Centre for Crop Systems Analysis (CSA):

- **Chair Crop and Weed Ecology**
- **Chair Crop Physiology**

MSc Thesis Guide

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October 2011

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Introduction

The Centre for Crop Systems Analysis (CSA) is the umbrella organization in which the chair groups Crop and Weed Ecology and Crop Physiology combine their research activities and operate together to realize the five research themes described below.

CSA capability statement

The theme of CSA is 'making more with plants'. In partnership with other groups, CSA contributes to the development of high quality plant production in sustainable agro-ecosystems through research and teaching. CSA's emphasis is on improvement and innovation of plant production at various levels of integration; from genotypes to cropping systems and production chains. Based on this work CSA also contributes to assessments of risks arising from climate variability and climate change. The groups core expertise is in the quantification of complex and often non-linear interactions between plants (or genotypes), management and the environment (GxMxE).

The group studies processes that determine the functioning of crops, weeds and grassland vegetations in relation to genetic, management, biotic and abiotic factors. This knowledge is integrated via sophisticated modelling tools to generate insights into complex systems interactions (e.g. predicting phenotypic responses to multiple traits in breeding programs; optimising crop management via functional-structural plant modelling; quantifying GxMxE interactions in a changing world; biochemical C_3 and C_4 photosynthesis modelling in relation to bio-based economy).

The group's experimental and modelling research assists in analysing and developing sustainable and profitable plant production chains and cropping systems in temperate, sub-tropical and tropical regions. These systems also include grassland systems managed for animal or biomass production. CSA's trans-disciplinary research covers various aggregation levels. This approach is conducted in close collaboration with many stakeholders – farmers, agribusinesses, policy makers and other scientists. The group is cognisant of global change processes and pays particular attention to climate-related risks and opportunities.

CSA's teaching comprises courses on cropping systems, biodiversity, soil-plant relations, population ecology, ecophysiology, crop physiology, crop modelling and crop and weed ecology, as well as their application to agricultural problems. In addition, student training involves supervision of MSc and PhD research projects.

Research themes

CSA concentrates its work on the following five themes:

1. Crop systems biology
2. Crop form and function
3. Designing climate-robust systems
4. Quantitative agro-ecology
5. Natural and social sciences interactions

The rationale of each of these themes is described in detail below.

1) Crop systems biology

Crop physiology is challenged to

- bring the information from functional genomics to the crop level,

- introduce true biological mechanisms in many current crop models,
- better understand the organization of the whole crop and its response to environmental conditions,
- fill the vast middle ground between '-omics' and relatively simple crop models, and
- promote communication across scales.

'Crop systems biology' is a discipline aiming at modelling complex crop-level traits relevant to global food production and energy supply, via building the links between 'omics'-level information, underlying biochemical understanding, and physiological component processes. Essential in crop systems biology is to properly map the organization levels and the communication systems between these levels for the different key processes, from the molecule or gene, all the way up to the crop. Photosynthesis and nutrient uptake are among these key processes under investigation.

2) Crop form and function

Plants respond to their environment by adapting their

- functions (e.g. light interception, photosynthesis, transpiration, N allocation) and
- structure or architecture (e.g. buds either break or remain dormant; size, shape and orientation of organs)

Functional-structural plant models (FSPM) are an innovative research method to investigate the complex interactions between function and structure. These models explicitly describing the development of the 3D architecture (structure) of plants as governed by physiological processes, which in turn are driven by environmental factors. FSPMs offer several options to develop a coherent research program that advances our understanding of plant (or: genotype) × environment × management interactions.

FSP-Modelling offers promise

- as a research tool in plant sciences,
- as a new tool supporting plant and crop management decisions, and
- in plant breeding through exploring morphological and functional aspects of plant ideotypes.

3) Designing climate-robust systems

Agriculture is arguably one of the most climate sensitive sectors in our global economy while food security is of global concern. Many developing countries remain heavily dependent on agriculture for national income, while agriculture occupies a special place in the national psyche of many developed nations. Hence, any effort that helps to reduce the vulnerability of this sector to climate related risks is likely to lead to considerable global benefits, both economic and social. Particularly in developing countries farmers' coping capacity is limited by (a) a lack of resources and (b) a lack of knowledge. This theme focuses on improving resource use efficiencies (eco-efficiencies) and filling knowledge gaps. It is designed to

- allow farmers, agro-business managers and policy makers to negotiate policy and management responses from a position of knowledge (this ensures that policy intent and management practices are aligned; it avoid or discourage 'perverse' policy incentives such as subsidising poor management practices);
- reduce costs associated with risks and change management by improving eco-efficiencies and supporting informed decision making; and
- increase enterprise profitability and environmental performance through early assessment of management alternatives.

The theme investigates better and more relevant ways to use new and enhanced climate information (including climate forecasts); it considers natural resource implications in conjunction with impacts on crop production and quality and it deals with farm-enterprise issues in addition to crop and cropping systems issues. The theme also engages directly with climate scientists and helps to negotiate priorities for climate research.

4) Quantitative agro-ecology

Agricultural systems are complex with many biota and management options leading to countless interrelationships and interactions. Pests, diseases and weeds threaten crop productivity, but natural enemies can suppress crop pests, while spatial strategies for deployment of crop species and genotypes at field and landscape level can help mitigate the impact of diseases. Weeds in cropping systems can be managed by a judicious combination of cultural and chemical control options in weed suppressive crop rotations. In this theme, we study the ecology of agricultural production systems using experimental approaches as well as a suite of innovative mathematical modelling tools. The objective is to design crop production systems that are productive, profitable, ecologically enriched, attractive, and sustainable.

This theme has three focal areas of research:

(1) Ecology of mixed plant systems. Modern, mechanised agriculture has led to monocultures with low biodiversity. There is ample evidence that diversified agricultural systems such as agroforests, mixed grass swards or (relay) intercrops can enhance productivity and promote resilience to biotic (pest, diseases) and abiotic stresses such as climate variability (including low frequency fluctuations). Whilst mixed plant systems are widely used in countries such as China, they are rarely exploited in the west. In collaboration with international partners we are pursuing this opportunity by modelling the structure and functioning of intercropping systems using FSPMs and cropping systems models.

(2) Ecology and management of weeds. The impact of weeds on agriculture systems performance is an important concern worldwide and constitutes a large share of crop production costs. This research focuses on

- integrated weed management by cultural and other control methods, including cropping systems design, to develop weed-suppressive crop rotations;
- ecology and management of the parasitic weed Striga hermonthica in sub-Sahara Africa; and
- weed seed predation as an ecosystem service in agricultural landscapes.

(3) Spatial ecology and epidemiology. Pest and disease problems in agriculture have an explicit spatial component as many agents need to migrate from one crop field to another between and within seasons to complete their life cycle. Natural enemies of pests are often dependent on non-crop habitats in the landscape for overwintering and alternative food. Hence, natural pest suppression is strongly influenced by landscape structure. Using temporal-spatial modelling in conjunction with empirical field work, scenarios for optimally pest suppressive landscapes are developed. Work on regional spread of disease is used to enhance disease risk management systems. Work in this theme is strongly linked to research conducted in the other themes.

5) Natural and social sciences interactions

CSA has an active program focusing on so-called beta-gamma integration through participation in INREF programs, WOTRO programs and programs financed by international donors such as the Bill and Melinda Gates Foundation, the WINROCK Foundation and others.

Major activities are on agronomic and social aspects of informal seed systems on several continents (including Africa, Asia and Latin America), gender issues in participatory plant breeding, the nexus between social systems, markets, production and climate risks in Africa and Asia, impact of HIV/AIDS on agriculture, farmer-managed biodiversity, wild-gathered foods, economic and spatial analysis of seed and air borne diseases.

Cooperation is intensive (via shared PhD projects) with chair groups from Social sciences (Sociology of households and consumers, Technology and Agrarian Development, Farm management) and Business administration.

Chair groups

Crop and Weed Ecology

Major changes in agricultural production systems will be needed to meet the requirements of society in the near future. In The Netherlands and Europe, production systems with minimum or no pesticides and organic farming systems are highly desired. That requires completely changed systems based on ecological principles as well as high-tech solutions. In developing countries, increased population pressure requires sustainable production systems that produce more on less land with less input. The Group Crop and Weed Ecology contributes to the development of such systems through research focused on an increased understanding and improvement of plant production systems at levels of integration ranging from plant organ to cropping systems. This is achieved by studying processes that determine the functioning of crops and weeds in relation to genetic, biotic and abiotic factors. However, attention is also given to the analysis and development of sustainable and profitable plant production chains and cropping systems for temperate and (sub)tropical regions. A systems approach as developed in Wageningen in the past decades is essential to achieve this. The research aims at an integrated approach by means of experimental research and modelling at various aggregation levels. To obtain critical mass the Group strongly collaborates with the other Groups in plant production, crop protection and soil science.

Main cropping systems studied are temperate arable cropping systems including crops such as potato, wheat, sugar beet and field-grown vegetables, temperate and (sub)tropical grassland systems, (sub)tropical cropping systems including crops such as rice in Asia and Africa and sorghum, maize and millet in Africa. With respect to weeds, the Group focuses on ecology and management of temperate and (sub)tropical weeds including annual, perennial and parasitic weeds.

Crop Physiology **Prof. Paul C. Struik**

Crop Physiology studies the basic life processes in the plant to understand the functioning of the plant at crop level in its interaction with other plants in the crop and with its environment, both a biotic and biotic. Plant processes are studied at lower levels of integration to better understand their role in determining crop performance in a diversity of production situations and to better modify their intensity, rate or direction. Therefore, upscaling of physiological phenomena from cell to meristem or tissue, organ, plant and finally crop, and downscaling of phenomena at the crop level to determinant processes at lower levels are crucial tasks of Crop Physiology. It is not enough to know all on the functioning of thylakoid membranes and chloroplasts to understand crop photosynthesis under water stress. On the other hand, if one wants to understand the tuber-size distribution of a potato crop it is necessary to understand the basics of tuberization, changes in direction of cell division in the stolon tip and changes in gene expression that control changes in sugar and protein metabolism.

The Chair Crop Physiology deepens the interaction between crop ecology, plant physiology and plant breeding. Moreover, Crop Physiology assists in maintaining and supporting the knowledge chain from molecular biologist to agronomist to enhance insight in the functioning of plant stands. Crop Physiology also contributes to an information stream from the agronomist to the molecular biologist to help the latter understand what is really important for a crop in practical farming.

Crop Physiology wants to play this role with the same overall aim that directs the activities of the Group CWE: it wants to contribute to the development of sustainable agriculture with high resource-use efficiency and a low need for external inputs. This implies that Crop Physiology is more interested in the behaviour of plants and crops under conditions limiting growth than in potential performance, so not only in potential yield, but also in stability of yield and stress resistance.

Crop Physiology will concentrate on the following (related) themes:

- Quantitative analysis of processes at sub-plant and plant level and their relation to physiological determinants of crop growth and development, testing conceptual frameworks with experimentation and crop modelling.
- Electron transport in photosystems of plants under stress.
- Micronutrient uptake and allocation in cereals.
- Crop physiology of secondary metabolite production.
- Gene-Plant-Crop relationships, by analysing and integrating genetically controlled determinants of growth, development and functional condition at different levels of aggregation.
- Physiological ideotyping of crops and predicting and testing of physiological behaviour of genetically modified plants.
- Characterizing the physiological basis of genotype × environment interactions.

Two examples may illustrate the contribution of Crop Physiology to plant science:

1. A crop is a community of individuals, each interacting with its neighbours. Dry matter production has been well investigated and modelled, but the phenology, organ dynamics (tillering, self-thinning, branching, flower initiation and realization), nutrient recycling, and the variation in these aspects are much less understood. The tuber-size distribution of a potato crop cannot be understood from sink-sink relations and sink-source relations within an ‘average plant’ or within a group of plants with a characteristic average and spread of behaviour). Within a crop, high-yielding plants give more tubers, but the same average tuber size as low-yielding plants. Why a certain number of tubers are set is still unknown. Tillering, tiller death and tiller establishment in wheat, production grasslands or turf are complex phenomena, but yet crucial for crop structure (how many producing units per unit area, how much leaf area at a certain stage, and what stay green potential) and thus yield, harvest index and quality of the produce. Flower production in cut roses depends on the cutting regime of the crop. Hemp for fibre production needs a high initial density to force the plants to produce the right ratio of bark and core, of good and poor fibres, even though it will result in the untimely death of many individuals and therefore in the useless accumulation of a considerable amount of biomass. Dynamics of the formation of production units, harvest organs and other plant parts are therefore essential. These dynamics are not merely a consequence of a simply understood combination of production processes with phenology, but require detailed analysis.
2. To increase the sustainability of the current production systems, growers need better understanding of the fundamental aspects of the relationship between the physiology of the crop and its sensitivity towards pests and diseases. Often plant behaviour results in a functional condition that determines the susceptibility or resistance to diseases. Nice

examples can be found in the (poorly understood) relationship between earliness of a crop cultivar and the susceptibility to fungal diseases in the foliage, for example in wheat and potato. Often it is even not known whether that relationship is genetic or physiological in nature. Using molecular markers for precocity and susceptibility, together with modern techniques in crop physiology and plant pathology research, allows us to understand the linkages between such phenomena and will, thus, assist breeders and farmers in developing strategies to control the diseases.

Thesis subjects

Theme 1:

Crop systems biology

Developing selection criteria for improved root system architecture in lettuce (*Lactuca sativa* L.) for organic and low-input agriculture

Supervisors

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Problem description

Lettuce demands high inputs of water and nutrients. Conventional lettuce growers can produce a continuous supply of high-quality lettuce, because crops are grown from transplants, with high levels of input, and with strict management of water and nutrient flows. Therefore, demands on root systems are minor and breeders breeding for conventional horticulture can afford to select genotypes with a high shoot: root ratio thus increasing harvest index and yield. Agronomic research has further contributed to the design of lettuce cropping systems where water and nutrient supply is abundant. Organic agriculture is not yet capable of providing a continuous supply of lettuce of a consistently high quality. Nutrient supply and water supply are less regular, less abundant, and more depending on (variable) environmental conditions, including physical, chemical, and biological soil conditions. As organic agriculture has fewer means to adjust the environment to the genotype, it needs varieties that are better adapted to variable low-input (organic) growing conditions. The expectation is that an improved root system can contribute to a better adaptation to low-input conditions.

Possible thesis subjects (24 up to 36 ECTS)

The following three issues are relevant: a) in order to be more robust under low-input and organic production conditions lettuce plants need to explore deeper soil horizons; b) there is genetic variation in root traits, which needs to be exploited; c) a better understanding of the physiological and genetic backgrounds of the relationship between root system architecture, resource capture, stress resistance, growing pattern, quality and yield is needed; an eco-physiological modelling approach will assist in obtaining that understanding; d)to be able to incorporate relevant root traits as selection criteria in a practical breeding programme an efficient selection method needs to be developed. To analyse and model the relationship of the shoot/root ratio of lettuce varieties in relation to their performance (including resource capture, field persistence and shelf life), several field trials with a limited (4) and with a large set (100) of varieties will be set up, weekly measuring a large set of growth parameters.

Period

Preferably starting spring 2010; most trials will last during the period March-July, and the pot trial during August-September.

Used skills

The work will done in the field at either the Seed company Vitalis or organic trial farm Droevendaal in Wageningen; the pot trail will be in the greenhouse in Wageningen.

Requirements

Background in crop science or biology.

Quantifying nitrogen efficiency in a large set of potato genotypes/varieties in response to contrasting N-input levels

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Problem description
The agronomy and physiology of nitrogen use efficiency (Nit-UE) in potato is extremely complex, due to genotype-specific effects of N-supply on crop physiological/ morphological characteristics related to Nit-UtE such as (a) the rate of leaf appearance, individual leaf growth, final leaf size, and the life span of individual leaves, (b) the number of lower and sympodial branches, (c) the overall rate of canopy development (e.g. increasing N supply levels accelerates crop development and advances the time when maximum canopy cover is reached), (d) light interception by the crop over time, (e) the rate of photosynthesis, (f) the onset of tuberization and (g) final tuber yield and harvest index. Moreover, N supply may affect tuber quality in terms of tuber size distribution, tuber dry matter content and protein content and quality. However, while there is detailed information available on N-fertilisation regimes required for optimum performance, there is little information on the performance of modern varieties /genotypes under limited nitrogen supply. This gap is filled in a PhD project which is part of a large international project (EU F7, NUE-CROPS). In this PhD project Agrico, one of the largest internationally operating potato breeding companies in the Netherlands and two chair groups of Wageningen University (CSA (f.k.a. CWE) and PBR) collaborate.

Possible thesis subjects (24 up to 36 ECTS)
There is an opportunity for 1-3 MSc students to collaborate in this large project connecting to one of the three following objectives:

(i) identify physiological/morphological markers for crop development and nitrogen uptake in an SH × RH population (100 genotypes);
(ii) phenotype an extensive potato germplasm collection (200 varieties/genotypes) under two different levels of N supply to identify the genetic variation in Nit-UE of modern European varieties;
(iii) quantify plasticity of Nit-UE in selected potato genotypes in response to contrasting N-input types, levels and supply pattern.

Period
Preferably starting spring 2010; most trials will take place from April until September.

Used skills
The work will be done in the field at Unifarm-Wageningen and at Agrico-Emmeloord including some lab evaluations. Field experimentation and phenotyping skills are most needed.

Requirements
Background in crop science or biology.

Evaluating the feeding value of starch in silage maize

Supervisor
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Description
Silage maize is important roughage for ruminants in the Dutch dairy industry. It has a relatively high digestibility, mainly due to its high starch content. Starch in maize silage is taken into consideration in assessing the feeding value of silage maize by the ear content of the plants and the starch content in the ears. No distinction is made in starch quality based on differences in rate and extent of starch degradability (caused by physical or chemical factors), and so possible differences in starch quality are not taken into account in predicted feeding value in the current feed evaluation systems. The major aim of the ongoing project is to gain insight into the relationships between starch properties and rumen fermentation and insight into the factors determining starch degradability. Final goal is to get tools to breed for genotypes with optimally degradable starch. In vitro fermentation of starch is studied with a fully automated time related gas production system. By measuring the rate of gas production upon the fermentation of starch samples in buffered rumen fluid, the degradation kinetics of starch can be analysed.

Possible thesis subjects
Using the gas production technique, rate and extent of starch fermentation will be determined on samples obtained from different experiments. Specific objectives are:

- To assess starch degradation of fresh and dried maize kernels as influenced by maturity stage, genotype and temperature treatment.
- Maize whole plant digestibility (fresh or dried samples) as influenced by maturity stage, genotype and location.
- Starch degradation (fresh or dried samples) as influenced by maturity stage, genotype, location and sowing time.
- Digestibility of silage as influenced by removal times from the silo.
- Digestibility of silage as influenced by different temperatures during ensiling and different removal times from the silo.

Used Skills
Samples of maize kernels and whole crops (fresh and dried) are available. The candidate will require general lab skills.

Requirements
Review of literature on starch and fermentation process to get insight into the project. Analysis of samples for gas production at ZODIAC, Wageningen University. Statistical analysis based on curve fitting. The topic is interesting for a student in Animal science (Animal nutrition), Crop Science (crop physiology) or Biology.

Period
The thesis work can start any moment after insight has been obtained on the principles and agreement has been reached on the work to be carried out but provided laboratory facilities are available.

Production of artemisinin, a secondary metabolite with antimalarial activity, in *Artemisia annua* L.

Supervisor

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Description

Artemisia annua L. (annual or sweet wormwood, Asteraceae) is an annual herb that produces the antimalarial compound artemisinin, a sesquiterpene lactone. *A. annua* is thus far the only economical source of artemisinin. Within the plant, artemisinin is found almost exclusively in the leaves and inflorescences. Leaves are most important, because in commercial production the crop is harvested before full flowering. Artemisinin is phytotoxic and its production is limited to very small glandular trichomes on the epidermis. Yields and concentrations of artemisinin in crops are very low and very variable. There is almost no insight in what is causing this, likely because of the complex processes involved in the production. In our study of artemisinin production we identify and quantify the processes at the level of the crop, individual organs and cells, which are underlying artemisinin formation in *A. annua* crops. We recently developed a simple model to explain artemisinin production in field crops and identified which processes might limit artemisinin yield. The project will be part of a larger project concentrating on plant constituents with effects on human health.

There is a myriad of interesting research topics. Research could for example focus on understanding and quantifying effects and interactions of the main external factors on processes underlying the target compounds. These processes include formation of the interesting organs (leaves) versus undesired organs (stems), differentiation of glandular trichomes on the leaves, (bio)synthesis of artemisinin and precursors in the trichomes or ways by which artemisinin is lost after formation. In addition, topics can concentrate on methodology development, e.g. on sampling techniques or on the development of a method for quantifying the trichome dynamics on leaves. Specific research projects are developed in co-operation with Plant Research International and other partners.

Period

For field studies the period between early spring and December is most suitable. For glasshouse and laboratory studies, the period is less critical. It is necessary to start planning the work well in advance.

Assessing and modelling crop behaviour of Arabidopsis

Supervisors
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Description
Establish crop growth characteristics of one or a selected number of Arabidopsis genotypes in a selected number of growing environments or stand densities, and design a crop growth model to simulate the genotype specific behaviour (if genotypes are used) or environment regulation of growth.

Arabidopsis is widely studied to understand gene-function relations. The up-scaling of individual plant behaviour to crop behaviour in dependence of the genotypic differences though is poorly understood. Crop growth models have been developed to simulate crop behaviour, but generally lack a genotype component that is directly linked to gene-function knowledge. Arabidopsis seems to provide an interesting option to improve genotype specific modelling techniques as currently established by Crop and Weed Ecology. In preparation of PhD projects we are looking for ambitious students who would like to tackle this interesting but largely unexplored area.

Location and period
The experiments are carried out in Wageningen. The thesis work can start at any moment after discussion of the principle, and as soon as facilities are available. Because of planning of the experiment, due time should be allowed between first contact and starting period. The crop cannot be sown between November and February to avoid too low light levels in the greenhouse.

Used skills
You will carry out a literature study of crop growth experiments and modelling carried out in different labs in the world with Arabidopsis. On the basis of earlier preliminary experiments done at CSA, available genotypes and interesting hypotheses, you will determine in collaboration with your supervisor what issues of crop growth will be tackled experimentally and/or in modelling. There is room for a more experimental or a more theoretical modelling related thesis in dependence of your personal interests and learning goals. There is also room to explore options to link the functional structural modelling approaches (see projects elsewhere in this guide) with this topic are available.

Zinc translocation in cereals and allocation to grains: source or sink limitations?

Supervisor

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Description

There are two major research question for this work.

- Determine the source of zinc in cereal or legume grains, is it the re-translocated zinc taken up before flowering or is it the zinc taken up after flowering?
- Determine whether grain allocation of zinc in cereals and legumes is mainly limited by uploading from the xylem to the phloem, by the phloem unloading to the grain (both source limitations) or by the ability of the grain to store the zinc (sink limitation).

There is a world-wide effort to enhance micro-nutrient density in staple crops in order to improve the nutritional quality of foodstuffs eaten by the poorer majority of the world population. Zinc is among the target micro-nutrients for this effort. An aspect the Centre for Crop Systems Analaysis Soil Quality groups from Wageningen University work on is the uptake and translocation within cereals of Zinc. A number of PhD studies are ongoing.

Studies carried out within this framework have established methods to grow zinc deprived rice, wheat and cowpea and have shown differences between these species but that potentially in wheat grain storage may be a limitation to grain zinc storage while in rice there seems to be a source limitation. There is a need for further in-depth studies to try to disentangle these two processes in order to establish what target properties breeders should be looking for. There is also interest to extend our database to other cereals, especially a C4 cereal like sorghum.

Location and period

The experiments are carried out in Wageningen. The thesis work can start at any moment after discussion of the principle, and as facilities are available. Because of planning of the experiment due time should be allowed between first contact and starting period.

Used skills

You will make a literature study of experiments carried out in different labs in the world to define your own set-up of experiment(s) that will allow you to establish whether both processes (source and sink limitation) play together or whether only one is important. Establishment of a computer model and its calibration can be part of the thesis work dependent on your learning goals.

Evaluation of sorghum genotypes for tolerance to *Striga*

Supervisor

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Description

Striga hermonthica is a parasitic weed on tropical cereals causing serious yield losses in Africa. The use of host crop varieties with improved resistance and tolerance against this parasite is a key component of an integrated control strategy. Breeding for tolerance is however seriously hampered by the absence of reliable and yet practical selection measures. The observation that the photosynthetic rate of tolerant genotypes is less sensitive to *Striga* infection offers a good starting point to search for suitable selection measures.

Main objective of the proposed thesis research is to develop a suitable selection procedure for *Striga* tolerance based on photosynthesis or related chlorophyll fluorescence measurements.

Leaf photosynthesis: measurement and modelling

Supervisors
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Description

Photosynthesis is the source of our food, feed, fibre and fuel. Increasing world population, economic development, and diminishing land resources require a critical increase of crop productivity per unit land. A starting point for improving the potential of crop production to meet the increasing demands is to increase both the efficiency and capacity of photosynthetic solar energy conversion. To this end, a quantitative understanding of photosynthetic processes in various crop types is important for predicting primary productivity under different environmental scenarios.

In general, C_4 species (e.g. maize and sorghum) have a higher photosynthetic capacity than C_3 species (e.g. rice and wheat), because C_4 crops possess extra features that lead to a higher CO_2 concentration at the site of Rubisco – the enzyme responsible for the binding of CO_2 during photosynthesis. This enzyme is not perfect because it also binds O_2 during a process that leads to photorespiration. The well coordinated functioning of different types of cells, accomplished through specialized leaf anatomy, in C_4 plants produces a high CO_2 concentration at the surface of Rubisco, strongly inhibiting photorespiration. However, the elevated CO_2 is sustained at the cost of extra ATP; as a consequence, photosynthetic photon use efficiency under limiting lights may not be higher in C_4 than in C_3 species. An interesting and diverse third class of higher plants (e.g. represented by species in the genera *Panicum*, *Moricandia*, and *Flaveria*) possess properties intermediate to the more common C_3 and C_4 types. Obviously, there are a lot of questions to be studied with regard to the functioning of these various types of photosynthesis.

There is an opportunity for 3-5 students to conduct their MSc research along this line. In these thesis studies, you will conduct a set of simultaneous measurements of gas exchange and chlorophyll fluorescence under various temperature, CO_2 and light conditions on leaves of plants. Gas exchange measurements will show the amount of CO_2 fixation during photosynthesis and chlorophyll fluorescence measurements will show the efficiency of electron transport of photosystem II under the same condition. The collected data will be combined with biochemical photosynthesis models for quantifying critical model parameters and sub-processes. In the end, you will be able to use these models as a research tool, for example, (i) to predict leaf photosynthesis for different environment scenarios, and (ii) to conduct a sensitivity analysis for identifying options with which photosynthesis can be further enhanced. The obtained quantitative understanding of photosynthesis in general may have strong implications for ameliorating sustainable bio-energy supply.

Physiological and genetic modelling of genotype-by-environment interactions

Supervisors
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Description
Genotype-by-environment interaction (GxE) on crop performance is an important research area in both crop physiology and quantitative genetics. To support the knowledge chain from molecular biology to agronomy, models for up- and down-scaling between genes and crops are needed. Such models have to be capable of predicting GxE. However, so far little success has been achieved towards predicting GxE using genetic or physiological models alone. We aim to combine the strength of physiological modelling and genetic mapping for a mechanistic unravelling of GxE effects on yield formation.

Our earlier study already proved the usefulness of integrating modelling and mapping. In view of the identified weakness of current crop-growth models, a novel physiological model that integrates knowledge on pathways of critical physiological and morphological processes is in development. There are strong effects of morphology on basic physiological processes such as photosynthesis, whereas photosynthesis also affects morphology; this mutual interaction needs to be unravelled. The GxE have been, are being or will be created experimentally in both segregating-population lines and variety collections in rice, barley and potato. The performance of genotypes under field conditions will be analysed based on model-input traits that will be determined by controlled-environment measurements. Genetic variation of the traits will be dissected into discrete genes and QTL (quantitative trait loci), using molecular-marker maps, linkage disequilibrium mapping, and available gene regulation information. The gene and QTL effects will be coupled to the model, resulting in a gene-based physiological model for fine prediction of GxE in any environment. The research will utilise complementary aspects of modelling and mapping. The enlightening understanding of the mechanisms of GxE on yield formation will enhance our capability of building a knowledge chain for up- and down-scaling between genes and crops.

Overall, this is an ambitious programme of the research theme ‘Crop systems biology’ in the Centre. We expect 2-3 MSc students to perform various parts of the work in the programme, which will probably be embedded into individual PhD projects. Students are expected to have a good background or/and strong interest in both crop physiology and genetics.

Crop simulation modelling: Science and art

Supervisors
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Description

Crop scientists have used various approaches to study the functioning of the crop. Dynamic crop growth models emerged in the mid-1960s with the pioneering work of Wageningen professor C.T. de Wit, who introduced von Bertalanffy's systems theory and Forrester's systems dynamics simulation method into crop science. In these models, constituting elements and processes are put together in mathematical equations. The rules by which the elements interact give rise to system behaviour illustrated by simulation, which may well be unexpected and even counterintuitive. This is the model heuristics, which, in turn, enhances the understanding of individual processes and the next-round modeling of the crop. Dynamic crop systems models have been used to support theoretical research activities and applied field management.

It is well recognized that complex crop traits, such as grain yield or water and nutrient use efficiencies, are regulated by the cumulative effects of (fluctuating) environmental conditions and their interactions on multiple intermediate component processes and feedback and compensation mechanisms, and of intra- and inter-plant competition at higher levels of aggregation. To unravel the underlying physiology and feedback mechanisms of crop growth, it is important to recognize that often the behaviour of the whole cannot be explained in terms of the behaviour of the parts in isolation. However, prevailing model concepts that demarcate crop production into potential, water-limited or nitrogen-limited levels, facilitating model development by focusing on one major factor at a time, cut the internal link among processes and therefore may not help to model individual processes that interact.

It has long been established that crop growth relies on the functional balance of contrasting components (e.g. shoots vs roots, sources vs sinks) and processes (e.g carbon metabolism vs nitrogen metabolism, assimilation vs dissimilation). In addition, crop growth is associated with many feedback features. Most existing crop models use experimental observations on these components as empirical input functions to guarantee model predictability over a certain domain. In contrast, along the aforementioned lines of thinking, we recently developed a more mechanistic crop model, GECROS, to overcome some of the weaknesses of earlier crop models. Preliminary model evaluation demonstrates that GECROS does allow a translation and extrapolation of input information at the single-organ level in a short-time scale to the crop performance in a continuously changing field environment.

The proposed MSc thesis study is meant for those who have already gained some basic knowledge in crop modelling (e.g. from courses 'Crop ecology', 'Designing sustainable cropping systems') and yet want to develop their modelling skill further. You are expected to explore and examine the philosophy of the GECROS model and use available collected data sets to evaluate the model under a wide range of environmental conditions. In the end, you will learn that the model can be a tool to answer a spectrum of research and practical questions, and realize that not only crop modelling is a science but also a good model is a piece of art.

Thesis subjects

Theme 2:

Crop form and function

How plants respond to a heterogeneous light distribution environment in intercropping

Supervisors

Junqi Zhu e-mail: junqi.zhu@wur.nl

Jochem Evers e-mail: jochem.evers@wur.nl

Description

Intercropping, the practice of growing two or more crops in one field simultaneously is widely used in Asia, Africa, and South America to enhance productivity, resource use efficiency and to reduce risks. While intercropping is widespread, the exact underlying crop physiological mechanisms that make intercropping advantageous may vary widely from one place to another. Strip intercropping of wheat and maize is widespread in northern China. This system is more productive than single crops of either species (we call this ‘over yielding’). It is hypothesized that enhanced radiation capture is the key mechanism for this intercrop overyielding. In part, this enhancement is related to the relay aspect of the system: wheat is sown about one month before maize, and maize keeps growing after harvest of the wheat (maize is harvested later than wheat). Understanding light capture in intercrops is complex, however. Plants in the intercrops respond to shading by their neighbours, resulting in differences in morphogenesis and growth among plants of the same species growing at different densities or different positions in an intercrop system.

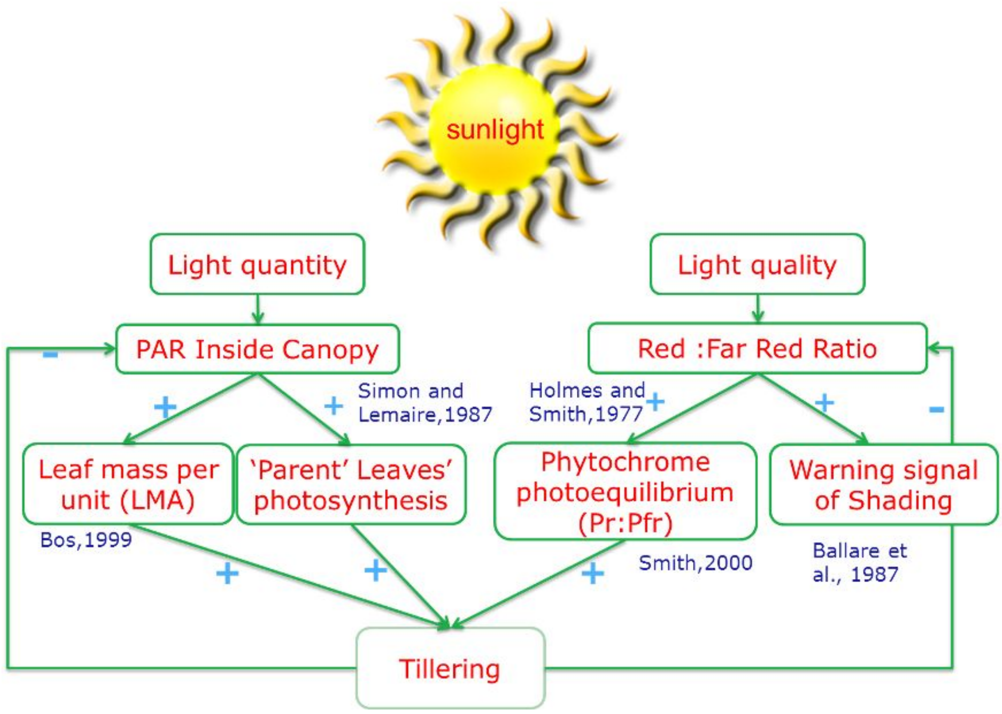

Fig. 1. Sketch of light's influence on plant architecture.

Fig. 2. Wheat/maize intercropping in northwest China

Fig. 3. Orientation of wheat leaves as a result of light foraging

Possible MSc subjects within this project are as follows:

1. Structural and functional adaptation of wheat in wheat-maize intercrop

This subject focuses on the hypothesis that wheat tends to colonize the empty space around it by modifying their tiller pattern and leaf spatial distribution as well as the leaf nitrogen content towards sites with high red/ far-red ratio (R: FR) and photosynthetically active radiation (PAR) (Fig 2 & 3). Such structural and functional adaptations enable wheat have a high yield production by avoiding mutual shading, and increasing light interception and light use efficiency.

Tillering is an important property in cereals and grasses crops either cereals and grasses. It enables these crops to cope with intraspecific competition by optimizing the formation number of ear-bearing shoots in relation to the resources available. Next to nitrogen availability, light plays an important role in the regulation of tillering. The number of tillers per plant and the rate of tiller appearance have been related to the intensity of PAR. However, reorientation of leaves and tillers also have been observed at early ontogenic stages of cereals. Plants tend to position their organs in spots where light interception is optimal; we call this ‘light foraging’. A low R: FR, caused by high absorption of red light and high scattering of far-red light by surrounding plant tissues, is considered to be a signal to the plant of the presence of neighbours.

To investigate the relationships between R: FR and leaf orientation, tillering and N profile, dedicated experiments will be conducted with variable light environments (created e.g. by different patterns of spacing). During plant development, leaf growth and leaf orientation will be measured twice per week; R: FR, PAR and leaf greenness will be measured once per week. ‘Digitization’ will also be done twice during the whole growing season which will enable us to reconstruct the 3D structure of plant in the computer. By using these measurements, we can quantify the relationship between leaf orientation, tiller pattern, leaf nitrogen content and light environment that mentioned above.

2. Structural and functional adaptation of maize in wheat-maize intercrop

This subject studies the shade avoidance phenomenon of maize in wheat-maize intercrop. Since maize is sown about one month later compared to wheat, so it is suppressed by wheat in the early growing season (Fig.4). Maize copes with this unfavourable environment with several structural and functional adaptations, such as leaf orientation, internode length, leaf length and width, leaf nitrogen content. Therefore, maize can reduce the negative influence caused by wheat.

In this subject, we hypothesized that these phenomenon can be quantified by studying their relationship with red/ far-red ratio(R: FR) and photosynthetically active radiation (PAR).

Fig 4. Intercropped maize in early growing season

Similar to wheat, the mechanism is light foraging and N distribution. The mechanism behind N distribution is that plants are able to modify their N distribution between different leaf layers in response to the light distribution. 'Plants put their N where the light is' one could say. This behaviour maximizes photosynthesis per unit of N. For intercropped maize, it was suppressed by wheat, and has a lower leaf nitrogen content at early stage. But after wheat harvest, the empty strips in between the maize rows will result in much better light conditions for maize than in the early growth stages when the wheat rows were still present. According to our hypothesis, we expect a significant change in leaf N content in maize after harvest of the wheat because the leaves are exposed to more light which may compensate the negative effects in the early growing season.

To study these phenomenon and investigate our hypothesis, dedicated experiments will be conducted with variable light environments (created e.g. by different patterns of spacing). During plant development, leaf growth and leaf orientation will be measured twice per week; R: FR, PAR and leaf greenness will be measured once per week. 'Digitization' will also be done twice during the whole growing season which will enable us to reconstruct the 3D structure of plant in the computer. By using these measurements, we can quantify the relationship between leaf orientation, leaf length and width, internode length, leaf nitrogen content and light environment.

Used skills
Reviewing literature; setting up and performing experiments; data analysis; oral and written reporting.

Requirements
Experience or affinity with detailed analysis of plant development

3D modelling of light extinction in wheat canopies in relation to row structure and solar angle

Supervisors
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Jan Vos e-mail: jan.vos@wur.nl

Description
In a plant the centres of growth (the sinks: expanding new organs) are spatially separated from the centres of substrate production (the sources: illuminated green tissues). The mechanisms that control the assimilation and distribution of carbon in wheat have been studied on the plant level (or: the 'global level'). However, to understand the processes that lead to the development of fertile shoots (tillers), a proper quantification of carbon assimilation and allocation at the organ level (the 'local level') is necessary. Especially the early development of tillers and their survival beyond the vegetative stage have been shown to be dependent on local processes. In this respect, the source strength, the sink strength, and the source-sink relations are of primary importance and need to be studied in detail.

The acquired knowledge will be applied in a virtual plant model of spring wheat, i.e. a model that takes the geometrical structure of the individual organs of the wheat plant explicitly into account. As yet, organ dimensions are implemented in the wheat model in a descriptive way. Over the next years the model will be extended with provisions to simulate carbon gain (photosynthesis) and partitioning (sink-source interactions). Ultimately, the model will calculate growth and development of plants, size, shape and orientation in space of each organ in relation to temperature and radiation absorbed by each element of the canopy. This means that source and sink strengths, as well as the source-sink relations need to be quantified in the 3D structure. Experiments need to be conducted to derive sink and source functions.

Several research questions need to be addressed. For instance: the distribution of source activity (photosynthetic capacity) in the plant canopy and how this changes with position and age of organs; relations between outgrowth of tiller buds and photosynthesis of parent leaves.

Within the above-mentioned framework several experiments are possible. Spring wheat plants will be grown in the greenhouse or in growth chambers. Sinks-source will be varied by using different plant population densities and varying light intensity. Measurements depend on the research question, but will include aspects such as:

- Monitoring of the appearance and life spans of organs (leaves, tillers);
- Monitoring of photosynthetic capacity and chlorophyll content and N content of leaves over their life span;
- Measuring dimensions and biomass of individual organs;
- Periodic measurement of light interception and red: far red ratios in the canopy;
- Data analysis and design relations that can be implemented in the model

Period
2010; experiment takes about 4 months.

Used skills
All aspects of experimentation (design, execution, data gathering); data analysis.

Requirements
Plant Sciences / Biology background

Tillering in grasses and cereals in relation to light quality and population density

Supervisors
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Description

Cereals and other members of the family of grasses (Poaceae) produce tillers (branches) during development. The number of tillers that are produced strongly depends on the environmental conditions and the extent of competition with other plants. For example, the number of tillers produced depends heavily of the population density the plants are grown at: a high density results in few to no tillers, whereas a low density can result in bushy plants growing many tillers.

This MSc subject focuses on the hypothesis that the number of tillers produced at a certain population density of plants depends on the ratio of red to far-red light (R:FR) within the plant canopy. The mechanisms behind this is based on the high absorption of red light and the high scattering of far-red light by plant tissues, resulting in low R:FR when population density is high, and a high R:FR when density is low. R:FR can be sensed by a plant, and consequently the plant can adjust its development accordingly. To investigate the relationship between R:FR and tillering, an experiment will be conducted with several Poaceae species, grown at a range of population densities. The hypothesis to be tested is that Poaceae species with small leaf blades and leaf sheaths tiller inherently more profusely than species with large leaves, but that in all species tillering ceases at comparable low R:FR ratios.

Used skills

Reviewing literature; setting up and performing experiments; data analysis; oral and written reporting.

Requirements

Experience or affinity with detailed analysis of plant development.

Branching pattern in *Arabidopsis thaliana* under contrasting light conditions

Supervisors
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Sander van der Krol e-mail: sander.vanderkrol@wur.nl
Jan Vos e-mail: jan.vos@wur.nl

Description
Plants are capable of adjusting their development to match the conditions they live in. In conditions of high competition for light with neighbouring vegetation, a plant invests more in height growth and less in branching; this phenomenon is part of the so-called 'shade-avoidance syndrome'. A key driver of shade avoidance is the ratio between red and far-red light a plant perceives. Light reflected of neighbouring plants have a low red/far-red ratio (since red light is mainly absorbed and far-red light is mainly reflected), which is interpreted as a signal for competition.

Most buds produced in the axils of leaves do not grow out into a branch, but remain dormant. In conditions of low competition, characterized by a high red/far-red ratio (>1.0), fewer buds stay dormant compared to conditions of high competition, characterized by a low red/far-red ratio (<0.2). The goal of this MSc subject is to gain insight into the extent of bud outgrowth into branches under contrasting red/far-red conditions in the model rosette plant *Arabidopsis thaliana*. Focus will be on the number of rosette and shoot branches, as well as the branching order (primary branching on the main shoot vs secondary branching on other branches). Next to wild-type Arabidopsis plants, *max*-mutants will be used, which produce more branches due to a deficiency in strigolactone (branch-inhibiting hormone) biosynthesis and signalling.

Used skills
Reviewing literature; setting up and performing experiments; data analysis; oral and written reporting.

Requirements
Experience or affinity with detailed analysis of plant development

Thesis subjects

Theme 3:

Designing climate-robust systems

Model evaluation of weather relationships determining spore production and infection risk in *Phytophthora infestans*

Supervisors

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Geert Kessel (PRI) e-mail: geert.kessel@wur.nl

Description

Management of potato late blight (PLB) relies on forecasting and backcasting of risk periods. A risk period is a time period during which the infection risk of a crop is high. Ideally, a crop is protected by applying a protective fungicide treatment just before a risk period occurs or directly afterwards. PLB control has become much more difficult since aggressive isolates of *Phytophthora infestans* have become prevalent since the introduction of the A1 mating type in the 1980s. It is suspected that current isolates of *P. infestans* infect, grow and sporulate at a considerably lower temperatures than was previously the case. Field experiments have been conducted in recent years to measure spore escape from infected crops in relation to weather. A simulation model for PLB epidemics will be used to determine whether those spore escape measurements are still in line with historical information on the response of *P. infestans* to weather. The result of the research will be used to adjust decision rules for forecasting and backcasting of risk periods.

The objective is to evaluate climate relationships for *Phytophthora infestans* to improve control decision rules.

Period

As soon as possible.

Locations

WU/PRI

The relevance of cultural control measures for weed management

Supervisor

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Description

Current weed management relies heavily on chemical weed control. To change this situation, cultural control is often suggested as a useful alternative. Cultural control encompasses any adjustment or modification to the general management of the crop, or cropping systems design, that contributes to the regulation of weed populations or reduces the negative impact of weeds on crop production. There are many examples of this, like an increased sowing density, a more uniform sowing pattern, row placement of manure and the use of more competitive cultivars. Obviously, all of these measures have potential to contribute to the reduction of the weed problem. What currently remains unclear however is the impact or significance of the various measures.

Recently a mathematical framework was developed for evaluating the effectiveness of cultural weed control. The model addresses both the short term (yield reduction in the current season) as well as the long term (weed population dynamics) consequences of specific measures.

Main objective of the thesis research is to make valid estimates of the contribution of various cultural control measures to integrated weed management. Analysis of literature data with the help of the mathematical framework will be used as the main methodology. The results will provide a solid basis for the improvement of current weed management strategies.

Extreme weather and climate events and their impact on crop production

Supervisor

Pepijn van Oort e-mail: pepijn.vanoort@wur.nl

Description

Climate is variable and changing. Apart from the long-term effects of increasing temperature and greenhouse gas concentrations, it is expected that more extreme weather and climate events will occur. Examples include, but are not limited to, extended wet and dry spells, high temperature extremes and winds. As part of this thesis, the student will investigate relationships between historical weather data, agricultural production statistics and other evidences of extreme weather/climate impacts on crops. This is the first step in establishing causality between hazard exposure and impact. This will be supplemented by an in-depth analysis of adaptation options, either by reducing the exposure to these risks via management changes or by outsourcing these risks (e.g. insurance). This desktop study will search the literature for evidence of (a) impact and (b) possible adaptation options followed by some clear recommendations for decision makers. The ultimate outcome from this study will strongly depend on the chosen study region. There is considerable flexibility in choosing the appropriate region and the final selection will depend on negotiations between the student and the supervisors. This study will be part of a broader initiative in this field and can potentially include more than one student.

Thesis work would include

- Literature review on sensitivity of agricultural production to extreme events
- Literature review of cropping calendars and development stages for crops in the study area
- Statistical analysis
- Generating hypotheses for further research

Weather and climate knowledge for improved in-season decision-making

Supervisor

Pepijn van Oort e-mail: pepijn.vanoort@wur.nl

Description

This project will initially focus on rice. At the start of the cropping season, farmers need to make some critical decisions (type of crop, crop variety, sowing date, irrigation regime etc). However, depending on the cropping system, farmers also need to make important decision as the crop develops (e.g. when to transplant, at what density, fertiliser regime etc). The merit of these decisions depends largely on prevailing and future weather conditions. For instance, in a dry year, a more drought tolerant crop (or crop variety) might perform better, depending on management. For many rice-growing regions some capability already exists to probabilistically forecast seasonal and intra-seasonal conditions based on phenomena such as the El Nino - Southern Oscillation and the Madden-Julian Oscillation.

During the growing season farmers make many decisions of which the outcome will be affected by yet unknown weather conditions. For instance, the need for irrigation water depends on how much stress the crop can tolerate and when the next rains are expected. Uptake of nutrients depends on nutrient availability and future growth potential, which in turn depends on expected solar radiation, temperature, water availability and nutrient availability.

Outcomes of cropping options are the integral effects of genotypes (G) by environment (E) by management (M) interactions (also referred to as GxExM). The importance of each of these factors varies and is subject to uncertainty of future weather conditions. Probabilistically quantifying this uncertainty is important for informed decision-making and risk management. This can be achieved by conducting uncertainty analyses that take existing knowledge based on seasonal climate forecasts and modelled crop responses into account. To achieve this, simulation models need to be run with historical climate records and then combined with future climate projections to assess the risk associated with different management options.

Objectives

- to link a crop growth model with a database of weather records to explore the expected impact and risk of various management techniques
- to statistically evaluate the model outputs
- to generate hypotheses for further research

Details (e.g. study region etc) will depend on the student's preference and data availability. This work will require some prior knowledge of climate systems and seasonal climate forecasting.

Optimising the weather

Supervisor

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Description

Crop growth models are an important tool in scientific research. One major domain of application is yield gap analysis, where actual yields are compared with (a) potential yields, (b) yields under water-limited conditions and (c) yields under nutrient-limited conditions. The difference between these conditions indicates how much scope there is for increasing production and can lead to changes in management that improve resource use efficiencies (water, nutrients).

So far, most simulation studies have used historical weather records to optimise production for specific locations. This included asking the so-called "what-if" questions for farm managers and plant breeders, such as: 'what would be the effect if I changed my management' or 'what would be the effect if we could change existing morphological or physiological traits'. This MSc thesis will take a 'reverse-engineering' approach to this problem. Here we will be asking: what would the ideal climate look like for optimum production? For this, we will use existing crop management and plant traits and optimise weather conditions for plant growth.

The outcomes of such a study is expected to yield several new insights. Specifically, it is expected to show: (1) to what extent weather is a production limiting factor, (2) what scope there is to further increasing production, (3) the model's suitability for studying impacts of climate variability and change (4) how sensitive the results are to management by environment interactions and (5) where in the world we might find climatic conditions that closely resemble the climatic optimum identified. In the first instance, this work would focus on rice as the modelled crop. Relevant simulation environments are APSIM-Oryza and ORYZA2000.

Objectives

- Literature review of how rice growth is affected by climatic variables
- Theoretical, model-based analysis of weather-crop interactions
- Comparison between optimum and actual weather conditions
- Generating hypotheses for further research

Second growth in potato / doorwas in aardappel

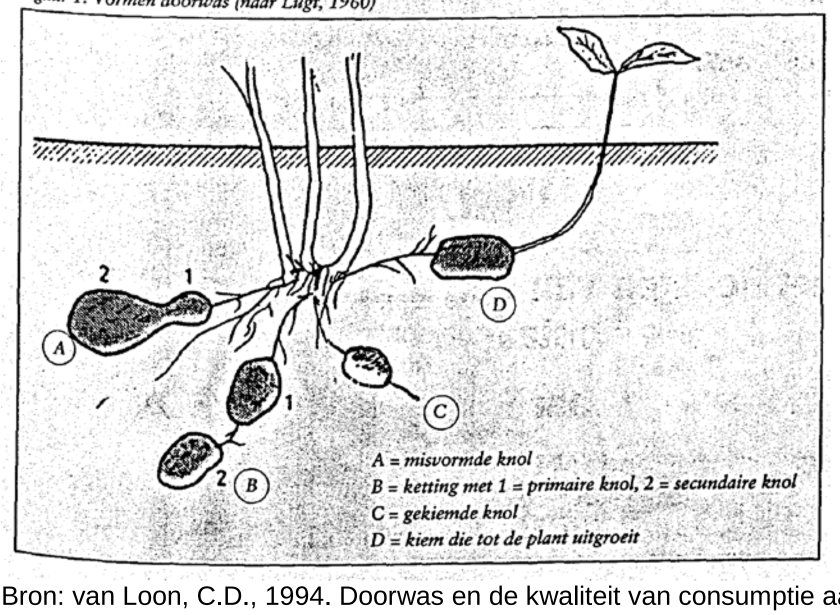
This subject is described in Dutch because it will require farmer interviews.

Supervisor
Pepijn van Oort e-mail: pepijn.vanoort@wur.nl

Omschrijving
Doorwas in aardappel leidt tot misvorming en opbrengst reductie in aardappel (zie figuur). Doorwas ontstaat wanneer de ondergrondse delen van de plant enkele dagen aan te hoge temperaturen worden blootgesteld. Kwalitatief is redelijk bekend welke processen leiden tot doorwas. Kwantitatief is echter weinig bekend, bijvoorbeeld hoeveel dagen moet het droog / heet zijn, hoe heet dan wel en wat is de interactie met management (ras, hoeveel beregend, zaai datum, bemestingsniveau) en bodem. Doorwas kwam in de laatste 50 jaar lang niet elk jaar voor, maar men is bevreesd dat het in de toekomst met klimaatverandering vaker voor zal komen. Om daarover uitspraken te doen is preciezere kennis nodig over voorkomen van doorwas. Het is nu al duidelijk dat 2010 een jaar zal worden met veel doorwas, in heel Nederland. Een ideale kans dus om doorwas nader te onderzoeken. In dit afstudeervak doe je eerst een literatuur onderzoek en interviews met experts naar wat bekend is over doorwas. Op basis daarvan stel je een enquête op die aan boeren door heel het land ingevuld wordt. Je koppelt de enquêtes aan KNMI weersgegevens en analyseert de resultaten statistisch.

Dit afstudeervak bevat
- Literatuur onderzoek naar doorwas
- Leren een enquete op te stellen
- Statistische analyse
- Wetenschappelijk rapportage

Figuur 1: Vormen doorwas (naar Lugt, 1960)



Bron: van Loon, C.D., 1994. Doorwas en de kwaliteit van consumptie aardappelen. Aardappelwereld, Augustus 1994, p. 5-6.

Open call for a project proposal
“Designing climate robust systems”

Supervisor

Pepijn van Oort e-mail: pepijn.vanoort@wur.nl

Description

“Designing climate robust systems” is one of the five themes that researchers at CSA (formerly CWE) are working on. Students are welcome to propose their own topic within this theme. Please find below the topic description.

Agriculture is arguably one of the most climate sensitive sectors in our global economy. Many developing countries remain heavily dependent on agriculture for national income, while agriculture occupies a special place in the national psyche of many developed nations. Hence, any effort that helps to reduce the vulnerability of this sector to climate related risks is likely to lead to considerable global benefits, both economic and social. Particularly in developing countries farmers’ coping capacity is limited by (a) a lack of resources and (b) a lack of knowledge. This theme will focus on the latter. It is designed to

1. allow practitioners and policy makers to negotiate policy and management responses from a position of knowledge rather than ignorance (ensure that policy intent and management practices are aligned; avoid or discourage ‘perverse’ policy incentives such as subsidising poor management practices);
2. reduce costs associated with risks and change management by supporting informed decision making; and
3. increase enterprise profitability and environmental performance through early assessment of management alternatives.

The theme investigates better and more relevant ways to use new and enhanced climate information (including climate forecasts); considers natural resource implications in conjunction with impacts on crop production and quality; deals with farm-enterprise issues in addition to crop and cropping systems issues.

Thesis subjects

Theme 4:

Quantitative agro-ecology

Soil fertility improvement strategies with respect to their contribution to *Striga* management

Supervisor/contact

Aad van Ast e-mail: aad.vanast@wur.nl

Lammert Bastiaans e-mail: lammert.bastiaans@wur.nl

Description

Parasitic weeds of the genus *Striga* (*Orobanchaceae*) strongly affect host crops such as sorghum (*Sorghum bicolor* [L.] Moench), pearl millet (*Pennisetum americanum* (L.) Beeke), maize (*Zea mays* L.), rice (*Oryza sativa* L.) and cowpea (*Vigna unguiculata* (L.) Walpers) and, as a consequence, they are important growth-reducing factors in crops in vast areas of the savannah zone in Africa (Parker and Riches, 1993). Although *Striga* spp. have long been pests in traditional cropping systems, they did not cause severe problems until 20-30 years ago, because these systems generally involved crop rotations, mixed cropping and, in particular, prolonged periods of fallow. As a result of the rapid human population growth in Africa and the increased demand for food supplies, cereal monocropping and intensive land use with little or no fallow have replaced the traditional cropping systems. These changes in cropping practices have resulted in soil depletion and degradation and a rapid increase in the extent and intensity of infestations of *Striga* spp.

Though it is often reported that *Striga* is a typical indicator of low soil fertility, it is far less established how environmental factors, like soil fertility, affect the host-parasite interaction. This project will focus on unraveling these underlying mechanisms. Initially three potential pathways will be investigated: i. a direct effect on the parasite; ii. an effect through the innate defense capacity of the host; iii. a change in micro-climate.

Ad i. Recently, accumulation of ammonium in the parasite following high nitrogen availability was reported to cause direct toxic effects on the parasite. How these phenomena relate to nitrogen source (organic – inorganic; nitrate - ammonium), each with their specific nitrogen release pattern, will be further investigated.

Ad ii. Soil fertility status will affect the vigor of the cereal plant, and through that its suitability to act as a host. The host plant might turn into a more nutritious substrate for the parasite, but increased host vigor might also result in an increased innate defense capacity of the host, for instance through an improved ability of the host to monopolize the assimilates it has produced. If legumes are intercropped to increase soil fertility, the competition between main and cover crop will affect the vigor of the host plant in a different way, but again affecting the interaction between host and parasite.

Ad iii. An increased soil fertility status will also affect the micro climate, particularly that of the canopy. A more profound growth of the host plant will affect the light attenuation in the canopy and consequently the ability of the parasite to produce its own assimilates. Perhaps even more important the transpiration rate of the parasite will be affected, following the lowered light intensity and the increased relative humidity. Transpiration rate is directly linked to the suction potential of the parasite. Similar phenomena will occur after the introduction of a cover crop.

Period

May – November.

Used skills and requirements

Various pot and field experiment setups, data analysis, writing scientific report.

No special requirements; Ecology and Management of Weeds would be a good preparation.

Remarks
Research is conducted in pot experiments in Wageningen and field experiments in Niger.

Effects of cowpea on *Striga* management in Sorghum cropping systems

Supervisors

Tjeerd Jan Stomph e-mail: tjeerdjan.stomph@wur.nl

Description

Striga hermonthica is a hemi-parasitic plant, severely affecting yield in many important agricultural crops in the semi-arid tropical regions of the world. Host plant crops include sorghum, millet and maize. After germination and attachment, *Striga* penetrates the root of the host, inducing reduction of photosynthetic rate in the host plant and withdrawing host carbon for their growth. In various crops, pathogenesis results in severe yield loss. Traditionally the system of shifting cultivation, consisting of one or more years of cropping followed by a long fallow period, in which the land is allowed to revert to bush or grass, ensured a strong depletion of the *Striga* seedbank during the fallow period. Therefore *Striga* effects were reduced as the seed bank was largely depleted when the next crop was grown. Recently farming systems have changed toward continuous monocropping of cereals to meet the increasing food demand of the population pressure. This resulted in a build up of the *Striga* seed bank and an increase in yield losses due to *Striga*. The same practices lead to a gradual deterioration of soil organic carbon and nutrient availability. Options to improve the sustainability of the systems are needed but difficult to formulate and understand.

The aim is to determine the potential role of cowpea intercropping or rotation cropping on population dynamics of *Striga hermonthica* under field conditions.

Used skills

Cowpea has been reported to potentially reduce Striga seed population through suicidal germination, but also its effects in intercropping on Striga performance would imply a reduced seed production compared to pure Sorghum stands. Both seed survival and seed production will be monitored trying to analyse the underlying causes of differences that are observed. Through the use of a population model the long-term effects of the inclusion of intercropping and rotation cropping will be assessed.

Period

Field work needs to be carried out during the cropping season July-October. Preparation of a workplan is needed before leaving to Mali, while reporting cannot be finished in October.

Location

The work is carried out in Mali or Niger, at the ICRISAT experimental facilities.

Parasitic weeds in rice production systems in sub-Saharan Africa

Supervisor/contact
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Description
Rice is a cereal of rapidly increasing importance in sub-Saharan Africa (SSA). Over the last three decades, production increased by 170%, whereas rice consumption increased by 300%, considerably widening the consumption-production gap. Weeds are the most important biological production constraint. Parasitic weeds, an important group of weeds in rice in SSA, are progressively spreading due to their invasive nature and adaptive abilities.

Besides competing with rice for resources, they parasitize on rice roots, withdrawing carbohydrates and water while exerting pathological effects which can result in total crop failure. The most important parasitic weeds in rice are the obligate hemi-parasitic witchweed *Striga hermonthica* (in West Africa) and the facultative hemi-parasite *Rhamphicarpa fistulosa*. The latter is a relatively new, but rapidly increasing parasitic weed in rice in both East and West Africa.

Parasitic weeds particularly affect the poor because of the geographical overlap with primary agro-ecological zones and agro-ecosystems and because poor farmers also generally have little means for pest control.

Given the expected environmental and land use changes in SSA, there is a strong need to develop locally adaptable and socially and economically acceptable strategies for prevention and control of these parasitic weeds. For this purpose the next questions have to be addressed:

- How do environmental conditions (e.g. temperature, soil moisture, nutrient availability) affect the life-cycle stages of parasitic weed species in rice, particularly of the relatively new *Rhamphicarpa*?
- How do these conditions affect the interaction between host and parasite (both *Rhamphicarpa* and *Striga*).

Methodology
Incubator, climate-chamber and greenhouse experiments will be conducted in Wageningen, The Netherlands, to assess environmental effects on parasitic weed success and on the host-parasite interaction.

Field work can be conducted in Tanzania.

Period
Throughout the year, but depending on the exact subject

Location
Studies can be conducted in Wageningen and Tanzania, depending on the exact subject

Evaluating weed suppressiveness of soil-incorporated and surface-placed cover crop residues in coffee production system in Ethiopia

Supervisors/contact

Mulatu Wakjira Jalata e-mail: mulatu.jalata

Lammert Bastiaans e-mail: lammert.bastiaans@wur.nl

Description

Coffee production systems in Ethiopia include forest, semi-forest, garden and plantation coffee. In all of these systems, weeds are important biotic production constraints and weed management is the major cultural operation requiring high cost, labour and time. Little is known about the composition and dynamics of the weed flora in these production systems. The small-scale coffee farmers in Ethiopia can not afford the purchase of herbicides, and on the other hand herbicides are not allowed when farmers want to certify for organic coffee production. As a result, slashing is the major method of weed control. Due to lack of labour, weed control is often restricted to slashing the weeds only once a year. Further, slashing is also the major means for the transmission of coffee wilt disease. Other mechanical weed control measures such as hoeing and cultivation can damage the root system of the coffee plant. Therefore, the small-scale farmers need alternative weed management practices that are inexpensive, safe to human health and environment and that require minimum time and labour. Replacement of the natural weed vegetation by a suitable cover crop is one such option, which is environmentally safe and could help improve the productivity and profitability of coffee. So far, this strategy is only rarely used. The overall aim of the project is therefore to identify suitable weed-suppressive cover crops for inclusion in coffee production systems. In this MSc thesis research, the weed suppressive and allelopathic potential of cover crop residue material, incorporated or applied as mulch, will be evaluated under greenhouse conditions. The experiments will answer the question: which cover crop residues have strongest weed suppressive potential when incorporated or placed on the soil surface as mulch and which traits are responsible? These experiments are therefore aimed at selecting the best method of placement of cover crop residue material for adequate weed suppression.

Methodology

Two pot experiments will also be executed with eight cover crop species, one with soil-incorporated residue and the other with soil-surface placed mulch to evaluate for their weed suppression potential under greenhouse conditions.

Period

July to December 2011

Location

Jimma University College of Agriculture and Veterinary Medicine, Ethiopia

Producing quality coffee: how quantitative can we get?

Supervisors
Jan Vos e-mail: jan.vos@wur.nl
TjeerdJan Stomph tjeerdjan.stomph@wur.nl

Description
Ethiopia is the centre of origin of coffee (*Coffea arabica*). Coffee plays an important role in the culture and economy of Ethiopia. Yet, so far Ethiopia has not sufficiently capitalized on its rich coffee heritage and fails to play a prominent role on the world market, in spite of its potential. High quality is an important prerequisite for enhancing Ethiopia's position on the world coffee market and thus improving the livelihood of the smallholder producers.

Many agronomic factors impact on yield and quality of coffee berries. These include coffee tree management (pruning, degree of shade from cover trees) and harvesting procedures. Sub-optimal plant nutrition is a well-known constraint, as are annually alternating yield patterns.

There are scattered data from experiments showing effects of these factors. Modelling allows integrating knowledge from several sources and it allows to extrapolate to conditions beyond the experimentally covered range. Ethiopian coffee sector could benefit from a quantitative model, capturing the effects of the main factors on yield and quality of coffee. The aim of a model is to quantify yield and bean size (S) as a function of key factors and processes, i.e.:

S = *f* (*leaf area and leaf area increment per tree, seasonal intercepted radiation per tree, number of berries per tree, resource availability per unit leaf area and per berry*)

The MSc thesis work includes
- articulate the objectives of a coffee production model
- the construction of a conceptual model of coffee production
- a critical review of modelling approaches that could serve the purposes
- data mining to parameterize the model
- producing an overview of knowledge gaps indicating research needs.

BSc thesis
- Also Bsc literature work can be done in conjunction with the development of the conceptual model

Period
The work can start any time

Low dosage systems and herbicide resistance

Supervisor

Lammert Bastiaans e-mail: lammert.bastiaans@wur.nl

Description

Increased concerns about environmental side effects of herbicides and the necessity to reduce cost of inputs have resulted in increasing pressure on farmers to reduce the use of herbicides. This has led to the introduction of low dosage systems, of which the Minimum Lethal Herbicide Dose (MLHD) is an example. A potential drawback of the use of reduced herbicide rates is the increased risk of weeds developing herbicide resistance.

The main aim of this thesis research is to conduct a risk assessment study on the development of herbicide resistance in Dutch agriculture, related to the use of low-herbicide-dosages. This involves different aspects like:

- Making an inventory on the use of reduced dosages in Dutch agriculture (e.g. in which crops and cropping systems are low dosage systems being used, which herbicides are involved and to what extent is the rate reduced).
- Developing a model to assess how low dosages affect the rate of herbicide resistance development

Life cycle aspects of perennial weed species

Supervisor
Lammert Bastiaans e-mail: lammert.bastiaans@wur.nl

Description
In organic agriculture, perennial weeds are an increasing problem. Tackling this problem requires a thorough understanding of the life cycle of these species. Many population models have been developed for annual seed producing weed species. These models have helped to identify the weak links of these weed species. Relatively few work in this area has been done for perennial weeds.

The main objective of the thesis research is to contribute to the development of a spatio-temporal population model for perennial weeds. Focus can be on experimental work, like the survival and spread of perennating structures, or on the modeling component. A combination of the two is also possible.

IPM and system analysis

Supervisors
Wopke van der Werf and others

Contact
Wopke van der Werf e-mail: wopke.vanderwerf@wur.nl

Description
Integrated pest management boils down to implementing a set of management techniques at strategic, tactical and operational level that ensure crop health and product quantity and quality at minimum costs and minimum damage to the environment. Enhancement of natural controls and crop resistance are key elements. Models are a valuable tool for comparing alternative management strategies (biological, genetic, cultural) and evaluating their advantages and disadvantages. Models for IPM in a range of systems have been and are being developed and can be further used, tested, developed and analysed.

Objective: Evaluation of management options in crop protection by modeling.

Period
Throughout the year.

Locations
Studies can be conducted in Wageningen or elsewhere in The Netherlands and abroad. Usually, the student will work in an ongoing PhD or post doc project, which ensures an optimal setting with abundant interaction and resources. Research can be carried out for a thesis subject or in the frame of a practical experience period.

What is the basis of early vigour, being an important trait of weed competitiveness of various crop species

Supervisor
Lammert Bastiaans e-mail: lammert.bastiaans@wur.nl

Description

Cultural control is often mentioned as an alternative weed management strategy, to reduce the strong dependency on chemical control. Breeding for more weed competitive cultivars is one of the options that has been explored for a variety of crops. Often early vigour, or the ability of a crop to grow relatively fast during its early growth stages, has been identified as an important trait. It is however by no means clear which individual traits or growth strategies underpin early vigour. A related question is whether cultivars that perform well under high input conditions are also performing well under low input conditions.

The main objective of the thesis research is to obtain a better understanding of the physio-morphological background of early vigour. A series of well-designed experiments or a combination of experimentation and modeling will be used to resolve this issue and to help improve breeding efforts in this area.

Life cycle parameters of weeds and vulnerability of weeds to seed predation

Supervisors
Wopke van der Werf e-mail: wopke.vanderwerf@wur.nl
Lammert Bastiaans e-mail: lammert.bastiaans@wur.nl
Ans Hofman e-mail: ans.hofman@wur.nl

Description

Weed population dynamics are strongly affected by seed mortality, and an annual loss of 25-50% is usually enough to slow down weed population growth substantially. It has been shown in non-agricultural ecosystems that seed predation is an important factor in limiting the population expansion of plant species. Research at CSA (formerly CWE) has indicated that predation of seeds on the soil surface is responsible for 18-57% seed loss in cereals. However, the magnitude of the loss depends on the weed species: total seed production, the timing of seed shed, the duration of the seed rain, and the period of time seeds are available on the soil surface.

The thesis research could include one or more of the following objectives:

- Determining the amount and the timing of seed production in arable fields.
- Determining the residence time of weed seeds on the soil surface.
- Determining the factors responsible for seed coverage by soil, plant debris, etc. These factors include soil type, weather (wind and rain), and morphology of weed seeds.
- Combining all available data to determine the consumption probability of weed seeds for specific weed species and weather data.

Period

Throughout the year, but depending on the exact subject.

Locations

Studies can be conducted in Wageningen, elsewhere in The Netherlands, but also abroad.

Weed seed losses and the impact on weed population dynamics

Supervisors
Wopke van der Werf e-mail: wopke.vanderwerf@wur.nl
Lammert Bastiaans e-mail: lammert.bastiaans@wur.nl
Ans Hofman e-mail: ans.hofman@wur.nl

Description
Seventy to 99% of the weed seeds that are produced annually cannot be retrieved from the seed bank or do not emerge as seedlings. Weed population dynamics are strongly affected by seed mortality, and an annual loss of 25-50% is usually enough to slow down weed population growth substantially. It has been shown in non-agricultural ecosystems that seed predation is an important factor in limiting the population expansion of plant species. Research at CSA (formerly CWE) has indicated that, depending on the weed species, predation of seeds on the soil surface is responsible for 18-57% seed loss in cereals.

Objectives:

- A thesis research could include one or more of the following objectives:
- An estimation of seed losses due to predation in potato, sugarbeet and other common crops in the rotation.
- An estimation of sub-surface mortality of weed seeds.
- An estimation of the mortality of submerged seedlings.
- Quantify the importance of seed mortality by incorporating seed predation into an excisting weed population model and performing a sensitivity analysis of the new version.
- Quantify the importance of seed predation in a crop rotation system using a modelling approach.

Period
Throughout the year, but depending on the exact subject.

Locations
Studies can be conducted in Wageningen, elsewhere in The Netherlands, but also abroad.

Metapopulation dynamics and plant disease

Supervisors

Walter Rossing (BFS) e-mail: walter.rossing@wur.nl
Wopke van der Werf e-mail: wopke.vanderwerf@wur.nl

Description

Plant diseases depend for their survival upon a combination of (1) survival in the specific field (local dynamics) and (2) spread among fields with host crops and between crop plants and wild hosts (spatial dynamics). For pathogens with a short survival period in crop fields, due to lack of persistent survival structures, and a lack of natural hosts, dispersal between fields is a key process in the survival of a regional pathogen population in a time frame of years to decades. The spatial distribution of crop fields (density, distance and pattern) may therefore be used as a tool in plant disease management. Reducing the regional dispersal may prevent plant disease.

During the last decade, landscape ecologists have intensively studied the dynamics of spatially fragmented populations, both experimentally and with models. We propose to use concepts of landscape ecology to investigate options for regional management of plant disease.

Objectives are:

- To develop a spatially explicit model for plant disease metapopulation dynamics, and apply the model to Botrytis elliptica, causal agent of 'fire disease' in lily.
- To explore the effect of spatial arrangement of crop fields at the regional level on plant disease metapopulation dynamics.

Period

Throughout the year, at least 5 months duration.

Requirements

Population dynamics and modelling skills.

Location

Wageningen.

Biodiversity and the natural control of pests and weeds

Supervisor

Wopke van der Werf e-mail: wopke.vanderwerf@wur.nl

Description

Natural antagonists can help reduce problems with pests and weeds in agricultural crops. However, we have only limited basic biological knowledge about the species spectrum of antagonists, their consumption rates with respect to noxious pests and weed seeds, their phenology and dispersal ability in agricultural landscapes. Field research is carried out to learn more about predator impacts on pests and weed seeds in relation to distance to late successional field edges with high species diversity. Moreover, pest attack in intercrops is being studied.

Objectives are:

- Determine predator impact on introduced pests or weed seeds in the field.
- Determine relationships between predation impact and distance to field edges.
- Determine predator impacts in mono- and intercrops.
- Determine sensitivity of selected pest and weed species to predation with population dynamic models.

Period

Throughout the year.

Location

Studies can be conducted in Wageningen or elsewhere in The Netherlands and abroad. Research can be carried out for a thesis subject or in the frame of a practical experience period.

Population biology of the granivorous groundbeetle, *Harpalus rufipes*

Supervisors
Wopke van der Werf e-mail: wopke.vanderwerf@wur.nl
Lammert Bastiaans e-mail: lammert.bastiaans@wur.nl

Description
Observations on cereal fields in the last two years have shown that the granivorous groundbeetle, Harpalus rufipes, is responsible for a considerable part of weed seed consumption on sandy soils. The beetles are therefore interesting from the viewpoint of weed control. On clay soils the number of beetles is much lower and most beetles are found within 20-30 meters from the field edge. The difference in prevalence of H. rufipes may be related to survival chances of larvae on either sandy or clay soils. In autumn, adult beetles migrate from the field to hibernate in shrubs and bushes. The larvae remain in the fields, where they hibernate in burrows and complete their life cycle on winter storage. It is possible that the burrows in clay soils are shallower and are more likely to be damaged by ploughing and tillage than the burrows on sandy soils.

Objectives:

- to compare survival changes of H. rufipes larvae in disturbed and undisturbed soil.
- to compare behaviour and survival changes of H. rufipes larvae in sandy and clay soils.

Approach
Adult groundbeetles, *H. rufipes*, will be caught in early summer to collect eggs. Larvae will be reared from those eggs. The larvae will be placed in observation chambers to study the burrowing behaviour of the larvae of different age, in different soil tyes. After a certain period of time, the soil will be disturbed and the effects on the behaviour, weight and survival of larvae will be studied.

Capture it if you can!
Develop a movement model for carabids

Supervisors
Bas Allema e-mail: bas.allema@wur.nl
Wopke van der Werf e-mail: wopke.vanderwerf@wur.nl
Walter Rossing (BFS) e-mail: walter.rossing@wur.nl

Introduction

Hedges, woodlots and field margins provide an important ecological infrastructure in agro-ecosystems. They provide overwintering and resource habitat for natural enemies of crop pests, but they also affect their movement, by providing corridors as well as barriers. In this project, we study how these structures affect the movement behaviour, patterns and mobility of carabid beetles in agricultural landscape mosaics.

We use video recordings of movement behaviour of carabids to predict population dispersal at the landscape level. Scaling up movement behaviour from centimetre to hectometre is a big challenge. We first simplify movement behaviour into a movement model and test this model by comparing simulation output with observations on population dispersal at field scale.

This modelling exercise teaches us which aspects in movement behaviour is important for predicting dispersal behaviour and allows us to study the relation between landscape composition and population dispersal.

Objective

To develop and test a movement model for carabids

Procedures

- Acquire walking tracks of beetles under different conditions in the field and/or greenhouse
- Mark-release-recapture experiments with carabids in the field
- Analyzing walking tracks from video recordings
- Building a movement model
- Testing model output against data

Experiences gained

- Working in a research team
- Setting-up and running a field experiment
- Recording and analyzing movement behaviour
- Developing a spatial explicit individual based model
- Programming in Matlab
- Writing a compact MSc thesis in the form of a publication

Capture it if you can!
Landscape composition and population dispersal of carabids: A simulation study

Supervisors

Bas Allema e-mail: bas.allema@wur.nl
Wopke van der Werf e-mail: wopke.vanderwerf@wur.nl
Walter Rossing (BFS) e-mail: walter.rossing@wur.nl

Introduction

Hedges, woodlots and field margins provide an important ecological infrastructure in agro-ecosystems. They provide overwintering and resource habitat for natural enemies of crop pests, but they also affect their movement, by providing corridors as well as barriers. In this project, we study how these structures affect the movement behaviour, patterns and mobility of carabid beetles in agricultural landscape mosaics.

We use video recordings of movement behaviour of carabids to predict population dispersal at the landscape level. Scaling up movement behaviour from centimetre to hectometre is a big challenge. We first simplify movement behaviour into a movement model and test this model by comparing simulation output with observations on population dispersal at field scale.

This modelling exercise teaches us which aspects in movement behaviour is important for predicting dispersal behaviour and allows us to study the relation between landscape composition and population dispersal.

Objective

To study the relation between landscape composition and population dispersal with the aid of simulations

Procedures

- Literature review on existing knowledge of population dynamics of carabids at a landscape scale
- Performing simulation experiments for different landscape compositions
- Statistical analysis of the simulation output
- Placing the conclusions in a larger perspective: What does it mean for landscape managers?

Experiences gained

- Working in a research team
- Reviewing literature
- Setting up and performing simulation experiments
- Programming in Matlab and/or Netlogo
- Writing a compact MSc thesis in the form of a publication

Thesis subjects

Theme 5:

Natural and social sciences interactions

Linking natural and social sciences

In the application of knowledge generated by the natural sciences and in the generation of new research questions, discussions and negotiations with the users of the knowledge are essential. In collaboration with partners from other disciplines, especially from the social sciences, we are involved in a range of projects in which natural sciences and social sciences converge.

Major activities are on agronomic and social aspects of local, informal seed systems in Africa, Asia or Latin America; gender issues in participatory plant breeding; impact of HIV/AIDS on agriculture; farmer-managed biodiversity; wild-gathered foods in Asia or Africa; economic and spatial analysis of seed and air borne diseases; and climate change related negotiations about innovations and adaptation.

CSA is involved in several major initiatives in which interactions between natural and social sciences are relevant. MSc thesis opportunities are abundant, especially in Africa and Asia, but are dynamic and will require tailor-made arrangements. Please contact Prof. Paul Struik about the latest state of affairs and opportunities.

Aims and components of MSc thesis work

In MSc thesis research you carry out your own scientific research project. This has four aims:

- to acquire general academic skills
- to learn how to do scientific research
- to collect and interpret results on a specific research topic of your own choice
- to contribute to the increase of scientific knowledge.

The thesis research includes:

- formulation of a research question or hypothesis
- gaining specific knowledge which you need for the research (literature study)
- making an experimental design and a work plan
- performing an experimental study (laboratory, pot and/or field work and/or computer modelling)
- arrangement, analysis and interpretation of the results
- drawing conclusions
- writing a thesis and/or scientific publication(s)
- oral presentation of your results (colloquium).

Getting started

When you have decided to do a thesis-subject at our group, you make an appointment with the teaching co-ordinator Mrs Ans Hofman, tel. 0317 484084, e-mail: ans.hofman@wur.nl. If necessary she will help you to make contact with your supervisor.

The secretariat will hand out the thesis contract. Both student and supervisor sign this contract, registering commitments regarding MSc thesis work. Among others, commitments are made on frequency of supervision meetings.

Supervisor

Your supervisor is an expert member of the scientific staff of the Centre for Crop Systems Analysis, or of the institute where you perform your thesis work. When you wish to co-operate in a current PhD research, the PhD student will normally be your supervisor. It is the supervisor's responsibility to keep your work in good progress. This means that he/she will

- introduce you to other members of the department whom you will meet during your research work
- introduce you into the subject
- take care of some literature to start with (see Appendix 1: “Handling literature references” for practical instructions!)
- tell you where your working place is
- make a time schedule together with you
- take care that you will get admission to the necessary facilities
- discuss the results with you
- discuss your draft report and your colloquium
- be present during your examination.

A good working relationship with your supervisor is a prerequisite for a good co-operation. When you encounter problems with your supervisor, please discuss these immediately with him/her. When this does not help, you can ask another member of the department to assist.

Prerequisites for a thesis

Specific preliminary knowledge is necessary to start MSc thesis work efficiently. There is no general rule for all students. The prerequisites depend on the thesis you do. You can make a choice between:

- Thesis Crop and Weed Ecology:	CSA-80418 up to CSA-80439	18-39 ETCS
- Thesis Crop Physiology:	CSA-80918 up to CSA-80939	18-39 ECTS

Depending on the MSc thesis project additional prerequisites may be formulated. This is to be determined by the supervisor and examiner.

Colloquia and Seminars

During your period as an MSc thesis student, you are supposed to attend the colloquia of other thesis students and seminars of staff members. Announcements are made by e-mail. Students who work on a thesis for more than 26 ECTS have to follow 8 colloquia or seminars. Students with a thesis up to 26 ECTS have to attend 5. This mainly is to broaden your view on the scientific field. You can also learn how to give a colloquium yourself by listening to others. You have to register the colloquia you have attended yourself.

You are also expected to give a colloquium on your own research work. This oral presentation informs interested persons and members of the department and colleague students about your research results. Besides, an oral presentation of your results is important as a practical training. (See Appendix 2 “How to give a colloquium?” for practical instructions). The date of your presentation should be agreed upon with your supervisor, examiner and the secretariat. An appointment for the colloquium should be made in time with the secretariat, tel: (4)85315.

Examination

An oral examination concludes your thesis work. At least two weeks before the final examination a definitive report has to be handed in in duplicate to the supervisor. One for the supervisor and one for the examiner. During the examination the research project will be discussed following your thesis. You are expected to be able to explain and defend your results and conclusions. At the end of the examination the mark will be given.

The following items are evaluated (according to the standard form 'Thesis evaluation Wageningen University'):

1. Research and competence (30-60%)
   - Commitment and perseverance
   - Initiative and creativity
   - Independence
   - Efficiency in working with data
   - Handling supervisor's comments and development of research skills
   - Keeping to the time schedule

2. Thesis report (30-60%)
   - Relevance research, clearness goals, delineation research
   - Theoretical underpinning,use of literature
   - Use of methods and data
   - Critical reflection on the research performed (discussion)
   - Clarity of conclusions and recommendations
   - Writing skills

3. Colloquium (5%)
   - Graphical presentation
   - Verbal presentation and defence

4. Examination (5%)

- Defence of the thesis
- Knowledge of study domain

Work and house rules

For your work at the department there are some house rules, which you have to obey strictly. The rules were developed to make sure that the available facilities could optimally be used.

- The secretariat will provide a guest card so you can use the print and copying facilities for your thesis. You will also be put on the mailing list of the group, so you will receive e-mails about colloquia etc. When there are problems with computers, contacts with ICT have to go through the supervisor.
- During the thesis period a photo of the student will be fixed on the photo board with information on supervisor, thesis subject, etc.
- Two copies of the **final** report should be delivered: one copy to the secretariat for the CSA files and one copy for the supervisor (and, if necessary also a copy for the organisation where the research was done). In addition to the paper versions, **a digital version of the final report including original data must also be submitted**. The costs for the preparation of the required number of copies of the report will be paid by CSA (please use your guest card). Binding facilities can be found at the service desk on the ground floor of Radix, next to the meeting rooms (W0, corridor E/F). Because of the high costs of colour prints, the thesis has to be copied black-white. If colour copies are necessary, please, contact the secretariat or supervisor beforehand.
- Expenses for the research will be paid by the chair group (via the supervisor).
- Opening hours building: Monday – Friday from 7.30 – 17.00 h.
  In special cases it is possible to enter the building in the evening (until 22.00 h) and/or weekends (from 9.00 – 17.00 h). Please ask permission from your supervisor.

Appendix 1: Handling literature references

You begin your research by reading literature and continue with that until the end. Your supervisor will provide you with the first scientific papers. After that, you will have to investigate yourself. You are strongly advised to create your own literature database using the programme Endnote.

You can search for articles in scientific journals in the databases available on the library web site: http://library.wur.nl/. Use for instance 'Scopus' or 'Web of Science' (see Most used resources).

Appendix 2: How to give a colloquium?

As with any other aspect of your thesis work, you can ask your supervisor for advice in preparing your seminar. You also should ask him/her to attend a rehearsal and comment.

Preparation

Whenever you start preparing a presentation it is good to ask yourself some preliminary questions:

- Why do I give this presentation, what is the occasion?
- What do I want to achieve with my presentation? What are my objectives?
- What kind of audience will I have?
- What do I consider most important about my topic? What are my priorities?
- What is my 'take-home message'?
- How much time do I have for my talk?

The set-up of your colloquium

- The starting point for any oral presentation is a clear set-up, like: Introduction – Research Question or Hypothesis or Aim – Materials & Methods – Results & Discussion – Conclusions.
- Any other set-up is okay, as long as the research question/aim of your work and conclusions are explicitly put forward. However, for inexperienced speakers, another set up is not recommended.
- It is absolutely necessary to present your research question/hypothesis/aim in a key phrase on a slide. Whenever possible, use PowerPoint!
- Summarize the bottom line at the end, coming back to the research question/hypothesis/aim presented in the introduction. End with the 'take-home-message'.
- Make sure your presentation does not last longer than 30 minutes. Therefore you have to practise (aloud!) before. If your rehearsal lasts too long, cut out information. You don't have to present everything you did. However, keep the presentation consistent (don't draw conclusions on results which are not presented).

The use of slides

You need to use slides in order to make sure that the audience can follow your line of reasoning. Take care of the following:

- Download and use the "huisstijl" PowerPoint template from Intranet (Information for staff) or contact your supervisor on what template to use.
- Slides are only useful if the audience can read them. Check this in advance in the back of the room you will use. Use large, bold letters (for instance: News Gothic or Arial, preferable font size 24. Minimal font size: 20). Never use upper case only. Use *italics* for emphasis.
- Don't use too many slides. For each slide you need at least one minute.
- Don't put too much information on one slide. Only show relevant information. Reduce large tables to maximally 12 numbers and 3 or 4 rows and columns. Don't add elaborate table headings. Figures and Tables from your thesis generally have to be edited before making them suitable for an oral presentation!
- Only use keywords, not sentences. Make sure the audience is listening and not reading!
- Make sure the slides support your talk, and not the other way around.

Your presentation

- Speak up loudly, not monotonously, show your enthusiasm. Use short sentences.
- Make sure everybody can read your slides, don't stand in front of them.
- Never turn your back to the audience, address them directly, and keep eye contact. Do not talk to the screen!
- Do not stay in the same position all the time. Do not put your hands in your trousers-pocket (!), but use them instead to emphasise what you are saying.
- Rehearse at least twice aloud, so that you do not need to think about how to formulate sentences during the presentation. This prevents "eh"s, and is necessary to make sure you do not exceed 30 minutes.
- Take care everything is functioning by the time your presentation is supposed to start. So be there well in advance.

Nerves

It is absolutely normal to be nervous. You even <u>have</u> to be nervous for a good performance! Do realise that also experienced speakers are nervous before a presentation. Try to appreciate the state of being nervous as a state of being sharp and focussed.

It is absolutely not necessary to be extremely nervous. You are the expert on the topic presented. The audience is there because of interest in your topic, not to tackle you. You are to create the right atmosphere: a well-prepared presentation shows your respect for the audience and creates the positive, lively atmosphere needed for a fruitful discussion of your results. In contrast, a sloppy, disorderly, indistinct presentation that lasts too long mainly causes irritation. So if everything is well prepared, nothing can go wrong!

Appendix 3: Directions for writing a thesis

The data and results arising from your research project must be made available for more than just the researcher and his team. It is therefore essential that you write a well-ordered and readable report.

The thesis has a standard layout. The style of writing should be business-like, avoiding elaborate and lengthy sentences.

It will be a very good exercise to write the report in English. Foreign researchers or students can use the results and it is possible to use the report at foreign job applications. An English report should have a Dutch résumé as well. A Dutch report should have also an English résumé. If the English language skills will inhibit a good report, the report can be written in Dutch.

A thesis report is usually constructed as follows:

Cover
With title (this should be short, it must include essential information concerning the research), name author, research group and date (month and year).

Title page
With title, name author(s), supervisor(s) and examiner(s), research group + postal address,, kind of thesis (code) and date.

Table of Contents
Make sure to list all that follows in the Table of contents, including the appendices.

Summary
Very short overview of the research, the factors investigated and the results. The aim of the summary is to offer the reader quick information about the main theme of the research. For this reason, it must be possible to read the summary independently of the thesis itself. You can write the summary best at the end.

Introduction
The framework within which the research is carried out is sketched in the introduction, followed by an account of the background of the problem and why it is considered important to carry out further research.

Make sure your experiment follows logically from the introduction

- Background, background problem and why that is important.
- Analysis of the problem or a specific part of the problem, including literature search. This should already point towards a certain direction of research. Identify what is known and what is not yet known.
- Scientific problem or hypothesis
- Research aim, as specific as possible. The aim should follow from what you wrote earlier and will be the basis for your discussion.

Materials and Methods
The way in which the research is carried out is described here. The results of the research are very much determined by the experimental set-up, the conditions under which the trial is performed and the way in which it is carried out. It is therefore extremely important to describe the set-up and implementation very carefully. For a good overview it is advisable to

divide this chapter into a number of sections. What these sections are usually depends on the nature of the research. For example:

- Experimental set-up. Here the factors with their variants are described, as well as the way in which various treatments are realized, which experimental design is used, and when and where the experiment was carried out.
- Cultural practices and conditions. Here the information must be given about several factors, even if they are not included as factors in the trial, because they could significantly affect the results (soil tillage, sowing date, row distances, average climatological conditions, experimental techniques).
- Measurements, observations and calculations, harvesting procedure, sampling methods, chemical analysis, drying methods etc.
- Statistical analysis, the way in which this was performed must be explained for each of the variables.

Results

The author's task now is to present the results of an experiment as clearly as possible. This is commonly done using tables and or figures, in which the author, via the text, illustrates the important effects by referring the reader to the table or figure concerned and, if necessary, offers further explanation. Make a systematic, logical and helpful subdivision of the results chapter into sections.

Whether to present the results in figure or table form largely depends on the nature of the numerical data. The advantage of a figure is that it is usually easy to interpret. It is essential in a research report, that when the experimental results are presented in a figure, the original data are mentioned in a table in an appendix. This is necessary because the results of this experiment are more likely going to be published with the results of other trials in a trade journal or in a scientific journal.

Discussion

The discussion is usually the most difficult part of the report, because you tend to focus on the results section and don't know what to add in the discussion. You must be able to comment your own research results. What are the limitations of the experimental method used? What is the general validity of the experimental results and how do they compare with what is known already? Do the results agree with those of other reports or do they contradict them? Is there an explanation why these results agree or not agree with previous work? Are there theories to be considered to explain why the observed phenomena or processes occur? Take care: the discussion is certainly not a repeat of the experimental results, but is a critical assessment which should be kept short.

The following are the major items to be treated in the discussion

- The achievement of the aim. Tell if and to what extent your aim was achieved and show from which data the reader can conclude that. Compare with literature. Don't be discouraged when your results were not like expected. This is also extremely important.
- The explanation of your findings. Couple the most important findings with other parameters observed (e.g. explain yield from light interception etc.) and knowledge from literature.
- Implications. Tell what the findings mean for the research field and practice (your background problem in the introduction).

Conclusions

The results and the discussion lead to one or more conclusions that can be drawn from the research. Try to summarize them in a few concise sentences. An even better idea is to list them step-by-step.

Recommendations for further research
Sometimes recommendations for further research can be suggested in a separate chapter.

References
Alphabetical list (of authors' names) of all the sources of literature used in the report (books, articles from journals, proceedings of congresses, etc.).

Appendices
Appendices should include the experimental lay-out, information of all further relevant information not yet provided, daily weather data, original experimental data, statistical analysis, and the exact data from figures. They may also include drawings and results which are either of too little importance or too detailed to be well presented in the report itself.