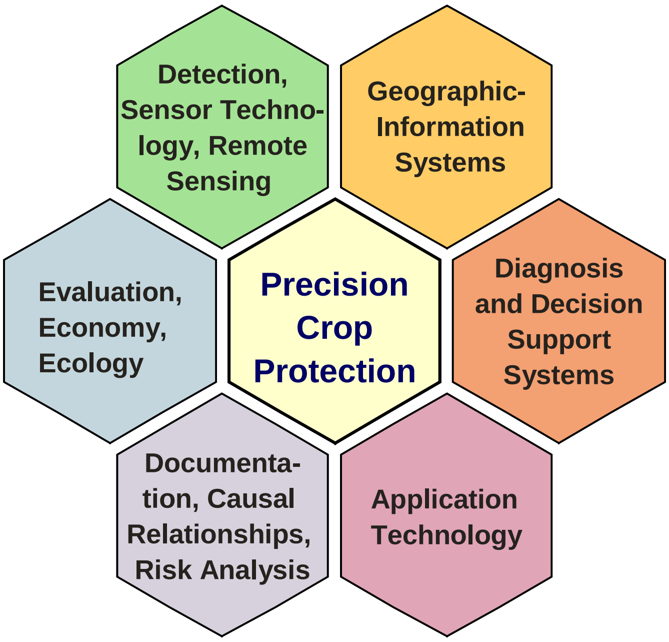
Program

and

Abstracts



2nd Conference on Precision Crop Protection

Bonn – Germany

October 10 – 12, 2007

Events like this are made possible through the financial support of donors, interested in promoting science.

Therefore, we would like to thank the German Research Foundation (DFG) for their generous support.

Timetable

Wednesday, October 10

17:00 – 19:00 Arrival and Registration

19:00 Welcome Reception

Thursday, October 11

9:00 Introduction

9:05 Welcome addresses: **Dr. Sebastian Granderath** (German Research Foundation, Bonn)
RD'in Dr. Karola Schorn (Federal Ministry for Nutrition, Agriculture and Consumer Protection, Bonn)
Prof. Dr. Jens Léon (University of Bonn, Agricultural Faculty)

9:20 **John Stafford** (Silsoe, UK): *A brief history of Precision Agriculture*

9:50 **Karl-Heinz Dammer** (Potsdam, GER): *Sensing plant parameters and variable rate fungicide and herbicide spraying in real time*

10:10 **John Heap** (Adelaide, AUS): *A spatial approach to managing soilborne diseases in Australia*

10:30 Coffee break

11:00 **Remote Sensing and Image Analysis**

Steven de Jong (Utrecht, NED): *Hyperspectral earth observation of vegetation and crops*

11:30 **Therese W. Berge** (Aas, NOR): *Evaluating an image analysis software as a decision tool for on/off patch spraying against broadleaved weeds in cereals*

11:50 **Martin Weis** (Hohenheim, GER): *Automatic weed recognition with image analysis and clustering approaches*

12:10 **Uwe Rascher** (Juelich, GER): Spatio-temporal variations of photosynthesis The potential of optical remote sensing to understand and scale light use efficiency and stresses of plant ecosystems

12:30 Lunch break

14:00 **Poster presentations**

15:30 Coffee break

16:00 **Sensing and Control of Weeds**

Roland Gerhards (Hohenheim, GER): *Managing weeds with respect to their spatial and temporal heterogeneity*

16:30 **Peter Schulze Lammers** (Bonn, GER): *Robotic weed control of the intra-row area in row crops*

16:50 **Anita Dille** (Manhattan, USA): *Variable rate application technologies for weed management*

17:10 **Carina Ritter** (Hohenheim, GER): *Can short-term gains in site-specific weed management be sustained over multiple years?*

18:00 Meeting of the EWRS Working Group *Site-Specific Weed Management* (Chairman Svend Christensen)

20:00 **Conference dinner**

FRIDAY, OCTOBER 12

8:30 **Sensing and Control of Diseases and Pests**

Forrest W. Nutter (Ames, USA): *Satellite imagery and precision disease control*

9:00 **Kerstin Groell** (Hohenheim, GER): *Spatial dispersal of plant diseases*

9:20 **Jan Kuckenberg** (Bonn, GER): *Monitoring nitrogen deficiency,* Puccinia recondita *and* Blumeria graminis *infections at leaf and canopy levels in wheat by laser-induced fluorescence*

9:40 **Cédric Bravo** (Leuven, BEL*): Crop sensing for site-specific protection in winter wheat*

10:00 **Manfred Stoll** (Geisenheim, GER): *Exploring the sensitivity of thermal imaging for* Plasmopara viticola *pathogen detection in grapevines under different water status*

10:20 Coffee break

10:50 **Mapping of Soil and Pests**

Harry Vereecken (Juelich, GER): *Non-Invasive methods in terrestrial research*

11:20 **Franz-Michael Mertens** (Bonn, GER): *On the importance of a local calibration for the interpretation of ECa data*

11:40 **Haddish Melakeberhan** (East Lansing, USA): *Spatio-temporal analysis of soil conditions and site-specific management of nematodes*

12:00 **Volker Kuehnhold** (Bonn, GER): *Spatial variability of crown-rot symptoms caused by the stem nematode* Ditylenchus dispsaci *on sugar beet and implications for control*

12:20 **Ludger Bornemann** (Bonn, GER): *Fast estimation of multiple soil parameters employing mid-infrared (MIR) spectroscopy*

12:40 Lunch break

13:40 **Application Technologies**

Svend Christensen (Odense, DEN): *Spraying robots in crops*

14:10 **Florian Schölderle** (Bonn, GER): *Functionality of a position-steered seed deposition against an agricultural background*

14:30 **Chung-Kee Yeh** (Taipei, TPE): *Actual tests of a variable-rate spraying system on a GPS-guided boom sprayer*

14:50 **Jan van de Zande** (Wageningen, NED): *Use-reduction of plant protection products using a canopy density spray system in bed grown crops*

15:10 Coffee break

15:40 **Mieke de Schampheleire** (Ghent, BEL): *Pesticide spray drift is affected by physicochemical properties of the spray liquid*

16:00 **Thorsten Krämer** (Bonn, GER): *Improving deposit characteristics and biological efficacy of glyphosate on easy- and difficult-to-wet weed species*

16:20 **Jiri Vondricka** (Bonn, GER): *Study on a mixing process for a real-time controlled direct nozzle injection system*

16:45 Concluding remarks and farewell

POSTER PRESENTATIONS

Sensing and Control of Pests and Weeds

1. **Dicke, Dominik**, Krohmann, P. (Bonn, GER): *Dynamics of weed populations under the influence of site-specific weed control - a 10 years study*
2. **Farouk, Mohamed Ahmed** (Sadat City, EGY): *Monitoring insect pests distributions in peach orchards during fruiting season*
3. **Franke, Jonas**, Menz, G. (Bonn, GER): *Comparison of multi- and hyperspectral remote sensing data for early disease detection*
4. **Ferrari, Alessandro**, Pertot, I. (Trento, ITA): *Perspective of biosensors use in greenhouse pest management*
5. **Graeff-Hönninger, Simone** (Hohenheim, GER*): Use of uninhabited aerial vehicles (UAVs) to detect plant diseases in winter wheat*
6. **Hamouz, Pavel** (Prague, CZE): *The saving potential of site specific weed management in winter cereals*
7. **Klem, Karel** (Kromeriz, CZE): *Weed detection using chlorophyll fluorescence imaging and artificial neural network*
8. **Kluge, Alexander**, Nordmeyer, H. (Braunschweig, GER): *Recognition of weeds with digital image analysis*
9. **Orlovska, G.M**., Shevchenko, T.P., Petrenko, S.M., Boyko, A.L. (Kyiv, UKR): *Mixed viral infection in sunflower plants*
10. **Stenzel, Irene** (Bonn, GER): *Incidence and spatial distribution of foliar sugar beet diseases assessed by digital infrared thermography*
11. **Zafari, Doustmorad**, Mohamadi, R. (Hamedan, IRI): *Anastomosis groups identity and virulence of* Rhizoctonia solani *isolates collected from potato in Iran*

Mapping of Soil and Pests

12. **Denzer, Heinrich,** Pessl, G. (Weiz, AUT): *FieldClimate.com Integrating agricultural field monitoring, irrigation and climate control and gives traceability to growers, packers, buyers and investors*
13. **Koleczek, Britta**, Amerlung, W., Welp, G. (Bonn, GER): *Characterizing the spatial variability of SOM, nitrogen and texture in arable soils of a water protection area around Cologne, Germany*
14. **Schlang, Norbert**, Steiner, U., Dehne, H.-W., Oerke, E.-C. (Bonn, GER): *Spatial distribution of Fusarium head blight in wheat fields*

Decision Support Systems

15. **Fratton, Stefano**, Tizianel, A., Pertot, I., Shtienberg, D. (Trento, ITA): *Development and evaluation of a decision support system (SafeBerry) to optimise treatments against strawberry powdery mildew*
16. **Ghosh, Sunil** (Cooch-Behar, IND): *Seasonal fluctuation in the population of Leucinodes orbonalis Guen. under the sub-himalayan region of West Bengal, India and its control on eggplant (Solanum melongena L.)*
17. **Kambrekar, Demanna Nagappa**, Kulkarni, K.A., Giraddi, R.S., Kulkarni, J.H., Fakrudin, B. (Dharwad, IND): *Management of chickpea pod borer,* Helicoverpa armigera *through nuclear polyhedral virus (HaNPV) isolates*
18. **Khodakaramian, Gholam** (Hamedan, IRI): *Identification and activity of potato rhizosphere fluorescent pseudomonads to control of potato soft rot disease under field condition*
19. **Nordmeyer, Henning** (Braunschweig, GER): *The potential of herbicide reduction in site-specific weed control*

Application Technologies

20. **De Schampheleire, Mieke**, Khachan Cano, C., de Backer, E. (Ghent, BEL): *Volatilisation chamber experiments to measure evaporation drift of pesticides from canopy surfaces*
21. **Lund, Ivar** (Aarhus, DEN): *Dynamic behaviour and biological efficacy of single herbicide droplets*
22. **Solovchenko, Alexei** (Moscow, RUS): *Reflectance-based techniques for non-destructive assay of skin flavonoids in apple fruits*

Oral presentations (in chronologic order)

Stafford, John V.

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A Brief History of Precision Agriculture

Keynote presentation

The historians amongst you may consider that precision agriculture started many centuries ago. Indeed, there are references in the writings of the early Jewish fathers to variable application of water to crops! However, 'modern' precision agriculture owes its origins to the vision of two scientists. Bob Schafer and his group at the National Tillage Machinery Laboratory in Auburn, Alabama, USA, developed their concept of 'custom-prescribed tillage' in the early '80s whilst Pierre Robert pioneered 'farming by the foot' in Minnesota, USA from the '80s through to his untimely death in 2003. Precision agriculture was high-profiled through the '90s by the very successful biennial conferences organised by Pierre Robert in Minneapolis and then by the European conference series that I initiated in 1997. Researchers have had their own scientific journal, Precision Agriculture, since 1999 again initiated by Pierre Robert and jointly edited with myself.

The enabling technology for precision agriculture has, of course, been GPS. It is a technology that was barely known in the civilian sector when we started using it for infield location at Silsoe Research Institute in the early '90s but is now ubiquitous. Its pivotal role in precision agriculture has been enhanced in recent years by the widespread take-up of automatic guidance – 'autosteer' – and will be further enhanced as the European 'Galileo' system comes on stream from next year. Although technology was the driving force, the precision agriculture 'umbrella' includes many disciplines such as soil physics, agronomy, crop science, remote sensing and information management.

Precision agriculture has been shown to give economic benefits and – qualitatively – environmental benefits and has been implemented for yield and soil mapping, fertiliser and herbicide application, individual plant management and precision guidance. However, it has yet to make significant inroads into site-specific pest and disease control where online detection may be difficult and accepted management practices conflict with the concept of spatially variable control. This conference should help to advance this aspect of precision agriculture.

Dammer, Karl-Heinz

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Sensing Plant Parameters and Variable Rate Fungicide and Herbicide Spraying in Real Time

Oral presentation

Real-time technology was developed and tested to variably apply herbicides and fungicides. An important step towards application of variable herbicide and fungicide rates is the development of online sensors for detecting plant parameters.

The sensor signal of the CROP-Meter (real-time sensor to measure crop biomass density) is correlated with the Leaf Area Index, a measurement characterising the plant surface and used for variable rate fungicide spraying in cereals. In eleven field trials, average fungicide savings of 22 % were achieved. Field scale strip trials were conducted with the sensor-operated field sprayer to analyse the yield and disease response of the crop. There was no higher disease occurrence and no yield reduction using the sensor controlled spraying technology.

In a winter wheat long term trial (5 years, 50 ha) at the “Landwirtschaftliche Produktivgenossenschaft e.G. Dabrun” yield, disease and economic effects of a CROP-Meter controlled fungicide application was investigated. In average 23.3 % fungicides were saved (7.26 €/ha) without a yield reduction. Due to a higher area performance of a CROP-Meter controlled field sprayer (fewer filling times) machine costs could be reduced (5.00 €/ha). After 5 years a yield of 73.48 dt/ha was obtained. There was no higher disease occurrence in areas with reduced application amount.

In the case of variable rate herbicide spraying the field sprayer was controlled by a weed sensor. Trials were conducted in farmers fields of cereal and pea. The aim was to quantify the influence of the real-time application of variable herbicide rates on the amount of herbicides used, yield and late weed infestation. In 13 field trials average herbicide savings of 25.6 % were achieved (cereals: 22.8 %, pea: 27.9 %). Compared with conventional application on average no yield reduction was caused by sensor-based herbicide application. When late weed infestation was checked shortly before harvest, no differences in weed density were observed between areas with reduced and areas with standard dosage.

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A Spatial Approach to Managing Soilborne Diseases in Australia

Oral presentation

Soilborne diseases cause significant yield losses in cereal crops, and their management often influences crop rotations. In Australia a commercial soil test has been developed to simultaneously measure inoculum DNA levels for many significant pathogens including cereal cyst nematode (*Heterodera avenae*), Fusarium crown rot of cereals (*Fusarium psuedograminearum and F. culmorum*), *Rhizoctonia solani* AG-8, root lesion nematodes (*Pratylenchus neglectus* and *Pratylenchus* thornei), and take-all (*Gaeumannomyces graminis*) var. *tritici* (Ggt) and var. *avenae* (Gga). A range of additional tests is currently under development.

Research using the soil inoculum DNA tests has shown that pathogen inoculum levels frequently differ between Precision Agriculture (PA) zones within paddocks. A range of spatial data layers were evaluated for usefulness in creating zones to segregate inoculum levels within paddocks, using a Partion Index (PI). Some layers were better suited to specific pathogens, but overall proximally-sensed and remotely-sensed layers were equally useful. Field plot fumigation research with cereals showed correlations between pre-sowing inoculum levels and root damage, but yield losses were not always well predicted. There was some evidence of differential damage per unit of inoculum between zones, but this was difficult to predict. Population levels of some micro-organisms, thought to be involved with suppression of soilborne diseases, were also found to differ between zones. This observation has important implications for investigations into beneficial soil biota.

Crop managers are encouraged to construct management zones within paddocks, test for levels of soilborne disease inoculum within zones, assume that damage per unit inoculum is constant between zones, and to implement appropriate VRT management strategies taking account of the yield potential for each zone. A prototype model for management of cereal cyst nematode (*Heterodera avenae*) is discussed. The model makes predictions for a number of PA zones within a paddock over several seasons, and incorporates initial population, multiplication rate, and grain yield loss.

De Jong, Steven M.

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Hyperspectral Earth Observation of Vegetation and Crops: Possibilities and Constraints

Keynote presentation

Hyperspectral remote sensing (or imaging spectrometry) refers to the registration of reflected sunlight in many, narrow spectral bands in the visible and near infrared part (400 to 2500 nm) of the electromagnetic spectrum. The first experiments with airborne imaging spectrometers were conducted in the United States in the late eighties by NASA and by the US Geological Survey. It was developed as a more quantitative remote sensing method to measure the components of the earth surface compared to the traditional low spectral and spatial resolution Landsat MSS and TM sensor systems. Important progress in image quality and in signal-to-noise of the spectra is achieved during the last 15 years. The many studies carried out in the field of hyperspectral remote sensing has significantly increased our understanding of the information content of the spectra. In the early days of imaging spectrometry emphasis was put on mineral and rock mapping. In a later stage other disciplines became interested in the applied use of hyperspectral remote sensing such as plant ecology, biomass and leaf area index mapping, crop monitoring, forest monitoring, water quality mapping, snow and ice hydrology, atmospheric vapour and aerosol mapping etc. Current operational airborne spectrometers are AVIRIS (NASA), HyMap (HyVista/DLR) and CASI (ITRES) while Germany is preparing the first true spaceborne spectrometer (EnMAP).

The physical basis of imaging spectrometry is that electromagnetic radiance (light) interacts with objects at the earth surface. Different molecular structures cause unique absorption bands in the reflectance spectra due to vibrational processes of atoms and due to electronic transitions of electrons. By analyzing these spectra in the images we are able to extract information on which objects are presented at the earth surface and to derive information about their status. Applications of imaging spectrometry for vegetation are found in biomass mapping, stress mapping, nitrogen mapping but also in mapping soil variability (iron content, clay mineral content). A wide range of algorithms is developed over the years to extract information from imagery such as the Red Edge position algorithms (REP), Spectral Angle Mapper (SAM) and Cross Correlogram Spectral Matching (CCSM).

New directions of research focus on the integrated analysis of spatial and spectral information in hyperspectral images. The pixel used to register reflectance is an artificial square put over the landscape without accounting for any spatial patterns that might exist. Object-based segmentation of images enables us to account for spatial patterns that exist in the landscape or within agricultural fields. The combined analysis of spatial patterns and best spectral wavelength position may yield improved mapping results compared to traditional ways of mapping.

During the presentation we will look at the basics of hyperspectral remote sensing, a selected number of analytical techniques, a number of case studies and future trends in the technology, image analysis and applications.

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Automated Weed Detection Using Digital Images as a Decision Tool for Site-Specific Weed Control in Cereals

Oral presentation

In order to implement site-specific weed control in cereals, a decision algorithm based on robust automatic image analysis to control spray decisions, i.e. either simply 'spray/no spray' or variable herbicide doses, is needed. Present work evaluated a prototype of the software *"WeedFinder"*, intended as a tool for automatic assessment of broad-leaved weedlings within cereals.

Images (0.27 m^2) were acquired near-ground by a digital pocket camera (Nikon Coolpix 5400) at the time for post-emergence herbicide treatment in two winter wheat fields. The user-adjustable parameters in *"WeedFinder"* were optimized during a sensitivity analysis. *"WeedFinder"* included a green/red ratio to segment vegetation (weeds and cereals) from background, and size and shape features of the vegetation to differentiate between crop and broadleaved weeds. Outputs were six weed and crop variables: number of broadleaved weedlings m^{-2}, "free" weedlings m^{-2}, "occluded" weedlings m^{-2}, vegetation ground coverage (proportion of pixels in the image covered by vegetation), weed ground coverage and cereal ground coverage.

Generally, the software over–estimated low weed infestation levels and under-estimated high weed infestation levels. Average correlation (Pearson's correlation coefficient) between *"WeedFinder"* and manual assessments on digital displays of the images were 0.837 (weed density) and 0.688 (weed ground coverage). Since a 'spray/no spray' approach was the intended application, the following threshold criteria - and values were used to classify images into 'spray': **criterion 1** (= total number of broadleaved weeds) > 175 plants m^{-2} (original threshold), > 130 (25% reduced threshold), > 220 plants m^{-2} (25% increased threshold), or **criterion 2** (= weed ground coverage / crop ground coverage) > 0.2.

Two classification methods to translate *"WeedFinder"* outputs into spray decisions were tested: either using the threshold criteria as a simple look-up table (**method 1**) or discriminant analysis (**method 2**). For method 1 the rates of correct classification into 'spray'/'no spray' decisions were 65-85%, depending on threshold level and - criteria included. With method 2, rates were better: 84-90%, depending on threshold level (only criterion 1 applied).

Although *"WeedFinder"* showed clear weaknesses, e.g. cereal-weed segmentation mainly based on size, it gave rather surprisingly high level of correct spray decisions (up to 90%).

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Automatic Weed Recognition with Image Analysis and Clustering Approaches

Oral presentation

Weed scouting is a prerequisite for site specific herbicide treatment. Since manual scouting methods are time and cost intensive, automatic measurement methods can lead to a reduction of costs.

The automatic recognition of weed types and density was achieved using bi-spectral images of red and infrared reflection on the field. Image processing and classification was used to differentiate between weed and crop species. After binarisation and noise filtering shape features are derived from the objects in the image. Classification of plants in natural environment is a difficult task, because their appearance changes continuously over different phenological stages. Additionally the segmentation process extracts incomplete and overlapped objects. This leads to high variations within the classes of interest. These variations are addressed by using an adapted classification scheme for multimodal distributed classes.

An image database with prototypes was built up and a total of 111 features were calculated for every object. The database can be used to train classifiers and adapt them to the situation in the field. Clustering approaches were used to establish a fully automated classification procedure with training images. A refinement of the training set for a given image sequence and the generation of database prototypes can be achieved with the results. The clustering results were also used to identify classes with similar feature sets.

The classification result was translated into weed infestation maps. These maps are the basis for the generation of application maps for the site-specific application of herbicides. The image processing and classification was applied to an image series taken in a *Beta vulgaris* field in April 2007.

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Spatio-Temporal Variations of Photosynthesis The Potential of Optical Remote Sensing to Better Understand and Scale Light Use Efficiency and Stresses of Plant Ecosystems

Oral presentation

Light use efficiency of photosynthesis dynamically adapts to environmental factors, which lead to complex spatio-temporal variations of photosynthesis on various scales from the leaf to the canopy level. These spatio-temporal pattern formations do not only help to understand the regulatory properties of photosynthesis, but may also have an constructive role in maintaining stability in metabolic pathways and during development.

Optical remote sensing techniques often failed to quantify photosynthetic light use efficiency within this fluctuating mosaic. In this presentation we summarize the results from several remote sensing projects for their potential to quantify light use efficiency from the level of single leaves to the canopy scale. The potential monitoring the fluorescence signal of chlorophyll by either active, laser induced or passive methods from a distance will be reviewed.

The need to scale leaf-level physiology to ecosystem responses and climate feedbacks has been emphasized recently in the context of global climate change research. During this scaling process a canopy is often regarded as a single- or multi-layer “big leaf”, even though natural canopies are complex 3-dimensional structures, exposed to a fluctuating light environment. In a case study the tropical rainforest mesocosm within the Biosphere 2 Laboratory, has been subjected to a series of 4-6-week drought treatments. Drought was attributed to both morphological and physiological responses, including increased leaf fall, reduced maximum photosynthetic electron transport rate at high light intensities, and stomatal closure. In this case study several optical remote sensing approaches were tested and compared to physiological on the leaf measurements, highlighting the potential and the limitations of remote sensing to quantify physiological status of photosynthesis.

Recently the FLuorescence EXplorer (FLEX) mission that proposed to launch a satellite for the global monitoring of steady-state chlorophyll fluorescence in terrestrial vegetation was selected for pre-phase A by European Space Agency (ESA). This method aims for mapping photosynthetic efficiency by quantifying steady state fluorescence in the so called Fraunhofer lines. The scientific background of this approach will be highlighted and first results from European campaigns in which steady state fluorescence was related to photosynthetic status of agricultural systems in Spain and Southern France. Linking these results with ecosystem flux measurements and regional carbon modeling shows the way how direct quantification of photosynthesis may reduce uncertainties to predict plant mediated exchange processes.

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Managing Weeds with Respect to their Spatial and Temporal Heterogeneity

Keynote presentation

Weed populations in arable fields have often been found to be spatially and temporally heterogeneous. This heterogeneity in weed distribution offers great potential for herbicide savings when weed control methods are directed to field sections with high weed infestation levels and no herbicides are applied in areas with no or few weeds. In several studies herbicides were applied site-specifically based on weed distribution maps and economic weed threshold models using GPS-controlled patch sprayers. In those studies, 20 to 70 % of herbicides were saved, efficacy of weed control was equal to conventionally managed fields and weed density in the following years did not increase.

The knowledge on the underlying mechanisms of spatial and temporal aggregation of weed populations is still lacking. This paper analyses if spatial aggregation of weed populations is a results of crop management and site characteristics. It was studied if aggregation is beneficial for weed populations under certain management strategies. Weed population dynamics parameters including emergence, mortality and seed production were assessed both in high density weed patches and at locations with low weed density. It was found that in weed patches a) number of weed seed produced was increased, b) mortality was decreased and c) crop competition was lower than in field section with low weed infestation levels. These findings give evidence for long-term stability of weed patches.

If fitness of weed species is higher in high density patches, weed control strategies need to created and tested that allow to adjust intensity of weed control to weed population density and fitness. So far, only one decision support system for site-specific weed control in winter wheat was developed in Denmark and it was found that efficacy of weed control was highest when weed competition, herbicide efficacy and weed population dynamics were taken into account for weed control decisions. Within the working group of the author a precise application technology for herbicides was developed and tested in field studies over a period of six years that allowed varying herbicide dosage and mixture depending on weed density and weed species composition. This technology is suitable for testing and realizing decision support systems for site-specific weed management.

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Robotic Weed Control of the Intra-Row Area in Row Crops

Oral presentation

As a component of successful non-chemical weed control intra-row weeding shall be considered as a final weed elimination procedure and not as a primary method. Conventional methods for inter-row weed control can handle with approximately 80% of the field area in row crops. However, the weeds occur in the remaining area between (intra-row) and around the crop plants (close-to-crop) have a much bigger impact on the development and yield of the plants.

Online detection of the single plant position and the plant/weed distinction are the bottlenecks of intra-row weeding but concerning the expeditious R&D in this field it is to expect that appropriate systems would be available on the market in near future. In the meantime, construction and adjustment possibilities of implements considering the role of soil properties and mechanics need to be optimised toward universal intra-row weeding tools, which can be used in different plant spacing systems, different plant intra-row distances and growth stages.

A virtual prototype of a system for intra-row weeding imitating the manual hoeing motions under the soil surface has been design. The hoeing tool consists of an arm holder and three or more integrated arms rotating around the horizontal axis above the crop row. Tests and simulations carried out with the virtual prototype have increasingly facilitated the design process and significantly shortened the path from the idea to the prototype. The physical prototype has been realised using servo motor with direct software control providing rotational speed adjustment according to the forward speed of the carrier, intra-row distance between plants and the observed position of the arms.

The presented concept of the intra-row hoeing system can fulfil the requirements; it has sufficient degrees of freedom to allow full adaptation to different crop species, different plant intra-row distances and plant growth stages. In combination with an inter-row hoe or installed on an autonomous vehicle, the developed robotic system could be a solution for accurate and rapid mechanical weed control.

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Variable Rate Application Technologies For Weed Management

Oral presentation

By bringing together information about weed spatial distribution and competitiveness, sprayer application technologies, and economics, we can begin to develop variable rate application (VRA) strategies for weed management. To economically manage weeds and use VRA technologies, there are still a number of challenges. One is to get good information about the spatial distribution of weed populations and second is to ensure that weed populations are not missed during the application process. We have proposed a two-pass system: variable or low rate soil-applied herbicide, followed by a map-based, foliar-applied herbicide in our row-crop systems of Kansas, USA. The objective of this presentation is to describe an approach to deriving an "economically optimal rate" to apply the postemergence herbicides, actual in-field applications, and to describe the equipment challenges and opportunities. Based on weed species, density, and size, potential crop yield loss is determined. From this value, the herbicide rate that reduces weed density and size is determined, and net returns are optimized. We are conducting field studies with eight different herbicide and weed species combinations to investigate the interaction between weed density and herbicide dose. The goal is to develop a generic algorithm for determining the economically optimal rate for use in VRA applications. The derived economically optimal rate may be below-label, however much research has been conducted to document that below-label rates are effective as part of an IWM plan. A VRA sprayer was built from commercially available equipment and tested on 10 different farmer fields. We mixed one concentration of herbicide product in the tank and changed our rates by changing the output volume applied in each grid cell. Several equipment and application challenges were identified and modifications were made. Overall, this commercial pressure-based VRA spray system was used successfully, but current studies include the use of pulse-width modulated nozzles to improve VRA of postemergence herbicides while maintaining spray patterns.

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Can Short-Term Gains in Site-Specific Weed Management be Sustained over Multiple Years?

Oral presentation

Over the past years several studies on site specific weed management demonstrated that this practice is reasonable and has been successfully implemented in research experiments, resulting in a significant reduction of herbicide use and environmental benefits. Most of these studies were based on short-term data, but does the profitability of the site-specific weed management remain stable over multiple years? It would be essential to know if the site-specific weed management does lead to an increase in weed density at locations where no herbicides or reduced rates were applied and if high density patches are persistent in density and location overtime. In order to test this long-term effects population dynamics of blackgrass (*Alopecurus myosuroides* Huds.) managed using site-specific methods were studied in three arable fields at the Bonn University Research Station Dikopshof, in Germany. This eight year dataset, which consists of two full crop rotations, allows examining long-term effects. Weed seedling emergence was assessed prior to post-emergence herbicide application from 1999 until 2006 in a crop rotation of winter wheat, winter barley, maize and sugar beet. The herbicides were applied with a DGPS-controlled patch sprayer based on weed distribution and density maps. The weed control thresholds were made based on an economic weed control threshold model and varied depending on field crop, weed infestation and weather conditions. The experimental fields were divided in 7.5 x 7.5 m pixels, for each pixel the herbicide application decisions were monitored over eight years. Estimation of profitability of the weed management was made on the basis of the weed control thresholds that were compared to previous years: in some pixels the situation remains stable, ameliorated or was getting worse. Out of this data consequences for further decision algorithms for the site-specific weed control could be drawn. In two of the observed fields, the average density of *A. myosuroides* remained stable through the eight years of study and in one field it even decreased. Sugar beet and maize were less competitive than cereals and thus, weed densities in years after sugar beet or maize was always higher. However, site-specific management coupled with competitive cereal grain crops in the rotation provided a buffering effect that reduced weed density. The site specific weed control appears to be effective and sustainable.

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Integrating Remote Sensing, GPS, and GIS Technologies to Manage Plant Diseases and Pests

Keynote presentation

Within the integrated disease/pest management paradigm, crop consultants, agrichemical representatives, and integrated extension workers all provide advice farmers on what strategies and tactics are needed to cost-effectively maintain high crop yield potentials. However, within the precision crop protection paradigm, it is critical that farmers understand that (for most crops), they are actually managing the amount of healthy green leaf area that will directly influence crop yields. To achieve site-specific attainable yields, crops are in a race to produce and maintain healthy green leaf area at a rate that greatly outpaces the rate that plant diseases and pests are removing healthy green leaf area. Remote sensing, GPS, and GIS technologies offer tools that can precisely estimate healthy green leaf area during the growing season, and more importantly, these technologies have tremendous potential to not only to detect crop stress, but to also accurately discriminate among the causes of crop stress. It is our hypothesis that plant diseases/pests remove green leaf area from crop canopies in unique temporal and spatial patterns that can be used to accurately identify (discriminates) the cause(s) of reduced green leaf area within crops. Thus, remote sensing, GPS, and GIS technologies have the capability to monitor crop health, as well as to accurately discriminate among the many biotic and abiotic agents that affect crop health. Example pathosystems will include *Cercospora* leaf blight, soybean rust, soybean cyst nematode, and lightning injury in soybean crops.

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Spatial Dispersal of Plant Diseases

Oral presentation

Today's agriculture is not only confronted with the production of food and animal food, but also with aspects of environmental protection. In today's crop production, there is an increasing pressure to reduce the use of pesticides, to decrease the environmental impact and to lower potential production costs. It is therefore imperative that pesticides are only applied when and where needed. Disease control might be more efficient if disease patches within fields could be identified and fungicides applied only to infected areas. Beside the actual identification of pathogens, spatial dispersion and distribution pattern play a decisive role for pesticide application. Different studies show that plant diseases like powdery mildew or Septoria leaf blotch show a spatial stability and that there is a well-defined connection between site-related factors and the appearance of plant diseases. Factors like surface moisture, surface temperature, leaf wetness duration, which are strongly correlated with differences in soil, leaf area index, micro climate and the supply of the plant with nitrogen, might play a major role in the spatial occurrence of these patterns. Information about the spatial pattern of diseases is important, because it helps to explain the complex dynamics of pathosystems, and may help to design site-specific management strategies for fungicide application. However, only little is known about the spatial dispersion and the distribution patterns of plant diseases especially as the degree of dispersion may change over time, thus giving both temporal and spatial dimensions for consideration in site-specific fungicide strategies.

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Monitoring Nitrogen Deficiency, *Puccinia recondita* and *Blumeria graminis* Infections at Leaf and Canopy Levels in Wheat by Laser-Induced Fluorescence

Oral presentation

Reflectance or laser-induced fluorescence (LIF) techniques enable fast and non-invasive estimation of plant nitrogen status in the field for site specific crop fertilisation. Pathogen infestations, occurring very patchy, could also be managed site specifically. However, only few studies are available on their remote sensing and discrimination from other crop disorders. LIF measurements in leaves under laboratory conditions showed that both nitrogen deficiency and prolonged pathogen infection induce chlorophyll breakdown and increase of F690/F740 ratio. For dark adapted leaves, discrimination of these stress types was possible by estimating spatial heterogeneity of combined fluorescence and reflection indices.

Recently developed MiniVegN fluorescence system (Fritzmeier, Germany) allows assessment of heterogeneities in crop canopies due to multipoint scanning. The objective of the present study was to test, whether high frequency fluorescence detection may enable discrimination of nitrogen deficiency and pathogen infections such as leaf rust (*Puccinia recondita*) and powdery mildew (*Blumeria graminis*) in wheat. The experiment was conducted in a growth chamber under constant environmental conditions. Fluorescence measurements were done in the light at leaf and canopy levels. During leaf measurements, sensor was moved from the middle to the top of leaf lamina. “Canopy fluorescence” was detected by sensor moving in the upper layers of plant rows. In order to estimate the possible sources of canopy heterogeneities, recordings from adaxial and abaxial leaf sides were compared.

Pathogen infections and nitrogen deficiency displayed an increased F690/F740 ratio in comparison to control on both tested levels, confirming our previous results. In all treatments, F690/F740 was tendentiously lower on the abaxial leaf sides. With appearance of first pustules, rust infected plants displayed highest heterogeneity of F690/740 on both leaf and canopy levels. In plants with mildew, the heterogeneity was less evident, probably due to the lower pustule density and/or a slight chlorophyll breakdown. However, at the end of experiment, canopy with severe nitrogen deficiency symptoms showed the same heterogeneity of F690/F740 values as that of rust infected plants.

The results show, that multipoint scanning fluorescence technique reveals spatial differences in fluorescence values at leaf and canopy levels. However, differentiation between nitrogen deficiency and pathogen infection may be difficult to accomplish due to variability of symptoms as induced by these kinds of stresses.

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Crop Sensing for Site-Specific Protection in Winter Wheat

Oral presentation

In order to reduce the effective amounts of fungicide sprayed on wheat fields, a new approach was developed. This method aimed at applying phytopharmaceuticals according to the required dose, observable through the health status of wheat plants. This implies to spray less or nothing on healthy field parts, while infested parts should be covered. The advantage would be double: less environmental loading by chemicals and reduced spraying costs for the field operator.

The objective of this work was to design a system for the contactless detection of foliar diseases. According to literature, there are numerous reasons why a pathogenic infestation of leaves should be detectable. During the development of the infestation, fluorescence imaging offers the possibility of observing a foliar infestation before it is visible by human vision. Disease presence is only detectable by reflection imaging and spectral reflection analysis when it becomes visible for humans. Both fluorescence and light reflection techniques were investigated in this work.

Fluorescence imaging seemed to provide accurate results on the field, but only in darkness. With spectral analysis, the development of yellow rust and leaf blotch could clearly be monitored. The stress caused by a disease was spectrally different from a nutrient deficiency. Field results were similar to the results obtained in greenhouse (same trends) but suffered from additional disturbance. Multi-spectral imaging (red, 620-690nm and NIR, 750-900nm wavebands) was used for indicating the presence of lesions on wheat leaves. Its results were very accurate but disease recognition was impossible.

A disease detection prototype was assembled using multispectral imaging and spectroradiometry. The prototype was mounted on a 15m spray boom. The multispectral camera was much more accurate than the spectroradiometer. The addition of the radiometer to the camera provided a small but substantial improvement of the disease detection efficiency. Using the prototype it was possible to reconstruct a disease presence map of the investigated field.

Finally a complete set of software tools is presented for providing the field operator a spray command map, indicating the field parts where to spray necessarily.

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Exploring the Sensitivity of Thermal Imaging for *Plasmopara viticola* Pathogen Detection in Grapevines under Different Water Status

Oral presentation

Spatial variability of leaf temperature was studied after inoculating grapevine leaves (*Vitis vinifera* cv. Riesling) with a fungal pathogen (*Plasmopara viticola*). Stomatal conductance measured by leaf gas-exchange and thermal imagery of infected leaves was compared under (a) biotic stress due to the pathogen and (b) different plant water status. The resolution of infrared measurements is evaluated and results of using this approach in a greenhouse study on grapevine leaves are presented. The high sensitivity of leaf temperature to stomatal conductance means that infrared thermography can be used to monitor irregularities in temperature distribution caused by the plant-pathogen interaction or other stress-related changes affecting the amount of water transpired. Instead of using the maximum temperature difference of inoculated and non-inoculated parts of the leaves, the frequency distribution of temperature obtained along a line has been analysed. There were clear differences in the temperature variability between the treatments. The frequency distribution of temperature successfully distinguished between designated areas of inoculated and non-inoculated positions of the leaf and between irrigated and non-irrigated plants. Furthermore, this approach allows the semi-automated analysis of leaf temperature. The paper describes the advantages of using infrared thermography to detect leaf pathogens at an early stage of development. The grapevine leaf can be adversely affected well before visible symptoms become evident. Thus, early and remote detection using thermal imagery has the potential for adoption in disease forecasting or pre-symptomatic diagnosis of biotic stress.

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Non-Invasive Methods in Terrestrial Research

Keynote presentation

Soils and groundwater systems are important natural resources sustaining life on earth. In the last century, the enormous expansion of industrial and agricultural activities has lead to an increased environmental pressure on these compartments. Especially soils are extremely important because they are an important regulator for our water resources and they sustain food production for humanity. Agricultural activities consume nearly 80% of the fresh water used throughout the world, and the majority of this water is used for irrigation. Irrigation of cropland has greatly increased food production, but has also had some drawbacks due to the amount of water that is being drawn from aquifers. Some of the major problems related with irrigation are excessive leaching of nutrients and pesticides, depletion of underground aquifers, ground subsidence, and soil salinization. As safe and effective use of soils and the deeper subsurface environment is a major challenge facing our society, there is a great need to improve our understanding of these compartments. In this respect, non-invasive methods such as remote sensing techniques and hydro-geophysical methods can contribute in a significant manner. In the last years, increased attention is given to the use of geophysical methods to derive parameters and state variables characterizing especially soils and surface near groundwater systems. Research in this direction is mainly driven by the fact that remote sensing techniques and geophysical methods allow continuous mapping in space and time of electro-magnetic properties which can be transferred to parameters or variables characterizing soil systems. In this lecture we will present different non-invasive measurement techniques that can be used to quantify soil parameters and variables from the pore to the regional scale. Specific attention will be given on the characterization of soil hydrological parameters and variables (e.g. hydraulic conductivity, soil moisture content and bulk electrical conductivity) using passive microwave and radar technologies, electrical resistivity tomography, spectral induced polarization and MRI-methods.

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On the Importance of a Local Calibration for the Interpretation of EC_a Data

Oral presentation

The apparent electrical conductivity (EC_a) of soils is increasingly used for precision farming purposes. It can be determined with EM38 (Geonics, Canada), a non invasive sensor working with a transmitting and a receiver coil and operating at a frequency of 14.6 kHz. In combination with a datalogger and a GPS receiver it is possible to measure about 6 ha per hour with about 430 points per ha. The sensor is already commercially in use. Nonetheless, in agricultural practice data are often used without adequate ground truth information on soil properties which are needed for a local calibration.

At several test fields with a high variability in soil texture and layering, we measured the EC_a with EM38. Additionally, the fields were conventionally mapped by drilling cores to a depth of 2 meters.

The measurement of the same field at several times offered different values of the EC_a, but the spatial patterns were similar at all times. The EC_a data of all fields revealed – as expected - a positive correlation with the clay content. But, if the EC_a data were calibrated for each field separately, the equations of the regression differed widely. Moreover, the coefficients of determination improved markedly when different fields were separately examined. For the silt and sand content, no general correlation could be found. Anyway, a local calibration offered significant correlations at some fields. Besides, with local calibration we found significant correlations between the thickness of the uppermost layer (loess over sandy-gravelly fluvial sediments and clayey weathered trachyte tuff, respectively), although the EM38 signal delivers *per se* no depth information.

Our studies indicate that there are no general algorithms to predict soil properties from the EC_a measured with the EM38. Therefore, the measurement of the EC_a can not substitute conventional soil mapping. But a local calibration with Ground Truth data allows to predict different soil properties with a very high spatial resolution. By combining EC_a measurements and conventional drilling, high resolution soil maps can be created with reduced costs and time. Such maps can be an important input for the precision crop protection concept.

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Spatio-Temporal Analysis of Soil Conditions and Site-Specific Management of Nematodes

Oral presentation

In the chemical-friendly era and in crops that can justify the cost-benefit analysis, it may have been easy to apply nematicides to manage nematodes and other yield-limiting biotic factors, and fertilizers, to overcome nutrient deficiency. In the process, the soil conditions changed and the environmental problems felt beyond the locations of applications. Consequently, the increasing pesticide and other soil input use restrictions driven by soil-, animal-, and ecosystem-health concerns have brought many challenges that transcend nematode management. When finding solutions to the restrictions, however, balancing technology, disciplinary and cross-disciplinary gaps, and satisfying human beings highly variable needs are critical. For example, site-specific (precision) management (SSM) has potential for application in managing nematodes and soil conditions in environmentally meaningful ways. Successful application of SSM, however, may be dependent on how agronomically, biologically, and ecologically integrated the plan in question is. Otherwise, SSM risks falling into the "Tried but did not last" category. With this background and in addition to describing the concepts and principles of SSM, this presentation will discuss the following three points: 1) Case studies of spatio-temporal analysis of soil conditions, yield and selected plant-parasitic nematodes in managed ecosystems. 2) Examine the relationship between integrated approach to soil fertility management and SSM leading towards potentially sustainable production systems. 3) Examine potential application of SSM lessons learned in managed ecosystems to natural ecosystems.

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Spatial Variability of Crown-Rot Symptoms Caused by the Stem Nematode *Ditylenchus dipsaci* on Sugar Beet and Implications for Control

Oral presentation

The stem nematode *Ditylenchus dipsaci* is a major concern in German and other European sugar beet production areas where it causes severe damage. Since no effective control measures are presently available, it is essential to understand the occurrence, distribution and local spread of this parasite within fields. The crown-rot symptoms of two infested fields were recorded in autumn 2006 using a GPS-linked digital camera. The symptoms were rated visually by indexing tuber-rot intensity at soil level following removal of foliage. The data obtained was analyzed using the SADIE software to detect clustering and the size of detectable clusters. The results obtained demonstrated that symptoms caused by *D. dipsaci* occur in clusters. The index of aggregation (I_a) was 1.77 and 1.88 respectively if the crown-rot of individual beets were taken into account. This indicates a strong aggregation of infested beets. When the index was applied to every second beet, the I_a decreased to 1.24 and 1.38 respectively indicating weaker clustering. All further reductions in number of beets sampled led to an I_a close to one, indicating random distribution of the observed symptoms. Our results showed that the cluster size of the tuber-rot symptoms is too small for site specific nematode management. Therefore, control measures for this nematode pest need to be applied to the entire field once infestations are detected.

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Fast Estimation of Multiple Soil Parameters Employing Mid-Infrared (MIR) Spectroscopy

Oral Presentation

On the field scale, soils are expressing large spatial and temporal heterogeneity, thereby crucially influencing plant-growth. Detailed information on soil parameters in adequate spatial and temporal resolution is a prerequisite for the effective application of site specific crop protection management practices.

Classical lab based soil analysis techniques are timely and costly and thus inadequate for the achievement of sufficient datasets for soil-based precision crop protection. In this work we present a combination of MIR-spectroscopy and multivariate data analysis as a fast and cost-effective tool for the estimation of multiple soil parameters.

MIR-spectroscopy is a minimum-invasive, still lab-based analysis method, where the diffuse reflectance of infrared light from dried, sieved and ground soil samples is measured. As the soil matrix itself is an extremely heterogeneous mixture of manifold molecules, classical methods of quantitative spectra evaluation fail to detect certain soil properties due to overlapping and interfering peaks. We applied partial least squares regression (PLS) in order to reduce the whole spectral information of about 3600 data points down to a couple of so called “Eigenvectors” and their corresponding weights (scores), simultaneously using the information about the soil properties of interest. Outstanding advantages of PLS are its robustness in terms of missing data and spectral noise as well as its immunity to multicollinearity.

Clustering the soil samples after their spectral properties, we put together specially fitted calibration sample sets out of several hundreds of soil samples. That way we are able to predict a number of constitutive soil properties from the MIR-spectra in validation sample sets. Soil properties were including not only total carbon and nitrogen contents, but also operationally defined carbon fractions, as well as texture, Fe-oxides and cation exchange capacity. Coefficients of determination were in each case >0.9 and standard errors of prediction were in some cases better than the standard deviations of the lab methods.

We consider MIR-spectroscopy as an adequate analytical technique for the creation of extensive soil data sets, being appropriate for the use in precision crop protection management systems. In our believe, this novel time- and cost-saving analysis also exhibits potential to replace entire scopes of classical lab-based soil analysis.

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Spraying Robots in Crops

Keynote presentation

Robot technology has been used in the industrial sector for decades and has in the past 10 years also found its way into greenhouses and animal production systems. Robots can take over tasks in the field that require great manual input or more precision operations than conventional machines can handle. For example, it is obvious to use a robot to gather stones or to let a robot control the use of herbicides with great precision. Technically speaking, robot technology is ripe for developing spraying robots to control weeds and, in the long run, other pests.

There is great potential in identifying weeds and limiting herbicide application to those areas where there is a need for weed control. It is necessary to differentiate between three different levels of precision and technology:

- ***Spot sprayer***, where the boom is divided into sections that are controlled by a combined camera-computer system that identifies weed occurrence and the control requirements. The camera-computer system can be mounted on the front of the tractor.
- ***Cell sprayer***, where each individual nozzle is made to spray small units such as 50 cm^2. A camera system is mounted on the boom and identifies the occurrence of weeds in each cell.
- ***Micro sprayer*** is technically speaking, very different from the spot sprayer and the cell sprayer. A micro pump with a high level of precision is used to target the individual plants with a jet. Each plant in the picture is identified and the weed plants are localized with a camera system.

Spot and cell sprayers look like conventional manned sprayers. Micro spraying requires very high precision, both with regard to identifying weed plants and targeting the jet. Such precision cannot be attained at the speeds that are normal for conventional, manned sprayers. The required precision can only be attained with a low speed and are therefore only realistic with an unmanned sprayer.

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Functionality of a Position-Steered Seed Deposition against an Agricultural Background

Oral presentation

Due to their broad effectiveness herbicides are mainly being used for weed control in sugar beet cultivation. Fewer approved substances as well as economical and ecological constraints currently lead to this alternative in order to optimize the attractiveness and efficiency of mechanical hoeing.

This DFG project of position steered seed deposition aims to create longitudinal and diagonal rows with a high accuracy in order to allow a mechanical weed control between and within the seed by this method of square seed. For this a tractor fitted with a hoeing tool is driving lengthwise as well as in right angles across the culture. Therefore it is necessary to distribute the plant spacing of generally 45 x 20 cm (this corresponds to an actual existence of 100.000 plants/ha) equally to e.g. 30 x 30 cm. If heavy machinery must be used, additional tracks have to be created in and across the driving direction.

In order to minimize plant injury, plant destruction or spillage with an at the same time high degree of weed control (effectiveness), 2 cm of plant position accuracy have been determined. This leads to an increasing specification of the position determination of the seed deposition with an accuracy of one centimetre.

For the production of a parallel seed suitable for diagonal drives not only the high deposition accuracy and synchronisation of the drilling unit is necessary but also the one of subsequent drives. Also to be considered should be any unevenness of the field, the exposition and fields which are not equiangular. This clearly shows the relevance of a precise deposition with not only a high relative but also with an absolute positioning accuracy.

As there no are single sensors available that have the reliability and required accuracy of one centimetre over the entire farming period at a speed of about 2 m/s, a multi sensor system consisting of a RTK-GPS receiver, a velocity sensor and a yaw rate sensor and a computer for the collection and processing of data is being used. For the position determination for the steering of the deposition mechanism a real-time and a high frequency analyzing approach will be necessary (Kalman filter). This article will illustrate the a.m. agricultural specifications and the resulting geodetic system functionality requirements

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Actual Tests of a Variable-Rate Spraying System on a GPS-Guided Boom Sprayer

Oral presentation

To meet the requirements in precision agriculture, a self-developed variable-rate spraying system on a boom sprayer that is automatically controlled by GPS (Global Positioning System) is discussed in this study. This system can control the different spraying volumes of pesticide or herbicide with a proportional flow control valve and it can therefore reach a better strategy for the protection of crop and environment by controlling the real-time dynamic position of the sprayer and the return flow of the variable-rate system. In this study, experimental methods are divided into four parts: dynamic simulation, nozzle correction, flow-rate measurement and field test. By using the simulation function of a GPS receiver, the field operation of the boom sprayer can be simulated in laboratory easily and the basic data of the system can be obtained. In order to eliminate some errors resulted from nozzles on the spraying booms, experiments are done several times by correcting these nozzles and it can then obtain an acceptable result. In the flow-rate measurement, the openings of a proportional flow control valve with different pump pressures are tested and various conditions of flow-rate and return flow are also obtained. Finally this boom sprayer is guided by GPS and operated in a paddy field to test its variable-rate system in a real situation. Experimental results show that with five different valve openings of 0%, 18%, 40%, 50% and 100% the flow-rate is linearly proportional to the time after the correction of nozzles. In addition, by field tests of the boom sprayer it is evident that the variable-rate system exhibits a good performance. Keywords: precision agriculture, variable-rate spraying, boom sprayer, GPS

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Use-Reduction of Plant Protection Products Using a Canopy Density Spray System in Bed Grown Crops

Oral presentation

Because of the high inputs of plant protection products of some crops an initiative is started to develop canopy (density) adapted spraying systems. Based on the principle that good crop protection is based on an even distribution on the plant and an equal amount per unit leaf area, smaller crops need a smaller amount of crop protection product than larger ones. The transition of the PreciSpray concept, from the orchard to arable crops, is in progress. A Canopy Density Sprayer (CDS) for bed-grown crops like flower bulbs is under development. This spraying system combines detailed crop information (spectrum analysis) with very accurate application techniques. The system sprays only when there are crop plants under the spraying nozzle(s). When leaves emerge from the soil only the leaves are sprayed: the sprayer operates as a patch sprayer. When the crop develops it forms rows and the CDS becomes a band sprayer. When the crop canopy covers the whole bed, only the bed will be sprayed but not the paths in between. When the crop develops to its maximum height (flowering) spray volume will be adapted to crop height or total leaf area to cover total leaf area uniformly. From intensive crop development studies it can be expected that reductions in agrochemical use vary from 25% in the full-developed canopy to 99% in the initial leaf stage.

First evaluations are performed to compare sensors and variable rate spray techniques to develop a Canopy Density Spray system for bed-grown crops in the laboratory. A prototype is built for outdoor use and first results are presented on use reduction of plant protection products, spray distribution on plants and the soil surface underneath and the biological efficacy in flower bulb growing.

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Pesticide Spray Drift is Affected by the Physicochemical Properties of the Spray Liquid

Oral presentation

Spray drift is defined as the quantity of plant protection product that is deflected out of the treated area by air currents at the moment of spray application. Spray drift is affected by 4 main factors: weather conditions, spray application technique, surrounding characteristics and physicochemical properties of the spray liquid. This research focused on the importance of physicochemical properties (surface tension, viscosity, evaporation rate and density) of spray liquids on drift.

Most researchers, that examined the drift-reducing effects of adjuvants, used solutions of the adjuvant in water, while it is generally known that not the physicochemical properties of the adjuvant itself, but the physicochemical characteristics of the complete spray mixture (pesticide formulation + adjuvant) are drift-determining. In this research, adjuvant/formulation combinations are examined, instead of using an adjuvant/water system.

Pesticide formulations can be subdivided into 5 important classes, according to their chemical composition, physical appearance and physicochemical properties: Emulsifiable Concentrate (EC), Suspension Concentrate (SC), Soluble Liquid (SL), Water Dispersible Granules (WG) and Water Dispersible Powder (WP). 10 pesticide formulations, 2 of each type, were selected to examine: Tilt® & Cytox® (EC), Ronilan SC® & Pyrus 400SC® (SC), Caddy 100SL® & Lannate 20SL® (SL), Euparen Multi® & Chorus® (WG), Paraat® & Kerb 50® (WP). The formulations were examined with and without the addition of the adjuvant Magic Sticker® (polyacrylate + sticking agents).

In a first part, laboratory tests were performed to measure surface tension, viscosity, evaporation rate and density of the spray liquids. Subsequently drift experiments were performed in the wind tunnel of the International Centre for Eremology (I.C.E.) at Ghent University, Belgium.

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Improving Deposit Characteristics and Biological Efficacy of Glyphosate on Easy- and Difficult-To-Wet Weed Species

Oral presentation

In addition to online detection and identification of weed species and the site-specific application of pesticides the reduction of active ingredient per unit of area contributes decisively to the success of precision agriculture. In this context, great advances were made on the basis of better agrochemical formulations and use of tank-mix-adjuvants. A precise adaptation of spray solution characteristics (e.g. by modification of surface tension) to the physicochemical properties of weed surfaces may enhance droplet retention and deposition of active ingredient on the target surface. Hence, the effective potential of herbicidal active ingredients should be further optimized to allow a high biological efficacy after a target-oriented agrochemical application. Previous studies have shown that ethoxylated rapeseed oil (RSO) surfactants can alter spray solution characteristics and biological efficacy of glyphosate, whereas results depended on the ethoxylation degree of the hydrophilic chain. The objective of the current study was to evaluate the influence of spray solution characteristics on the deposit properties and their relation to biological efficacy of glyphosate formulated with a rather lipophilic (RSO 5) or a rather hydrophilic (RSO 60) surfactant. Experiments were conducted with the four weed species *Chenopodium album*, *Setaria viridis*, *Stellaria media*, and *Viola arvensis*, which were evaluated (dry matter) 8-10 days after herbicide application. Moreover, single droplets of the spray solutions were studied in a scanning electron microscope with integrated x-ray microanalysis in order to characterize and quantify the droplet spreading area and the area effectively coated with active ingredient residues. Results showed an increased droplet spreading (glyphosate + RSO 5) up to sixfold for the difficult-to-wet species *C. album* and *S. viridis*, and up to threefold for the easy-to-wet species *S. media* and *V. arvensis*, respectively, in comparison to unformulated glyphosate. RS0 60 enhanced the droplet spreading area twice as much. In addition, both adjuvants induced a more homogenous a.i. distribution on the plant surfaces. Biological efficacy ranged from 30 % (in relation to untreated control; treatment: glyphosate + RSO 5, *S. media*) to 70% (treatment: glyphosate solely, *V. arvensis*). For *S.* viridis and *S. media* the initial droplet spreading area and area of a.i. distribution correlated with biological efficacy.

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Study on a Mixing Process for a Real-Time Controlled Direct Nozzle Injection System

Oral presentation

In a conventional crop sprayer the water-pesticide mixture is prepared in advance. In a direct injection systems (DIS) the carrier and pesticides are maintained in separate containers and the mixture is prepared shortly before the application. Thus the final concentration can be changed “on demand”, if any control system is used. The crucial factor of every DIS is the response time of the system caused by the preparing of the mixture in hydraulic system. In order to control the pesticide application in real-time, the response time has to be significantly reduced. To do so, the distance between the injection point and nozzle orifice has to be minimised. However, the whole homogenising process must be finished, before the mixture enters the nozzle orifice.

The focus of this study was on reducing of the time delay caused by the mixing process by achieving desired mixture homogeneity of CoV 5 %. This mixing time depends indirectly on the flow rate and directly on the mixing chamber volume. Thus the aim of the optimisation is the mixing chamber volume reduction.

Direct nozzle injection system for site-specific pesticide application demands a high-performance mixing process, enabling homogenising of carrier and different injected chemicals in different flow regimes. Using Computer Fluid Dynamics software (CFD) four different mixing configurations (three different static mixers and empty pipe) have been compared. Consequently the results have been experimentally verified.

It has been stated, that the static mixers are suitable for the operation in the direct nozzle injection system. They reduce the mixing time under 100 ms be achieving demanded mixture homogeneity.

Poster presentations (in alphabetic order)

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FieldClimate.com Integrating Agricultural Field Monitoring, Irrigation and Climate Control and Gives Traceability to Growers, Packers, Buyers and Investors

Poster presentation

Actual monitoring devices of METOS are reporting data automatically to the FieldClimate.com web server. Where users build their data management using their climate and soil moisture monitoring, tracking and logistic recorders, tunnel and greenhouse monitors, storage and silo monitors. Multiple accesses from many work places for different purpose and from everywhere in the world is given. Data are maintained and backup is taken. Data used from traceability can be accessed by packers, buyers and investors. Spray diary and crop diaries are hold on this site too. Actuators controlled by SMS can be started and stopped form FieldClimate.com. This control can be automated by making activation or shut off a function of climate or soil moisture data. FieldClimate.com is the central place to manage monitoring and control for farms and gardening. For every individual farm maintained and managed for thousands of farms.

Our traditional market is vine and fruit protection where we offer a range of disease forecast models which are widely used since years. For vegetable growers it offers the possibility to use a wide range of plant disease models for crops like asparagus (*Stemphylium, Puccinia*, *Botrytis*), carrots (*Alternaria, Cercospora, Sclerotinia*), tomatoes (*Phytophthora, Alternaria, Botrytis*), potatoes (*Phytophthora, Alternaria*), strawberries (*Botrytis, Sphaerotheca*). For broadacre crops we offer models for wheat, canola, sunflowers, sugar beets and more. Growers can set up a database with crop stage information and a spray dairy. This data can be linked to climate data and to disease model outputs again. This can help to understand success and problems in plant protection.

The integration of soil moisture sensors, evapotranspiration, a soil water balance model and devices to control irrigation valves from remote are making FieldClimate.com to a virtual irrigation controller. FieldClimate.com offers the possibility for automated irrigation on base of sensor values and ET. This automation can be monitored from everywhere where internet access is given.

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Volatilisation Chamber Experiments to Measure Evaporation Drift of Pesticides from Canopy Surfaces

Poster presentation

Pesticides have many beneficial uses in agriculture areas, and they are extensively used throughout the world. Pesticides can evaporate from crop and soil surfaces, during or after application, and enter into the atmosphere. The rate and extent of the evaporation depend on the crop, the weather conditions (wind speed, temperature, humidity, atmospheric stability), and the physicochemical properties of the pesticide (Henry coefficient).

In this research the influence of the Henry coefficient (H) was examined. 6 pesticides, representative for Belgian farming and with various vapour pressures, were selected: *Trifluralin* & *Endosulfan* (high H), *Lindane* and *Diazinon* (medium H), *Dichlorvos* (low H) and *Metalaxyl-m* (very low H). Evaporation experiments were conducted in a volatilisation chamber (1.2 m length x 1 m height x 0.3 m width). A constant wind was generated with a fan. Temperature and relative humidity were kept constant. Grass boxes (0.25 m x 0.35 m) were sprayed with constant doses of 1 $kg.ha^{-1}$ of following active ingredients: *Trifluralin*, *Endosulfan*, *Lindane*, *Diazinon*, *Dichlorvos* and *Metalaxyl-m*, and placed in the chamber.

The air at the outlet of the chamber was sampled through glass tubes, containing adsorbing Supelco beads (SupelpakTM-2). The glass tubes were connected to a pump, sucking air at a constant rate of 1.2 l/min. Sampling was performed at an interval of 1h, for a total sampling period of 6h. After sampling, the Supelco beads were ultrasonically desorbed in acetone. The acetone fractions were dried over Na_2SO_4 and analysed with GC-MS to determine the exact concentrations of active ingredients.

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Dynamics of Weed Populations under the Influence of Site-specific Weed Control - a 10-Years Study

Poster presentation

In the context of a plant protection product reduction program, the herbicide use in Germany will be more strictly reduced to the extend that is absolutely necessary. With site- specific weed control the amount of herbicides used can be decreased significantly without loosing performance. There has been little research on the question whether or not long term site-specific weed control leads to an increase of weed populations.

Experiments were conducted from 1998-2007 on five arable fields to study dynamics of weed populations under the influence of site-specific weed control. Four fields were sown in a winter wheat, winter barley, maize and sugar beet rotation and one field was sown to continuous maize. A regular 15 * 7.5 m grid was established in all fields. Weed seedling density was counted before and after post-emergent site-specific herbicide application in a 0,4 m² quadrate frame placed at all grid intersection points. A decision algorithm based on weed thresholds was used for patch spraying.

In sugar beet the dominating weed species were *Chenopodium album*, *Fumaria officinalis* and *Viola arvensis*. In maize, major weed species were *Chenopodium album*, *Polygonum arviculare* and *Viola arvensis* and in winter wheat and winter barley *Veronica hederifolia*, *Galium aparine* and *Alopecurus myosuroides* .The major weeds in continuous maize were *Galinsoga parviflora*, *Solanum nigrum* and *Echinochloa crus-galli*.

Site-specific weed control resulted in high herbicide saving rates. For most species, spatial distribution and density of weeds in the rotation fields were very stable over all years. Areas of the field that were not sprayed according to the weed threshold model and areas that received a reduced rate of post-emergent herbicides did not increase in weed seedling populations within the 10 years of study. However, weed seedling density has increased in continuous maize.

All fields of the rotation were ploughed every year, burying weed seeds in deeper soil layers, while continuous maize has been cultivated without ploughing until 2002. So in continuous maize there was no failed germination, indicating that most weed seeds accumulated in the top layer of the soil.

The knowledge of weed seedling populations dynamics can be transferred to fields where Precision Farming has not been practised yet.

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Monitoring Insect Pests Distributions in Peach Orchards during Fruiting Season

Poster presentation

Absence of field infestation records negatively affects the credibility of the Integrated Pest Management (IPM) decision. Consequently, the application of precision agriculture basics was necessary to obtain visual representation of insect distribution counts instead of statistically maintained tabular data. This research was carried out at Al - Mahroosa farm - Gaber Ibnhayan village, 101 Km. Cairo-Alexandria desert road. Data collected on regular weekly investigations of adult counts in a well spatially distributed pattern of 18 pheromone and sticky traps in 15 feddans of Florida peach examined through two successful picking seasons 2005-2006. Obtained data was demonstrated in contour maps of adult presence in the investigated area. The mentioned data showed precisely hot points which require to be treated. One of the benefits of these procedures was the significant reduction of pesticides quantities applied in the orchard.

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Perspective of Biosensors Use in Greenhouse Pest Management

Poster presentation

Greenhouse environment may create favourable conditions to several plant pest and diseases. Pest/pathogen assessment is commonly based on their visual detection or symptom appearance, which causes high monitoring cost. Moreover, when the symptom appears it could be too late to prevent crop losses. Automated biosensors, which can early detect and/or quantify the presence of the pest/pathogen in the greenhouse, could be of strategic importance in the future, both for optimizing treatment schedule and for saving time and money. This review aims at describing the state of art in the field of biosensors and at providing an overview on potential application in greenhouse pest management. A biosensor is a compact analytical device, incorporating a biological or biomimetic recognition element, which interacts with an analyte and responds in a manner that can be detected by a transducer. Biosensors can be classifies by their biorecognition systems: biocatalytic, immunological, and nucleic acid based. In addition, whole microorganisms, insect antennae, animal or plant whole cells, tissue slices or molecular imprinted polymers could be also incorporated in the biosensing system. Depending on the method of signal transduction, biosensors are divided into different groups: electrochemical, optical, thermometric, piezoelectric or magnetic. The attractiveness of biosensors is the high specificity coupled with real time analysis in complex systems. It is well established that biosensors play a significant role in medicine clinical analysis, food/water analysis, environmental monitoring, bio-warfare pathogens, explosive detection and agriculture. Few works describe the use of biosensors for detection and identification of infectious diseases and pests on crops. In addition despite of a great optimism for the potential development of biosensor, there is only little technology transfer from laboratories to commercial application. In order to have market success, the desired biosensor for field application must have low detection level and respond to characteristic of cheapness, rapidity, and continuousness and with long lasting biological (or biomimetic) devices. Moreover, it should produce automatically interpretable results or with limited human input required.

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Comparison of Multi- and Hyperspectral Remote Sensing Data for Early Disease Detection

Poster presentation

The temporal dimension of crop diseases in respect to their sensor-based detection plays a major role in Precision Agriculture. In context of a detection of these phenomena, however, the temporal dimension depends on the spectral resolution of the used remote sensing data because improved spectral resolutions may result in earlier detection of crop stress. In previous studies it could be demonstrated that multispectral data is not suitable for early detection of crop diseases due to their low spectral resolution. In contrast to multispectral sensors, which record reflected radiance in broad spectral bands, hyperspectral sensors are able to collect data in various spectrally narrow and continuous bands. In theory, this allows – in addition to a differentiation of photosynthetic active and non-active material – for a more detailed analysis of the phenological stage and the condition of vegetation. However, the question arises how beneficial hyperspectral data for early disease detection is in comparison to multispectral remote sensing data. The present study was carried out in order to compare the potential of hyperspectral and multispectral remote sensing data for quantification of powdery mildew (*Blumeria graminis*) severity in wheat. Remote sensing data covering a wheat field experiment were acquired by the airborne hyperspectral Mapper (HyMap) on 28 May 2005. The HyMap data was resampled to the spectral characteristics of the multispectral QuickBird sensor, which allows for a direct comparison of multi- and hyperspectral data due to identical image characteristics. A spectral mixture analysis was applied to each data type, in order to estimate the sub-pixel fraction representing a reference spectrum – Powdery mildew infected wheat – that was derived by an optimal endmember selection procedure. A correlation analysis between the abundances and in-field collected powdery mildew severity data (percentage infected leaf area) was performed to validate the results. For hyperspectral data, a positive correlation was found with $r = 0.82$ and $r^2 = 0.67$, whereas for the multispectral data only poor accuracies could be achieved. With these high crop disease detection accuracies for hyperspectral data, even early disease detection seems thus to be possible.

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Development and Evaluation of a Decision Support System (SafeBerry) to Optimise Treatments against Strawberry Powdery Mildew

Poster presentation

Powdery mildew (caused by *Podosphaera aphanis*) is a serious disease of strawberry in warm and dry climates or in greenhouses. The pathogen causes foliar damage but can also infect fruits, especially on susceptible cultivars. Disease control is based on extensive use of chemical fungicides usually applied on a weekly schedule (more than 12 treatment for each growing cycle), but, even with such strict fungicide application program, the control is often unsatisfactory, chemical residues are above the maximum residue level, and environmental impact is high. The purpose of this research is to develop a decision support system (DSS) to optimize fungicide application on strawberry against powdery mildew. The system (SafeBerry) is based on a set of rules which define the infection risk level and on suitable pesticide to existing risk level and plant phenological stage. Nine different strategies (untreated control, two conventional and six strategies suggested by SafeBerry) were tested in four locations in Northern Italy. Strategy SafeBerry6 performed as well as the conventional strategy in controlling powdery mildew in all location, by reducing, in some cases, the number of sprays up to 30%. A web-based version of SafeBerry was also developed.

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Seasonal Fluctuation in the Population of *Leucinodes orbonalis* Guen. under the Sub-Himalayan Region of West Bengal, India and its Control

Poster presentation

Eggplant (*Solanum melongena* L.) is one of the most common, popular and principal vegetable crop grown in India and other parts of the world. *Leucinodes orbonalis* Guen. is the key pest infesting eggplant with international importance causing heavy damage in all eggplant growing areas. It is very difficult to control this pest since it feeds inside the shoot and fruit and there is every possibility to retain toxic residues in the fruits as they are plucked at a frequent interval and are consumed after little cooking. In the sub-himalayan region of West Bengal, India the pest was found to be most active during summer and rainy season particularly during May-August and caused 49.51-80.95% damage to fruits. Peak infestation (80.95% fruit damage) was noticed in the first week of June (22^{nd} standard week) when the mean temperature, mean relative humidity and weekly rainfall were 27.77°C, 79.24% and 81.20 mm respectively. The pest became less active during winter months particularly during December-January. The borer infestation showed significant positive correlation ($p = 0.05$) with maximum and mean temperature, minimum and mean relative humidity and rainfall, whereas, with maximum relative humidity the correlation was negative but non-significant. The insecticides evaluated at field level for *L. orbonalis* control on eggplant revealed that avermectin (Vertimec 1.9 EC; 0.5ml/l) was found relatively more effective for suppression of dead heart caused by the pest, closely followed by *Beauveria bassina* (Bals.) Vuillemin (Biorin 107 conidia/ml; 1ml/l) and Bacillus thuringiensis Berliner (Biolep 5 x 107 spores/ml; 1g/l).Significantly lower level of fruit damage was obtained from avermectin treatment closely followed by DDVP (0.05%) (Nuvan 76 SL; 2ml/3l) against untreated control. Rest of the insecticides, including neem formulation (Neemactin 0.15 EC; 2.5 ml/l) and malathion (0.05%) (Malathion 50 EC; 1.0 ml/l) were less effective. None of the insecticides evaluated produced satisfactory result against *L. orbonalis*. However, avermectin, besides being environmentally safe, was effective for a longer duration and could thus be recommended for Integrated Pest Management programme on eggplant.

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Use of Uninhabited Aerial Vehicles (UAVs) to Detect Plant Diseases in Winter Wheat

Poster presentation

Agriculture incurs significant costs annually in diseases control. Sensor technologies in precision farming lag behind in its use of suitable online-techniques to guide the design and application of strategies and tactics for site-specific disease control. The site-specific management of diseases has been difficult to achieve because suitable sensor tools have not been available and are sparely available yet. On the other hand, existing sensor technologies in the area of e.g. fertilizer management are now widely accepted by scientists and farmers as being valuable tools to help design management strategies and extrapolate these technologies to areas beyond the original purpose. The aim of this project was to foster the development of a suitable, site-specific sensor technology for the detection of plant diseases. Therefore the use of a UAV was evaluated. The UAV is essentially a low cost version of the unmanned drones used for military applications. UAVs might help to provide crop imagery when other technologies cannot. The earliness of disease detection and the possibility of quantification were two major criteria as well as the handling and transferability of the tested techniques to practice.

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The Saving Potential of Site-Specific Weed Management in Winter Cereals

Poster presentation

Weed population occurrence is spatially heterogeneous within the fields. The higher is the variability, the more favourable is the use of precision weed control. Weed mapping was carried out on 3 fields in central Bohemia to characterise the spatial structure and temporal stability of weed populations over six years (1999-2004). A rectangular grid 40 x 40 m was established with the use of GPS along the wheel track lines, a quadrate of 1 m^2 in two replications (i.e. sample area of 2 m^2) was used for identification and counting of all weed species at every grid point. Moreover, *Galium aparine* was sampled over an area of 10 m^2 at each point. Weed mapping was always performed in April, just before post-emergence herbicide application. Application maps were created for each year using Unprog software. Based on damage thresholds and herbicide sensitivity, weed species were divided into four groups and total weed coverage was also taken into account. Three thresholds were defined for every group and assigned to three herbicide doses (60 %, 100 % and 120 % of recommended dose). Following values were used as the lowest thresholds: *G. aparine* - 0.2 plants m^{-2}, *Cirsium arvense* - 0.2 plants m^{-2}, other dicotyledonous 15 plants m^{-2} *Apera spica-venti* - 3 plants m^{-2}, total weed coverage 3 %. For *G. aparine*, the theoretical herbicide savings ranged from 44 % to 92 % depending on field and year. *C. arvense* was present in one field only and herbicide treatment was required on 13 - 23 % of this area. Other dicotyledonous are also distributed patchy and 58 – 97 % of the field area would not be weed-managed. A distinct reduction in herbicide use would have been possible in case of *A. spica-venti*. Theoretical herbicide savings ranged from 82 % to 99 %. Weed coverage was mainly low and underlined large potential of herbicide savings.

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Management of Chickpea Pod Borer, *Helicoverpa armigera* through Nuclear Polyhedral Virus (HaNPV) Isolates

Poster presentation

Baculoviruses are naturally occurring pathogens that are specific to a single or a few related insect species. They are environmentally safe, produce no toxic residues and are harmless to non-target animals including beneficial insects and vertebrates.

Helicoverpa armigera is a major production constraint both in agricultural and horticultural crops. The extent of loss has been estimated to the tune of $ 5 billion on various crops worldwide. In case of chickpea and pigeonpea the estimated loss is about $ 27 million. On the other hand to combat this pest on various crops around $ 1 billion is being invested on insecticides worldwide. Therefore, in addition to the huge losses caused by this pest directly on various crops, there are several losses accruing from the deleterious use of insecticides on environment, human and animal health.

Field evaluation of different HaNPV isolates against *Helicoverpa armigera* (Hubner) in chickpea ecosystem at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad Karnataka India during 2002-03 and 2003-04. Among the various isolates, the performance of HaNPV isolate collected from Gulbarga and Coimbatore was better in terms of their ability in recording higher larval mortality during all the sprays. BPM and PCI isolates recorded least per cent larval mortality as compared to other isolates. The data presented on pod damage revealed the superiority of Gulbarga (11.11%) and Coimbatore isolates (11.88%) in recording lower pod damage. BPM (20.63%) and PCI (21.73%) isolates recorded highest pod damage and on par with each other. However, the treatment with recommended insecticides recorded least per cent pod damage (08.26) as compared to other treatments. Similar trend was found as far the incremental benefit cost ratio (IBCR) is concerned. Gulbarga (2.88) and Coimbatore (2.83) recorded higher IBCR followed by Dharwad isolate (2.39). However, the IBCR in the crop treated with insecticides was highest (5.20) compared to other isolates.

Thus, Coimbatore and Gulbarga isolates of HaNPV which are found virulent against *H. armigera* can be well exploited in the management of the pod borer under field condition on various host crops of *H. armigera*.

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Identification and Activity of Potato Rhizoshphere Fluorescent Pseudomonads to Control of Potato Soft Rot Disease under Field Condition

Poster presentation

Potato soft rot disease caused by *Pectobacterium carotovorum* is one of the devastating potato diseases in all potato growing area in Iran. Potato rhizosphere soil and tubers were collected from three regions with different climate including Hamadan, Damavand and Qasere-Shrin. A total of 96 fluorescent pseudomonad strains were isolated on *Pseudomonas* agar F medium. Results of phenotypic features characterization from 40 representatives showed three species including *Pseudomonas aeruginosa*, *P. putida* and *P. fluorescens* (bv. II, III & IV). Assessment of antagonistic activity of 20 representative strains of these species toward *Pectobacterium carotovorum* the causal agent of potato rot disease indicated that they could inhibit growth of pathogen and significant differences among the strains regarding their antagonistic activity were observed. Application of six selected strains based on the laboratory results in two concentrations to control of potato soft rot disease under field condition showed significant differences among the strains but not between the two applied concentrations. Tested strains could reduce the potato rot disease caused by *P. c*. subsp. *carotovorum* between 2.5 to 38.75 %.

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Weed Detection Using Chlorophyll Fluorescence Imaging and artificial Neural Network

Poster presentation

A new approach to automate the weed identification using specific characteristic features in fluorescence kinetics of individual plant species was examined. We employed the chlorophyll fluorescence imaging technique using an open imaging fluorometer FluorCam. The measurement on *Apera spica-venti*, *Galium aparine*, *Stellaria media*, *Tripleurospermum inodorum* as representatives of weed species and *Triticum aestivum*, *Brassica napus*, *Beta vulgaris*, *Helianthus annus* as crop representatives were made at two different growth stages. The measurement shows high discrimination ability of the method at cotyledons or first leaf (in monocots) stage with decreasing sensitivity by later measurement. To improve the recognition accuracy, we used the artificial neural network classifier, trained on at least 100 plants. The classification rate for discrimination between crops and *G. aparine* ranged from 90 to 100%. In the experiment with discrimination between individual weed species, the discrimination rate ranged between 85 and 100%. Fluorescence imaging combined with artificial neural network represents a feasible alternative in development of automated weed recognition methods.

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Recognition of Weeds with Digital Image Analysis

Poster presentation

Weed infestations have an aggregated or clumped distribution because of variable weed characteristics, soil factors and environmental conditions. Herbicide use can be reduced if the spatial distribution of weeds within agricultural fields is taken into account. For this site specific weed control technical solutions are required for weed recognition. Digital image analysis is suitable to recognise weed species, groups of species and crops by plant characteristics (e.g. shape and color). By image processing it is possible to analyse digital images and to realise an automatic weed mapping. An image capture and processing system was developed to detect weeds in winter wheat. The system used commercial available digital cameras (color CMOS and CCD cameras connected by firewire bus), a personal computer and recognition software. Near ground images were taken under natural lighting conditions on winter wheat fields in march of 2006 and 2007. The images represented sample areas of about 0.09 m2 (area 350 x 263 mm). In the image processing the images were taken in BAYER pattern and transformed to YUV color space by camera and then transferred into other color spaces like RGB, HIS or CIELab by the computer system to separate clearly green (plants) from other color values (background). By using a corner detection algorithm like the Canny detector a differentiation between single plant-objects was executed. These objects were identified by using feature detecting algorithms. The algorithms are implemented in JAVA which is platform independent by its interpretation technology and can be operated also on embedded systems. The study includes image collection, image transformation, the recognition of weeds and the classification of weeds. The differentiation between plants (weed/weed; weed/crop) and the predefinition of weed threshold values build up the basis for decision making in site specific weed control. Herbicide application was done above defined weed threshold values, otherwise field areas remained untreated. The performance of algorithms was assessed by comparing the results with a manual classification, showing an acceptable recognition rate. The results show the feasibility of automatic weed mapping based on image processing. The algorithms will be reengineered for real time applications.

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Characterizing the Spatial Variability of SOM, Nitrogen and Texture in arable Soils of a Water Protection Area around Cologne, Germany

Poster presentation

The spatial variability of soil organic matter (SOM) contents within arable fields has gained almost no attention in the past. However, if SOM is spatially correlated, so will the soil parameters that depend on it. While our previous experiments documented positive correlations between clay content and SOM, no relationships between SOM and N_{min} were found, the latter contrasting with findings elsewhere. The objective of our present study is (i) to assess the spatial distribution of texture, SOM and mineral nitrogen (N_{min}) of arable sites and (ii) to analyse whether relationships between these parameters exist along a texture gradient. Our study is conducted in a water protection area where it is of particular importance (i) to minimize nitrate N losses which could be enhanced by a high SOM mineralization potential, and (ii) to avoid pesticide leaching to the ground water.

On 40 representative arable sites, we mapped the apparent soil electrical conductivity (ECa) as it is positively related to the clay content. Composite soil samples of the top horizon (0-30 cm) were collected on 3-5 points per hectare, representing the range of the ECa data. Samples where analysed for texture, C_{org}, N_t and N_{min}.

Ordinary statistics and geostatistical tools such as variogram models and kriging are applied to describe the spatial variations. Cross-correlation of SOM, texture and N_{min} are also checked. The results are discussed in view of their utilization for precision farming purposes.

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Dynamic Behaviour and Biological Efficacy of Single Herbicide Droplets

Poster presentation

Weed occurrence and density vary significantly in the field, and the largest reduction in herbicide use could theoretically be achieved with single plant application of the smallest sufficient dose or droplet of herbicide. The advantages of this application method are also a reduction in the soil surface loss as well as in the spray drift.

Applying herbicide to single weed plants represents a challenge in terms of the need for ultra-precise targeting and rapid response; related aspects of spray formulation and droplet application technology are key factors for optimal biological efficacy.

Experience from liquid formulation in connection with conventional spray application tests is not valid for single droplet application, which probably could be explained by the differences in the contact that the liquid has to the surface of the plant leaves. However by introducing novel liquid formulation technology it is possible to prevent the single droplets from bouncing off the target and as so to increase the retention. An additive like polymer has a very high elongational viscosity and is preventing the formation of satellite droplets in the transport situation, which optimize the precision in targeting the weed plant.

Unfortunately some of these additives tend to react with components in agricultural herbicides and could have a negative influence on the biological efficacy. Therefore the biological efficacy for all the introduced formulations was examined to be able to eliminate additives with negative effects.

Drop On Demand (DOD) application systems were used for applying droplets at single weed plants. The dynamic aspect of droplet transport and impact on the surface of weed plant leaves were investigated by use of a high speed video camera and by use of software for calculating the droplet velocity and – size.

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The Potential of Herbicide Reduction in Site-Specific Weed Control

Poster presentation

Weed densities and species are highly aggregated within agricultural fields. Due to patchiness of infestations, uniformly spraying fields can result in an unnecessary use of herbicides. Up to now, chemical weed control in agricultural practice does not take into account the spatial distribution of weeds. Normally, farmers make a spray decision according to the occurrence of main weeds and select herbicides uniformly for the entire field. Consequently, field areas will be treated with herbicides unnecessarily. Site specific weed control can restrict the treatment to the quantity necessary and represents a minimising strategy in herbicide use. Experiments in site specific weed control were carried out in winter wheat in the northern part of Germany (1999-2006). Weed distribution (species and densities) was estimated and field maps were created for single weed species (Galium aparine) and groups of weed species (grass and broad-leaved weeds). Weed maps and threshold levels formed the basis for spray decision and subsequent spatially herbicide application. Above threshold values herbicide application was done, otherwise field areas remained untreated. Aggregated weed distribution with weed free areas could be estimated within all fields and years. The weed maps demonstrated that grass and broad-leaved weeds had different distribution pattern. The field areas to be treated with herbicides for single weed species e.g. Galium aparine, or groups of species (grass and broad-leaved weeds) varied from year to year. In the comparison of years the field area sprayed against broad-leaved weed varied in an average from 27 to 72%, against grass weeds from 15 to 100% and against Galium aparine from 24 to 69%. Individual values of single fields showed a variation in treated areas from 0 to 100% for all weed groups. Averaging the results for all fields and years (1999-2006), the total field area treated with herbicides was 39% for grass weeds, 44% for broad-leaved weeds (without Galium aparine) and 49% for Galium aparine. Anyway, site specific weed control reduced herbicide use compared to broadcast application.

Reference

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Mixed Viral Infection in Sunflower Plants

Poster presentation

Results of studying of mixed viral infection in sunflower plants in different ecological regions of Ukraine are presented in this work.

The sensetivity to different species of sunflower of the Ukrainian and foreign selection to the most widespread pathogens of viral ethiology is admitted. Tested species and lines are infected by the isolates of Tobacco mosaic virus, Alfalfa mosaic virus, Cucumber mosaic virus and Tomato spotted wilt virus. These conclusions were proved by the methods of electron microscopy, indirect enzyme linked imunnoassay, method of plants indicators, immunoblotting and analysis of viral proteins using electrophoresis.

Morphological, structural and antigennic properties of viruses are studied. It was proved that all these viruses are the members of appropriate taxonomic groups. Seed infection is admitted for TMV, TSWV, CMV. The infection of sunflower by microscopic fungus *Sclerotinia sclerotiorum* on the background of mixed infection was observed.

The system of decreasing of virus reproduction using the treatment of the seed and plants in the process of their ontogenesis by the biological stimulators and chemical compounds of different origin is developed. Some of these viruses were selected by for the carrying out of different model experiments.

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Reflectance-Based Techniques for Non-Destructive Assay of Skin Flavonoids in Apple Fruits

Poster presentation

Phenolic compounds such as flavonoids, particularly flavonols (represented chiefly by quercetin glycosides) protect fruit plants against pathogens, UV radiation and other stressors and therefore play a key role in the resistance to unfavorable environmental conditions and biotic stress. In this connection it is important to have a simple, rapid and precise non-destructive technique for flavonoid assay. This work aimed to devise and algorithm for estimation of sum of flavonols im apple fruit skin. Spectral properties of flavonols of three varieties (Golden Delicious, Antonovka and Renet Simirenko) of on-tree ripen anthocyanin-free apple fruit were investigated with reflectance spectroscopy. The results of spectral and biochemical analyses suggested that fruit reflectance in a broad spectral range 365–430 nm is strongly dependent on and, in sunlit fruit surfaces, governed by flavonols. The build up of skin flavonols (mainly, rutin and other quercetin glycosides) resulted in a dramatic decrease of fruit reflectance in this range, flattening of the spectrum and extending the region with low reflectance (4–5%) to ca. 410 nm. The spectral features observed suggest that flavonols exert a significant contribution into screening of excessive radiation not only UV-A, but in the short-wave bands of chlorophyll and carotenoid absorption in the visible part of the spectrum as well. To retrieve quantitatively flavonol content from reflectance spectra, we tested the applicability of an inversion technique, developed for non-destructive leaf pigment assessment. The model for flavonol content assessment was suggested in the form {1/R(410)-1/R(460)}*R(800) , where R(lambda) is reflectance at wavelength lambda. The model was linearly related to flavonol content between 8 and 220 $nmol/cm^2$ with the coefficient of determination $r^2 = 0.92$ and root mean square error of flavonol estimation of 20 $nmol/cm^2$ regardless of cultivar, chlorophyll and carotenoid content.

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Spatial Distribution of Fusarium Head Blight in Wheat Fields

Poster presentation

Fusarium head blight (FHB) is one of the most important diseases in wheat. It is caused by a complex of species of the genus *Fusarium*. The infection leads to crop losses due to the formation of shrivelled kernels. Far more important is a loss of quality since some of the species related to FHB are able to produce mycotoxins. These mycotoxins are a severe risk for human and animal health because of their hormone like effect or their carcinogenic or even acute toxic potential. In Western Europe more than eight species are involved in the disease complex (*Fusarium graminearum, F. culmorum, F. avenaceum, F. poae, F. tricinctum, F. equiseti, F. sporotrichioides, F. crookwellense*, etc.) with *F. graminearum* and *F. culmorum* reported to be the most important. Studies on the spatiotemporal dynamics of diseases are the prerequisite to understand and manage them in a site-specific way in order to reduce mycotoxin contamination.

The spatial distribution of FHB has been studied in two wheat fields in Germany in 2004. After grid sampling (grid of 20 m x 20 m) wheat kernels were inspected microbiologically for infection by *Fusarium* species. Data on the frequency of infected kernels as analysed by SADIE statistics demonstrated a random distribution within fields for most *Fusarium* species. At one site, *F. tricinctum*, *F. avenaceum* and *F. sporotrichioides* were aggregated to some foci, frequency of *F. poae* infected kernels showed a gradient. More information on the spatial distribution of FHB and other diseases is necessary in order to define management zones for site-specific disease control or sampling plan for the collection of representative disease assessment and mycotoxin monitoring.

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Incidence and Spatial Distribution of Foliar Sugar Beet Diseases assessed by Digital Infrared Thermography

Poster presentation

Cercospora leaf spot and powdery mildew, caused by the fungus *Cercospora beticola* (Sacc.) and *Erysiphe betae* (Vanha) Weltzien, respectively, are the main yield-limiting foliar diseases in sugar beet production. Reducing the area of fungicide application would be cost-saving and beneficial to the environment.

This study should evaluate whether digital infrared thermography can be used to determine areas within fields, which are most at risk of infection and are worth of spraying. Low canopy temperature of fields is normally due to a dense and vital plant stand with a high transpiration rate. For infection and development both pathogens rely on high relative humidity, which is known to vary within fields. The necrotroph pathogen *Cercospora beticola* survives on dead plant material, while the obligate pathogen *Erysiphe betae* is bound to vital plant material. Their spatial and temporal distribution was assessed at three field sites, two of them heterogeneous in soil and topography, one homogeneous. Disease occurrence was compared with the canopy temperatures derived by digital infrared thermography.

Results indicate that areas with temperatures above average were less prone to disease, than those below average. Images of canopy temperatures resembled maps of disease occurrence. This was especially obvious for fields with variation in soil and topography and subsequent heterogeneous plant development. However, other factors which determine the distribution of the pathogens, like wind, shall be taken into account when delineating areas of risk.

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Anastomosis Groups Identity and Virulence of *Rhizoctonia solani* Isolates Collected from Potato in Iran

Poster presentation

Of 58 isolates of *Rhizoctonia solani* collected from tubers and potato plants grown in Hamedan and Kurdistan provinces, 56 belonged to AG-3 and one isolate belonged to AG-4. one isolate didn't anastomose with any of the tester cultures (AG-1-IB, AG-2-2-B, AG-3, AG-4, AG-5, AG-6, AG-8, AG-9, AG-10, AG-11 and AG-13) used. All of the collected isolates were multinucleate. In somatic compatibility groups (SCG) determinate test, 56 isolates that belonged to AG-3 divided to 43 groups. In vitro, radial growth rate of AG-3 isolates, as a group, was significantly slower than that of AG-4 and unknown isolates. AG-4 isolate's growth rate was faster than other isolates. As a group, AG-3 isolates were significantly more virulent than AG-4 and unknown isolates, whereas virulence of AG-4 and unknown isolates was approximately similar. The high incidence and virulence of AG-3 isolates indicate that AG-3 is the major cause of Rhizoctonia disease of potato in Hamedan and Kurdistan provinces, while AG-4 is less important.

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