Thesis topics (March 2021)

*Horticulture and Product Physiology group (***HPP***)*



Students....

Students are welcome to do their BSc- and MSc-thesis research with one of the staff members, postdocs and/or PhD students of the chair group Horticulture and Product Physiology group (HPP) of Wageningen University (read the requirements you have to meet, which are presented on the HPP-webpage: http://www.wur.eu/hpp >> Education >> MSc- and BSc-thesis subjects HPP and Internships at HPP).

The BSc- and MSc-thesis topics of HPP are spread over themes encompassing pre-harvest environmental plant physiology to post-harvest product physiology, and are connected to horticultural production world-wide. The emphasis is on, *but not restricted to*, modern glasshouse production.

Yearly, many students participate via BSc- and MSc-thesis's. During their research period MSc-thesis students enroll a community of students and staff (known as STAIR [**ST**udents **A**ctive **I**n **R**esearch]), which facilitates the development of important research related skills such as proposal writing and presenting, progress presentations and research discussions.

Topics are *example* topics....

In this document you will find a list of possible actual topics. The list gives you an impression of the subjects we are working on. The actual definition of subjects is always affected by interests of students, equipment and facilities available and other students already working on the same project. If you have some ideas or proposals by yourself we can always discuss them.

For BSc- and MSc-students......

Most proposed topics in the list are primarily described as MSc-thesis topic. In general, parts of many of the described topics can also be done as BSc-thesis.

Interested? Always contact the coordinator.....

If you want to participate in a student-research-proposal at HPP, **always** contact the coordinator of the student-research-projects (Dr. Ep Heuvelink).

ep.heuvelink@wur.nl tel. 4 83679

Make sure you do this in time:
Many of the listed topics require some preparation and certainly early planning from the student and researchers involved. This also takes time and may cause study delays if not initiated in time.

Although this document contains an extensive list of topics, it is not complete and may continuously be subject to changes.
For the latest version check our website: http://www.wur.eu/hpp >> Education

Table of Contents

Pre-harvest topics

Impact of defoliation on nitrate futile cycling

Supervisors:

Yifei Zhao (PhD candidate), Prof. Dr. Leo Marcelis

Description

Nitrate influx, via a proton symporter ($NO_3^-/2H^+$), costs two ATPs for every nitrate molecule. Although efflux itself is a down-hill process from the thermo-dynamical perspective, it reduces the efficiency of net nitrate uptake and results in a seemingly waste of energy. The futile process of nitrate uptake is defined as nitrate futile cycling. Better understanding of futile nitrate cycling will advance our knowledge on plant N physiology and can potentially increase crop N uptake efficiency.

There are various factors regulating plant nitrate uptake by internal N demand. Several studies have reported that the balance between the availability of C metabolites produced by photosynthesis and the levels of nitrate uptake at root. Here we would like to investigate the possible impact of defoliation on nitrate uptake at root by affecting the photosynthetic activities and thus the carbohydrate availability in plant.

BSc/MSc and ECTS:

MSc-thesis: 24-36 ECTS
This project has room for several students.

Type of work:

Conduct experiments in climate room on Arabidopsis
Nitrate flux measurements
Sugar content analysis
Destructive and non-destructive measurements on plant growth and development
Molecular analysis on nitrate transporter related genes if possible
Data analysis

Location:

Wageningen

Planning:

In consultation with supervisors

The effect of root perturbation in hydroponic systems on nitrate futile cycling

Supervisors:

Yifei Zhao (PhD candidate), Prof. Dr. Leo Marcelis

Description

Nitrate uptake plays an important role in plant growth. Nitrate influx is regarded as secondary active uptake as it occurs at the expense of ATP from proton pumps. Several studies reported passive nitrate efflux. The seemingly futile process of nitrate influx followed by nitrate efflux is termed “futile cycling”, which is usually more pronounced at high nitrate concentrations. The extent to which this “futile cycling” of nitrate influx and efflux happens, varies between plant species and external environment conditions. Since nitrate influx consumes energy, an increase in futile cycling results in higher net energy cost for nitrate uptake.

There are indications that root perturbation stimulates nitrate efflux. However, root perturbation in a hydroponic system is often unavoidable. In this research, we would like to investigate the long-term effect of root perturbation caused by hydroponic system during growth on nitrate futile cycling and the consequences for plant growth.

BSc/MSc and ECTS:

MSc-thesis: 24-36 ECTS

Type of work:

Conduct experiments in climate room on Arabidopsis
Nitrate flux measurements
Destructive and non-destructive measurements on plant growth and development
Molecular analysis on nitrate transporter related genes
Data analysis

Location:

Wageningen

Planning:

In consultation with supervisors

Vegetative growth and climate fluctuations: the role of a dynamic assimilate pool

Supervisor(s):

Cristina Zepeda (PhD Candidate), Dr. Ep Heuvelink

Description:

Precise control of indoor climate in greenhouses ensures steady crop production and allows higher yield largely independent of outside temperatures. This rigid climate set points require high energy inputs. There is an increasing interest in reducing CO_2 emissions. We can achieve this through flexible climate management schemes based on crop physiological processes. Crops are quite robust to variations in humidity, CO_2, light and temperature. Previous research has shown that temperature integration regimes with longer integration periods and flexible set points allow a reduction of 13 % in energy input.

The overall objective of the project is to investigate the effect of climate fluctuations on tomato growth and development. Additionally, we want to investigate the effect of climate fluctuations on the diurnal and long-term course of sugars. The research includes experiments focused on (1) temperature amplitude (2) integration period, (3) light level and (4) relation between temperature and light (phase and counter phase). This data will be used to extend a supply/demand carbon balance model for vegetative growth .

BSc/MSc and ECTS:

This project has room for several BSc or MSc thesis students

Type of work:

Conduct experiments in growth cabinets with tomato plants
Sugar analysis (lab), destructive and non-destructive measurements on plant growth and development
Data analysis

Location:

Wageningen

Planning:

In consultation with supervisors

How is fruit set affected by different temperature integration regimes?

Supervisor(s):

Cristina Zepeda (PhD Candidate), Dr. Ep Heuvelink

Description:

Fruit set is a temperature and light-sensitive process that depends largely on the balance between source and sink strength. Previous research has shown that plants are flexible to day-to-day and long-term fluctuations in temperature and light, however this research has been done mainly on vegetative plants. The complexity of describing fruit set derives from the cumulative effects of environment and physiological processes from pollen development until fruit set. To be able to apply the 'temperature integration' concept on a full grown crop, we need to understand the mechanisms behind fruit-set and how are these affected by climate fluctuations. The overall objective of the project is to investigate the effect of different temperature integration regimes on fruit set in full-grown tomato plants. This data will be used to extend and validate a fruit-set model that can allow us to predict the effect of different temperature and light integration regimes on yield.

BSc/MSc and ECTS:

This project has room **for several** BSc or MSc thesis students

Type of work:

- Conduct experiments in greenhouse compartment
- Destructive and non-destructive measurements on plant growth and development
- Measurements on flower and fruit set (e.g. pollen germination)
- Data analysis

Location:
Wageningen

Planning:
In consultation with supervisors (flexible start. Possibility on starting from March 2021)

Characterization of macronutrient (N, P, K, Ca, Mg, S) deficiencies in *common hazel (Corylus avellana L.)*

Supervisor(s):

Michele Butturini

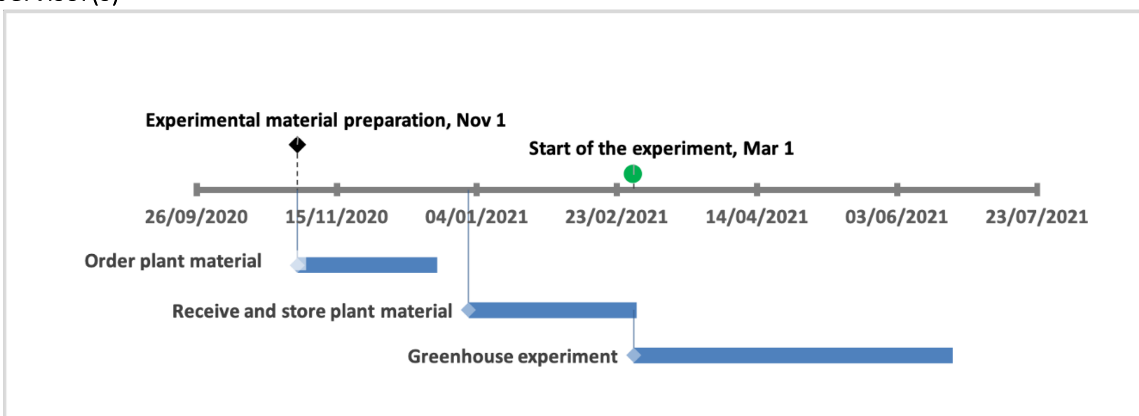
Description:

Current knowledge gaps in plant nutrient (fertilizer) demand of common hazel (*Corylus avellana* L.) crops might cause environmental impact and result in yield loss due to nutrient deficiencies and lack of growth stimulants. To ensure a long-term sustainable *C. avellana* cultivation and empower the *C. avellana* farming community, the knowledge level of mineral nutrition should be improved. To improve the current knowledge level the identification of macronutrient and micronutrient deficiency is a must. At present, a visual diagnostic decision support tool to monitor the nutritional status of *C. avellana* orchards is missing. Juvenile *C. avellana* plants form a suitable model to create a picture library, as they can be grown in a greenhouse under fully controlled conditions. The aims of this project are: (i) Study the nutrient uptake of juvenile *C. avellana* plants in relation to growth rate and developmental phase during a two-month period after bud break; (ii) Create a visual diagnostic decision support tool in the form of a picture guide for macroelements deficiencies using juvenile *C. avellana* plants. Altogether, this basic research will support *C. avellana* cultivation around the globe and will facilitate the supply of the right fertilizers, in the right amount and at the right time.

BSc/MSc and ECTS: MSc-thesis: 24-36 ECTS

Description of the type of research: At the beginning of 2021, 200 dormant *C. avellana* cv. Giffoni of 2 years old will be purchased from a hazelnut nursery. The experiments will be conducted in a 32 m^2 climatized greenhouse compartment. The plants will be grown in pots with a solid substrate (e.g. washed sand). Treatments consisting of nutrient solutions lacking a specific macronutrient (N, P, K, Ca, Mg, S) will be applied. A pilot study on micro elements (Cl, Fe, Mn and B) deficiency will be performed as well. Nutrient analysis of leaves and recording of basic morpho-physiological traits like biomass accumulation and phyllochron will be performed. The NPEC phenotyping equipment (e.g. MARVIN: mobile phenotyping module by PSI) will be used for the image acquisition of the deficiency visual symptoms.

Planning: Starting in January/February 2021 or later - to be arranged in consultation with the supervisor(s)



New fertilization concepts for improved nitrogen use efficiency in horticultural systems

Supervisor(s):

Dr ir Sander van Delden (daily supervisor)

Description:

Nitrogen (N) is an essential element for crop growth, development and subsequently product quality. Roughly 1 to 5% of total plant dry matter consists of N, which is an integral constituent of proteins, (co-)enzymes, nucleic acids, chlorophyll, phytohormones and secondary metabolites. Therefore plant nitrogen supply is an important cultivation factor. Not only the dose of nitrogen matters for crop production, also the form in which it is supplied (NH_4^+ and NO^- ratio) can affect crop growth and quality via several mechanisms. In nature, crops can take up nitrogen in three general forms: organic (e.g. urea, amino acids), ammonium (NH_4^+) and nitrate (NO^-).
In hydroponic systems mainly NH_4^+ and NO_3^- are supplied (generally in 1 to 10 ratio). NH^+ uptake acidifies the nutrient solution, NO_3^- uptake alkalizes the nutrient solution. At a molecular level NH^+ has lower energy costs for uptake and assimilation than NO_3^-, but high NH^+ dose causes cell damage. Additional to dose and nitrogen form, timing of nitrogen supply, that is moment of the day and developmental stage, can also enhance nitrogen efficiency.
The objective of this thesis is gaining novel insights in plant N efficiency by experimentally integrating findings on dynamic N supply and N form (NH_4^+ : NO^- ratio) and timing.

There is room for personal interest and insights, i.e. specific research questions can be formulated by the student.

BSc/MSc and ECTS:

MSc-thesis: 24-36 ECTS

Type of work:

Green house, growth cabinets, preparing nutrient solutions, lab experiments and analysis.

Plant(s): *Lettuce*

Methods:

Measuring several morphological and physiological parameters (biomass, leave number, transpiration, Fv/Fm, mineral content)

Planning:

to be arranged in consultation with the supervisor(s)

Modeling plant nutrient demand

Supervisor(s):

Dr ir Sander van Delden (daily supervisor)

Description:

Plant nitrogen (N) supply is an important cultivation factor. Suboptimal N fertilization in terms of dose, timing, and form can decrease crop commercial value, impact the environment and reduce crop health benefits for humans. Therefore optimal N fertilization in horticultural systems by continuously monitoring and predicting diurnal and seasonal plant N demand would be beneficial on many levels. Accordingly, this research gives emphasis to development of a dynamic model quantifying and predicting plant N demand.

There is room for personal interest and insights, i.e. specific research questions can be formulated by the student.

BSc/MSc and ECTS:

MSc-thesis: 24-36 ECTS

Type of work:

Model work in MATLAB, Python or R.

Methods:

Literature study, testing existing models and writing new model code.

Planning:

to be arranged in consultation with the supervisor(s)

Plasma Ponics: the effects of plasma water on plant cultivation

Supervisor(s):

Dr ir Sander van Delden (daily supervisor)

Description:

Plant nitrogen supply is an important cultivation factor. Suboptimal N fertilization in terms of dose, timing, and form can decrease crop commercial value, impact the environment and reduce crop health benefits for humans. The Haber-Bosch N fixation process of BASF is a landmark in industrial history and enabled the green revolution. Yet, at that time also an industrial plasma process was developed named Birkeland-Eyde process.

After 100 years, today's plasma technologies are on an entirely different standard of efficiency and selectivity. Nitrogen fixation by means of plasma techniques can instantly and locally confer N_2 into plant usable N species. This N fixation process is accompanied by the production of several different reactive oxygen species (ROS) that can both beneficial and detrimental to plant growth depending on dose and type of radicals.
During this thesis you will test the effects of plasma water on lettuce and tomato seedlings.

There is room for personal interest and insights, i.e. specific research questions can be formulated by the student.

BSc/MSc and ECTS:

MSc-thesis: 24-36 ECTS

Type of work:

Experimental work. Dose response experiments

Plant(s): Lettuce and tomato

Methods:

Measuring several morphological and physiological parameters (biomass, leave number, transpiration, Fv/Fm, mineral content).

Planning:

In consultation with the supervisor

Need for Speed: Accelerate Flowering of Lettuce with Far Red

Supervisor(s):

Yongran Ji (Daily supervisor), Dr. Ep Heuvelink

Description:

Vertical farming is a novel technology where plants are grown on many stacked layers with LED light. Lettuce (*Lactuca sativa*) is one of the most important crops in vertical farming. Lettuce is a quantitative long-day plant belonging to the Asteraceae family with 2n=2x=18 chromosomes. Based on its morphology, lettuce can be classified into four major types: romaine, iceberg, butterhead and non-heading (Simko *et al.*, 2014). Bolting, which is the rapid elongation of stems in lettuce, marks the the transitioning from vegetative to reproductive growth. This is an irreversible process that causes the loss of marketability of the crop. Bolting is a trait that has been intensively selected against in the breeding programs to ensure a robust production in the open-field or in the greenhouse where natural variation in climate and weather affects the growth condition of the crop. Recent development of vertical farming provides an exciting alternative where crops will grow in a 100% artificial climate condition that is accurately controlled. Hence, the variation in climate factors such as light, humidity and temperature are minimal. Dedicated breeding programs are urgently needed to select cultivars optimized for the production in vertical faming systems. Speed-breeding is a new method that uses tailor-made growth conditions, especially with a growth system like the vertical farming, to shorten generation time and accelerate breeding programs. Lettuce has a life cycle of over 100 days, which varies largely between different types and genotypes. Flowering time, which consists of the time between germination to bolting, and from bolting to anthesis, takes up most of the seed-to-seed cycle in lettuce. The development of LED lighting triggers much new research on the effect of light quality on plant growth and development. Far-red (FR) radiation (700-800 nm) triggers a set of morphological and physiological responses termed shade avoidance syndrome that features stem elongation and accelerated flowering in Arabidopsis, which is also a long-day plant with bolting for flowering (Casal, 2012). Despite some recent studies of FR effect on lettuce growth (Jin *et al.*, 2021; Legendre & van Iersel, 2021), it is not known whether FR influences the development and flowering of lettuce, especially under flower-promoting conditions (high temperature, long-day, with vernalization). In this research, we aim to shorten the seed-to-seed cycle in lettuce in vertical farming. Specifically, we will study the effect of additional FR on bolting and flowering in lettuce. Furthermore, we will study whether the accelerated development will affect seed quality in terms of germination rate.

BSc/MSc and ECTS:

MSc-thesis: 24-36 ECTS

Type of work:

Phenotyping in climate chamber (maybe also partly in Greenhouse), gene expression measurements
Plant: *Lettuce*

Methods:

Measuring several morphological and physiological parameters (leaf number, plant height, etc.), monitoring plant development and flowering, gene expression analysis.

Planning:

ASAP Spring 2021

The light response of photosynthetic induction

Supervisors:

Dr. Ningyi Zhang & Dr. Elias Kaiser

Description:

Plants in nature or greenhouses are often exposed to rapidly changing light intensities, which has major impacts on these plants' photosynthesis rate. The rapidity with which a plant can respond to a change in light intensity is often measured using photosynthetic induction: a plant initially exposed to a low light is suddenly exposed to high light, and its photosynthesis rate is measured, using gas exchange (GA) and/or chlorophyll fluorescence (CF) methods. Most research characterizing the rate of photosynthetic induction uses one specific low and another specific high light intensity (for example, a step change between 0 and 1000 µmol m^{-2} s^{-1}), ignoring the fact that the rate of photosynthetic induction is probably strongly affected by the specific light intensities used.

To obtain a better understanding of the light response of photosynthetic induction and its dependence on genotypic variation, you will measure the dynamics of photosynthesis in a number of relevant genotypes. Work will be conducted using the Li-6800 or Li-6400 photosynthesis system. This work could be a very important stepping stone for modelling and phenotyping efforts on crop growth in the field.

MSc/Bsc and ECTS:

Can be tailored to M.Sc. major thesis (36 ECTS) or research practice (24 ECTS)

Type of research:

Gas exchange measurements, data analysis

Planning:

Project can start immediately - to be scheduled after consulting with the supervisor

Using seedlings to predict photosynthetic induction in mature plants?

Supervisor:

Dr. Elias Kaiser

Description:

Plants in nature or greenhouses are often exposed to rapidly changing light intensities, which has major impacts on these plants' photosynthesis rate. The rapidity with which a plant can respond to a change in light intensity is often measured using photosynthetic induction: a plant initially exposed to low light is suddenly exposed to high light, and its photosynthesis rate is measured, using gas exchange (GA) and/or chlorophyll fluorescence (CF) methods. We know that the rate of photosynthetic induction is strongly affected by genetically determined components – but how early in the plant's life can these differences be detected reliably? This is the key question you will answer in this project!

In this M.Sc. thesis project, you will grow several tomato genotypes and perform GA+CF measurements on the plants multiple times during their development, from seedling to mature plant. Work will be conducted using the Li-6800 or Li-6400 photosynthesis systems, as well as the FluorCam CF imaging cabinet.

MSc/Bsc and ECTS:

Can be tailored to M.Sc. major thesis (36 ECTS) or research practice (24 ECTS)

Type of research:

Gas exchange measurements, data analysis

Planning:

Project can start immediately - to be scheduled after consulting with the supervisor

Exploring the interactive effects of temperature and CO2 on dynamic photosynthesis

Supervisors:

Dr. Ningyi Zhang & Dr. Elias Kaiser

Description:

Climate models predict future concurrent increases of temperature and CO_2 concentration. Increased temperature and CO_2 affect many plant physiological processes, including photosynthesis. Most T+FACE (increased temperature + free-air CO_2 enrichment) experiments focus on steady-state photosynthesis and long-term acclimation of leaf photosynthetic machinery to these conditions. However, under natural conditions, light intensity frequently fluctuates, which means leaf photosynthesis hardly reaches steady-state levels. When a low-light adapted leaf is suddenly exposed to high light, leaf photosynthesis progressively increases (a process termed photosynthetic induction). Studies have shown that elevated CO_2 increases photosynthetic induction, and increased temperature slightly affects photosynthetic induction by speeding up induction at the initial phase of increasing light intensity. However, it is not yet clear how temperature and CO_2 concurrently affect photosynthetic induction.

This project aims at exploring the interactive effects of CO_2 and temperature on photosynthetic induction and loss of induction. Results from this project will not only help to explain some yield changes observed in T+FACE experiments, but also help to understand plant growth in greenhouses in which temperature and CO_2 are frequently manipulated simultaneously.

MSc/Bsc and ECTS:

Can be tailored to M.Sc. major thesis (36 ECTS) or research practice (24 ECTS)

Type of research:

Gas exchange measurements using LI-6800 or LI-6400, data analysis

Planning:

Project can start immediately - to be scheduled after consulting with the supervisors

Photosynthetic induction at high CO2: quantifying the "dipping" effect

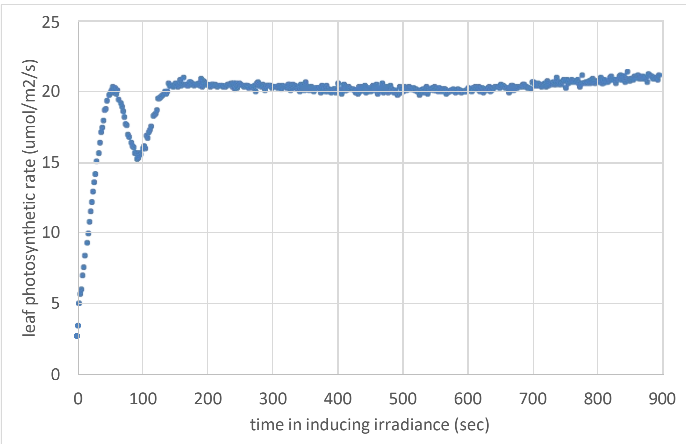
Supervisors:

Dr. Ningyi Zhang & Dr. Elias Kaiser

Description:

Irradiance frequently fluctuates under natural conditions and in greenhouses. When light intensity suddenly increases, leaf photosynthesis progressively increases rather than instantaneously increasing to the steady-state level (a process termed photosynthetic induction). The main limiting processes for photosynthetic induction are typically described as RuBP (ribulose-1,5-bisphosphate) regeneration, Rubisco (ribulose-1,5-bisphosphate carboxylase oxygenase) activation and stomatal opening. Studies have shown that at high CO_2, photosynthesis induction tends to be faster mainly due to faster Rubisco activation rate and a reduction in stomatal limitation. Interestingly, we found that when CO_2 level was very high (e.g. 1000 ppm, Fig. 1), leaf photosynthesis was quickly induced at during the first 50-60 seconds, followed by a "dip" in photosynthesis rate for 1-2 minutes, after which photosynthesis rate stabilised. This "dip" is most likely caused by the insufficient activation of sucrose phosphate synthase (SPS), an enzyme in the triose utilization pathway following CO2 fixation by Rubisco. This slow activation of SPS leads to a transient phosphate limitation in the chloroplast, which negatively feeds back on assimilation rate. Nevertheless, the "dip" is not well described and characterized in literature. The aim of this project is to (1) explore to which CO_2 concentration does the "dip" happen and (2) quantify to what extent does the "dip" affect leaf net carbon gain during photosynthetic induction.

Fig. 1. Photosynthetic induction curve measured at 1000 ppm CO_2. The leaf was firstly adapted to a light intensity of 50 µmol m^{-2} s^{-1}, then at time point 0s, light intensity increased to 1000 µmol m^{-2} s^{-1}.



MSc/Bsc and ECTS:

Can be tailored to M.Sc. major thesis (36 ECTS) or research practice (24 ECTS)

Type of research:

Gas exchange measurements using LI-6800 or LI-6400, data analysis

Planning:

Project can start immediately - to be scheduled after consulting with the supervisors

How large is a xylem vessel? Let’s hear it!

Supervisors and contact:

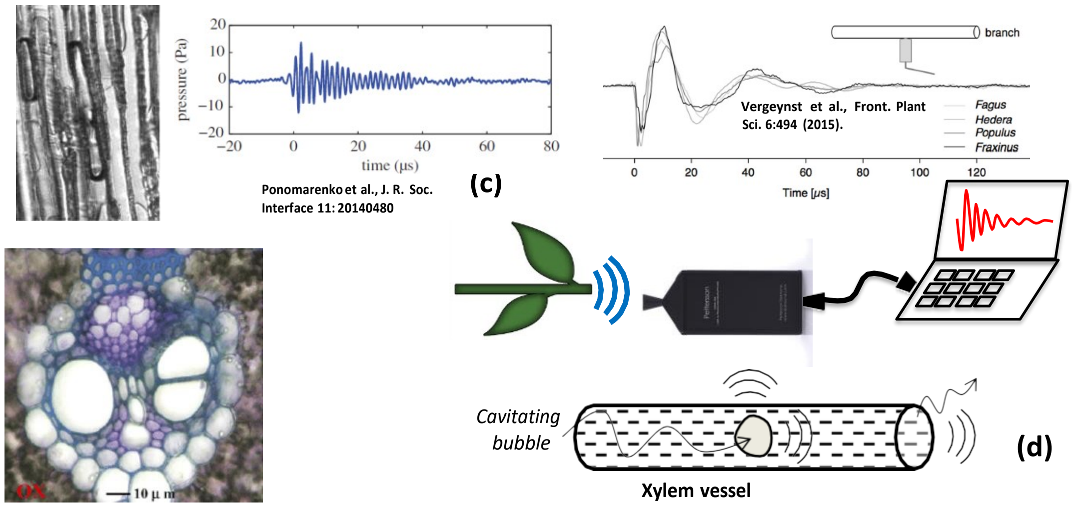
Dr. Elias Kaiser (Wageningen University of Research): elias.kaiser@wur.nl
Dr. Satadal Dutta (Precision and Microsystems Engineering, TU Delft) : s.dutta-1@tudelft.nl
Dr. Gerard J. Verbiest (Precision and Microsystems Engineering, TU Delft): G.J.Verbiest@tudelft.nl

Project background:

Non-invasive and early monitoring of drought-stress in crop plants is helpful not only for precise irrigation plans, but also it can provide a wealth of novel physiological insight into plant dynamics. Several plant physiologists have reported on broadband ultrasonic emission (UE) from drought-stressed plants, which are largely attributed to cavitation, i.e. micro air-bubbles that form within the tubular water-conducting tissue (xylem) of plant stem. A systematic study of the time and frequency domain behaviour of the UE events in various plant species can reveal information about the physical properties of the xylem such as geometry, and acoustic stiffness. However, this information requires validation via optical imaging of the xylem under a microscope. This work will be a part of the Plantenna project, a 4TU collaboration funded by NWO, where you have the chance of working in a multidisciplinary team involving researchers on plant ecophysiology (WUR) and dynamics of micro/nano systems (TU Delft). Work location can be either in Wageningen or Delft, or divided between both places, depending on your preferences.

(a)

(b)



Credits: S. Kant et al., Plant Physiology, vol. 151, pp. 691-701 (2009).

Fig. 1 Examples of (a) longitudinal (in Scots pine) and (b) transverse (in rice) cross-section images of the vascular bundles in plant stem. (c) Time-domain signals corresponding to ultrasound bursts as reported in the indicated references. (d) Schematic measurement set-up to record the emissions using the M500-USB broadband sensor, followed by signal processing to model a xylem vessel.

Task description (MSc thesis, 24-36 ECTS):

You will record ultrasound pulses from a range of plant species (with varying morphology of vascular tissue) in a controlled lab environment with a commercial sensor. Subsequently, you will perform time and frequency domain analyses of the data to extract physical dimensions of the xylem tissue. This should then be correlated with optical imaging (invasive) of the vascular tissue. To add to the scientific knowledge, another novel experiment that can be conducted by you (depending on personal motivation) is preparing a mechanical analogue of a cavitating air bubble in a capillary tube, to mimic the dynamics of the xylem vessel. While you are expected to work towards a valuable MSc thesis, the results will have a strong contribution to publications in reputed conferences/journals.

References:

1. I. Khait et al., bioRxiv, 2018 (doi: 10.1101/507590).
2. Ponomarenko et al., J. R. Soc. Interface 11: 20140480.

Diurnal gas exchange: interaction between foliar and non-foliar tissues

Supervisor(s) and contacts:

Dr. Silvere Vialet-Chabrand (HPP-WUR), Dr. Rob Schouten (HPP-WUR)

Description:

Fruit growth results from the balance between influx of water, nutrients and assimilates and losses due to fruit transpiration and respiration (Windt *et al.*, 2009). Water influx in the fruits occurs in part through the xylem in competition with the rest of the plant, and for that reason fruit growth is sensitive to changes in foliar transpiration (Hanssens *et al.*, 2015). Assimilates can originate from foliar photosynthesis or from the fruit itself in proportion that varies between species (Cocaliadis *et al.*, 2014; Simkin *et al.*, 2020). For example, the surface area of a mature green cucumber (*Cucumis sativa* L.) fruit is comparable with that of a functional leaf and makes an important contribution in term of photo-assimilates to fruit growth (Sui *et al.*, 2017). In tomato, fruit photosynthesis is present at early developmental stage, but there is still a debate on the importance of its contribution to the growth (Cocaliadis *et al.*, 2014). Therefore, gas exchange can be an important determinant of the fruit growth even though its diurnal variations are not well characterized, especially in interaction with foliar tissues.
In this project, you will perform diameter measurements and diurnal gas exchange measurements on attached fruits of tomato/cucumber at different developmental stage using a custom gas exchange chamber (Li-6800). To study the effect of the whole plant on the fruit gas exchange, the plant canopy will be subjected to different diurnal environmental conditions (high/Low light, High [CO_2]).

MSc/Bsc and ECTS:

Can be tailored to M.Sc. major thesis (36 ECTS) or research practice (24 ECTS)

Type of research:

Gas exchange measurements, data analysis

Planning:

Project can start immediately - to be scheduled after consulting with the supervisor

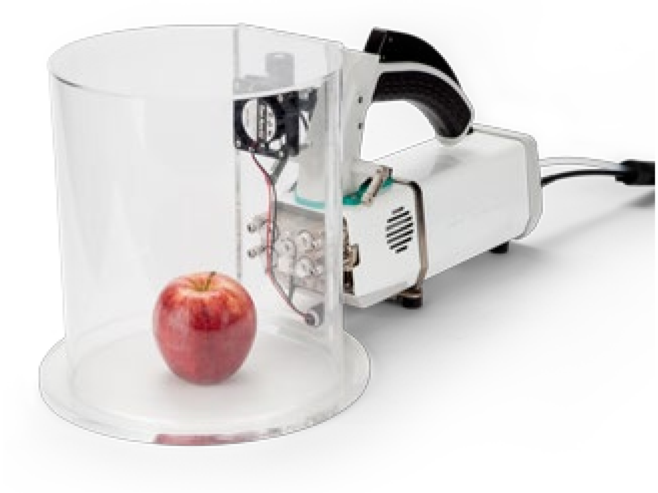


Fig. 1. Example of custom gas exchange chamber to measure fruit gas exchange.

References

Cocaliadis, M.F., Fernández-Muñoz, R., Pons, C., Orzaez, D. and Granell, A., 2014. Increasing tomato fruit quality by enhancing fruit chloroplast function. A double-edged sword?. Journal of experimental botany, 65(16), pp.4589-4598.
Hanssens, J., De Swaef, T. and Steppe, K., 2015. High light decreases xylem contribution to fruit growth in tomato. Plant, cell & environment, 38(3), pp.487-498.
Simkin, A.J., Faralli, M., Ramamoorthy, S. and Lawson, T., 2020. Photosynthesis in non-foliar tissues: implications for yield. The Plant Journal, 101(4), pp.1001-1015.
Sui, X., Shan, N., Hu, L., Zhang, C., Yu, C., Ren, H., Turgeon, R. and Zhang, Z., 2017. The complex character of photosynthesis in cucumber fruit. Journal of experimental botany, 68(7), pp.1625-1637.
Windt, C.W., Gerkema, E. and Van As, H., 2009. Most water in the tomato truss is imported through the xylem, not the phloem: a nuclear magnetic resonance flow imaging study. Plant physiology, 151(2), pp.830-842.

Influence of mitochondrial respiration on diurnal stomatal behaviour

Supervisor(s) and contacts:

Dr. Silvere Vialet-Chabrand (HPP-WUR)

Description:

Photosynthesis, the primary determinant of plant biomass depends on light intensity and CO_2 availability at the sites of carboxylation. Stomatal conductance (g_s), a measure of the ease at which gas diffuses through stomata over the leaf surface is closely correlated with the rate of carbon assimilation (A) under steady state conditions, although the mechanisms co-ordinating the two are not clear. The coordination between A and g_s is an unexploited avenue to increase plant productivity (Wu *et al.*, 2019) and is thought to be due in part to the energy requirements of stomatal movements that are fulfilled at different time of the response by mitochondria and/or chloroplasts. Indeed, Mawson (1993) highlighted that the translocation of protons across the guard-cell plasmalemma, the first step of stomatal apperture is an energy-requiring activity. His study suggested that both guard-cell chloroplasts and mitochondria contribute in synergy to supply energy to BL-induced proton pumping by guard-cell protoplasts, as both were inhibited by low [O_2]. Preliminary results have highlighted the importance of mitochondrial respiration for rapid stomatal responses in interaction with the circadian clock, and further experiment are required.

In this project, you will perform gas exchange measurements on leaves of tomato/cucumber using a gas exchange chamber (Li-6800/6400). Under low [O_2] to inhibit respiration, the stomatal response to step changes in light intensity will enable to quantify the importance of respiration in driving stomatal movements.

MSc/Bsc and ECTS:

Can be tailored to M.Sc. major thesis (36 ECTS) or research practice (24 ECTS)

Type of research:

Gas exchange measurements, data analysis

Planning:

Project can start immediately - to be scheduled after consulting with the supervisor

References

Wu A, Hammer GL, Doherty A, von Caemmerer S, Farquhar GD. **2019**. Quantifying impacts of enhancing photosynthesis on crop yield. *Nature Plants* **5**: 380–388.

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Leaf boundary layer conductance: the final frontier for diffusion

Supervisor(s) and contacts:

Dr. Silvere Vialet-Chabrand (HPP-WUR)

Description:

Leaf-boundary-layer conductance (g_b) represents the ease of diffusion through the air layer formed along the leaf surface due to reduced velocity and is mainly influenced by air speed. Under low air speed (e.g. within a plant canopy), g_b is an important limiting factor on energy budgets, transpiration and photosynthesis that can be more important than stomatal conductance (g_{sw}) (Kimura *et al.*, 2016; 2020). Methods to measure g_b are increasingly needed to improve air mixing in greenhouses and vertical farms, and to derive g_{sw} from thermal or gravimetric measurements used for example in phenotyping platforms. Different techniques exist to measure g_b (Brenner & Jarvis, 1995; Stokes *et al.*, 2006) but are not widely used due to technical limitations or because of their reduced reliability under fluctuating environmental conditions. Easy to use and affordable sensors are required to map and monitor the effect of air mixing on plant growth and development in indoor farms.

In this project, you will work on a newly develop sensor to measure g_b and compare the results with other methods described in the literature. Once the sensor has been tested and validated, it will be used to map the air mixing in a greenhouse. A diffusional model will then be used to predict the potential limitations of transpiration and photosynthesis that leaves can experience.

MSc/Bsc and ECTS:

Can be tailored to M.Sc. major thesis (36 ECTS) or research practice (24 ECTS)

Type of research:

Energy balance, modelling, data analysis

Planning:

Project can start immediately - to be scheduled after consulting with the supervisor

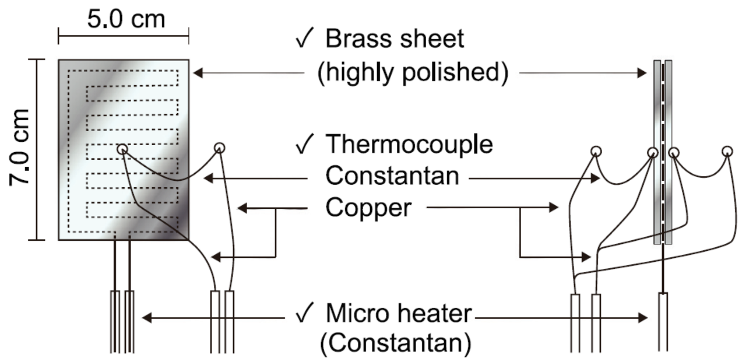

Fig. 1. Schematic diagrams of an artificial leaf for evaluating leaf-boundary-layer conductance: side (a) and front (b) views. The width and length of the leaf are based on the mean characteristic dimension of actual tomato leaves. A micro-heater of fine constantan wire was zigzagged and enveloped within highly polished brass sheets, and a pair of T-type thermocouples was attached to each side of the leaf to detect the leaf–air-temperature difference; one junction was attached to the leaf surface, and the other was placed 1.5 cm away from the surface.

Fig. 1. Example of boundary layer conductance sensor.

References

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About time: How light influences anthocyanin biosynthesis and stability in lettuce.

Supervisor(s):

Dr. Sarah Courbier (sarah.courbier@wur.nl; daily supervisor) and Prof. dr. Leo F. M. Marcelis

Project description:

Global food demand is increasing due to the growing human population and pushes breeding towards highly productive cultivars. As production increases, the nutritional quality (minerals and phytochemicals) of these crops usually decreases. However, minerals and phytochemicals contained in food are essential for human metabolism and have been associated with reduced risk of diseases. Anthocyanins are phytochemicals responsible for the red and purple colour of fruits and vegetables (red cabbage, grapes, etc.). Even though, anthocyanins have strong antioxidant properties, too much of these compounds can negatively impact plant growth and taste. Therefore, an optimized content of these molecules in plants is desirable.

In this project, you will investigate the effect of different light environments on lettuce physiology, growth parameters and anthocyanin homeostasis in several green and red lettuce cultivars. You will also study the stability of anthocyanins at the pre and post-harvest stage. In parallel, you might also be involved in designing a time-lapse imaging system to follow the coloration through time under different light treatments.

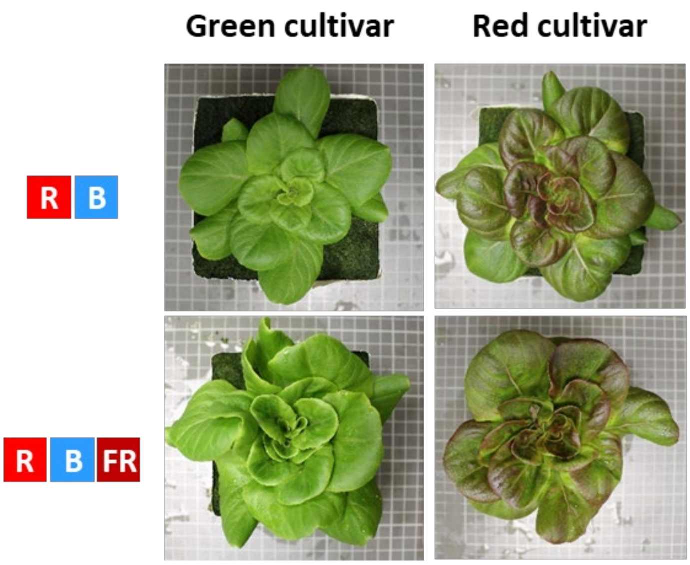


Figure 1: Green and red lettuce plants grown for 21 days after transplanting under Red and Blue LEDs (RB; top row) or under Red and Blue LEDs with supplemental far-red LEDs (RBFR; bottom row).

BSc/MSc and ECTS:

MSc-thesis: 24-36 ECTS; also BSc thesis possible (18 ECTS)

Type of work:

lettuce cultivation, phenotyping, photosynthesis measurements, sugar analysis, HPLC, qPCR, data analysis

Planning:

In consultation with supervisors (flexible start. Possibility on starting from May 2021)

Vertical farming versus conventional farming: A comparative study

Supervisor(s):

Dr. Sarah Courbier (sarah.courbier@wur.nl; daily supervisor) and Prof. dr. Leo F. M. Marcelis

Project description:

Vertical farming is an emerging practice consisting in cultivating crops under full LED conditions on vertically stacked layers which provides numerous advantages compared to conventional farming (*i.e.* greenhouses). Firstly, vertical farms can be implemented in existing empty buildings or warehouses allowing for locally-grown fresh produce thereby reducing transport costs and associated pollution. Secondly, these facilities are based on sustainable, efficient and fully-controlled cultivation methods providing optimal quality vegetable throughout the whole year irrespective of the seasons of the fluctuating weather. Lastly, water, land and pesticides use are greatly reduced in vertical farms. Even though vertical farms seem to represent a true revolution in the production of fresh vegetables, one outstanding question remains to be answered: Is vertical farming providing better/healthier produce compared to conventional farming? This is what you will attempt to find out.

This project will focus on lettuce, one of the most important crop in vertical farming and most economically valuable leafy vegetable crops worldwide. In this project, you will compare different growth conditions on lettuce growth and nutritional value to better evaluate the health benefits of crops grown in vertical farms compared to other methods. This knowledge could help promoting the use of vertical farming methods to provide better and healthier lettuce crops on the market.

BSc/MSc and ECTS:

MSc-thesis: 24-36 ECTS

Type of work:

lettuce cultivation, phenotyping, antioxidant activity, HPLC, data analysis.

Planning:

In consultation with supervisors (Possibility on starting from September 2021)

Exploring the interaction between abiotic and biotic defence for tomato plants growth

Supervisor(s):

Martina Lazzarin (PhD-candidate), Davy Meijer (PhD-candidate)

Description:

Light spectral composition influences plant growth and metabolism, and has important consequences for their interactions with plant-feeding arthropods. For instance, in tomato, low red to far-red (R:FR) light ratios stimulate plant growth but reduces resistance to several herbivorous arthropods. Additionally, light itself can also be a source of stress, inducing the production of radical oxygen species and photoinhibition, which in turn can affect plant defences against herbivores. The consequences of abiotic stress on plant's defence against plant-feeding arthropods remains unclear. In this project, we will use different light treatments to induce light stress and investigate whether this influences the plant's defence against plant-feeding arthropods.

BSc/MSc and ECTS:

The workload of this project can be adjusted to represent either a B.Sc. (18 ECTS) or M.Sc. (ECTS: 24 or 36 ECTS) thesis

Type of work:

Tomato plants will be grown in a climate room in which an artificial light regime will be created with LED technology. Photosynthetic performance will be assessed by chlorophyll fluorescence measurement. Herbivory performance measurements will involve counting spider mite eggs or aphid nymphs.

Planning:

The project can start from June- to be scheduled after consulting with the supervisors.

Investigating the potential of an artificial solar light spectrum for tomato plants photosynthesis

Supervisor(s):

Martina Lazzarin (PhD-candidate), Dr. Steven Driever

Description:

Changes in light spectrum influence several processes, including the balance of excitation pressure between photosystems in the chloroplast. A short imbalance can quickly be adjusted by physiological mechanisms taking place from seconds to minutes. A prolonged imbalance can lead to changes in stoichiometry of photosystems, which in turn might influence light absorption and photosynthesis. Changes in light spectrum are sensed by photoreceptors. These mediated morphological responses further impact light interception ability (of single leaves, but also of the whole plant). We have a unique experimental set-up in which we can mimic the solar light and measure whole plant photosynthesis. We would like to explore how changes in light spectrum impact in the long term photosystems stoichiometry of individual leaves and investigate how this influences plant photosynthesis.

BSc/MSc and ECTS:

The workload of this project can be adjusted to represent either a B.Sc. (18 ECTS) or M.Sc. (ECTS: 24 or 36 ECTS) thesis

Type of work:

Tomato plants will be grown in a climate room in which an artificial solar light regime was created with LED technology. Individual and whole plant photosynthesis can quantified. Measurements can be done in a set of photoreceptor mutants.

Planning:

The project can start from Sep- to be scheduled after consulting with the supervisors.

Spectral (LED) influence on floral induction in Chrysanthemum

Supervisor(s):

Sharath Malleshaiah and Dr. Ep Heuvelink

Description:

Chrysanthemum is a high-value ornamental crop that flowers only in short-days (SD). For year-round production, growers employ blackout screens to create SD in the greenhouse under natural long days. In winter, short-day lengths combined with low light intensities result in low daily light integral, limiting greenhouse production. Therefore, supplemental light is needed to achieve higher daily light integral (DLI) for photosynthesis without compromising flowering; this will allow growers to produce better quality and higher yield (more stems per m^2). Energy-efficient LED's can be used, which have the additional possibility to influence the light spectrum. We tested whether it would be possible to induce flowering under long-days by applying a dynamic light spectrum.

We observed it is possible to obtain flowering in chrysanthemum under long days (15h) by active control of the light spectrum. 11hours of red-blue (RB) light extended with four hours of blue (B) light resulted in a similar flowering response as under SD. However, this was not possible under greenhouse conditions with solar light (SL) during 11h. The obvious difference between the SL spectrum and RB LEDs is that a significant amount of far-red or green light. Either far-red or green light could be responsible for non-flowering under 11h of full-spectrum solar light extended with blue in a greenhouse condition.

We are interested in exploring a lighting strategy to induce chrysanthemum flowering by designing lighting stategy that can revert the SL spectrum's inhibitory effect using LEDs.

MSc and ECTS:

MSc-thesis: 24-36 ECTS

Type of work

Will be greenhouse or climate chamber experiments, and the candidate is expected to conduct the experiment and performing measurements of physiological and morphological parameters. Also, possible to do gene expression analysis to understand molecular mechanisms associated with chrysanthemum flowering; florigen (*CmFTL3)* and anti-florigen (*CsAFT* and *CsTFL1*) genes.

Planning

Start: in consulting with supervisors.

Literature

SharathKumar et al, (2021). https://www.frontiersin.org/articles/10.3389/fpls.2020.610041/full

Lettuce growth model 2.0 – Investigating the limits of crop productivity

Supervisor(s):

Dr. ir. Ep Heuvelink (Plant Sciences), Dr. Cecilia Stanghellini and Ilias Tsafaras (Greenhouse Horticulture)

Description:

The expansion of the urban population has resulted in an ever increasing interest in urban food production. Urban farming is considered a promising development in the light of societal challenges regarding food security and urbanization, and sustainable crop production (FAO 2011, Colding & Barthe 2013). Substantial attention is given to production in closed plant production systems, or socalled plant factories and vertical farms, which rely solely on artificial illumination.

These plant factories and vertical farms currently focus on the production of leafy greens. These types of closed plant production systems typically combine high-density crop production, a limited volume and lack of natural ventilation. This induces a high demand for cooling and vapour removal. Preferably, production temperatures would be increased, to minimise said cooling load. The existing lettuce growth models (Van Henten, 1994; Van Henten et al., 1994) have not been calibrated for production at such elevated temperatures (Graamans et al., 2018). Additionally, the effects of root zone temperature (He et al., 1998b, 1998a; Thompson et al., 1998; Frantz et al., 2004) and high daily light integrals have not been taken into account.

This research features numerous experiments focusing on the effects of air temperature, root zone temperature, and light intensity on the production of lettuce. This data can be used to increase the precision and applicability of existing lettuce growth models for plant factories. These models can then be used to optimise the production of lettuce in plant factories for energy use efficiency.

Type of work (for a number of students, one could focus more on experimental work or more on modelling):

- make a research plan;
- get acquainted with crop models and their programming;
- analyse existing lettuce models with respect to temperature, light and other production factors;
- program a structural growth model for lettuce, which is able to simulate light absorption, crop photosynthesis, leaf growth and plant development; and
- conduct numerous lettuce production experiments in order to gather experimental data that can be used for model development, calibration and/or validation.

BSc/MSc thesis:

MSc thesis 36 ECTS

Planning:

Flexible - In consultation with the supervisors.

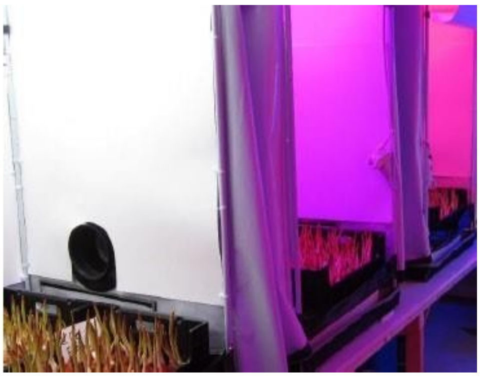
MSc-thesis or Internship: Controlling flowering and morphology of Lily cut flowers with light

Supervisor(s):

External supervisor: Sander Hogewoning (info@plantlighting.nl)
Contact HPP: Wim van Ieperen

Description:

Plant Lighting B.V. (Bunnik, the Netherlands) is looking for a student to participate in a research project starting in October 2019. Both MSc-thesis or internship is possible.
The project is about controlling flowering and morphology (length, leaf orientation) of cut Lily flowers. Being a quantitative long-day plant, lily flower development time is sensitive to the photoperiod and light spectrum. This is controlled by the photoreceptors in the plant. The aim is to unravel which photoreceptors are involved in flowering response, and by which lighting strategy the ideal plant response is realized (ideal light intensity, spectrum and photoperiod).
The growth-experiments under different lighting conditions are performed in the state-of-the-art facilities of Plant Lighting in Bunnik. Responses of the lilies in climate chambers are compared with the plant response of control plants in the greenhouse. The results are being used by growers for optimization of greenhouse production and possibly switching to production in multiple layers (vertical farm).
The student is expected to participate in most aspects of the research: Setting up the experiment (lighting etc), plant measurements and communication with growers. The project takes ~6 months (a bit shorter or longer is possible, also 3 or 4 days per week). Preference for a Dutch speaking student for communication with growers. Possibility for a research position (job) after graduation.
Plant Lighting staff has a scientific background in plant physiology and will supervise the student together with the supervisor from WUR. Check www.plantlighting.nl for more info on the company.
In case of a MSc-thesis you should contact Wim van Ieperen first at wim.vanieperen@wur.nl - for an Internship you can contact Sander Hogewoning directly at info@plantlighting.nl.

Internship and ECTS:

Internship credits up to 24 ECTS; for MSc-thesis 24 or 36 ECTS

Location:

Bunnik, the Netherlands

Planning:

To be arranged in consultation with the supervisor(s)

Does light spectrum influence fruit set in sweet pepper?

Supervisor(s):

Sijia Chen (PhD candidate) and Dr. Ep Heuvelink

Description:

Fruit set indicates the initiation of fruit growth derived from flowers, and the cessation of this process is termed as abortion. Fruit set or abortion is a crucial development process in the plant life cycle, and it is also a main determinant of crop yield. In sweet pepper, up to 80% of all flowers can abort. This results in a low yield as well as a strong cyclical pattern in fruit set, where periods with high fruit set are alternated with periods with low fruit set, causing unstable market supply and product price. Therefore, understanding how fruit abortion can be influenced by the growth environment is of great importance.

Fruit set and abortion is responding to various environmental signals, where light quality could be an important factor. However, this has hardly been studied so far. From preliminary experiments, supplementary far-red light reduced fruit set in sweet pepper, however its mechanism is still unknown. Multiple questions are addressed: Is this process related to hormonal balance (e.g., auxin, ethylene) in shade avoidance syndrome? Does FR promote fruit sink strength of sweet pepper? Is the low PSS (phytochrome photostationary state) achieved by high blue: red ratio has the same effect on fruit set as adding FR? More questions can be put forward after discussion with supervisors.

This topic can have 1-2 students each time. To investigate these questions above, the students need to set up and conduct greenhouse/climate chamber experiments, collect and analyze plant tissue samples in labs. With the completion of this study, the students are expectedto have deeper understanding on plant reproductive development, and the interaction between plantand light environment.

BSc/MSc thesis:

MSc-thesis: 24-36 ECTS

Type of work:

Greenhouse and/or climate room experiments with LEDs; destructive and non-destructive morphological measurements. When appropriate: plant anatomical study (under microscope); plant hormone measurements; sugar analysis; along with gene expression analysis (qPCR).

Planning:

Project can start immediately - To be scheduled after consulting with the supervisors

How high temperature delays photoperiodic floral induction in Chrysanthemum

Supervisor(s):

Sharath Malleshaiah and Dr. Ep Heuvelink

Description:

Chrysanthemums are one of the most valuable ornamental commodity of floriculture sector to use as cut flowers and potted plants owing to their colourful 'capitulum'. Production of this ornamental beauties is quite challenging due to their largely depend on day length (photoperiod) and temperature. Chrysanthemum is an obligate short day plant demanding long hours of darkness for floral induction and development. For year round cut-flower production of chrysanthemum, greenhouse growers regulate light by bringing photoperiod closer by shading with blackout screens or extended further by night breaks with artificial lighting. However these blackout screens poses extra anomaly by rising the temperature under the blackout screens which results into delayed flowering (Heat delay). We are interested in elucidation of influence of how high temperature influence physiological mechanisms which cause delay in flowering using molecular biology techniques.

We will use different heat sensitive and tolerant chrysanthemum genotypes to study how higher temperature delay flowering both in terms of physiological and molecular mechanisms. And to determine the extent of heat delay in chrysanthemum we like to investigate the effect of high temperature on set of florigen (CmFTL3) and anti-florigen (CsAFT and CsTFL1) genes in influencing flowering trait and along with other phenotypic traits involved in the floral transition.

MSc and ECTS:

MSc-thesis: 24-36 ECTS

Type of work:

This work is executed by climate chamber experiments and the candidate is expected to conduct the experiments and performing measurements of physiological and morphological parameters, along with gene expression analysis using qPCR.

Planning:

Start: In consultation with supervisors

Effects of light quality on plant water relations, leaf development and stem elongation

Supervisor(s):

Dr. Wim van Ieperen

Description:

Several topics can be studied within this framework. These projects are of fundament scientific interest, as not much is known yet about the role of light quality during plant development on water relations and the underlying (molecular) mechanisms of light quality effects on leaf development and stem elongation. It is also of practical interest for horticulture e.g. because (1) the use of LEDs might enable the control of hardening of young plants before transplanting and (2) the use of LEDs might enable the production of compact potplants in greenhouses without the use of growth regulators.

BSc/MSc and ECTS:

Bsc thesis (18 ECTS)
MSc-thesis: 24-36 ECTS

Type of work:

Crop: tomato

Measurements: these topics include building and development of methodology, growing plants under different light qualities, measurements of physiological (*e.g.* photosynthesis and transpiration) and morphological parameters.

Requirements

Planning:

Start in consultation with Dr. Wim van Ieperen

Thermal imaging for high through put stomata phenotyping in tomato

Supervisor(s):

Prof. Dr. Leo Marcelis

Description:

The capability to non-destructively capture plant traits is a key advance in high-throughput phenotyping. Stomatal regulation is an important indicator of plant photosynthesis and water relations. Stomatal responses to light is of critical importance and rapidly captured responses will provide insight into the plant growth status. The dynamic changes in stomatal conductance in response to a change in light intensity and the variation of the response among different genotypes will be characterized in this study. Out of a core collection of 40 genotypes, contrasting genotypes (in stomatal responses) will be selected. Plants will be adapted to either high or low light intensity, and then placed in the other environment. During these changes in light intensity, thermal imaging will be used to assess dynamic stomatal responses in a controlled environment with red and blue LED lighting. A thermal index (I_G) will be calculated from thermal imagery and evaluated for suitability for screening of dynamic stomatal conductance and compared to parallel stomatal conductance measurements using a porometer. The results will be discussed in relation to their potential for high throughput plant phenotyping applications.

The main objective of this work will be to develop a methodology for use of IR thermography for high throughput phenotyping of stomatal conductance and to assess dynamic opening and closing of stomata in response to light intensity stimulus.

BSc/MSc and ECTS:

MSc-thesis: 24-36 ECTS; also BSc thesis possible (18 ECTS)

Type of work:

Climate chamber experiments Crops: tomato plants
Measurements: Thermal imaging, porometry

Planning:

Can start from February 2017 (in consultation with the supervisors)

Understanding and predicting the Phenotype of Phalaenopsis Orchids in different environments

Supervisor(s):

Evelien van Tongerlo (PhD-student), Dr. Wim van Ieperen

Description:

Phalaenopsis is one of the most economically important ornamental crops. Selection of new varieties is often done by manual assessment of colour, shape and number of flowers. Important cultivation characteristics, such as growth duration and responses to the greenhouse climate are not taken into account. Consequently, rates of growth and development may later appear to be disappointing. Breeders are lacking (early) selection criteria for production and product quality. Therefore failure of new varieties is often only known after several years.

The aim of this project is to develop reliable phenotyping techniques for Phalaenopsis, which takes into account the cultivation performance in modern greenhouse environments in relation to the climate. To do so, we will investigate the interactions between temperature, light intensity, light spectrum and genotypes on the processes of growth and development. Besides that, we'll look at the effects on photosynthesis and carbon budgets.

Photosynthesis is the primary source for carbohydrates in plants. Phalaenopsis employs Crassulacean Acid Metabolism (CAM) photosynthesis. This implies that CO2 is taken up at night and stored as free malate in vacuoles. In CAM plants, stomata are closed during the largest part of the light period and opened during the dark. Nocturnal and diurnal CO2-uptake can readily be obtained by gas exchange measurements. However, measuring gas exchange is not suitable for large scale phenotyping. It will also not provide information about instantaneous CAM photosynthesis rates during the light period, though it can be used to measure shifts between CAM and C3 in the light in dedicated experiments. However, measuring gas exchange is not suitable for large scale phenotyping. Chlorophyll fluorescence (CF) has already been applied successfully as a tool for screening of genotypes of C3 crops, but largescale chlorophyll fluorescence protocols still need to be developed for CAM plants such as Phalaenopsis.

BSc/MSc and ECTS:

Bsc thesis (18 ECTS)
MSc-thesis: 24-36 ECTS

Type of work:

Crop: Phalaenopsis
Measurements: Plant growth measurements, gas exchange, chlorophyll fluorescence

Planning:

Any time, but if you are interested contact the supervisors as soon as possible because of long-term planning

Water stress and light quality: Coordination of Leaf hydraulic conductance and stomatal conductance at different light qualities (i.e. under LEDs and Sun-light)

Supervisor(s):

Dr. Wim van Ieperen

Description:

When leaves adapt to environmental conditions they apparently show coordinated responses with respect to photosynthesis and water relations. This requires some kind of internal organisation, which might possibly be under the control of an environmental factor. Recently we showed that the conductance for water transport in the leaf lamina (K_{leaf}) and stomatal conductance (g_s) are highly correlated, even when plants are grown under distinct different light qualities (Savvides et al., *Journal of Experimental Botany, 2012*) which might point to a specific role for some photoreceptors (i.e. phytochromes, cryptochromes etc). This topic is of fundament scientific interest, as not much is known yet about the role of light quality during plant development on water relations. It is also of practical interest for horticulture e.g. because the use of LEDs might enables the control of hardening of young plants before transplanting.

BSc/MSc and ECTS:

MSc-thesis: 24-36 ECTS

Type of work:

Crops: tomato, cucumber

Measurements: the topic includes building and development of methodology, growing plants under different light qualities, measurements of K-leaf, stomatal conductance and stomatal -aperture, -size and -densities. Measurements of photosynthesis and transpiration and biomass accumulation

Planning:

Start in consultation with supervisor

For this MSc-project basic technical skills are required (further info: wim.vanieperen@wur.nl)

Improving homogeneity in cut chrysanthemum production

Supervisor(s):

Dr. Jochem Evers (CSA – Crop System Analysis) – Dr. Ep Heuvelink (HPP)

Description

Chrysanthemum is one of the most important horticultural ornamental crops worldwide. Much research has been done on the response of chrysanthemum to environmental factors such as temperature, light, and their interaction. This research is being used to optimize chrysanthemum production. However, the single most persistent issue in production of this ornamental crop is the variation within the product: individual chrysanthemum plants grown simultaneously in the same conditions differ from one another in terms of stem extension, branching, leaf area, biomass, and flower number and size. Adding to this complexity is the rapid introduction of new varieties, each with their own particular responses to environmental signals.

This MSc thesis topic aims at improving the homogeneity of chrysanthemum production by finding optimal plant traits for production. This entails mapping the suit of responses chrysanthemum shows to environmental signals (notably light), quantifying those responses, and formulating management protocols as well as directions for chrysanthemum breeding. This research will be done in collaboration with Deliflor, the largest chrysanthemum breeder worldwide (www.deliflor.nl).

Type of work

This study will include one or more of the following components: measurements in current chrysanthemum production situations, performing small-scale experiments to quantify crop responses to manipulation of environmental variables, and integration of new and existing knowledge in a simulation model of chrysanthemum growth and development based on the principles of functionalstructural plant modelling. The exact contents of the work can be tailored towards the learning goals of the student to a certain extent.

Location

Wageningen (WUR Crop Systems Analysis; WUR Horticulture and Product Physiology) Maasdijk (Deliflor)

Contacts:

Jochem Evers (jochem.evers@wur.nl) Ep Heuvelink (ep.heuvelink@wur.nl)

Planning:

Start in consultation with supervisor

Analysis of realistic 'genotype by environment' interactions simulated using a crop growth model with a large number of physiological parameters

Supervisor(s):

Dr. Ep Heuvelink and Prof.Dr. Fred van Eeuwijk (WUR Biometris)

Description:

A different response of genotypes across environments is frequent in multi-location trials and is known as genotype by environment interaction (GxE). The study and understanding of these interactions is a major challenge for breeders and agronomic researchers.
To better understand the GxE a simulation study may be conducted using a crop growth model with a large number of physiological parameters, to obtain yields for different genotypes in different environmental conditions. Yields of different genotypes across environments should be analysed with some of the standard techniques to study GxE (e.g. AMMI models, mixed linear models, etc.) in order to answer questions such as:

(i) are the GxE interactions significantly important? (e.g. are crossovers present in the data?);
(ii) which kind of parameters make the GxE stronger?
(iii) which characteristics (regarding parameter specification) should have the genotypes to have higher yield in a particular environment?
(iv) which parameters are the most important to explain the final yield?

BSc/MSc and ECTS:

MSc-thesis: 24 or 36 ECTS

Type of work:

Desk study thesis on modelling/simulation/analysis. This paper gives a good idea of the kind of work we have in mind: https://doi.org/10.1002/csc2.20476

Requirements:

Interest in quantitative methods. Some knowledge of crop growth models and good statistical knowledge, preferably including multivariate methods.

Planning:

In consultation with the supervisor(s).

Source-sink ratio and negative feedback of low sink strength on crop photosynthesis

Supervisor(s):

Dr. Ep Heuvelink

Description:

Light is the most important growth factor determining crop yield in greenhouses. In northern regions including The Netherlands, low light levels limit photosynthesis and consequently growth during a large part of the year. On the other hand in summer time there are periods with too high intensities, which may lead to photo-damage or reduction of the quality of produce.
The overall objective of this project is to identify and quantify possibilities for increasing Light Use Efficiency (LUE; g per MJ intercepted PAR) in greenhouse crops. The MSc thesis work will focus on the reduction in LUE which may result from a limitation by sink demand. Occurrence of feedback inhibition of photosynthesis may limit LUE. In this project the importance of sink demand for LUE will be investigated in tomato cultivars with different fruit sizes (sink strengths).

BSc/MSc and ECTS:

MSc-thesis: 24 or 36 ECTS

Type of work:

Determine the source-sink ratio for several tomato cultivars.
Determine whether tomato cultivars differ in their feedback inhibition of plant growth.
Greenhouse experiment and laboratory measurements, including leaf photosynthetic properties, stomatal conductance, content of carbohydrates, leaf area expansion and orientation.

Planning:

In consultation with the supervisor(s)

Investigating light spectrum effects of LED inter-canopy lighting in greenhouse tomato and cucumber

Supervisor(s):

Dr. Ep Heuvelink and ir. Tijmen Kerstens

Description:

Vine crops, specifically tomatoes, represent one of the largest segments for electric lighting in horticultural applications. Furthermore, cultivators are constrained by inadequate lighting conditions during winter months and high operating costs for traditional lighting systems. LED lighting systems are becoming increasingly efficient and cost-effective, yet understanding of spectral effectiveness within PAR and beyond requires further investigation. In this study we aim to assess the effectiveness of several light recipes in the context of inter-canopy lighting. The objective of this study is to evaluate the effects of different light spectra in inter-canopy lighting on growth and development in greenhouse tomato production.

BSc and MSc and ECTS:

BSc-thesis 12 or 18 ECTS or MSc-thesis: 24 or 36 ECTS

Type of work:

A greenhouse experiment is conducted. Several students can participate, with an individual focus on topics like: Growth and yield component analysis – destructive harvests & photosynthesis and light interception; light distribution and spectral changes in the canopy.
Fruit quality – sugar content & shelf life

Planning:

Start in September 2021

Farred brings higher tomato yield nearby

Supervisor(s):

Dr. Ep Heuvelink and ir. Tijmen Kerstens

Description:

Dutch greenhouse horticulture is world leading with an export value of 16 billion euro. However, it contributes to 10% of the natural gas consumption and this gas consumption represents 25% of the total annual costs of a nursery. The use of energy for lighting is the main bottleneck to decrease energy use. Supplemental lighting is commonly provided by High Pressure Sodium (HPS) lamps however, Light-Emitting Diodes (LEDs) are receiving recently a lot of attention and are much more energy-efficient. Most common is the application of red LEDs combined with a small fraction (<10%) of other wavelengths. However, in tomato, addition of farred (FR) to supplemental red/blue LED light substantially improves yield, primarily because of an increased assimilate partitioning to the fruits. Our group recently published a paper (Ji et al., 2020, New Phytologist) demonstrating that this increased partitioning to the fruits by FR radiation results from increased fruit sink strength via simultaneous upregulation of sugar transportation and metabolism. Additional FR may improve fruit quality, as increased sugar concentration and higher Brix values for tomato fruit grown under additional FR have been reported.

Important scientific and application questions to optimally make use of additional FR still remain unanswered and are studied in this project. The ultimate goal of this project is to substantially reduce energy use in greenhouses by optimising the spectrum of LED light, while maintaining or even improving production and product quality.

BSc/MSc and ECTS:

MSc-thesis: 24 or 36 ECTS

Type of work:

Greenhouse or climate room experiment; most likely investigating dose-response curves for farred in 2 cultivars. Determination of growth and biomass partitioning (destructive measurements), leaf area and determination of fruit sink strength will be conducted.

Planning:

In consultation with the supervisor(s)

Avoiding tipburn in vertical farming of lettuce

Supervisor(s):

Paul Kusuma and Dr. Ep Heuvelink

Description:

Vertical farming is a novel technology where plants are grown on many stacked layers with LED light. The ambition of the vertical farming industry is to warrant a secure and sustainable vegetable supply: no pesticides, no nutrient emission, only 2-4 litres water per kg produce, at least twentyfold less land use, lower food mileage, less waste and lower energy use per kg produce compared to greenhouses.

Tipburn, i.e. brown necrotic edges of the leaves, is a widespread problem in the production of leafy vegetables. The phenomenon is highly unpredictable and effective control procedures are lacking. Vertical farming opens up possibilities to grow leafy vegetables without tipburn, however this potential is not yet realised. Tipburn is generally considered as a consequence of local calcium (Ca) deficiency resulting in faster cell wall degradation, loss of membrane integrity and premature senescence. Understanding tipburn requires understanding of calcium distribution which is directly related to transpiration distribution in the plant.

BSc/MSc and ECTS:

MSc-thesis: 24 or 36 ECTS

Type of work:

Climate room experiments. Determination of growth, tipburn incidence, calcium distribution in the plant under different climatic conditions and for contrasting cultivars.

Planning:

In consultation with the supervisor(s)

Medical cannabis

Supervisor(s):
Wannida Sae-Tang & Prof.dr. Leo Marcelis

Description:
The global market for medical cannabis is rapidly growing and some countries have now also legalised the recreational use of cannabis. Multiple medical benefits for cannabis have been described (Hill et al. 2015; Whiting et al 2015). The major compounds of medical interest are cannaboids. The plant produces over 100 cannaboids, of which tetrahydrocannabinol (THC), Cannabidiol (CBD) tetrahydrocannabinol (THC), and Cannabidiol (CBD) are the most abundant compounds of interest, but other compounds might also be very important. These cannaboids are produced in glandular trichomes, which are most abundant in floral buds of cannabis plants. Also terpenes produced in the plant are relevant and they may synergistically interact with the medical effects on cannaboids (from website Bedrocan).

Application of cannabis compounds for medical purposes requires that the production meets standards of the farmaceutical industry. Amongst others this implies that the production process is completely controlled and that absolutely no pesticides are used. A high level of control can be realised in greenhouses, but even better in indoor farms without solar light.

BSc/MSc and ECTS:
MSc-thesis: 24-36 ECTS

Type of work:
In this research we will perform a number of experiments in climate chambers to study effects of LED Lighting on different growth stages of the cannabis plant (propagation, development, morphology, flower induction and content of cannaboids; per student project one of these topics will be studied).

For more info on this exciting topic contact Leo Marcelis (Leo.Marcelis@wur.nl)

Planning:
In consultation with the supervisor.

Unraveling Environmental Effects on Excess Light Energy Dissipationin CAM-Photosynthesis of Orchids

Supervisor(s):

Wim van Ieperen; Maarten Wassenaar

Plant Species:

Phalaenopsis

Description:

Phalaenopsis is an economically important ornamental crop in the Netherlands, which employs Crassulacean Acid Metabolism (CAM) photosynthesis as a basic source for CO_2-assimilation and growth. Phalaenopsis is an epiphyte which a natural habitat in trees and relies on water taken up by aerial roots. CAM-photosynthesis is also found in various drought-resistant species and receives increasing interest due to its potential to produce under particularly harsh environmental conditions. A hallmark of CAM-photosynthesis is stomatal closure during the day-time (to save water) and stomatal opening during the night to allow CO_2-uptake which is biochemically stored (often in malate) for later use in photosynthesis during the following day.

Several student projects are available and will focus on unraveling the regulation of excess excitation energy dissipation, which occurs during the afternoon when ample light is still present and the malate-pool that provides CO_2 can become depleted. Specific attention will be given to daylength and wavelength-specific responses as well as to the influence of drought-stress.
You will use combined optical (Chlorophyll Fluorescence, 820 & 540nm absorbance) and gas-exchange techniques to measure linear and cyclic electron- and proton flows that are important for (the regulation of) photosynthesis. The research is lab-based. We expect to have a measuring system for stable C-isotope ratio measurements in our lab soon, which then may become part of the research.

We are searching for enthusiastic, scientifically-curious MSc and BSc-students with interest in fundamental (leaf level) physiological research on photosynthesis. Some affinity with advanced technical work and related problem solving is recommended. You will be working with a team of photosynthesis-researchers in the HPP-CSA photosynthesis lab.

BSc/MSc and ECTS:

BSc thesis (18 ECTS) or MSc-theses: 24-36 ECTS

Planning:

Starting possibilities: in consultation with supervisors

Contact:

wim.vanIeperen@wur.nl

Desk study: Is the use of interlighting in greenhouse production beneficial or wasteful?

Supervisor:

Dr. Elias Kaiser

Description:

In modern greenhouse production, plants are often grown in relatively tall, optically dense canopies –example are tomato, cucumber and bell pepper. Often, supplementary lighting installed above the plants (toplighting) is used to stimulate growth. The introduction of LEDs, which emit much less heat than traditionally used HPS lamps, has made it possible to place lamps closer to plants, enabling "interlighting", a technique in which lights are placed in between plants as well as above them.

Theoretically, interlighting has many advantages: it delivers light to parts of the canopy that would otherwise be strongly shaded, thereby improving the distribution of light across the plant, theoretically improving light use efficiency, growth and yield. Also, it changes the acclimation state of leaves lower in the canopy (which changes their respiration and photosynthesis rates), and might even increase the formation of vitamins in the fruits growing close to interlights. Despite these theoretical benefits, few experimental reports have shown interlighting to actually be beneficial for yield, compared to toplighting, and in these reports the comparison between different treatments may not have been done correctly.

In this literature review and meta-analysis, you will compile published data on the effects of interlighting on whole-crop, leaf and fruit level, and will critically analyse these data, taking into account the correct basis of comparison. You will compare different experimental approaches, and may define a list of criteria for designing the ideal experiment(s) to determine the effects of interlighting in the future.

MSc/Bsc and ECTS:

M.Sc. minor (24 ECTS) or major thesis (36 ECTS)

Type of research:

Desk research: collection, classification, and analysis of data. Careful analysis of experimental setups

Planning:

Project can start immediately - to be scheduled after consulting with the supervisor
This is a continuation of an earlier student project

Desk study: Meta-analysis of photosynthesis dynamics – would you like to crunch data?

Supervisor:

Dr. Elias Kaiser

Description:

In nature, leaves are often exposed to fluctuations in light intensities, causing photosynthesis to respond at various time scales. While we are only starting to realize how important these fluctuations are for plant productivity, most photosynthesis research is still done under conditions in which all light intensities are stable. Hence, research on photosynthesis dynamics is still in its infancy relative to other branches of this science. One tool that is currently lacking is a comprehensive database of published results. Such a database could be used to address questions regarding the effects of genotype, growth and measurement environment, leaf age (etc) on, for example, stomatal and biochemical limitations underlying the response of photosynthesis to rapid changes in light intensity.
If you are interested in digging into existing data and searching for patterns, and if you already have or want to develop some solid coding skills, then this project might be something for you!

MSc/Bsc and ECTS:

Can be tailored to B.Sc. thesis, M.Sc. minor (24 ECTS) and major thesis (36 ECTS)

Type of research:

Desk research: collection, classification, and analysis of data. Database building

Planning:

Project can start immediately - to be scheduled after consulting with the supervisor
This is a continuation of an earlier student project

Developing a functional-structural plant model of *Artemisia annua*

Supervisor(s):

Dr. Ningyi Zhang, Prof. dr. Leo F.M. Marcelis

Description:

Artemisia annua is an important medicinal species. Its secondary metabolite, artemisinin, has been used in the treatment of malaria, as well as several cancers and viral diseases. In many developing and underdeveloped regions, artemisia plants are growing by local farmers. In most cases, plant growth and artemisinin content are not optimized due to lack of knowledge on cultivating this species. Functional-structural plant (FSP) models can be used to explore optimal canopy structure and crop settings for higher yield production. However, such a tool is not yet available for artemisia. The objective of this project is to develop an FSP model of artemisia to optimize artemisia plant growth, development and biosynthesis of secondary metabolites.

BSc/MSc and ECTS:

M.Sc. thesis: 24-36 ECTS

Type of research:

This can be a pure-desk study. FSPM will be developed under the platform of GroIMP.

Planning:

Starting time can be determined after consulting with the supervisor.

Pre- to Postharvest Topics

Low temperature and low light intensity storage to increase shelf-life of butterhead lettuce

Supervisors:

Elias Kaiser and Rob Schouten/Ernst Woltering

Description:

We have found before that quality deterioration of lettuce during postharvest storage is delayed by low temperature in combination with very low light levels (about 5 µmol m^2s^{-1}). This is likely caused by ongoing photosynthesis and greatly reduced respiration rates. Think of using of LED lighting in your fridge to keep lettuce tasty for longer! To find out more about this exciting phenomenon, we aim to investigate the effect of low light intensity/light quality (white/blue/green) and light pulsing (blue-green-blue and green-blue-green), on:

1. shelf-life, especially with regards to sugar and ascorbic acid content.
2. stomatal conductance and transpiration, especially with regards to green light pulsing
3. Rates of photosynthesis and respiration. Is it possible to quantify photosynthesis and respiration accurately in these challenging conditions (low temperature/ low intensity)?
4. The role of a signaling sugar (trehalose-6 phosphate (T6P)). T6P is linked with stomatal opening, photosynthesis (sucrose synthesis) and senescence. Can you quantify T6P in senescing butterhead lettuce, using state of the art HPLC/LCMS-MS systems?

Likely, you will build small containers with a variety of light LED modules stored in the cold, and investigate one or more of the options stated above. Alternatively, we invite you to come up with your own innovative approach to investigate the effects of low temperature/low light intensity on lettuce quality.

Start date is flexible, but depends on Corona restrictions that limit lab use.

MSc/Bsc and ECTS:

M.Sc. minor (24 ECTS) or major thesis (36 ECTS)

The use of short term LED lighting before harvest to improve quality of Lettuce

Supervisor(s):

Qianxixi (Xixi) Min, Prof. Dr. Ernst Woltering

Description:

In recent years, vertical farming (plant factory) has been fast developed and the its concept has been spread worldwide. Lettuce, as one of the major crop grown in vertical farming has become a model plant in experimental research. Lettuce is a perishable leafy vegetable that generally has a short shelf life. Thus, beside the production yield, longer shelf life and better postharvest performance has become a hot topic in lettuce cultivation under controlled environment.

The undesirable conditions in processing, storage and transport are the reasons limits the shelf life of lettuce. A series of visual\sensorial disorders will show up along the storage, such as tissue browning, pinking, yellowing and wilting. These visual quality disorders became the limits of consumer acceptance and shelf life. Vitamin C and carbohydrates play an important role in inhibiting the mentioned quality disorders. Thus the products with high level of vitamin C and carbohydrates are reported also have longer shelf life and better visual quality performance.
The biosynthesis and\or accumulation of vitamin C and carbohydrates has been reported to rapidly respond to light treatments. This make it possible to produce lettuce with high level of vitamin C and carbohydrate by give a short-term light treatment just before harvest, in such a way extend the shelf life of lettuce products. This short-term pre-harvest lighting can be easily applied in vertical farming system, and became a strategy for vertical farming to produce vegetables with good quality.

Our research is focused on the effects of short term pre-harvest lighting on the quality of lettuce. Short term pre-harvest lighting may be different combinations of light intensity, light sum, spectrum, and photoperiod that is applied about 1 week before harvest. Quality of the harvested product is defined by vitamin C and carbohydrates content in the lettuce before and after harvest and by postharvest visual quality and shelf life.

Type of work:

Crops: Lettuce
Measurements:

- Measurements in climate chamber on lettuce (morphological and physiological parameters) and climate conditions in vertical farming system (Light condition, temperature);
- Quality measurements during postharvest storage (lab analysis of chlorophyll, vitamin C, carbohydrate, visual quality and shelf life);
- Data analysis (basic statistics, or sensory data analysis)

Experiments might take place in Philips city farming at Eindhoven. Some traveling is to be expected between Wageningen and Eindhoven. Lab work will take place in HPP lab.

Requirements

Highly motivated team members with the interests products quality. Skilful in data analysis and statistics are preferred

BSc/MSc thesis:

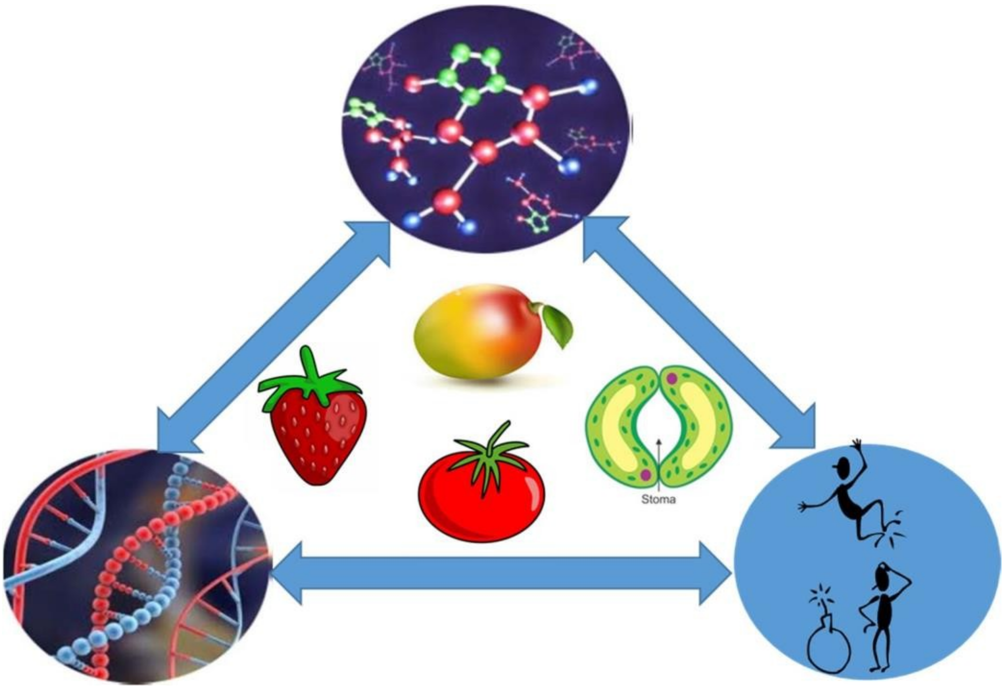
MSc thesis 36 ECTS

Planning:

In consultation with supervisors

Post-harvest topics

Post-harvest quality of fruits, flowers and vegetables



Influence of preharvest conditions
Chilling injury, LED lighting, vase-life, tree factor

Postharvest Physiology & Biotechnology techniques
Colour, firmness, HPLC, qPCR, GC-MS, CRISPR-Cas9, modelling

Supervisor(s):
Dr Rob Schouten, Dr Julian Verdonk, and Prof Dr Ernst Woltering

BSc/MSc and ECTS:
MSc-thesis: 24-36 ECTS.

Planning:
Flexible starting time.

Topics available:

Vase life of cut flowers

- Investigate the influence of preharvest conditions on postharvest quality, vase life. RH during preharvest has effect on quality (vase life). Stomata malfunction is caused by high humidity during preharvest, and is possibly genotype dependent. Bouvardia, Chrysanthemum, topics available.
- Transport of cut flowers can lead to quality problems. What is exactly happening and why is quality affected in some genotypes and not others. Chilling injury, sugar leakage, high humidity during transport. Chrysanthemum, Bouvardia, Gerbera, Rose topics available.
- Stomata functioning can be badly influenced by high RH during pre- and or post- harvest. Gene expression in good and bad lines, and observations using stomata analyses are part of this topic. Chrysanthemum and Rose topics available, as well as mere theoretical ones using Arabidopsis and bean.

Type of work:

Postharvest Phys. Techniques:

- Vase life measurements
- Stomata functioning
- Enzyme assays for chilling injury
- Transport/Storage simulations
- Postharvest treatments, LED lighting, cooling, humidity
- Bacterial counts

Postharvest Biotech. Techniques:

- Stomata functioning assays
- Molecular biology: DNA, RNA, RT-(q)PCR

Chilling injury in Tomato

- Tomato, as a (sub-) tropical fruit suffers from chilling injury (CI). CI occurs before or after harvest, in the field, during transport, storage and marketing. Symptoms are numerous, and include tissue browning, pitting and discoloration of the skin, uneven ripening, and increased disease susceptibility. We want to investigate the role of preharvest factors by growing plants of small tomato cultivars in growing cabinets and vary light and temperature. We also have projects that explore the potential of CA (Conditioned Atmosphere) to reduce CI incidence primarily by lowering the oxygen level during postharvest storage. Finally, we have projects that aim to develop volatile and enzymatic markers to screen fruit cultivars for their ability to benefit from CA and MAP (Modified Air Packaging).

Type of work:

Pre-Postharvest Phys. Techniques:

- Non-destructive measurements (firmness, colour)
- Enzyme assays

- Conditioned atmosphere storage
- Growing tomato plants under varying amounts of light and temperature stress

Postharvest Biotech. Techniques:

- Molecular biology: DNA, RNA, RT-(q)PCR
- HPLC, GC-MS

Tomato Lycopene Bioavailability

[Project together with Dr. Edoardo Capuano FQD (Food Quality and Design)]

- A very red tomato contains more lycopene than a light red tomato. However, the bioavailability (how much gets absorbed in your body) of lycopene, an important health-promoting compound, might be the same. Manipulation of tomatoes by postharvest cold and light treatments. We hypothesize that if we can create softer tomatoes with the same colour that we can drastically improve the bioavailability of lycopene. We will measure use bioavailability of lycopene by in vitro digestion.

Type of work:

Postharvest Phys. Techniques:

- Non-destructive measurements (firmness, pigment, etc.)
- Modelling
- HPLC analyses and bioavailability assays

LEDs grow Quality: Light conditions and the effect on quality related compounds

- Investigate the regulation and biosynthesis of specific classes of agronomically important secondary metabolites in species that are valued for their production of such compounds. We will grow plants under different light conditions to modulate these specific chemical pathways.
- Glucosinolates in rucola, bimi and Arabidopsis
- Volatile aroma compounds in the herbs basil, mint and cilantro
- Lettuce and other leafy vegetables keeping quality
- Biosynthesis of other quality related compounds: carotenoids, vitamin A, C, and E, phenylpropanoids, etc.

Type of work:

Postharvest Phys. Techniques:

- Shelf life
- Water loss
- Microscopy
- LED lighting

Postharvest Biotech. Techniques:

- Molecular biology: DNA, RNA, RT-(q)PCR
- HPLC, GC-MS
- Microscopy

Quality of processed lettuce, cucumber and tomato: what is translucency?

- Translucency (glassiness) is a serious problem in processed products, but up till now we don't understand the mechanism that leads to glassiness. We have found a number of clues, though. We can for instance transfer the glassiness that often happens in cut tomato to cut cucumber (that never shows this), and we can quantify the process. Can you come up with smart experiments that provide insight in the nature of this problem?

Type of work:

Postharvest Phys. Techniques:

- Translucency measurements
- Slicing (thickness, sharpness of the knifes)
- Microscopy
- Modelling
- Temperature treatments
- Ethylene treatments

Postharvest Biotech. Techniques:

- Enzyme assays
- Molecular biology: DNA, RNA, RT-(q)PCR
- HPLC
- Microscopy

CRISPR-Cas9 projects

- We have projects to design and test CRISPR-Cas9 approaches for the species below. It is the goal to test the constructs in transient expression systems like *Nicotiana benthamiana*, Tobacco or Petunia.
- The target gene will also be tested, for example during ripening, or growth conditions, using qPCR. It is also necessary to clone the target DNA in a binary vector.
- Co-transformation of a construct that contains the target gene or region of the species of interest and the CRISPR-Cas9 construct that will cut it, will give us an idea if it will work.
- This thesis will be a great way to learn the newest molecular biology tools. We will use Golden Gate, Gateway, and traditional restriction enzyme cloning. Also, qRT-PCR, and a lot of bioinformatics will be part of the thesis. Transient agrobacterium transformations, and the start of tissue culture to make real transgenic plants will all be part of your work.

Type of work:

Postharvest Biotech. Techniques:

- Tissue culture:
- Plant transformation: Stable, transient, protoplast transformation
- Molecular biology: DNA, RNA, RT-(q)PCR, Cloning (gateway, golden gate, traditional RE cloning)

Strawberry projects

- We have projects to study the effect of preharvest conditions on postharvest quality, shelf life and flavour life.
- We have projects to study the link between strawberry colour, proanthocyanidin content and Botrytis incidence.
- We would like to identify genes and gene products that are involved with shelf life and postharvest quality. Once identified, we will characterize them, and if possible manipulate expression in plants to prove functionality.

Type of work:

Postharvest Phys. Techniques:

- Microscopy
- Shelf life
- Stomatal function
- Colour measurements
- LED lighting
- Modelling

Postharvest Biotech. Techniques:

- Molecular biology: DNA, RNA, RT-(q)PCR
- HPLC, GC-MS
- Microscopy
- Tissue culture, and transgenic plant production

Petunia scent and colour: Manipulate scent and/or colour in Petunia

- Investigate the biosynthetic pathway and regulatory elements of scent and colour production. Manipulate gene expression through overexpression, silencing or CRISPR-cas9
- Change the smell of petunia flowers. Introduce genes that produce volatiles that are not present in the headspace of wild type Petunia flowers. Additional, use inducible expression to switch it on when you want (dexamethasone/steroid inducible expression)

Type of work:

Postharvest Biotech. Techniques:

- Tissue culture:
- Plant transformation: Stable, transient, protoplast transformation
- Molecular biology: DNA, RNA, RT-(q)PCR, Cloning
- Metabolite analysis: HPLC, GC-MS
- Enzyme assays
- Cell biology: subcellular localization of compounds (Anthocyanins located in the vacuole, Carotenoids in the chromoplasts)

Marigold regulation of Carotenoid biosynthesis

- Manipulate biosynthesis pathway in Marigold to change composition of carotenoids. Change colour or health benefits (Vitamin A).
- Golden Marigold. Introduce the golden rice construct to see the effects on marigold flowers.
- Study regulatory network of carotenoid biosynthesis. Investigate transcription factors that regulate colour, and study the effect of their manipulation on secondary metabolism (colour, scent, health related compounds).

Type of work:

Postharvest Biotech. Techniques:

- Tissue culture:
- Plant transformation: Stable, transient, protoplast transformation
- Molecular biology: DNA, RNA, RT-(q)PCR, Cloning
- Metabolite analysis: HPLC, GC-MS
- Enzyme assays
- Cell biology: subcellular localization of compounds (carotenoids loc. in the chromoplasts)

Tomato carotenoid manipulation

- Tomato has a huge pool of lycopene; can this be used to produce lycopene breakdown products like lutein and or Astaxanthin? These compounds are highly valuable pigments and strong antioxidants.
- Manipulate biosynthesis pathway in tomato to change composition of carotenoids. Change colour or health benefits (Vitamin A).
- Golden tomato. Introduce the golden rice construct to see the effects on tomato fruit.
- Study regulatory network of carotenoid biosynthesis. Investigate transcription factors that regulate colour, and study the effect of their manipulation on secondary metabolism (colour, scent, health rel. compounds).

Type of work:

Postharvest Phys. Techniques:

- Colour measurements
- HPLC

Postharvest Biotech. Techniques:

- Tissue culture:
- Plant transformation: Stable, transient, protoplast transformation
- Molecular biology: DNA, RNA, RT-(q)PCR, Cloning
- Metabolite analysis: HPLC, GC-MS
- Enzyme assays
- Cell biology: subcellular localization of compounds (carotenoids loc. in the chromoplasts)

Tomato Stay Green:

- During tomato ripening, chlorophyll breakdown and lycopene biosynthesis coincide and are regulated by a Stay Green Protein (SGP). But not only colour, also firmness is regulated by this amazing protein family! This means that SGP are vital to tomato quality attributes such as colour and firmness behaviour.
- We want to study this regulation by manipulating of expression (CRISPR-cas9 and OX lines) , and study the effect on ripening processes.
- Stay Green proteins also affect firmness. We will study the link between SGR proteins and expression and activity of pectin breakdown enzymes with the aim to model the interactions.

Type of work:

Postharvest Biotech. Techniques:

- Tissue culture:
- Plant transformation: Stable, transient, protoplast transformation
- Molecular biology: DNA, RNA, RT-(q)PCR, Cloning
- Metabolite analysis: HPLC, GC-MS
- Enzyme assays

Postharvest Phys. Techniques:

- Colour measurements calibrated to assess chlorophyll and lycopene levels
- Non-destructive firmness measurements
- Storage at varying temperatures
- Modelling

Mango projects:

- Mangoes hardly ripens on tree, but quickly ripens after harvest. We want to identify the 'tree factor' compound in e.g. the milky white sap from the harvest wound. Also, we want to investigate the effect of e.g. removing leaves from mango branches in a Spanish orchard.
- Study the production of mango volatiles during development and ripening, and identify genes responsible for their production.
- For the study of processes in relation to quality and shelf life, we would like to identify genes and gene products involved with shelf life and postharvest quality. Once identified, we will characterize them, and if possible manipulate expression in plants to prove functionality.

Type of work:

Postharvest Biotech. Techniques:

- Molecular biology: DNA, RNA, RT-(q)PCR, Cloning
- Metabolite analysis: HPLC, GC-MS, LC-MS
- Enzyme assays

Postharvest Phys. Techniques:

- Non-destructive firmness measurements
- Storage at varying temperatures
- Ethylene treatments
- Preharvest treatments such as thinning, steam girdling

Potted plants (internships)

- Transport conditions reduce quality. Possible topics to study is the effect of darkness, ethylene, cold and mechanic damage. Effect of growing conditions (preharvest) on quality. Petunia, Chrysanthemum topics available. In collaboration with Syngenta, Dümen Orange, etc.
- Postharvest problems with transport of cuttings. Transport in plastic bags, cold and wet, some cultivars have problems rooting and show other quality problems afterwards. Poinsettia, Geranium topics available.

End of topics as grouped under title '*Post-harvest quality of fruits, flowers and vegetables*'

Post-harvest topics (continued)

Quality improvement of cut monocot flowers

Supervisor(s):

Supervisor(s): Prof. dr. Ernst Woltering (also Wageningen Food & Biobased Research - FBR)

Description:

Many monocot flowers (e.g. ginger, tulipa, iris) have a short vase life. The flower senescence in these flowers is not regulated by ethylene, so available solutions to block ethylene (STS, 1-MCP) generally have no impact in these flowers. In addition, in monocot flowers there is no problem with vascular blockage so solutions developed for this disorder (biocides, surfactants) have no impact in monocots. The flower senescence in monocot flowers is generally thought to be related to the hormonal status, Especially plant hormones from the group cytokinins and gibberellins when applied to cut stems may positively affect the vase life.
To get more insight in the factors affecting the vase life of monocot species and to develop new pretreatment solutions, we are in need of a literature study on:

- Physiology of senescence in monocot species
- Effect of plant hormones (and other compounds) on vase life and quality of monocot species

BSc/MSc and ECTS:

BSc-thesis: 18 ECTS

Type of work:

Literature study

Requirements:

Location:

Wageningen

Planning:

Can start anytime in consultation with supervisor.

Photosynthesis, respiration and stomatal characteristics under low light conditions in green vegetables

Supervisor(s):

Prof. Dr. Ernst Woltering (also FBR), Dr. Rob Schouten and Dr. Wim van Ieperen.

Description:

In fresh cut lettuce and other green vegetables stored at low temperature and low light intensity, there is significant sugar accumulation, this greatly improves the shelf life. At low temperature, very low light levels can already lead to photosynthetic sugar production. Light may also stimulate stomata opening, leading to increased water loss. Applying light postharvest is not common practice. We would like to find novel strategies to use light in a most effective way in the postharvest phase.
The aim of the research will be to determine the photosynthetic efficiency of green vegetables under a variety of conditions of low light (spectral properties, intensities, periodicy) and low temperatures. This will give insight in the behaviour of the photosynthetic and respiratory systems under these conditions. In addition, we will study the response of stomata to these conditions. The accumulation of carbohydrates (glucose, fructose, sucrose, starch) and possibly ascorbic acid as plant quality markers will be monitored.

BSc/MSc and ECTS:

MSc-thesis: 24-36 ECTS

Type of work:

Crop(s): lettuce
Methods: LICOR for measurements of dark respiration and photosynthesis, light response curves; HPLC for measurements of carbohydrates; chlorophyll fluorescence imaging for determination PSII activity; microscopy to study stomata opening.

Planning:

Laboratory experiments that can be started in consultation with the supervisors; the exact nature of the experiments may change depending on start time.

Long-term storage of roses: physiological/biochemical basis of leafquality problems

Supervisor(s):

Prof. Dr. E. J. Woltering (also FBR) and Dr. Ir. Bastiaan Brouwer (FBR - Fresh Food & Chains)

Description:

Following long term storage, many rose cultivars (but not all) show leaf quality problems during the vase life. Leaves rapidly develop black lesions that later turn brown and may lead to complete leaf dehydration and abscission. The cause of this phenomenon is not known. It is vastly unpredictable and a major bottleneck for long term storage or sea shipment in industry.
We want to develop an better understanding of the leaf problem in roses. Currently there are many hypothesis. It may be a form of chilling injury (cells die due to accumulation of oxidative compounds) or it may be related to the carbohydrate status (sugars are used or transported out of the leaves during the storage, leading to dying of the cells). Also the leaf mineral or hormonal status may play a role.

Experiments will be performed with roses, or only stems with leaves, or excised leaves of sensitive and less sensitive cultivars. Materials will be stored for 5 weeks at low temperature. Several measurements will be performed to test different hypothesis. First of all a microscopy study to characterize the cellular status of the cells in the diseased lesions. In addition, this may be storage related changes in stomatal functionality, photosynthesis parameters, sugar and mineral status, cell membrane integrity, and more. Also we will apply different treatments before storage (with carbohydrates, plant hormones, minerals, ..) to further test the hypotheses and to alleviate the leaf problems.

BSc/MSc and ECTS:

MSc-thesis: 24-36 ECTS

Type of work:

We will work with roses, different cultivars. We will apply microscopy, several physiological and biochemical measurements.

Location:

Axis building, Food & Biobased research (Wageningen Campus)

Planning:

In consultation with supervisor

Long-term storage of roses: its effect on xylem hydraulic conductance

Supervisor(s):

Prof. Dr. E. J. Woltering (also FBR) and Dr. Ir. Bastiaan Brouwer (FBR - Fresh Food & Chains)

Description:

We recently found that following long-term cold storage the stomata are less functional. It means that the flowers rapidly develop a negative water balance when placed in the vase (transpiration exceeds the uptake). Later during the vase life, the stomata become functional again, probably due to the developing water stress as xylem vessels become blocked. Also the xylem properties change during storage.

We want to develop an better understanding of the loss of xylem hydraulic conductance during long term storage and after flowers are put in vases. Loss of xylem hydraulic conductance can be due to changes in the vessel system, air embolisms, bacteria or wound-reactions.

BSc/MSc and ECTS:

MSc-thesis: 24-36 ECTS

Type of work:

We will work with roses, different cultivars, from Dutch growers, quality and vase life assessments, water uptake and transpiration, xylem resistance measurements, bacterial counting, ...

We will apply a variety of chemicals and technologies that are hypothesized to improve xylem hydraulic properties

Location:

Axis building, Food & Biobased research (Wageningen Campus)

Planning:

In consultation with supervisor

Avoiding the development of bitter taste in papaya

Supervisor(s):

Prof. Dr. E. J. Woltering also (FBR) and Dr. Ir. Bastiaan Brouwer (FBR - Fresh Food & Chains)

Description:

As part of a running project on papaya quality, we are interested in measuring the bitter flavour in papaya fruit flesh, what causes it and how it spreads through the papaya.
Ways of assessing the bitter flavour range from lab work to the use of highly specialized equipment. The ultimate goal of the project will be to provide knowledge to understand under what conditions the bitter flavour occurs.

Goals:

1) Quantifiably measuring the bitter taste or its causing agents in papaya fruit flesh.
2) Prevent bitter flavour from developing in papaya fruit flesh.

BSc/MSc and ECTS:

MSc-thesis: 24-36 ECTS

Type of work:

- Literature study and setting-up trial plan
- Preparing experiments
- Learning how to work in the lab
- Performing measurements + quality measurements (firmness, colour, taste) Analyzing data
- Writing report

Planning:

- We expect this work to take up to a maximum of 6 Months (including introduction, setting up plan, designing experiments, performing them, analysing the data and writing report).
- Since papaya will not be available throughout the year, the starting date of the project will be discussed with the applicant.