- Plants' functional adaptations to climate change and cambium plasticity



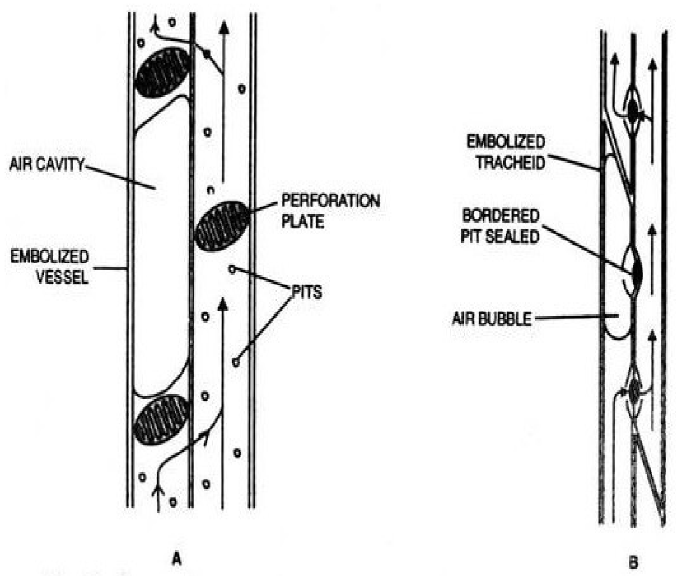
Xylem functioning and its significance for plants' survival

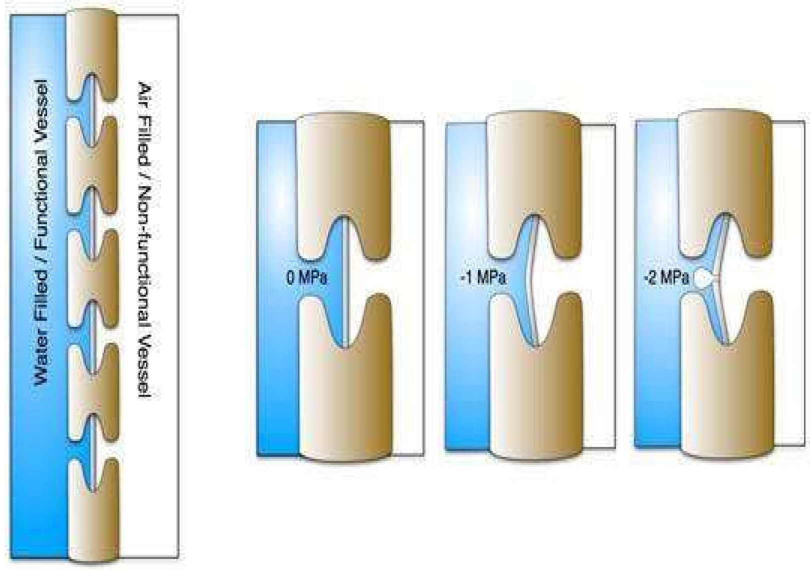
- Transport systems in plants:
  xylem and phloem tissues
- Continuous network of conduits:
  root-stem-leaf transport

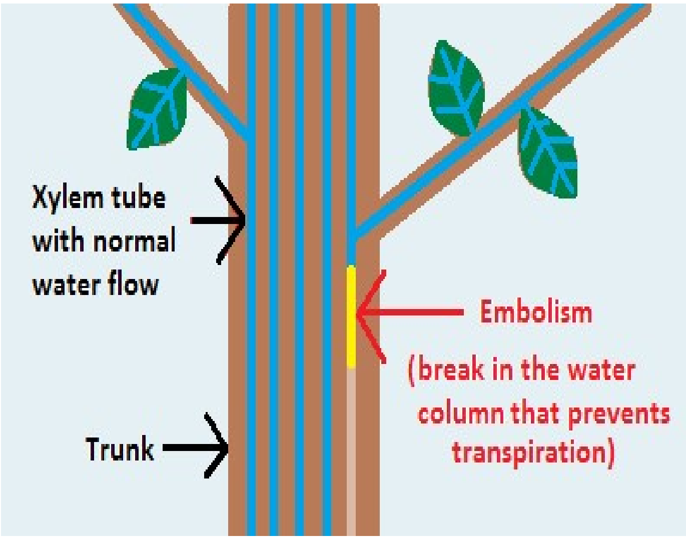




Constant environmental changes cause cavitation and embolism occurence



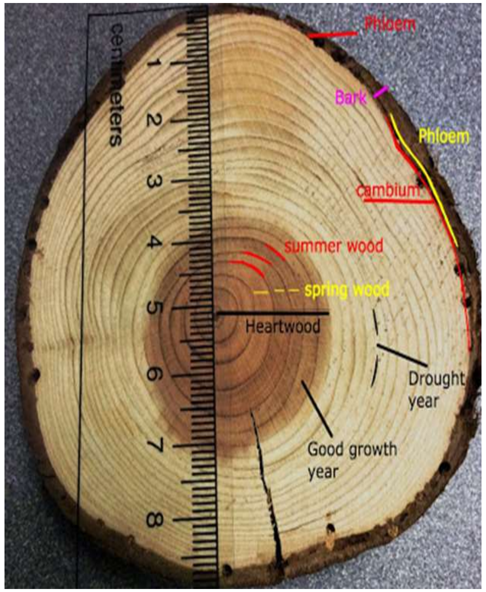


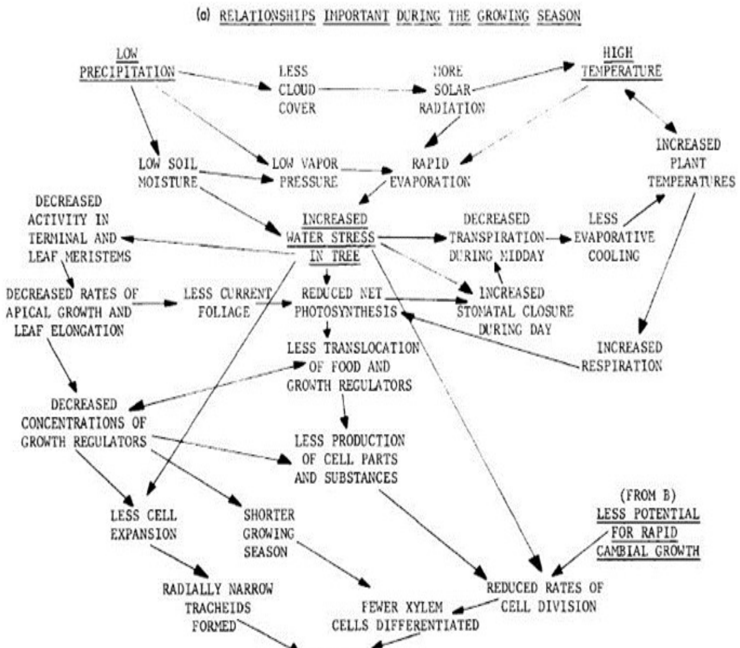


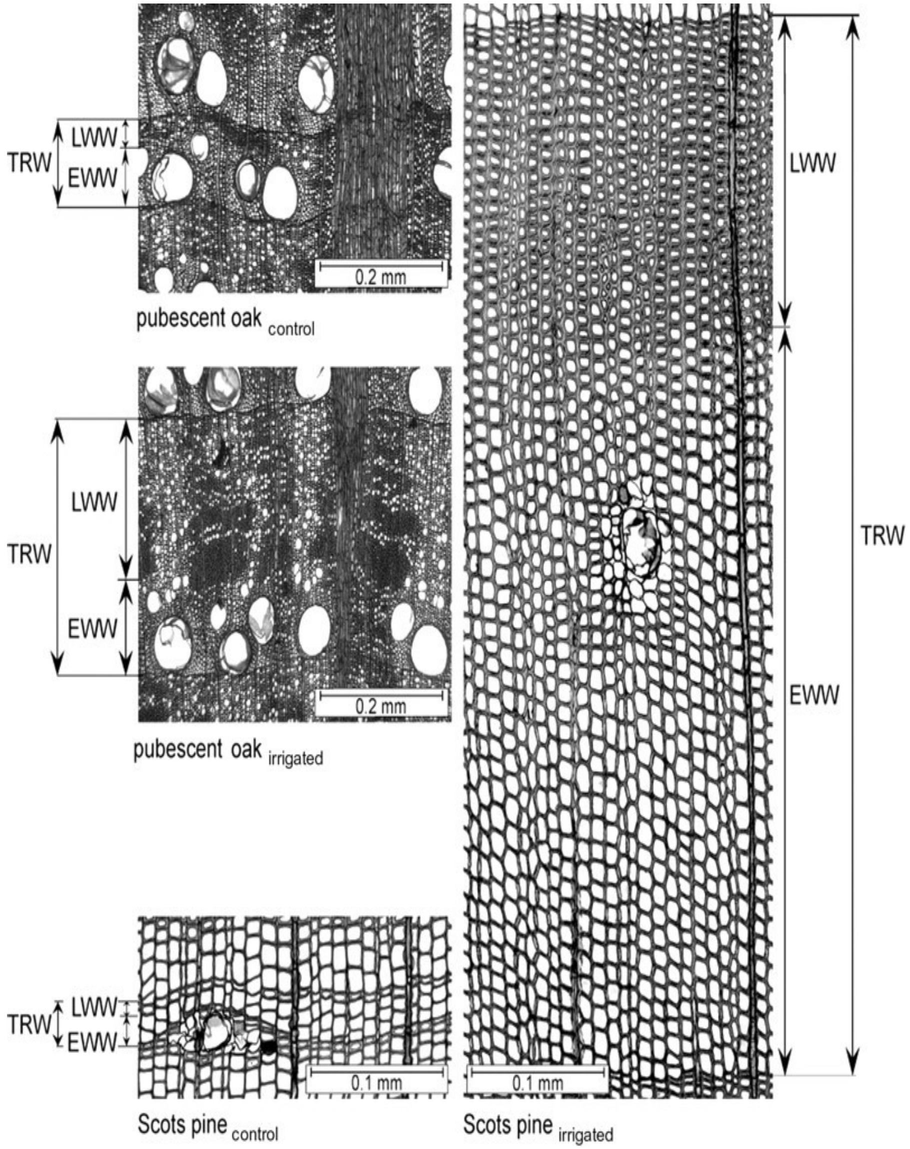
Without cambial plasticity and adaptations, first drought event would cause water path breakage, tough to recover from.

Linking xylem hydraulic properties to environment and vice versa

- ❑ Tree-ring anatomy – definition and significance of this methodological approach
- ❑ Diagrams and models – simplification of hypothesized physical or physiological interrelationships







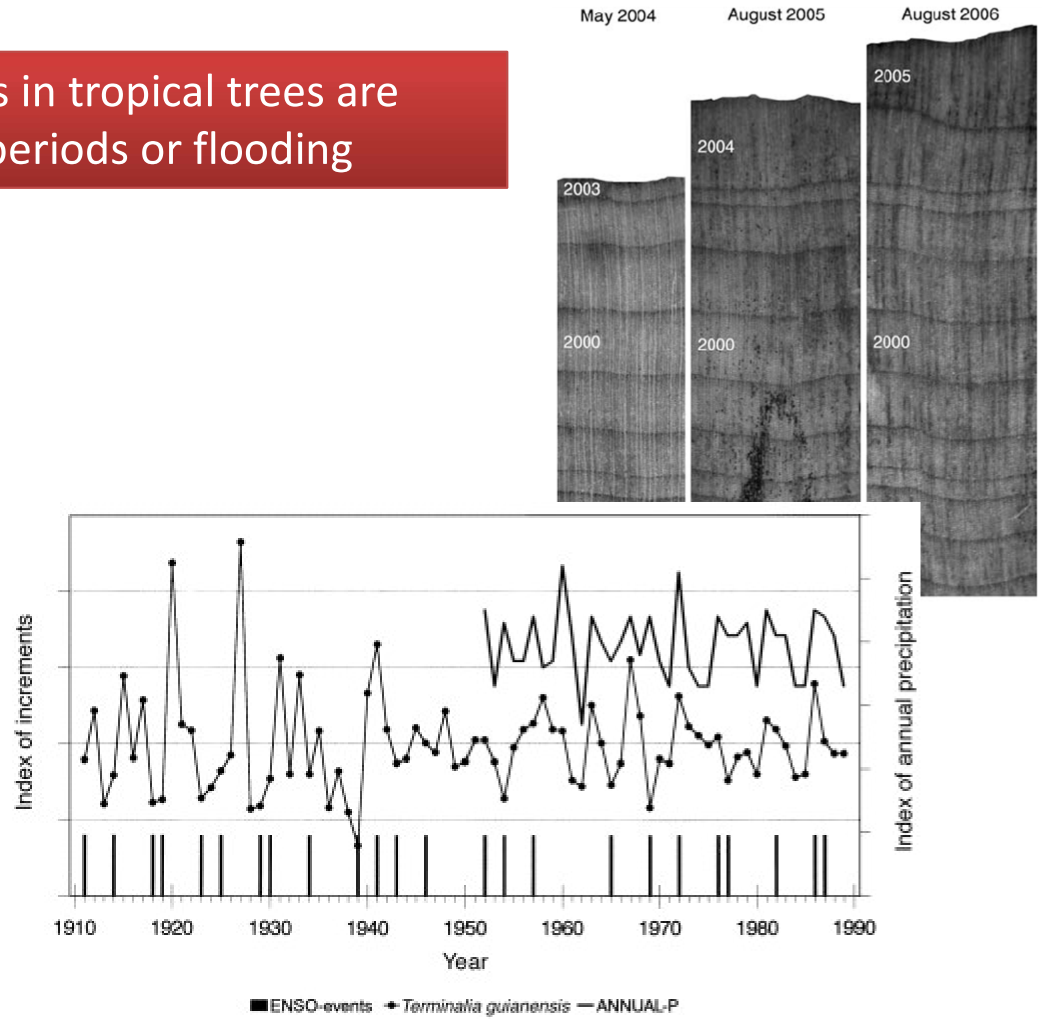
(Above) Tree rings of the drought year 1976 in control and irrigated pubescent oak and Scots pine. Abbreviations: TRW, tree-ring width; EWW, earlywood width; and LWW, latewood width (from Eilmann et al., 2009).

- Wood-anatomical modifications can greatly differ depending on tree metabolism and species specific wood structure, as well as on the timing of the season when the particular environmental event occurs
- Modifications of xylem tissue, regarding cell size, number and shape
- Seasonal pattern of adaptations
- Species-specific responses to contrasting water supply
- Importance of previous growing season conditions
- Bimodal patterns of cambial activity and cell differentiation towards xylem or phloem production

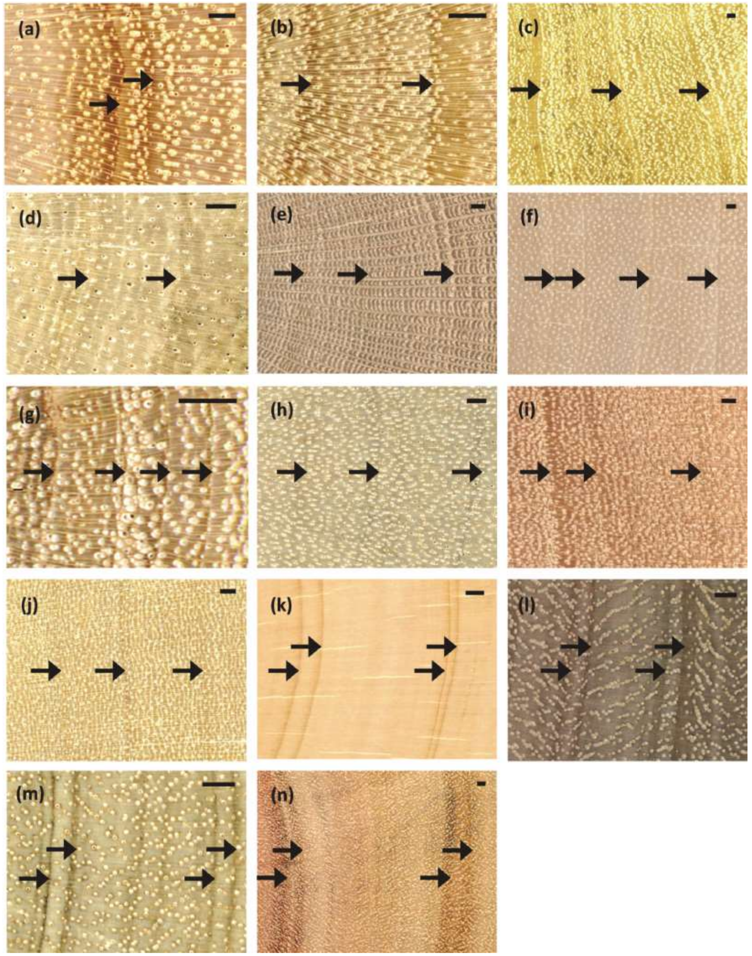
Drought/flooding stops and starts

Cambial dormancy and annual rings in tropical trees are induced by annually occurring dry periods or flooding

In 1995., 1999. and 2002. Worbes Martin have shawn that even regular shoot rings can form two small false rings related to two occasions of precipitation during the dry season, with 50 mm rainfall over one or two days, followed by dry periods of up to three weeks.



Images of the transverse surface of wood samples of tropical tree species showing annual tree rings produced under a bimodal precipitation regime



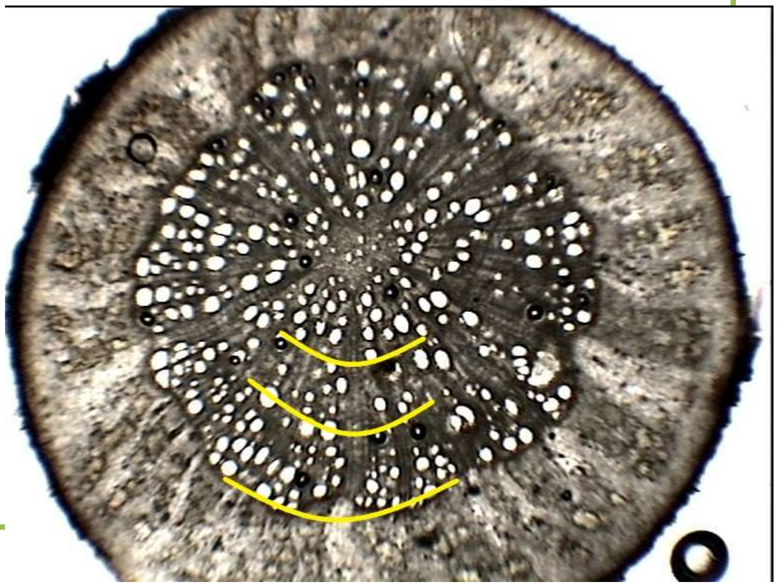
Acacia mearnsii (a),
Bridelia micrantha (b),
Combretum molle (c),
Croton macrostachyus (d),
Grevillea robusta (e),
Mangifera indica (f),
Markhamia lutea (g),
Persia americana (h),
Syzygium cuminii (i),
Trilepisium madagascariensis (j),
Cupressus lusitannica (k),
Eucalyptus camaldulensis (l),
Eucalyptus grandis (m),
Eucalyptus saligna (n).

David et al., 2014.

What about roots

- Buffered by surrounding soil
- Positioned deeper in the ground
- Lower fluctuations in precipitation and temperature
- Don’t have annual rings?

New approach in breeding strategies



Important questions that will define good size controlling rootstock

Soil solution uptake and conduction by cohesion-tension theory depends on a complex system consisting of the soil, the plant (rootstock, scion and their interaction) and the atmosphere.

→ *To wich extent do the rhizosphere and atmosphere influence root and shoot formation and xylem characteristics*

Pertinent literature and results obtained from 2010 – 2018 sugest that the outermost xylem ring is the most responsive for solution axial conductance.

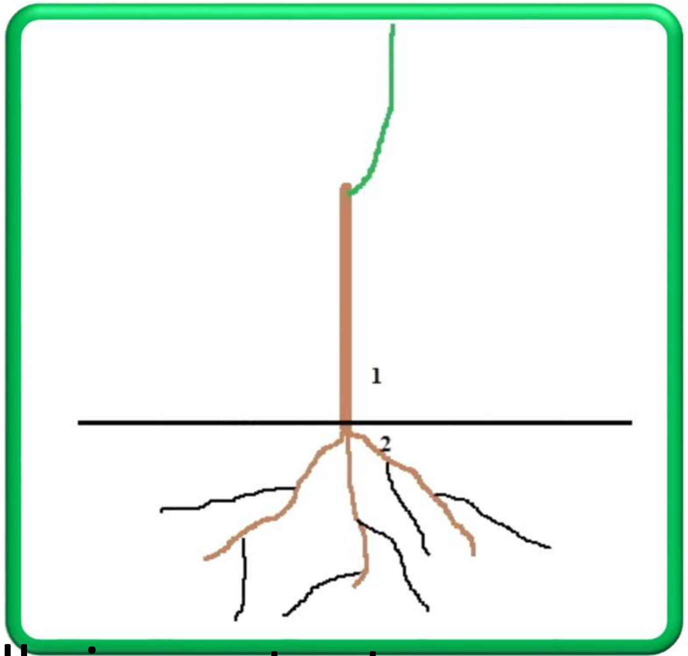
→ *To wich extent do the rhizosphere and atmosphere control root and scion cambial activity?*

↓

If the cambial activity and new xylem production is mainly driven by the environmental factors, is there any rootstock selection capable to alter xylem vessels size and number.

Rootstock requirements
- a cherry story-

- Size controlling effect
- Good anchorage
- High compatibility
- High productivity
- Fruit size and quality



Both rootstock parts are equally important – rootstock stem and root system.

Instead of 10 m tall unmanageable trees – dwarf fruit trees suitable for intensive pedestrian orchards

‘Oblačinska’ sour cherry/Lara next to the red currant bush

‘Oblačinska’ sour cherry/Summit

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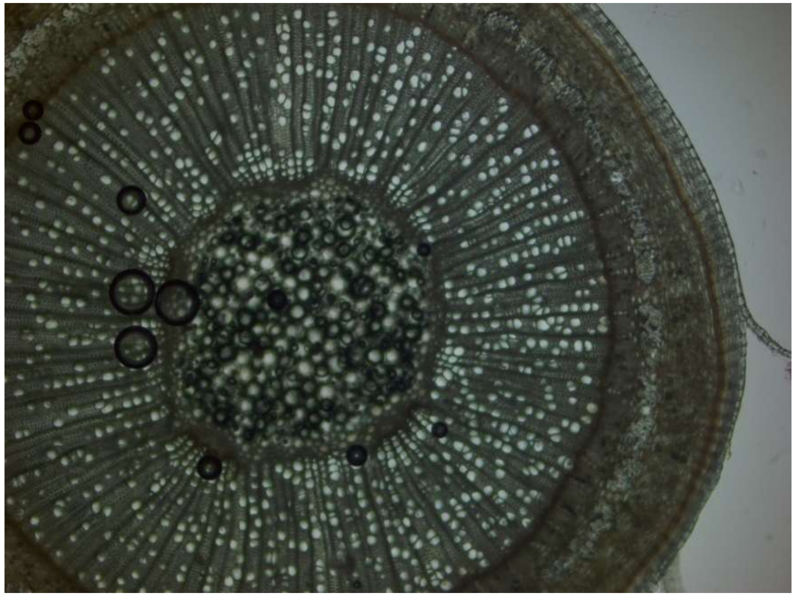
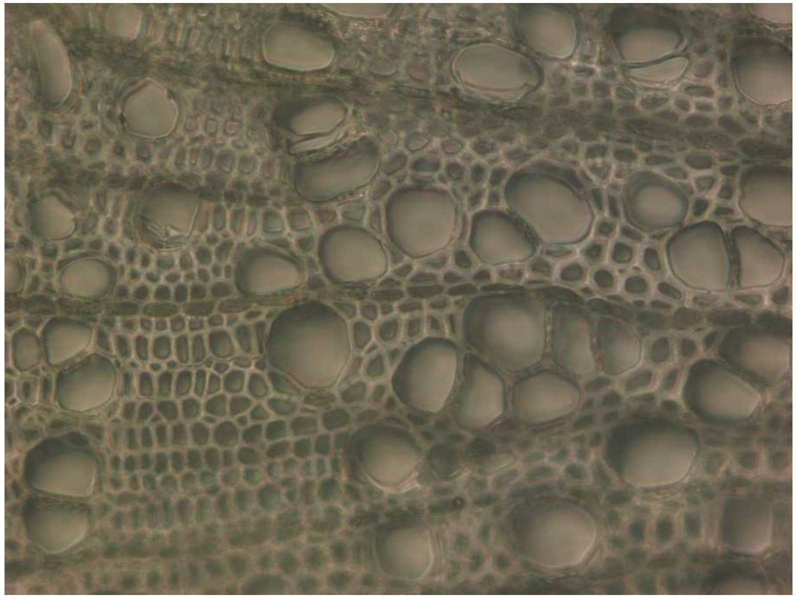
Anatomically assisted cherry rootstock selection

- Macro characteristics



- Micro characteristics

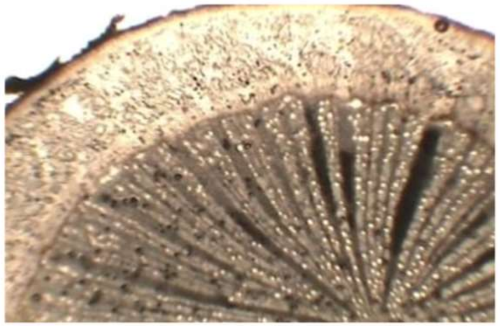


Based on the anatomical measurements, theoretical axial hydraulic conductance is calculated according to the expression given by Tyree and Ewers (1991), based on Hagen-Poisseuille's law:

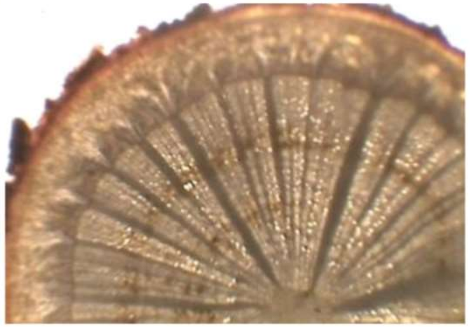
$$k_h = \frac{\pi \cdot \rho}{128 \cdot \eta} \sum_{i=1}^{n} d_i^4$$

where *d* was the diameter of the vessels in meters, ρ was the fluid density (assumed to be 10^3 kg m^{-3} for water at 20ºC) and η was the viscosity (assumed to be 1.002 10^{-9} MPa s for water at 20ºC).

Ring-like formations in one-year-old roots strongly differed

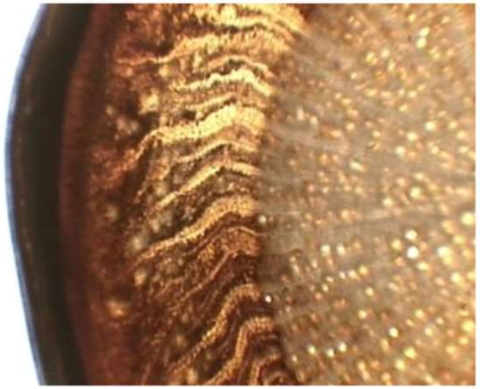


P. fruticosa sel. SV 2



Gisela 5 rootstock

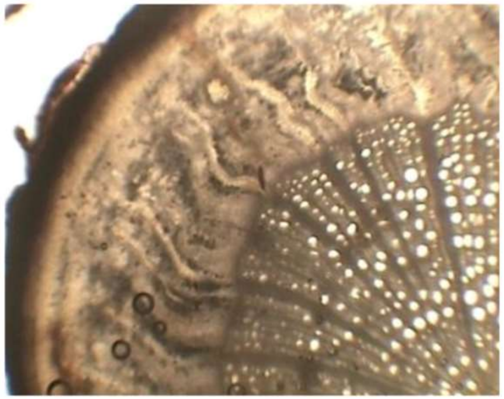
'P. cerasus'OV16



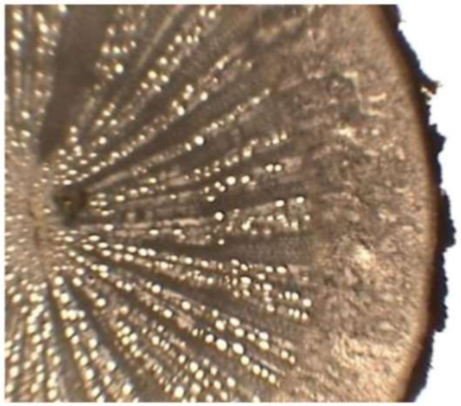
P. fruticosa sel. SV 5

P. mahaleb

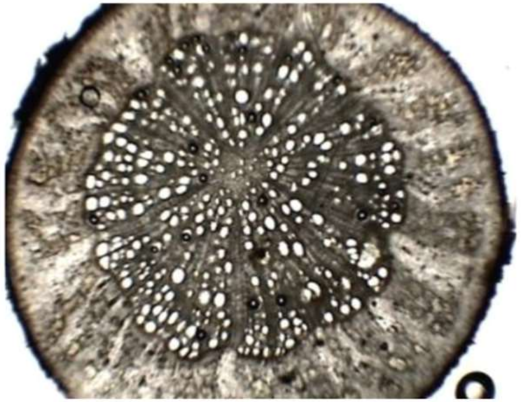
'P. cerasus'OV18



P. fruticosa sel. SV 4



PHL-A rootstock



'P. cerasus'OV33

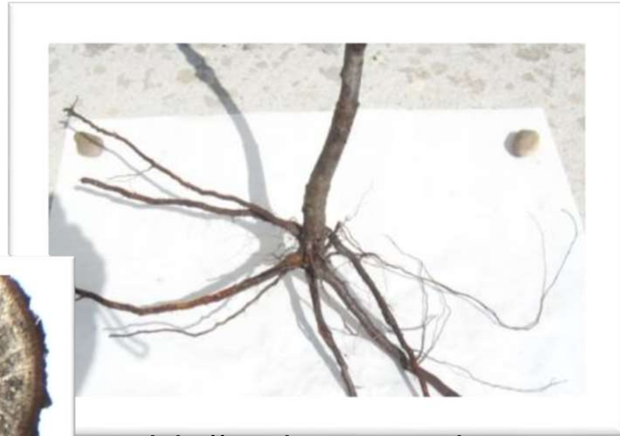
Contrasting sites

Table 1. Sampling locations coordinates and altitudes for investigated cherry species.

Species	Locality	Longitude	Latitude	Altitude
European ground cherry	Fruška gora	19° 55' 01'' E	45° 09' 39'' N	327 m
Oblačinska sour cherry	Dešilovo	21° 37' 35'' E	43° 17' 34'' N	398 m
Oblačinska sour cherry	Prokuplje	21° 32' 54'' E	43° 13' 46'' N	274 m

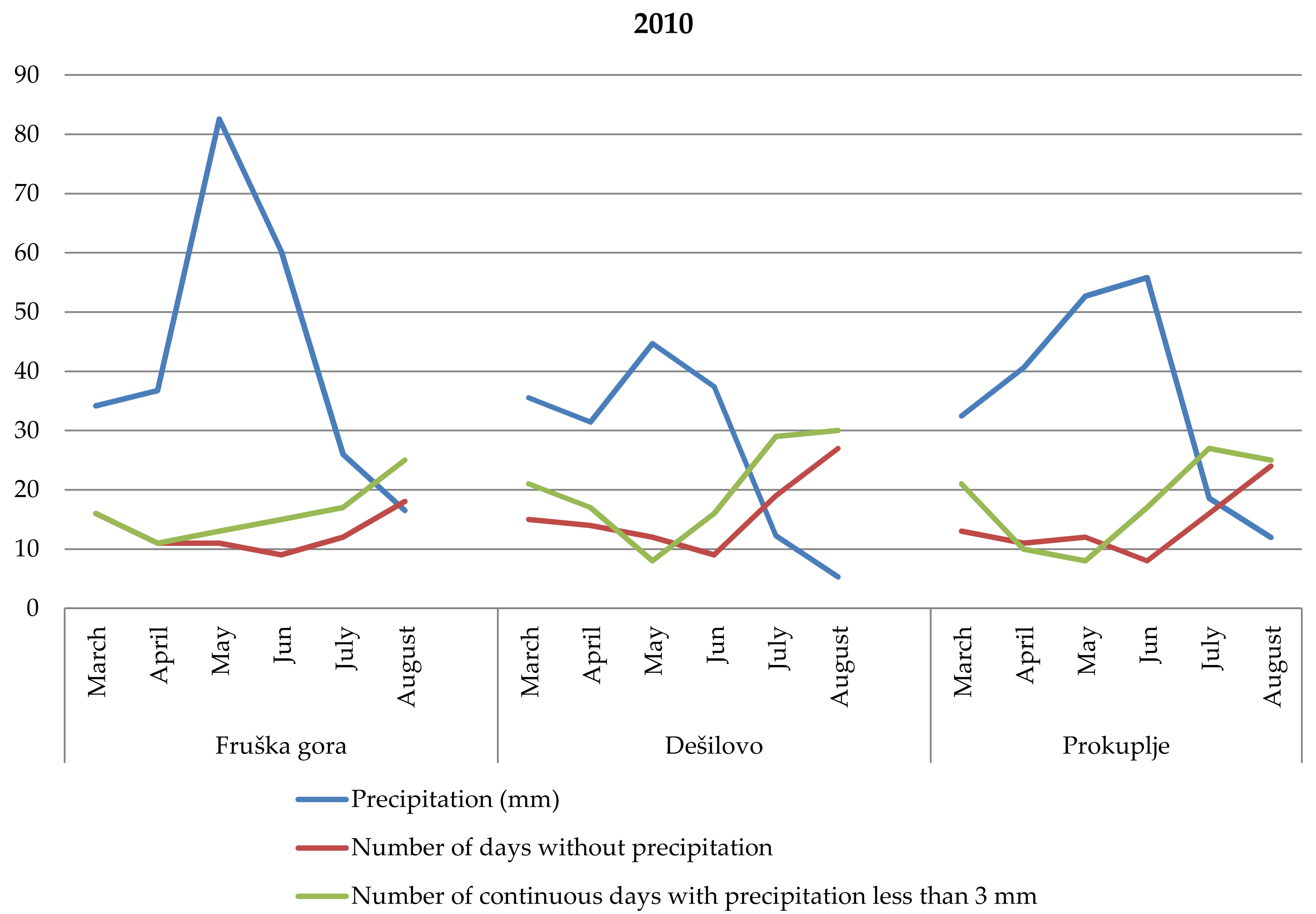
Contrasting genotypes

European ground cherry



Oblačinska sour cherry

Meteorological data – ERA 5



Results

- European ground cherry genotypes were characterized with greater cross section area, with values 27.93±3.70 mm^2 in SV2 and 33.35±10.1 mm^2 in SV4.
- Oblačinska sour cherry genotypes from locality Dešilovo were characterized with far lesser cross section area (from 7.24±3.81 mm^2 in OV18 to 17.52±3.75 mm^2 in OV14), than genotypes from Prokuplje.

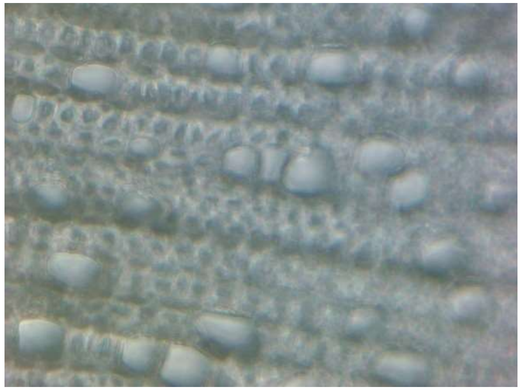
Whole one ring missing in genotypes from Dešilovo

Prokuplje

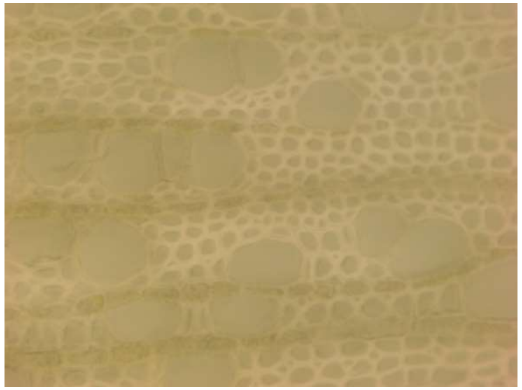
Dešilovo

Results

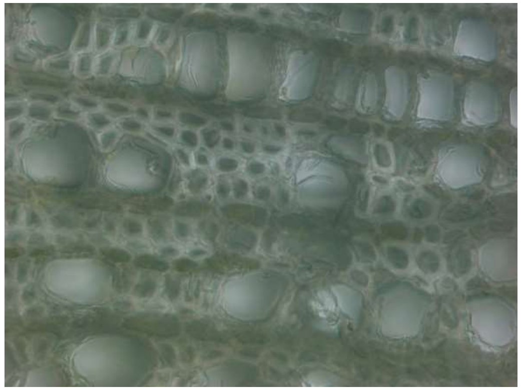
- European ground cherry genotypes followed typical semi-ring porous pattern - vessel lumen area decreased as the roots matured from 944.40±72.9 μm^2 to 915.93±36.1 μm^2 in SV2 and from 1530.30±1306.70 μm^2 to 1399.15±921.3 μm^2 in SV4
- Oblačinska sour cherry genotypes had very large vessel lumen areas, ranging from 701.38±92.88 μm^2 in OV33 inner zone to 2353.34±676.5 μm^2 in OV16 outer zone



Fruška gora



Prokuplje



Dešilovo

Correlation analysis

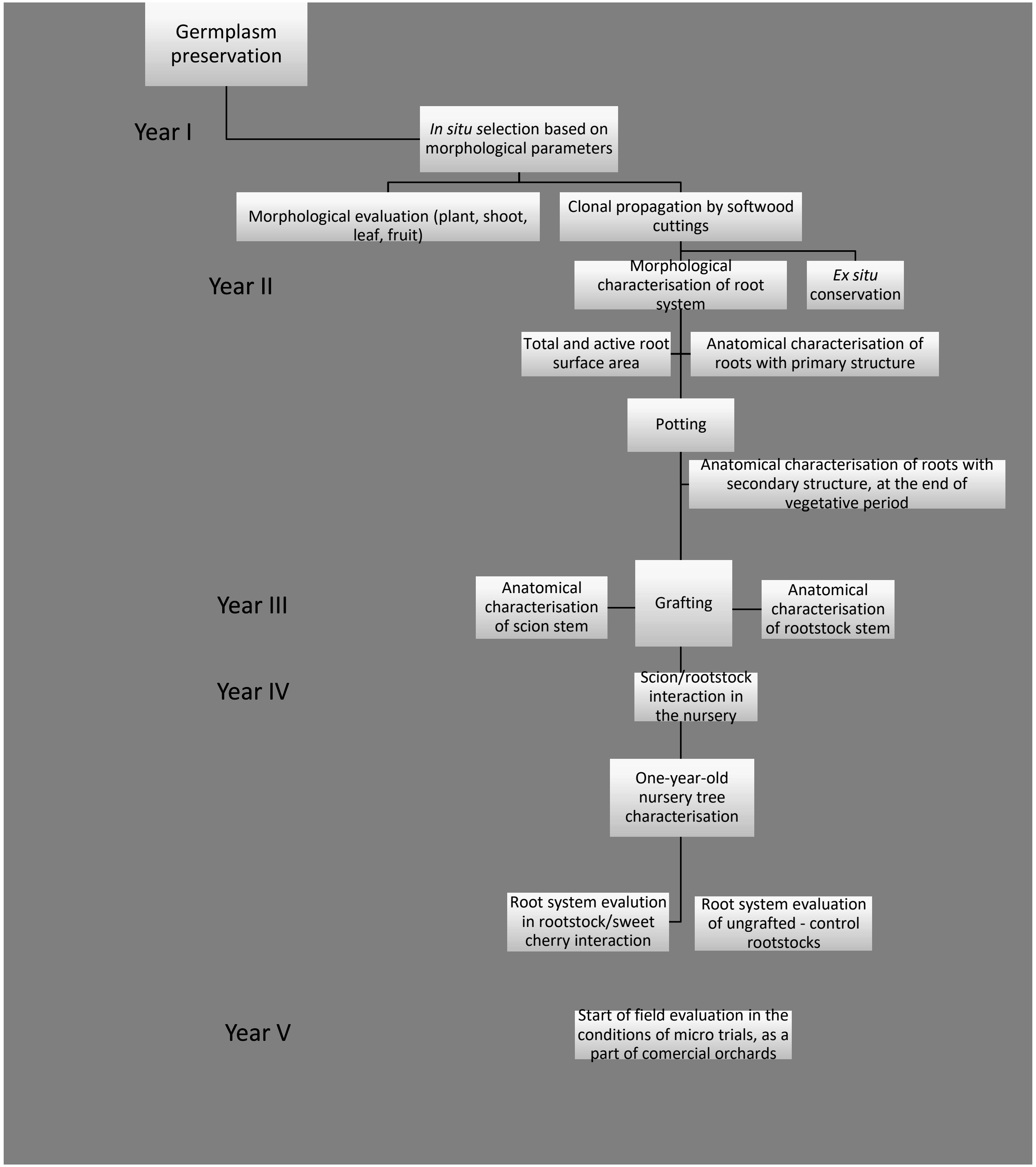
- Overall precipitation and its' monthly distribution, as well as monthly sum of temperatures and monthly average temperatures (except for August) were in statistically significant positive correlations with cross-section area, % of secondary wood and wood/cortex ratio, whilst in statistically significant negative correlation with % of secondary cortex.
- Number of dry days during May was in a statistically significant negative correlation with above mentioned cross-section characteristics, whilst in positive with secondary cortex percentage, average vessel number in inner root zone and average vessel number on a complete cross-section area.
- Number of dry days during July and August showed statistically significant negative correlation with all investigated cross-section characteristics (except for secondary cortex percentage that was positive).

Cambial activity did not cease with drought events – very young large vessels were produced during dry days.

Conclusions, or just a begining....

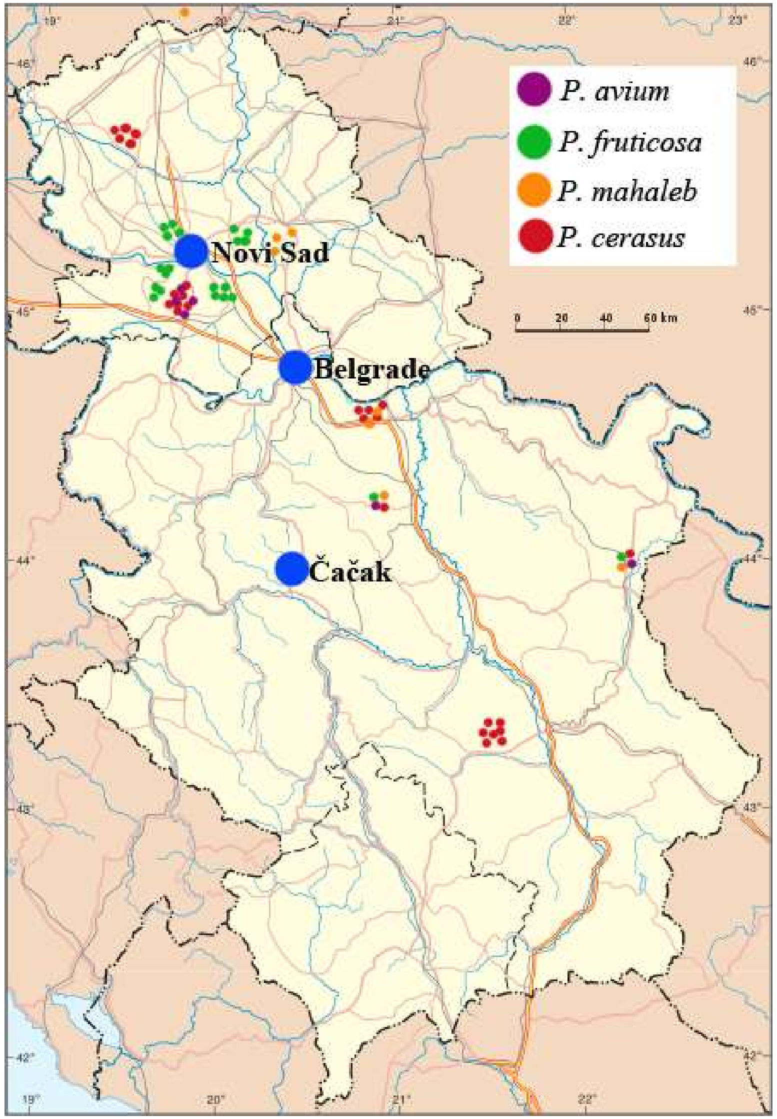
- Under environmental signals both investigated species altered their radial root growth **imprinting stops and starts** in cambial activity that resulted in intra-annual false rings occurrence.
- Along the false rings European ground cherry followed the usual early-late wood **pattern**, while oblačinska sour cherry produced larger vessels as an alternative to smaller cross-sections and weaker shallow root system.
- Changing environment conditions triggered the **shifts** of large and small vessels throughout the false rings, but their size seems to be mainly **genetically controlled**.
- For future breeding purposes and size-controlling prediction models development of an equal importance will be the determined environmentally related xylem plasticity as well as genetically controlled conduit size.

SELECTION STRATEGY IN THE TERMS OF ALTERED PRECIPITATION REGIMES

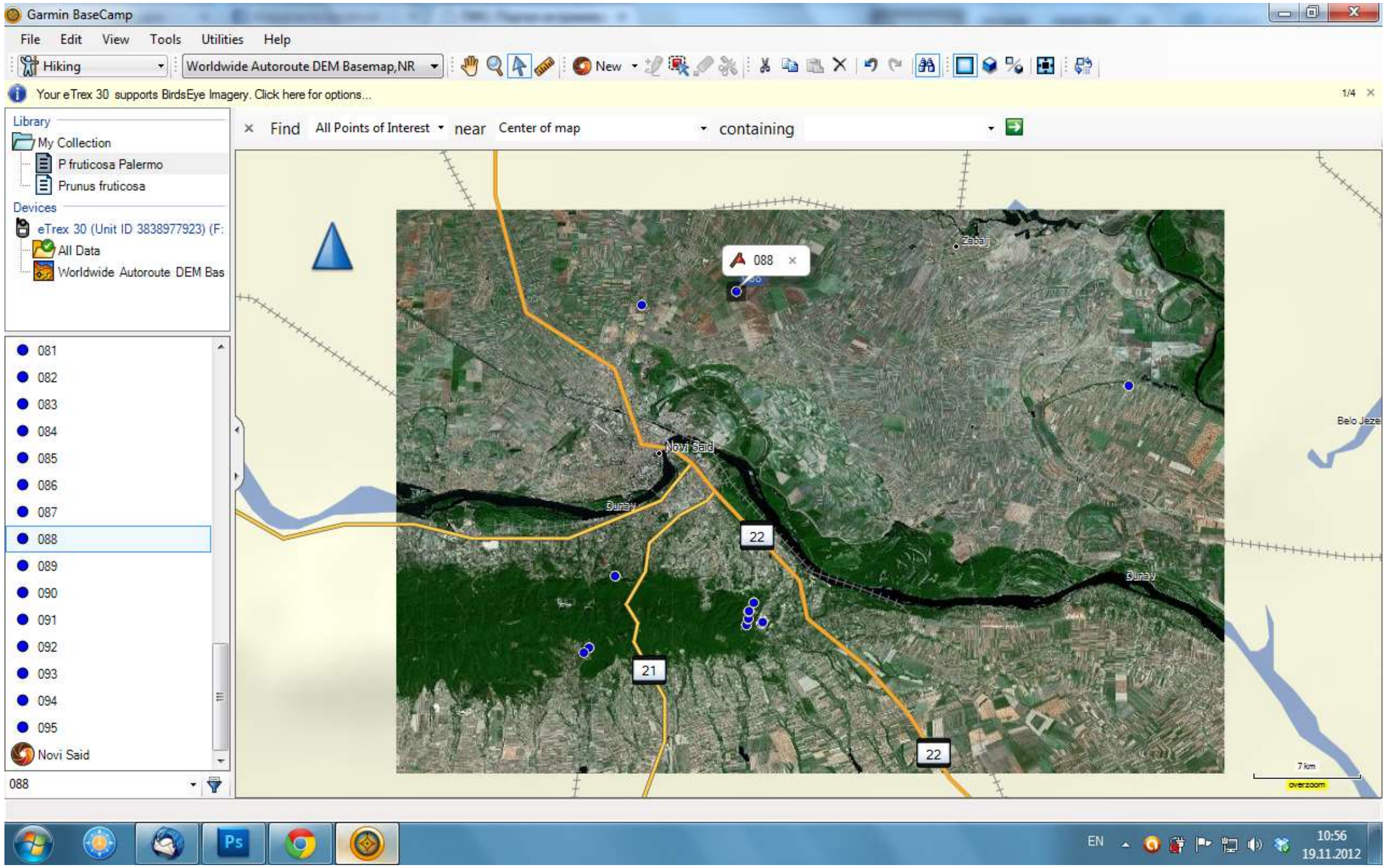


Valuable asset of germplasm preservation work is network of collaborators.

Farmers are the most affected by the climate change! 4 months with no significant precipitation!



In situ and *on farm* accession mapping using GPS record keeping program



Morphological characterisation

- **Plant and shoot**:

  Plant vigour, plant habit, branching, one-year-old shoot coloration, one-year-old shoot thickness, one-year-old shoot length of internode, number of lenticels, size and position of vegetative bud in relation to shoot. (9)

- **Fruit *(in situ)***

  Fruit petiole length, fruith weight, fruit stone weigth, stone/fruit ratio, fruit color, fruit shape. (6)

- **Leaf:**

  Leaf blade length, leaf blade width, length/width ratio, leaf blade shape, angle of apex, length of tip, shape of base, petiole length, presence of leaf nectaries, number of nectaries, position of nectaries, color and shape of nectaries. (13)

In situ material
Plants grown first year in pots

Vegetative propagation of *Prunus* genotypes

- Softwood cuttings
- Micropropagation

Acclimatization

- Gisela6

- SV1 and SV2

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Method of methylene blue absorption by root surface

TSA and ASA: Active root surface area represents radial root system conductivity
Differences in the cortical thickness and presence of suberized exodermis

Colt

PHL-A

Prunus fruticosa SV4

Prunus mahaleb

Prunus cerasus ‘oblačinska’ OB14

ARA combined with previously mentioned anatomical characteristics

Radial cross sections:

Roots **Rootstock stem** **Scion shoot**

- **Cross-section characteristics:**

  cross-section area,

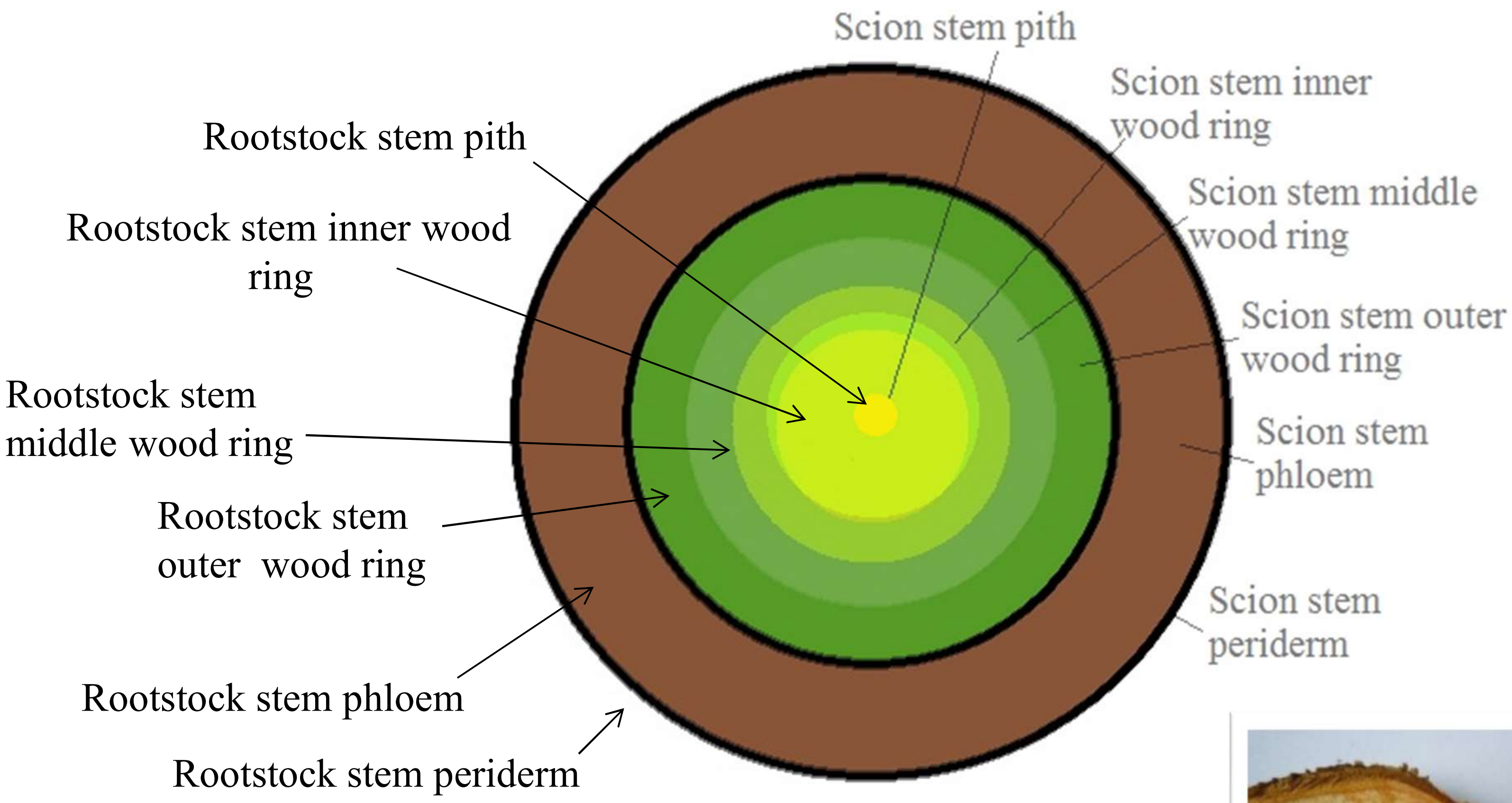
  cross-section diameter, periderm area, phloem area, secondary wood (wood) area, wood/phloem ratio.

- **Secondary wood (xylem) characteristics:**

  xylem area, ray area, vessel area, average vessel size, number of vessels, afiliation of vessels to different size classes (<700 μm^2, 700 - 2000 μm^2 and > 2000 μm^2, for roots, and < 300 μm^2, 300 - 700 μm^2 and > 700 μm^2 for stems.

Rootstock stem/scion shoot anatomical characteristics

Rootstock / scion pith overleping, hydraulic conductivity



Simulation of functional plant constituents hydraulic conductivity

- **Functional root system hydraulic conductivity**

  $K_{h\ (Rc)} = (K_{h\ (R)} \times C_{wu})$

  Theoretical root system hydraulic conductivity corrected for the coefficient of active surface area

- **Functional rootstock stem hydraulic conductivity**

  $K_{h\ (RStf)} = K_{h\ (RSt)} - K_{h\ (RSt\text{-}ir)}$

  Theoretical rootstock stem hydraulic conductivity reduced for the coefficient of inner ring hydraulic conductivity

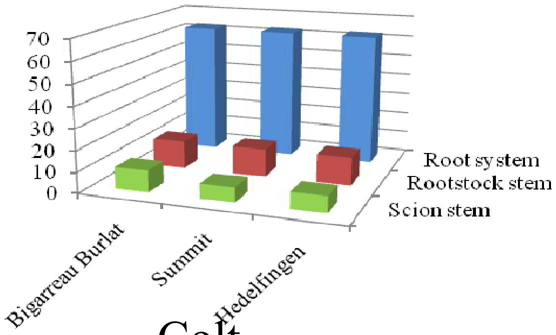
- **Functional scion stem hydraulic conductivity**

  $K_{h\ (SSt)}$ **(all three secondary wood rings)**

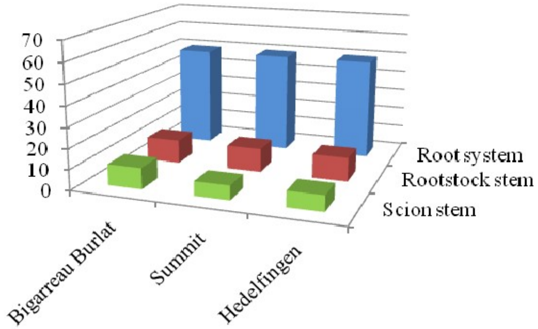
Theoretical scion stem hydraulic conductivity = Functional hydraulic conductivityIt is in agriment with estimated hereditary scion vigor

Functional hydraulic conductance of cherry tree constituents (10^{-5} kg m/MPa s)

Prunus avium



Prunus mahaleb



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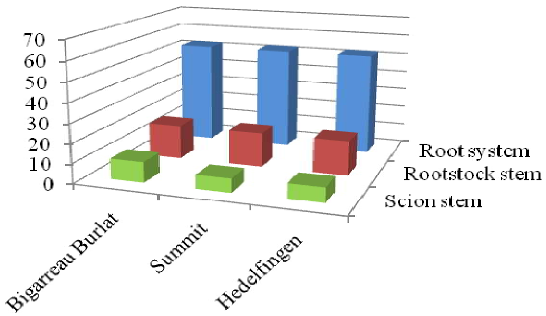
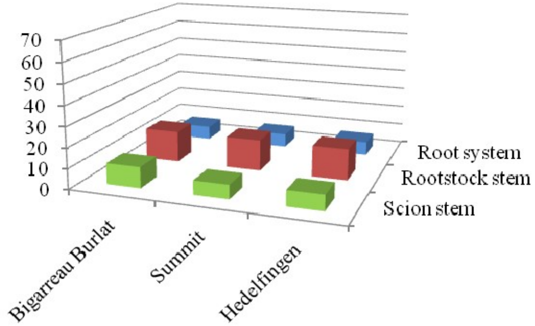
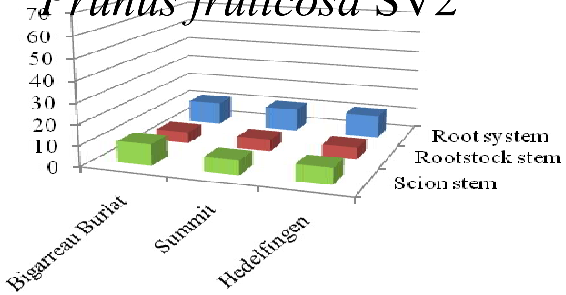


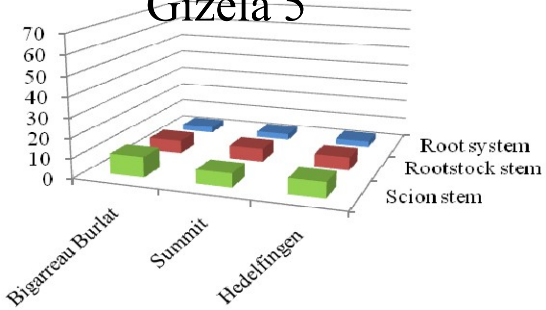
Prunus cerasus ‘oblačinska’



Prunus fruticosa SV2

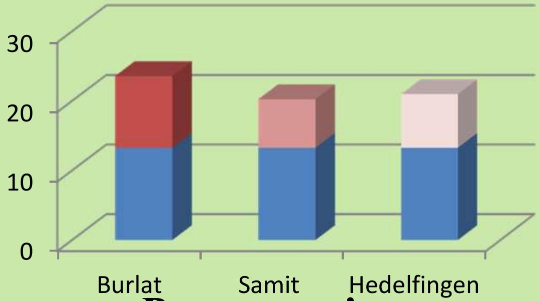


Gizela 5

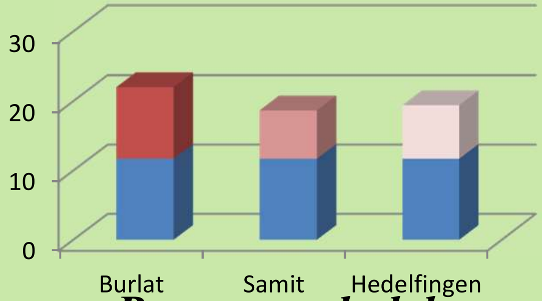


Plant vigor simulation model based on functionl hydraulic conductance

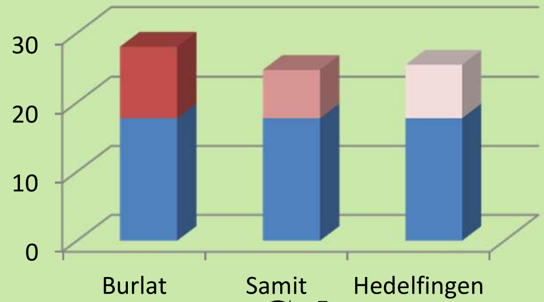
In vivo tested model



Prunus avium



Prunus mahaleb



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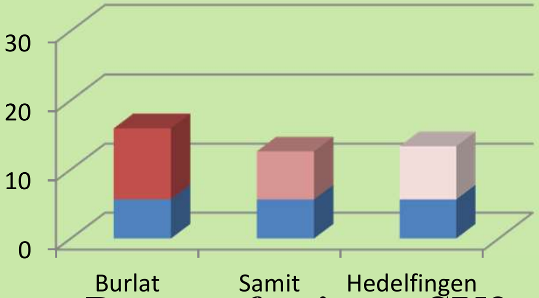
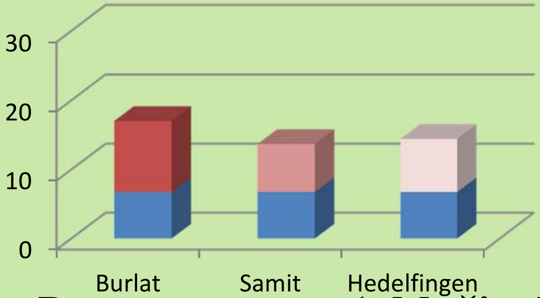
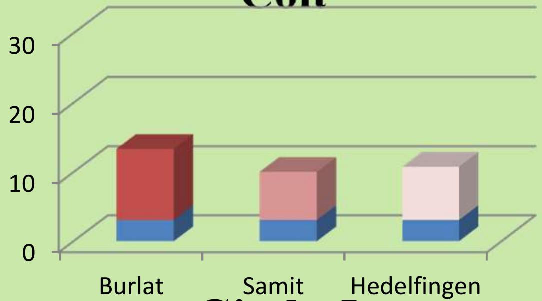


***Prunus fruticosa* SV2**



***Prunus cerasus* 'oblačinska'**



Gisela 5

Specific rootstock / scion interactions

Sweet cherry
Sylvia

Future research and challenges

- Heritability of the main anatomical properties.
- Trials with different water regimes.
- Radial and axial capacity characterisation in different water regimes.
- Selection of both adaptive and productive rootstocks.

Serbia for Excell

European Commission

Thank you for your attention