Practical:
Functional-structural plant modelling in GroIMP

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WUR – SDAU Course

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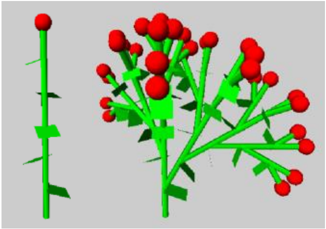
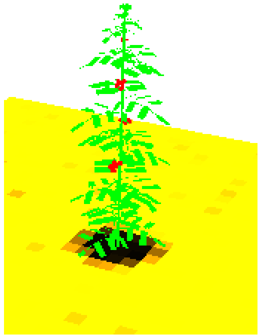
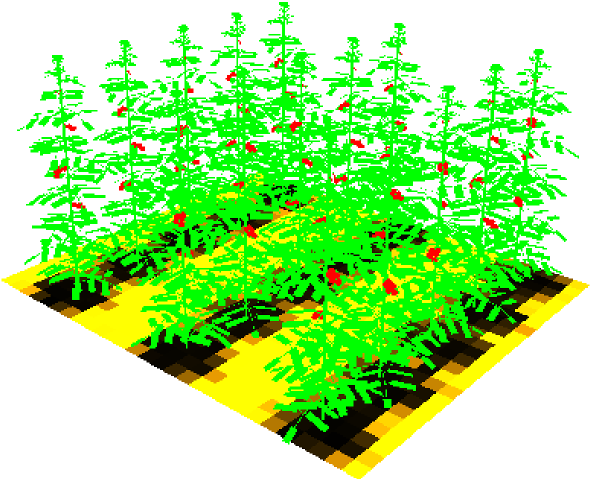
Outline

- **Practical introduction**
- **Part 1:** Introduction to GroIMP & plant development example (~15 min)
- **Part 2:** Tomato model (simplified) – finding optimal plant architecture (~20 min)

Break (~10 min)

- **Part 3:** Tomato model (simplified) – finding optimal architecture at the crop level (~30 min)

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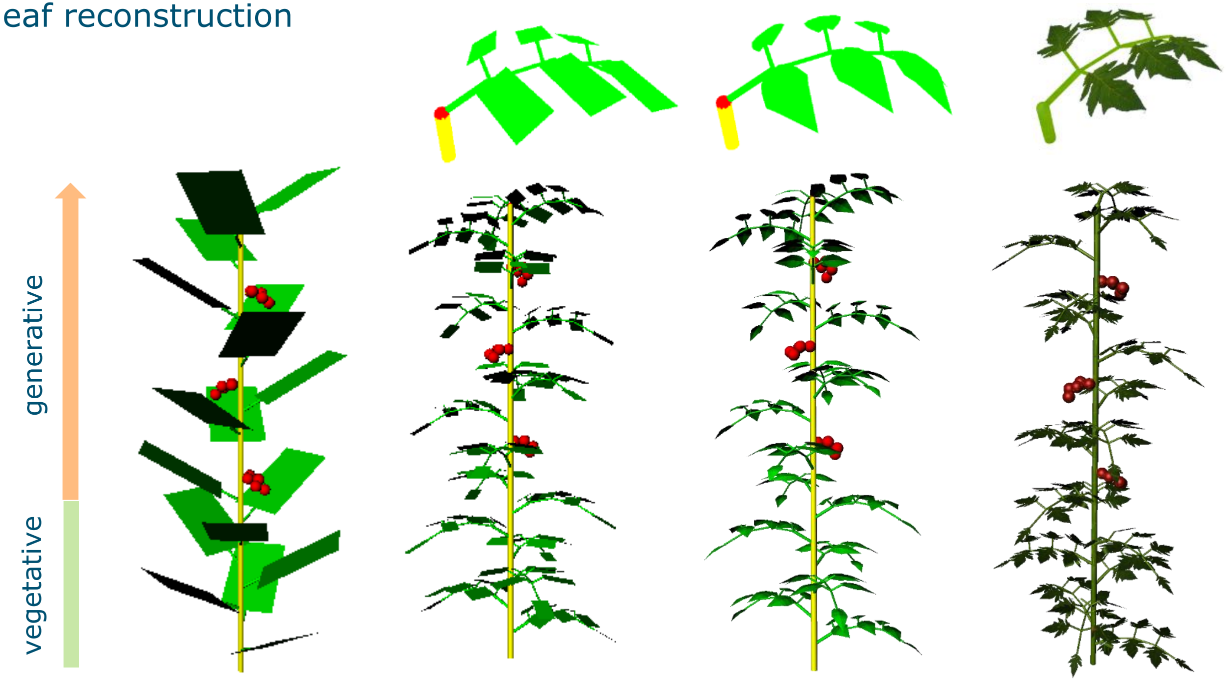
Tutorial: Tomato architecture in XL

Optional

https://wiki.grogra.de/doku.php?id=tutorials:simple-tomato-model

- Learn step-by-step how to create tomato plant architecture with simplified development
- Try different options for leaf reconstruction



Instructions for texture mapping

Optional

Menu: Panels > Explorers > 3D > Shaders

Shaders: Object > New > Lambert (2 clicks or F2 to rename)

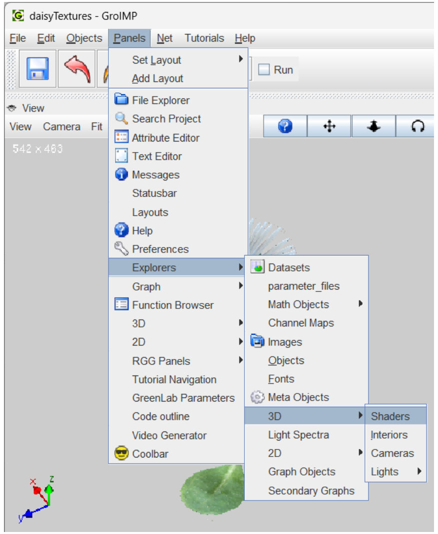
Attribute Editor: Diffuse colour > Surface Maps > Image;

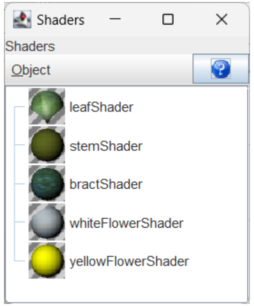
Image > From File

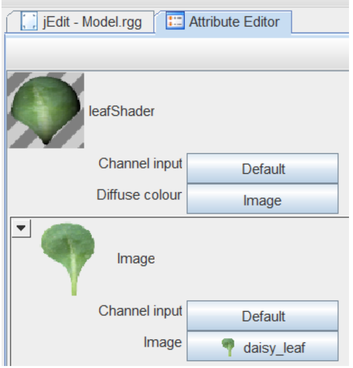
Photographs with removed background

gimp.org (with alpha channel, png file format)

Model under: File
> Example projects
> FSPM > daisyTextures





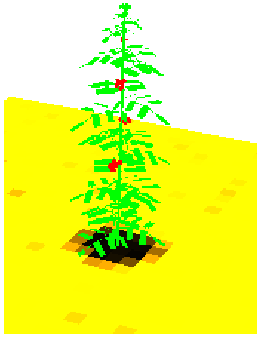


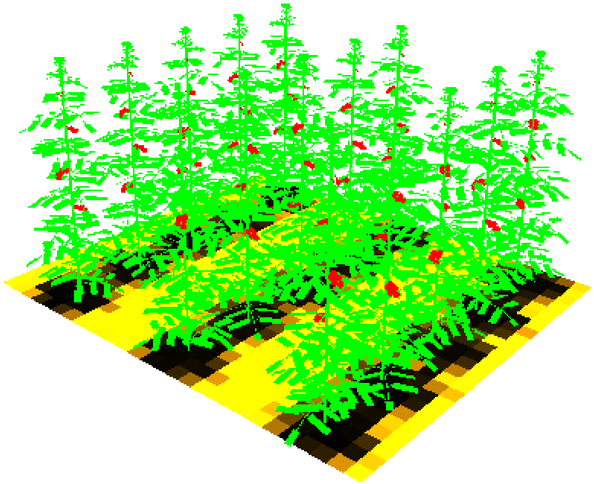
Create a reference in XL:

const ShaderRef leafSh =
shader("leafShader");

Simple tomato model

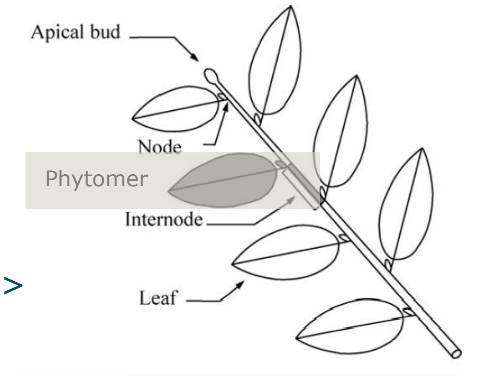
- Model functionality
    - Organ appearance rate
    - Organ extension modelling
    - Light modelling
    - Biomass modelling
    - Plotting simulated outputs





- Virtual *(in silico)* experiments with the model

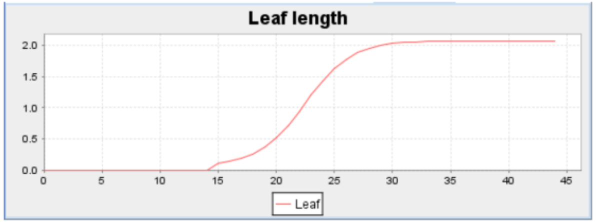
Model functionality

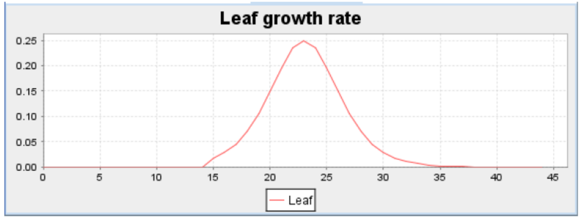


(acc. Barthélémy & Caraglio, 2007)

- **Phyllochron** - time span between the appearance of new phytomers -> more precise timing of development

- **Organ extension** – gradual increase in size as a function of age; described by a logistic curve

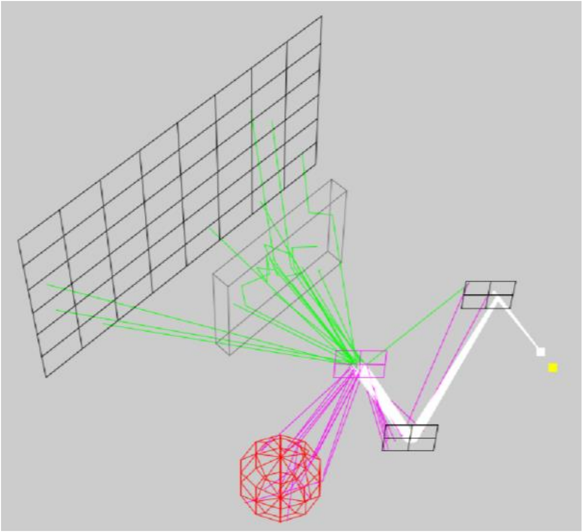




$$\frac{dW}{dt} = \frac{kW_{max}e^{(-k(t-t_m))}}{(e^{(-k(t-t_m))}+1)^2}$$

Model functionality (cont.)

- **Light modelling** using a (modified) 3D raytracing approach
- Light model calculates how much light is absorbed by each object in the scene
- Material properties of an object (a shader) define how much light will be reflected, transmitted, and finally absorbed
- Requires a light source in the scene



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Model functionality (cont.)

- **Biomass production –** calculated using a photosynthesis model
- Here, we assume a simple linear relationship between biomass and radiation (*used often in crop models*)
- We will use absorbed radiation

Biomass = RUE x PAR

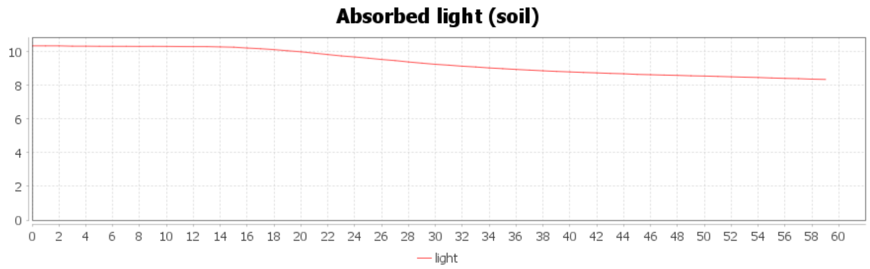
RUE – radiation use efficiency

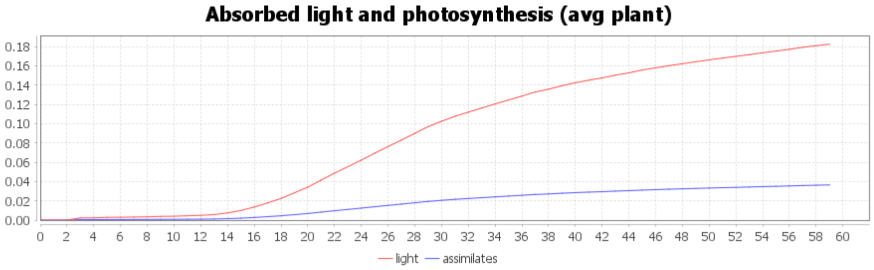
PAR – photosynthetically active radiation

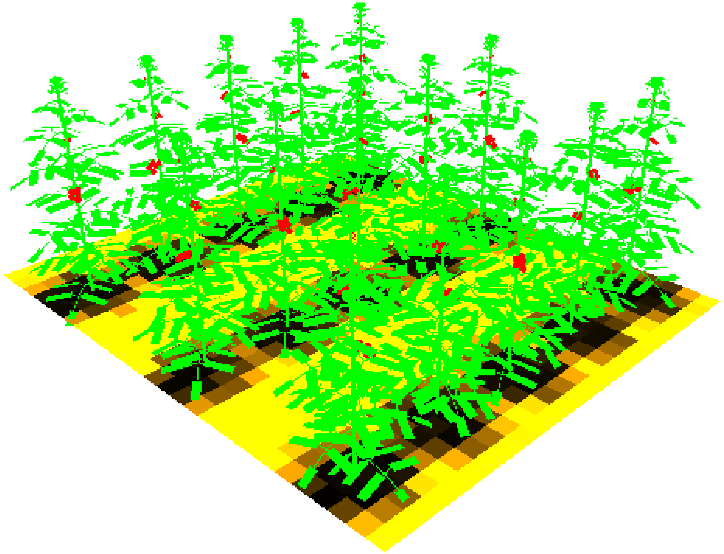
Hu *et al.*, 2025, COMPAG

Model functionality (cont.)

- Determining how much light arrives at the soil







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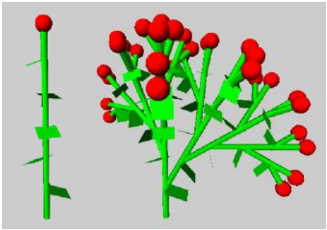
Example model: simple_development_rggRules.gsz

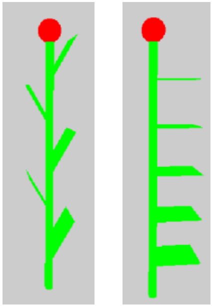
Part 1 (~15 min):

Introduction to GroIMP & plant development example



- We will use this simple example to learn the very basics of the XL language and manipulation in the GroIMP platform.
- Follow the instructions on top of *Model.rgg* to learn the model functionality
- Make changes to model parameters and observe the effect on the new structure
    - What is the value (approximately) of LEAF_ANGLE and PHYLLOTAXIS_ANGLE that would lead to these structures:

?

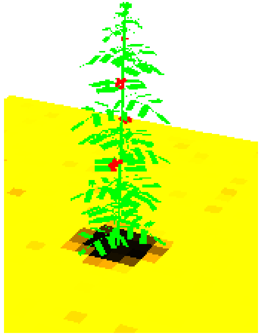


Part 2 (~20 min):

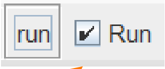
Example model: simple_tomato_growth.gsz

Tomato model (simplified) – finding optimal plant architecture

- The aim of this example is to learn how to make changes to plant architecture
- Imagine you are a breeder and want to design a new tomato cultivar that leads to higher biomass production (model output: as) *Try to maximise this value*
- Make changes in *parameters.rgg* for the leaf and internode parameters (think first about your strategy)
    - Work with a single plant: set NR_ROWS = 1, NR_PLANTS = 1



```
plant on average:
absP: 0.22766000237315884
as: 0.045532001153111144
```



Select 'Run' & press 'run' ONCE to run the simulation automatically

```
// leaf parameters
const double MAX_LEAF_LENGTH = 0.40;
const double LEAF_WL = 1;
const double PETIOLE_WIDTH = 0.01;
const double PHYLLOTAXIS_ANGLE   = 137.51;
const double LEAF_ANGLE = 60;
const int NB_LEAFLET_PAIRS = 3;
```

```
// internode parameters
const double MAX_INTERNODE_LENGTH = 0.08;
const double INTERNODE_WIDTH = 0.02;

const int INTERNODE_LENGTH_TM = 10;
const double INTERNODE_LENGTH_K = 0.3;
```

Part 3 (~30 min):

Example model: simple_tomato_growth.gsz

Tomato model (simplified) – finding optimal architecture at the crop level

- The aim of this example is to find out if the optimal architecture that you designed in Part 2 leads to the best performance (in terms of biomass production) at the crop level
- Find out if there is an architecture that performs even better in crop conditions – how does it differ from single plant situation?
- Default crop size: NR_ROWS = 3, NR_PLANTS = 5
- Besides leaf and internode parameters, you are also allowed to change the planting pattern

```
const double ROW_DIST = 1.2;
const double PLANT_DIST = 0.6;
```

Try to maximise this value

```
plant on average:
absP: 0.18344355691144193
as: 0.03668871192899279
```