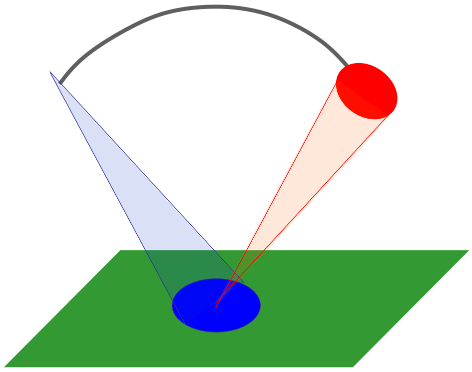
Program

and

Abstracts



3rd Conference on Precision Crop Protection

Bonn – Germany

September 19 – 21, 2010

Organizing team:

Erich-Christian Oerke, INRES – Phytomedicine, University of Bonn
Ingrid Sikora, INRES – Phytomedicine, University of Bonn
Wolfgang Förstner, IGG – Photogrammetry, University of Bonn
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Gunter Menz, Geography – RSRG, University of Bonn
Jürgen Schellberg, INRES – Crop Production, University of Bonn
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Ulrike Steiner, INRES – Phytomedicine, University of Bonn
Gerhard Welp, INRES – Soil Science, University of Bonn

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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

Sunday, September 19

17:00 – 19:00	Arrival and Registration
19:00	Welcome Reception with Evening Buffet
	Welcome address by **Dr. Barbara Riesche** (German Research Foundation, DFG)

Monday, September 20

9:00		Introduction
9:05		Welcome addresses
9:20	K1	**Wolfgang ZORNBACH** (Federal Ministry of Food, Agriculture and Consumer Protection, Bonn, GER): *Sustainable use of plant protection products under the new plant protection legislation in the European Union*
9:50	O1	**Alexandre ESCOLÀ-AGUSTÍ** (Universitat de Lleida, Lleida, ESP): *Electronic canopy characterization and real-time dosing of plant protection products in precision fructiculture/horticulture. The PULVEX-ACT and OPTIDOSA projects*
10:10	K2	**Margaret A. OLIVER** (University of Reading, Reading, UK): *Geostatistics in Precision Agriculture*
10:40		Coffee break
		Sensing and Control of Weeds
11:00	K3	**Michael NØRREMARK** (Aarhus University, Horsens, DK): Technologies for precision weed control
11:30	O2	**César FERNANDEZ-QUINTANILLA** (Centro de Ciencias Medioambientales,Madrid, ESP): *Weed patches: optimizing sampling and spraying resolution*

11:50	O3	**Roland GERHARDS** (University of Hohenheim, Stuttgart, GER): *Results of site-specific weed management in arable crops – spatial and temporal dynamics of weed populations, herbicide savings and persistence of weed patches*
12:10	O4	**Alistair J. MURDOCH** (University of Reading, Reading, UK) / **Robert A. PILGRIM** (Murray State University, Murray, KY, USA): *Automated identification and geo-referencing of black-grass patches in arable fields using machine vision*
12:30		Lunch break
13:50	O5	**Martha N. OKUMU** (University of Pannonia, Keszthely, HUN): *The use of remote sensing in precision weed control*
14:10	O6	**Roy LATSCH** (Research Station Agroscope Reckenholz-Tänikon, Ettenhausen, SUI): *Organic treatment and automatic detection of broad-leaved dock*
14:30	O7	**Ard T. NIEUWENHUIZEN** (WUR - Plant Research International, Wageningen, NL): *Precision detection and spraying of volunteer potato plants in sugar beet fields*
14:50	O8	**Victor RUEDA AYALA** (University of Hohenheim, Stuttgart, GER): *From key research concepts in weed harrowing to an automatic adjustment of the intensity*
15:10	O9	**Angela RIBEIRO** (Spanish National Research Council (CSIC), Madrid, ESP): *Design and development of a precision spraying system*
15:30		Coffee break
15:50		**Image processing**
15:50	K4	**Michael SCHAEPMAN** (University of Zurich, SUI): *Imaging spectroscopy at different scales*
16:20	O10	**Henrik S. MIDTIBY** (University of Southern Denmark, Odense, DK): *Independent feature base plant classification*
16:40	O11	**Sabine D. BAUER** (University of Bonn, Bonn, GER): *Methods for the improvement of pixelwise classification results for the automatic detection of leaf diseases*

17:00 O12 **Rasmus N. JØRGENSEN** (University of Southern Denmark, Odense, DK): *RoPDeF - semi-automated and web-based Route Plan Designer of full-scale Field trials for tractor guidance systems*

17:20 O13 **Marcus JANSEN** (Forschungszentrum Juelich, Juelich, GER): *Non-invasive phenotyping of model- and crop plants*

17:40 O14 **Lutz PLÜMER** (University of Bonn, Bonn, GER): *Advanced machine learning methods for early detection of weeds and plant diseases in precision crop protection*

18:00 O15 **Joanna POST** (University of Bonn, Bonn, GER): *CROP.SENSe.net – Networking sensor technology R & D for crop breeding and management*

20:00 **Conference dinner**

Tuesday, September 21

Sensing and Control of Diseases and Pests

8:30 K5 **Zoran CEROVIC** (Centre Universitaire Paris-Sud, Orsay, France): *Optical sensors based on plant fluorescence*

9:00 O16 **Kathrin BÜRLING** (University of Bonn, Bonn, GER): *Differentiation between N-deficiency and leaf rust (*Puccinia triticina*) in wheat (*Triticum aestivum*) by means of UV laser-induced fluorescence*

9:20 O17 **Anne-Katrin MAHLEIN** (University of Bonn, Bonn, GER): *Hyperspectral imaging and image analysis for the detection and differentiation of sugar beet diseases*

9:40 O18 **Thorsten MEWES** (University of Bonn, Bonn, GER): *Improving wheat disease detection with hyperspectral data using data reduction techniques*

10:00 O19 **Forrest W. NUTTER, Jr.** (Iowa State University, Ames, IA, USA): *Developing integrated GPS, GIS, and satellite remote sensing technologies to locate the epicenters of plant disease foci*

10:20 Coffee break

10:40 P1 – P31 **Poster presentation**

12:30 Lunch break

Application Technologies

13:40 K6 **Harold THISTLE** (USDA Forest Service, Morgantown, USA): *Modeling of pesticide deposition and airborne transport from aerial, ground and passive releasers*

14:10 O20 **Martin WALGENBACH** (University of Bonn, Bonn, GER): *Construction and investigation of a field sprayer with direct nozzle injection of plant protection products*

14:30 O21 **Kim J. ANDERSSON** (University of Southern Denmark, Odense, DK): *Novel precision targeting system for laser weeding of dicots*

14:50 O22 **Rob CONNELL** (Lincoln Ventures Ltd., Lincoln, NZL): *Drift reduction characteristics of pulse-width modulated spray control*

15:10 O23 **Corné KEMPENAAR** (WUR - Plant Research International, Wageningen, NL): *Variable rate application of pesticides in potato and tulip*

15:30 O24 **Johanna GUDE** (University of Bonn, Bonn, GER): *Weeding by laser application*

15:50 Coffee break

Decision Support Systems and GIS

16:10 K7 **John D. MUELLER** (Clemson University, Blackville, SC, USA): *Nematode management zones based on soil texture*

16:40 O25 **Karl-Heinz DAMMER** (Leibniz-Institute of Agricultural Engineering (ATB), Potsdam, GER): *Variable rate growth regulation in winter rape in autumn by a camera controlled field sprayer*

17:00 O26 **Rabiu O. OLATINWO** (University of Georgia, Griffin, GA, USA): *The TSWV risk calculator: A weather-based assessment tool for managing risk of tomato spotted wilt of peanut in Georgia, United States*

17:20 O27 **Charles OVERSTREET** (Louisiana State University, Baton Rouge, LA, USA): *Using verification strips to define nematicide response areas to the Southern root-knot and reniform nematodes in* *cotton in the Alluvial soils of the mid-South, USA*

17:40 O28 **Thorsten ZEUNER** (Central Institution for Decision Support Systems in Crop Protection, Bad Kreuznach, GER): *Use of geographic information systems in crop protection warning service*

18:00 Concluding remarks and farewell

Poster presentations (in alphabetic order)

P1 **Andújar, Dionisio, A. Escolà-Agustí, J. Dorado, C. Fernández-Quintanilla** (Madrid / Lleida, ESP): *Using ultrasonic sensors for weed detection*

P2 **Balsari, P., G. Doruchowski, P. Marucco, Ard T. Nieuwenhuizen, M. Tamagnone, J.C. van de Zande, M. Wenneker** (Grugliasco, I / Skierniewicze, POL / Wageningen, NL / Zetten, NL): *Evaluation of a crop identification system and an environmentally dependent application system in apple orchards*

P3 **Basi, Sabin, M. Hunsche, G. Noga, L. Damerow, P. Schulze Lammers** (Bonn, GER): *Potential use of a monodroplet generator as an alternative application device for a precise weed control*

P4 **Berdugo, Carlos A., U. Steiner, E-C Oerke, H-W Dehne** (Bonn, GER): *Evaluation of physiological effects of fungicides in wheat by infrared (IR) thermography*

P5 **Berge, Therese W., S. Goldberg, D. Løvås, J. Netland, Ø. Overskeid** (As, NOR): *Developing Sweedy - a robot for weed control in swedes (*Brassica napus *ssp.* rapifera*)*

P6 **Chachalis, Demosthenis, V. Kati, D. Taskos, S. Stamatiadis** (Athens / Goumenissa / Kifissia, GRE): *HydroSense: Weed mapping by using ground-based sensing systems in cotton in Greece*

P7 **Chojnacki, Jerzy** (Koszalin, POL): *Effect of changes of liquid static pressure on entomopathogenic nematode viability*

P8 **Coelho-Netto, R.A., Forrest W. Nutter, Jr.** (Manaus, BRA / Ames, USA): *Moko disease of banana: use of GPS and GIS tools to map disease risk*

P9 **Dörpmund, Malte, X. Cai, M. Walgenbach, J. Vondricka, P. Schulze Lammers** (Bonn / Beijing, GER / PRC): *Residual disposal and cleaning of direct injection systems for pesticide application*

P10 **García-Torres, Luis, D. Gómez-Candón, J.J. Caballero-Novella, M. Gómez-Casero, J.M. Peña-Barragán, M. Jurado-Expósito, F. López-Granados** (Cordoba, ESP): *Use of SARI® software for remote images processing in precision crop protection*

P11 **Heijting, Sanne, S. de Bruin, A. Bregt** (Wageningen, NL): *Farmers' point of view on within-field variation*

P12 **Hillnhütter, Christian, A.-K. Mahlein, T. Mewes, R.A. Sikora, E.-C. Oerke** (Bonn, GER): *Multitemporal and multisensoral investigations of canopy symptoms in sugar beet fields caused by* Heterodera schachtii *and* Rhizoctonia solani

P13 **Hozayn Mahmoud Abdalla, Mahmoud** (Cairo, EGY): *Allelopathic potential of 16 flax varieties against burclover (*Medicago polymorpha *L.) weed*

P14 **Kaspersen, K., Therese W. Berge, S. Goldberg, J. Netland, Ø. Overskeid, T. Stølan** (Oslo / As / Rena, NOR): *Estimation of weed pressure in cereals using digital image analysis*

P15 **Keller, Martina, C. Gutjahr, M. Weis, R. Gerhards** (Hohenheim, GER): *Response of weed coverage to herbicide dose as an integral part of a decision support system for precision weed management*

P16 **Kuhlmann, H., Florian Schölderle** (Bonn, GER): *A multi-sensor system for the generation of a rectangular formation of sugar beet plants – approach for the longitudinal drive and the turn-around*

P17 **Mahlein, Anne-Katrin, R. Zito, A. Taheri, E.-C. Oerke, J. Hamacher, C.A. Berdugo** (Bonn, Germany): *Multi-sensoral detection of physiological changes in cucumber leaves during pathogenesis of CMV, CGMMV, and powdery mildew*

P18 **Nordmeyer, Henning, O. Richter, N. Sandt** (Braunschweig, GER): *Modelling spatio-temporal weed population dynamics for site specific weed control*

P19 **Páez, Francisco C., V.J. Rincón, J. Sánchez-Hermosilla** (Almería, ESP): *Methodological proposal for three-dimensional modeling of tomato plant in greenhouse and the optimization of spray application by computational fluid dynamics (CFD) techniques*

P20 **Pahlavanravi, Ahmad** (Zobol, IRN): *Crop combination and crop diversification in Jiroft watershed*

P21 **Pinto, Francisco, U. Rascher** (Juelich, GER): *Remote sensing of photosynthetic efficiency using sun-induced chlorophyll fluorescence signal obtained by a hyperspectral imaging method*

P22 **Ponmurugan, Ponnusamy, D.N. Kambrekar (**Tiruchengode / Bijapur, IND): *Evaluation of* Streptomyces *species for the biological control of rhizome rot disease in Indian turmeric plantations*

P23 **Sabah, Razi** (ALG): First study of thrips in Feva bean in Sdid Okba at Biskra

P24 **Sadighi, Hassan** (Teheran, IRN): *The use of GIS in determining the environmental/agricultural land potentials: Case study of Varamin area in south of capital, Tehran, Iran*

P25 **Santoro, Franco, S. Gualano, K. Djelouah, A.M. D'Onghia** (Valenzano, ITA): *Spectroradiometric measurements to assess Tristeza-diseased citrus plants*

P26 **Schlang, Norbert, H.-W. Dehne, U. Steiner, E-C. Oerke** (Bonn, GER): *Patterns of Fusarium head blight and mycotoxin contamination of wheat*

P27 **Scholz, Christine, A. Mahlein, S. Pätzold, G. Welp** (Bonn, GER): *Mapping spatial variability of soil organic carbon on the field scale via airborne hyperspectral images*

P28 **Schmidt, Kai** (Bonn, GER): *Analysis of (hyper-)spectral signatures*

P29 **Sökefeld, Markus, M. Weis, C. Gutjahr, R. Gerhards** (Hohenheim, GER): *Sensor and application tech-*

*nology for precision weed management - weed sensors, GIS, spraye*r

P30 **Tomkiewicz, Dariusz** (Koszalin, POL): *A plant-based sensor for monitoring plant biological condition*

P31 **Tomkiewicz, Dariusz** (Koszalin, POL): *A neural network classifier for counting insecticidal nematodes on digital images*

Abstracts

I Keynote presentations (in chronological order)

K1

Zornbach, Wolfgang

Sustainable use of plant protection products under the new plant protection legislation in the European Union

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The new plant protection legislation of the European Union, the so called Plant Protection Package, will come into force from the year 2011 on. Some elements will come later. This new legislation is a perfect background for new developments and technologies in plant protection, including precision farming approaches. The Directive 2009/128/EG of the European Parliament and the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides asks for specific risk reduction methodologies. Integrated pest management is one of the most important elements of the directive. The general principles of integrated pest management will have to be followed by all users of plant protection products from 2014 on. In future new plant protection equipment has to follow EU-standards (EN-Norms), which include requirements for worker safety as well as for the environment.

Looking back to the last twenty years in particular technical developments lead to tremendous reductions of risks to the environment, to consumers and to workers. These technical developments were mostly new active substances and new plant protection equipment. It is expected, that within the next twenty years in particular plant protection equipment will play a central role in further reductions of risks. Exact, site-specific and goal oriented sprayings with the right dosage and according to the relevant risk management measures will ensure, that the goals of national action plans on the sustainable use of plant protection products in the EU-Member states will be met. This is a great chance for new technologies, like robotic, senor supported spraying or probably equipment with online contact to GIS supported decision support systems, which provide site-specific information about necessary plant protection measures.

The new legislation is in this context a challenge for modern farming technologies and supports their implementation. These technologies will help governments to fulfil the requirements of their national action plans, they will also help farmers to fulfil the requirements of the new EU-legislation.

K2

Oliver, Margaret A.

Geostatistics in Precision Agriculture

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Precision agriculture (PA), of which precision crop protection is an essential part, and geostatistics are dynamic and complimentary subjects that have spatial variation at their core. The strong relation between them is likely to increase as more information on the soil and crops becomes available from sensors and on-the-go technology. There is a variety of geostatistical techniques that can be applied to a range of issues in PA such as sampling, prediction, mapping, decision-making, variable-rate applications, economics and so on. The scene is set with some background on the history and basic theory of geostatistics, together with the history of precision agriculture and of geostatistics in precision agriculture. The two core techniques of geostatistics, variography and kriging, are described with examples. Knowing the spatial scale of variation is important to ensure sampling is adequate and the results are accurate. Both traditional geostatistical and 'state-of-the-art' approaches to guide and optimize sampling will be considered. Many environmental variables that are relevant to precision agriculture vary in both time and space. Space-time geostatistics is a useful extension to spatial geostatistics for precision agriculture. Many field properties can be expensive to measure and geostatistics enables secondary information that is relatively cheap to obtain to be incorporated into the mapping of soil and crop attributes to improve the accuracy of their predictions. The methods include cokriging, the multivariate extension of ordinary kriging, kriging with external drift and simple kriging with local means. To manage fields site-specifically for nutrients and water requires detailed and accurate maps of crop nutrients and the soil's moisture content. If such detail is unavailable an interim solution is to use geostatistics to identify site-specific management units (SSMUs) to resolve the spatial variation. Recent and exciting developments in the application of geostatistics to PA show that management-class and local-response experiments can be analysed geostatistically. Geostatistical simulation is relatively unknown in PA, but it provides a means to mimic the spatial and or temporal variation of relevant processes. Simulation incorporates uncertainty into modelling to obtain a more realistic impression of the variation. Case studies will be used to demonstrate geostatistical applications to PA.

K3

Nørremark, Michael

Technologies for precision weed control

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There is a growing need for development of innovative technologies applicable for biological systems according to the increasing world-wide political pressure to reduce dependency and/or use of pesticides in order to reduce the impact of agriculture on environment. Advances in precision weed control technologies can contribute significantly to better weed management while preserving the environment and costs. Precision weed control is here defined as technology and weed management tools that apply herbicides and/or physical weed control in an arable crop while taking into account factors such as weed monitoring, weed patchiness, seeding pattern, threshold values, weed control efficacy, operational capacity and profitable crop yield.

Precision weed control methodologies have already brought several major advances in weed management, including optical sensors for remote sensing of weeds and row guidance, decision support systems, injection spraying systems and variable rate application equipment for sprayers. A review of commercial and future technologies and management tools that has been demonstrated as fully operational precision weed control systems shows that they reduce herbicide usage from 10-100% while managing weed populations at an acceptable level. The lower range reflects the potential savings from systems commercial available today and the higher range reflects what could be expected from researched systems.

The key note addresses an analysis of the state-of-art, benefits and the main challenges for research and innovation of alternative weed control measures using the progressing technologies ICT, GNSS, GIS, computer vision and robotics. Automatic systems for robust monitoring and mapping of weed species and densities followed by automatic upload of treatment maps to site-specific sprayer controllers and/or physical weed control tools is key to the breakthrough of some of the reviewed technologies and weed management models having different approaches towards substantial and profitable reduction of herbicide usage. The potentials for herbicide saving increases with increasing spatial resolution of weed control. However, taking the deposit to ground and spray drift to air effect into account the greatest saving is achieved when weed seedlings are treated individually.

For the future we can imagine a paradigm shift in research toward species adapted control measures, micro-site specific weed management, real time monitoring of crop and weeds and the integration of the environmental and agronomical demands in the control-loop of the sprayer, physical weed control tool, and seeder.

K4

Schaepman, Michael E.

Imaging spectroscopy at different scales

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Radiometric earth observations in the solar reflected domain of the electromagnetic spectrum are influenced by five dimensions. These are a spatial, spectral, directional, temporal and to a lesser extend a polarization dimension. The dependency of these domains is a critical issue when up- or downscaling Earth observations. By using examples from the domain of Earth System related spectroscopy their interrelationship is demonstrated. Particular focus will be on the retrieval of the biochemistry and structure of vegetation at scales ranging from molecular to (agro-)ecosystems. Vegetation pigment and non-pigment retrievals using empirical and physically based approaches are discussed as well. Horizontal and vertical canopy heterogeneity is assessed and how retrievals can profit from particular arrangements of the vegetated surface. The talk will conclude with an assessment of current and future challenges when trying to build complete observational systems allowing to bridge relevant scaling gaps currently existing using state-of-the-art imaging spectrometers.

K5

Cerovic, Zoran G.

Optical sensors based on plant fluorescence

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Chlorophyll fluorescence (ChlF) has been used for years as a proxy for photosynthesis and as an indicator of presence of abiotic and biotic stress. The introduction of the pulse-amplitude modulation (PAM) techniques facilitated the sensing of this variable ChlF in the field in presence of daylight [1]. In the last fifteen years new generations of fluorescence-based plant sensors have emerged. On the one hand, the development of the ChlF-screening method [2-4] revealed in vivo epidermal absorbers. On the other hand, UV-induced blue-green fluorescence was used to detect the presence of pathogens [5] or nutritional stress [6] and water stress [7] in leaves. Both these techniques, which are dedicated to the detection of plant constituents of leaves and fruits, are implemented now in portable sensors for field research and agriculture. When mounted on vehicles, they can be used to perform real-time on-the-go proximal sensing of crops yielding maps of homogenous zones for differentiated agricultural practice [8, 9].

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K6

Thistle, Harold

Modeling of pesticide deposition and airborne transport from aerial, ground and passive releasers

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The USDA Forest Service is the steward of over 75 million hectares of federal forest and range lands and provides support to additional millions of hectares of private land. The large tracts of land in locations ranging from urban parks and urban interfaces to very remote landscapes present equally wide ranging pest management issues. The areal extent of this land and its remote and often rugged physiography dictated the use of aerial spraying to combat large pest outbreaks. A Lagrangian droplet trajectory model known as AGDISP was developed to predict deposition from these aerial spray operations. As time passed, emphasis moved from protection of timber to multiple land use strategies and wide area aerial spraying became less common. Aerial spraying is currently used for smaller area treatment of invasive species. The primary large area aerial application currently being performed is the release of laminated flakes impregnated with pheromone used to disrupt mating of a major forest defoliator. Increased scrutiny of pesticide application has led to interest in modeling spraying by ground sprayers. In the Forest Service, ground spraying is often done by ATV mounted and backpack sprayers. A relatively simple ground sprayer model was recently added to AGDISP and data collection is planned to extend this model to backpack and ATV applications. AGDISP and a closely related model named AgDrift are regulatory models utilized by USEPA to evaluate health and ecological risks of pesticide application. These models are also used by The US Fish and Wildlife Service as well as the National Marine Fisheries Service to set buffer zones around endangered species. A separate family of models has been developed to quantify the dispersion of semiochemicals from passive releasers placed in the plant canopy to alter insect chemical signaling. Semiochemical strategies had been developing empirically with regard to spacing, placement etc. in the canopy. From an engineering standpoint the system is comprised of the emission of a gas (elution), dispersion of a gas and interaction with a living organism. A Gaussian puff model based on extensive data collection has been developed to optimize placement of passive releasers in forests.

K7

Mueller, John D., T.L. Kirkpatrick, C. Overstreet, R.F. Davis, W.S. Monfort, A. Khalilian, W.G. Henderson, Jr.

Nematode management zones based on soil texture

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Nematode management in cotton in the southern U.S. has relied upon uniform-rate application of nematicides across entire fields. Nematode distribution and population density, however, is rarely uniform. A site-specific nematicide placement (SNP) system based upon soil texture has been developed. Because the distribution of many nematode species can be strongly correlated with soil texture, maps delineating soil textural changes based on soil electrical conductivity (SEC) are used to delineate nematode management zones. These zones become the basis for targeted sampling, and ultimately nematicide application prescriptions. In South Carolina, Columbia lance nematode, *Hoplolaimus columbus*, management using the SNP system resulted in significant decreases in the quantity of nematicide applied while maintaining acceptable yields. Site-specific applications of aldicarb at + 1.1% accuracy and 1,3-dichloropropene (1,3-D) at + 2.1% accuracy, coupled with zone management maps typically increased yields by 5% while reducing aldicarb applied by 34% and 1,3-D by 78%. Similar studies in Arkansas with the southern root-knot nematode (SRK), *Meloidogyne incognita*, indicated that acceptable yield could be maintained with the SNP system with a resulting decrease of 37- 42% in the amount of 1,3-D that was applied. In these studies it was apparent that SRK population densities increased with increasing sand content up to a point, then decreased as sand content approached 100%. Damage potential to cotton, however, increased with increasing soil sand content. In Louisiana, the influence of soil type on SRK was even more dramatically illustrated using the SNP system. In these studies, although 6 SEC management zones were defined, only cotton in the sandiest zone sustained damage from SRK, resulting in a substantial decrease in the 1,3-D that was necessary. In Georgia management zones with the lowest SEC (highest sand levels) typically had the greatest SRK population densities. In most fields more than 50% of the variability in SRK distribution was explained by the correlation between the edaphic-terrain variable and nematode density. SEC, followed by elevation and then slope had the greatest influence on the canonical predictor variable. In all four states management zones were used to decrease nematicide inputs while still increasing yields.

Abstracts

II Oral presentations (in chronological order)

O1

Escolà-Agustí, Àlexandre[1], J.R. Rosell[1], R. Sanz[1], E. Gil[2], L. Val[3], E. Moltó[4], S. Planas[1]

Electronic canopy characterization and real-time dosing of plant protection products in precision fructiculture/horticulture. The PULVEXACT and OPTIDOSA projects

[1] Dep. d'Enginyeria Agroforestal, Universitat de Lleida; [2] Dep. d'Enginyeria Agroalimentaria i Biotecnologia, Universitat Politècnica de Catalunya; [3] Dep. Mecanització i Tecnologia Agrària, Universitat Politècnica de València; [4] Centro de Agroingeniería, Instituto Valenciano de Investigaciones Agrarias, Spain
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A research group composed of several centres from Catalonia and Valencia, Spain, (Universitat de Lleida, Centre de Mecanització Agrària, Universitat Politècnica de Catalunya, Universitat Politècnica de València and Institut Valencià d'Investigacions Agràries) has developed new electronic tools for precision application of plant protection products that include electronic characterization of fruit tree canopies. The work has been carried out in apple and pear orchards, citrus groves and vineyards in the framework of projects PULVEXACT (2002 - 2005) and OPTIDOSA (2007 - 2010), funded by the Spanish Ministry of Science and Education.

Rapid and accurate canopy characterization has been investigated by using two approaches: based on ultrasonic sensors and based on lidar sensors. The former was used until the latter was found to be more accurate. Lidar sensors are able to obtain range estimations every degree in the vertical transverse plane of the canopy. The current implementation of this system allows using real-time information of height, width and canopy volume to generate leaf area surface and leaf area density estimations off-line.

Two different outcomes have been obtained. One is a set of decision support tools to help producers choose an optimal volume application rate to be used by considering the most important parameters connected to the process. This software has been named DOSAVIÑA for vineyards, DOSAFRUT for pear and apple orchards and DOSACITRUS for citrus groves. The other outcome is a real-time variable rate sprayer prototype named Fluxpro. This sprayer is capable of estimating the canopy volume every 10 - 20 cm along the row while accordingly modifying the dose rate on-the-go. The estimation of canopy parameters can be done either by ultrasonic or lidar sensors.

Ultrasonic and lidar sensors are able to accurately characterize tree and bush canopies for many scientific and commercial purposes. When applied to dose adjustment together with real-time variable rate technologies, electronic canopy characterization helps spray applications to be more efficient. In field trials, variable rate applications have proved to reduce drift up to 60% without affecting theoretical efficacy. Decision support tools in vineyards have proved to reduce the amount of applied products by approximately 40%.

O2

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Weed patches: optimizing sampling and spraying resolution

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The high cost of weed detection technologies is a major deterrent for their commercial introduction. In this regard, the spatial resolution at which weed mapping is conducted is likely to be a major factor in determining its cost effectiveness. Mapping errors increase as the distance between sensors and the distance between images is increased. Since an increasing resolution may have an important associated cost, it is relevant to find out the optimal resolution that may provide a reliable description of weed distribution and a practical patch-spraying system. Various questions arise when trying to define this resolution: how patchy are different \`target´ weeds? What sizes and shapes have these patches? At what distances weed data should be taken? Which is the optimal size of spraying units?

To elucidate some of these questions, studies were conducted with various weeds and crops. *Avena sterilis* infestation level was scored visually from the cabin of a combine at harvest time in 31 commercial winter barley fields considered as infested by this weed. Only 22% of the total area surveyed was actually infested. Almost 90% of the infested area was formed by large patches (> 500 m^2). Large patches were irregularly-shaped but small patches were more regular in forms. *Sorghum halepense* infestation was assessed in 38 commercial maize fields following the same procedure than in the previous case. The area actually infested by this weed was 16%. More than 90% of the infested area was formed by patches larger than 250 m^2.Patches gained shape complexity as patch size increased. On average, patches were twice longer in the direction of tillage than perpendicular to tillage. The distribution pattern of these two weeds allows to focus patch spraying on the largest patches, using relatively simple technologies. In the case of maize fields infested by *Datura* sp. and *S. halepense*, studies conducted when maize was at the 4 to 6 leaves stage have shown that it is possible to obtain reliable weed maps with optical sensors spaced less than 4.5 m among them. A minimum treatment unit of 3 by 3 m seems feasible.

O3

Gerhards, Roland, M. Sökefeld, D. Dicke, C. Ritter, H. Oebel, M. Weis, C. Gutjahr

Results of site-specific weed management in arable crops – spatial and temporal dynamics of weed populations, herbicide savings and persistence of weed patches

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Weed populations have been found to be distributed heterogeneously in time and space within agricultural fields. They often occur in aggregated patches of varying size or in stripes along the direction of cultivation. The spatial distribution of weeds has often been ignored in weed management and weed science. With a large within-field variation in weed occurrence, patch spraying, based on the need for weed control, may reduce treatment costs as well as herbicidal loading to the environment. A major step towards a practical solution for site-specific weed management was the development of precise and powerful sampling techniques to automatically and continuously determine in-field variation of crop cover and weed seedling populations. A system for site-specific weed control in sugar beet, maize, winter wheat, winter barley, winter rape and spring barley was developed and tested during the past 11 years. The system includes on-line weed detection using bispectral digital image analysis and weed species classification, computer-based decision making and GPS-controlled patch spraying. Herbicide use with this map-based approach was reduced in winter cereals by 6 to 81 % for herbicides against broad-leaved weeds and 20 to 79 % for grass weeds herbicides. Highest savings were achieved in cereals followed by sugar beet, maize and winter rape. Efficacy of weed control varied from 85 % to 98 % indicating that site-specific weed management will not result in higher infestation levels in the following crops.

Patches of several weed species including *Alopecurus myosuroides*, *Matricaria chamomilla* and *Fumaria officinalis* remained stable in location over several years of study even when effective weed control methods were applied in every year. This indicates that preventive and curative methods of control are needed to suppress existing weed patches.

The results indicate that spatial variation in weed density and weed species composition must be considered in the decision rules for weed control methods to determine the economic optimal herbicide dose with respect to the spatial heterogeneous weed distribution, weed competition and population dynamics.

O4

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Automated identification and geo-referencing of black-grass patches in arable fields using machine vision

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Black-grass (*Alopecurus myosuroides*) typically occurs in patches in arable fields. Farmers in the UK and Europe, however, frequently spray whole fields to control the patches. Although technology exists to confine spraying to patches and in spite of environmental and economic benefits, adoption of patch spraying by arable farmers is, however, negligible. A major reason for low adoption is the difficulty of constructing weed maps and manual mapping is unpopular with farmers and agronomists. As a prelude to automating the weed mapping process using machine vision, this paper explains a new research on identifying black-grass in winter wheat after Zadoks growth stage 39 using machine vision corresponding to times when farmers would typically be applying fungicides to their crops.

Software algorithms will be described which distinguish black-grass from the cereal crop. It will further be demonstrated that use of appropriate algorithms on red, green, blue signals as detected by CCDs in conventional digital cameras provides allows detection of the black-grass and its distinction from the cereal crop. Hypotheses tested include (1) the accuracy of weed identification by machine vision based on one or several field surveys at different growth stages will be adequate to identify weeds and weed patches with the precision needed to create herbicide application maps and (2) images required for mapping can be captured as an adjunct to normal farming operations in each field.

A prototype machine vision system was attached to farm machinery (sprayers and combine harvesters) on two farms from June to December 2009, images being captured at times of chemical application and harvesting. Optimal times for black grass identification in wheat in the UK were from black-grass head emergence until completion of seed shedding. Detection after seeding was not possible. Images were also captured of early season seedlings although identification of grass seedlings to species level is not possible at that growth stage. The system detected on average 47% of black-grass heads in images with black-grass densities ranging from 0 to 1200 heads per square metre. In terms of the images, all images containing black-grass were classified as containing black-grass so that there were no false negatives in terms of images. As these images were smaller than one square metre in area, this performance is deemed satisfactory for end-users. Some false positives were, however, recorded and ongoing software development and fine tuning is in progress to reduce the numbers of false positives.

Late season mapping clearly highlights failure of control and places where seed bank replenishment is likely and hence where infestations are most likely in the following growing season. The potential of automated the process of weed mapping and the value of this approach in comparison to real time weed detection and control, will be discussed.

O5

Okumu, Martha Nelima

The use of remote sensing in precision weed control

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Weeds typically occur in patches rather than uniformly across a field; however, conventional management practices rely on whole-field management. Site-specific weed management (SSWM), applying control measures only where weeds are located at densities greater than those that cause economic losses, has tremendous potential for economic and environmental benefits. Herbicide use could be reduced either by applying it only to weed-infested areas or by applying a low dose rate to the whole field and normal dose rate to weed patches. In the effort of developing precision agriculture tools, remote sensing and associated spatial technologies have been commonly considered as an effective technique for weed patch delineation, where weed infestations are detected based on variations in the plant canopy spectral response. They can also be invaluable assets for detection of invasions, assessment of infestation levels, monitoring rate of spread, and determining the efficacy of mitigation efforts for weed management. The benefits of precision weed management arise from use of information about the spatial variability of weeds. In combination with other technologies such as global positioning systems and geographic information systems, sampling strategies can be devised to efficiently determine the location of weed populations in agricultural situations. The benefits of the remote sensing depend on the spatial distribution of weeds. The more patchy the distribution, the greater the potential for precision weed management. Maps created from remote sensing or sampling allows site-specific weed management of only the areas requiring corrective action. One method of site-specific weed management centers on a map-driven sprayer. In this system the location of weeds in a field is mapped and the weed map is used to program a sprayer that is capable of variable rate and prescription applications. Traditional sprayers limit the range of application rates and are not suitable for site-specific control strategies. Current commercially available systems can detect green vegetation and activate a herbicide spray nozzle. Advantages of these systems include: elimination of wasted chemical, limited operator exposure, automatic on-the-go selection of herbicide application rates, and control of multiple injection modules with different herbicides.

O6

Latsch, Roy, J. Sauter

Organic treatment and automatic detection of broad-leaved dock

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Broad-leaved dock (*Rumex obtusifolius*) is still the most frequently mentioned problem on pastures and meadows on organic farms in Switzerland. As herbicides are forbidden in organic agriculture, farmers can only eliminate these extremely competitive plants by digging them out by hand, which is strenuous work.

In many research institutes in Europe and overseas, scientists are working on various procedures and strategies for reducing this hard manual labour. In-house findings and literature data on the efficiency of bioherbicides, pathogens, herbivorous insects, various forms of grassland management, thermal treatment and mechanical treatment are being compiled. Both the literature review as well as ART's own findings show that the application of bioherbicides such as acetic acid and saline solution are not successful in the treatment of dock plants. In addition, a broad range of thermal trials have been conducted using microwave technology, infrared heating devices, dry heat and hot-water heat. Microwave technology has shown itself to be effective, but is too energy-intensive to gain practical importance. Hot-water treatment shows promise, providing the application problems can be solved. Digging out the plants has been very successful, but the holes left behind create major problems. Milling the plants in the soil can induce a multiplication of dock plants as they resprout from small pieces of root. A combination of digging out and separating plants and soil could be a promising approach to solving the dock problem.

To automate the single-plant treatment, computerised recognition is necessary apart from the treatment. The prototypic 'SmartWeeder' 3D sensing and treatment unit, comprising an infrared laser and a high-resolution smart camera for generating three-dimensional images, will be presented. This prototype is able to recognise and spray individual plants. For practical use, the recognition rate will have to be improved.

O7

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Precision detection and spraying of volunteer potato plants in sugar beet fields

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Volunteer potato plants are a major weed problem in Western European cropping rotations. They are a source for the spread of disease, nematodes, and pests. For example they spread *Phytophthora infestans*, that causes late blight in potato crops. However, the control of Phytophthora infestans requires large amounts of pesticides that farmers, environmental groups, and politicians want to reduce. This is stressed by the framework directive on the sustainable use of pesticides, EU directive 2009/128/EC. Therefore, adequate control of volunteer potato plants and weeds is required. Volunteer plants are best controlled by application of glyphosate. This ensures control of haulm and tuber, and re-growth is inhibited. Currently available machines have a high risk of sugar beet crop injury and have a high labour demand, requiring a practical innovative solution. The stakeholders of the problem asked for a solution and an automated precision detection and spraying system was designed and tested.

With machine vision a plant specific detection system was made. Real time algorithms detect up to 1 m s^{-1} travel speed with a resolution of 1 cm^2 for three sugar beet rows where glyphosate has to be applied onto volunteer plants. After detection of individual potato plants in the sugar beet row, a micro sprayer applies targeted droplets of gel and glyphosate onto the weeds. A gel instead of water was used because no splash and drift to adjacent crop plants is allowed.

The prototype system that integrated real-time detection and targeted individual droplets at volunteer plants was tested in experimental fields. In one of the fields 96.6% volunteer potato classification and 8.0% sugar beet misclassification was achieved. In an experiment where also the sprayer was activated, over 80% of the weed potato plants were destroyed and only up to 2% of the sugar beet plants were destroyed, mainly due to incorrect detection, not as a result of spray drift. The precise positioning of droplets facilitates further developments into precision application of nutrients and pesticides on crops and weeds in agricultural fields.

O8

Rueda-Ayala, Victor, M. Weis, R. Gerhards

From key research concepts in weed harrowing to an automatic adjustment of the intensity

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Mechanical tools for whole crop cultivation control weeds by burying due to soil movement and uprooting plants. The challenge of weed control by mechanical means –such as weed harrowing– is to find the right timing and intensity of the cultivation, to obtain the highest control effect and the least crop damage. Relation of weed control efficacy and crop damage is measured as selectivity. Research has been focused on the key concepts to successful mechanical weed control: selectivity, crop tolerance and recovery, competitive ability of weeds, new emergence and contributions to yield gain. Based on this research and own field experiments in winter and summer cereals from 2007 until 2010, an algorithm for site-specific weed harrowing has been developed. Variability of the soil and weeds was measured with different sensors. Bi-spectral cameras were used to determine the coverage of weeds and crop with soil and recognition of weed composition. A sensor measuring the vertical power transmission was used to calculate the soil resistance to the forward movement of the harrow. The tractor was connected to a RTK-DGPS for positioning, which allowed the creation of maps for weed distribution, crop–weed coverage and soil resistance. Different timings and levels of intensity were tested in previous experiments and realized by changing the tine angle and speed of the harrow. One, two or three number of passes were additionally tested to control weeds and break the soil crust, when higher compaction was measured (>100 Newton) mainly in the case of early spring applications in winter cereals. Results of the experiments showed high variability in weed- and crop coverage and soil resistance within the fields, hence permanent adjustment of the intensity was necessary to avoid crop damages. A model control system based on analog input of continuous percentage (0 – 100%) values of resistance, leaf coverage, and weed density was developed based on the results of the field studies. Intensity levels which achieved at least 80% weed control and caused no yield loss were used as the best possible settings for automation. The technology was also used to create application maps and the different intensity settings were tested in additional experiment for off-line harrowing application and improving the algorithm for site-specific weed harrowing.

O9

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Design and development of a precision spraying system

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Precision Agriculture (AP) is composed of different technologies that can be combined by farmers to form a system that meets their needs and management style. As a result, the rate of adoption for these component technologies varies widely. Of particular interest is the site-specific weed management of weeds, i.e. spraying only where there are weeds.

This research describes the reliability of a precision spraying system developed at the CSIC for weed control. The equipment uses a GPS receiver with a 20 Hz update rate, providing an extremely accurate and robust GPS location in almost any environment. It is a more cost-effective price than traditional dual-frequency RTK systems, with accuracy to within 0.2 m when the OmniSTAR correction signal is activated. The precision spraying system is also formed by a standard PC used to control a commercial 10 m sprayer. The chassis is divided into five sections of 2 m that can be independently opened or closed. Both opening and closing controls are simultaneous, so that at the same time can be open various sections while the rest remains closed. Likewise all open sections have the same flow. The control of the sprayer sections is made from the PC, inserting a data acquisition device through an electronic circuit that converts the outputs of the data acquisition device in the potential differences required to move the motors that open and close the sprayer sections. Software has been implemented to run on the PC. The software allows users to introduce their application map by a user-friendly graphical interface. This program controls completely the spraying process, comparing at each time the GPS location to the position on the map, making decision of spraying and sending the signal to the sprayer for opening and closing sections.

Several testing has been conducted to verify the performance of the developed spraying equipment. Results shows a good performance in very different situations that range between big patches, that require open simultaneously the 5 sections of the bar, to weed spots that need the activation of a unique section for a very short period of time.

O10

Midtiby, Henrik Skov

Independent feature base plant classification

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Several authors have classified and discriminated crop and weeds with variable success. Ãstrand (2005) combined the regularity of distances between crop plants in the row with colour-, shape- and moment-based features for sugar beet, achieving classification rates of up to 94%. However, with occluded plants, the classification rate decreased to around 50% and because of the use of colour features the system required constant illumination by lamps. Neto et al. (2006) developed and tested individual leaflet extraction based on connected components, fuzzy clustering and a genetic optimization algorithm from images of young field plants in multiple species clusters. Weis and Gerhards (2007) used shape and skeleton based features to discriminate between four plant classes with an accuracy of 99.1%. Feyaerts et al. (1999a; 1999b) used the spatial dimension in a tree-based cluster algorithm, making it possible automatically to collect and label training samples for crops emerging in rows. The plant pixels within the rows were classified using the spectral dimension and a dynamic algorithm that continuously adjusted the spectral signatures separating crop and weed according to the prevailing growth and illumination conditions. The algorithm proved to be able to recognize crops and weeds with an accuracy of almost 94%, enabling a significant herbicide reduction, from 15 to 67% (Feyaerts et al., 1999b). However it is difficult to compare the classification performance of the different approaches across the authors. Hence this work introduce an open image database of crop and weed species consisting of 1013 stereo image pairs of *Brassica napus* (oilseed rape), *Zea mays* (maize), *Solanum nigrum* (nightshade), *Apera spica-venti* (windgrass), *Centaurea cyanus* (cornflower) and *Hordeum vulgare* (barley). Extraction of 34 different features representing representing shape and color information is performed. The suitability for accurate plant classification using the set of features is investigated. Using this set of features the plants are classified with an accuracy of 96%. The three most significant features (skeletonMean, ConvHullAreaRatio and formfactor) are identified and can maintain a success rate of 88%.

O11

Bauer, Sabine D., W. Förstner

Methods for the improvement of pixelwise classification results for the automatic detection of leaf diseases

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For precision crop protection it is essential to know the spatial distribution of the infected areas in the field. Due to their economical impact in Germany we are interested in the automatic detection of leaf diseases on sugar beet plants. For our analysis we use multispectral images in high resolution from single leaves taken in a lab under well controlled illumination conditions. We want to distinguish healthy leaves or leaves which are either infected with the leaf spot pathogen *Cercospora beticola* or with the rust fungus *Uromyces betae*.

Previous investigations have shown that the leaf spot disease *Cercospora beticola* and the rust *Uromyces betae* can be classified with an accuracy from more than 93% in the median by a pixel wise classification with an adaptive Bayes classifier using Gaussian mixture models. However, pixel wise classification methods generally do not exploit the spatial distribution of the leaf diseases.

In this paper we investigate two methods for improving the result of pixel wise classifiers. The first method smoothes the output label images from the pixel wise classification and generates connected components. At best each leaf spot is detected as one connected component. These connected components are classified again into the different leaf diseases in a next step. The second method uses a Markov random field explicitly modeling the spatial structure. In contrast to the first method the Markov random field takes the neighbourhood information into account and operates directly on the pixel wise result.

O12

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RoPDeF - semi-automated and web-based Route Plan Designer of full-scale Field trials for tractor guidance systems

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Earlier works have shown field trial design to be very labour extensive, even when combining auto-guidance systems and conventional machinery (Jørgensen et al., 2007; Nielsen et al., 2008). Designing routes for such semi-automated systems, in a controlled manner, is both, resource demanding and complicated. Additionally, different types of auto-guidance systems vary in their file formats and operational requirements, which creates an unnecessary burden for the field trial managers and researchers operating on different computational platforms such as Windows, Mac or Linux. This work demonstrates a methodological proof of concept for a software solution for assisting in the development and deployment of georeferenced routes, to be used for full scale field trial designs assisted by auto-steering solutions. The software works in conjunction with Google Earth, for importing field boundaries, and for viewing and validating completed field trial designs. The software is platform independent and online distributed, by means of the Java development environment. This work shows a novel cross platform software application for semi-automated and web-based Route Plan Designer of full-scale field trials for tractor guidance systems (RoPDeF) and the steps needed to lay out full scale multi-treatment setups, georeference them via e.g. Google Earth and how to transfer them to an auto-guidance tractor computer. A case study was used as demonstrator. In June 2010 a field test was established ensuring that representative data was collected, spanning the expected operational domain of a future, real-time, crop-discriminating cell spraying module, based on computer vision. The main purpose of the tests were to acquire field images of crops and weeds, while simulating several kinds of lighting conditions, crop appearances, and weed densities.

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O13

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Non-invasive phenotyping of model- and crop plants

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In agri- and horticulture as well as in nature plants are exposed to environmental factors that may cause stress. Both, the genome of a plant and the environmental factors, have impact on the phenotype of a plant. Therefore, stress tolerant crop plants are a central aim of breeding. Plant phenotyping needs sensors that can capture developments of phenotypes with high sensitivity. Development and optimization of phenotyping sensors for model- and crop plants is a central task of the Jülich Plant Phenotyping Centre.

GROWSCREEN FLUORO enables phenotyping of the model plant Arabidopsis thaliana. It analyses growth, morphology and photosynthesis at a throughput of 60 plants per hour. Images acquired by an imaging chlorophyll fluorometer are analysed with a computer. The projected leaf area is shown as a mask image. Within the mask, fluorescence parameters are captured with spatial resolution. They are displayed as integrated numerical values and colour-coded images. Furthermore, the mask images serve to calculate morphological factors. With this method, it is possible to analyse the impact of environmental factors on plant populations and to compare lines with different genetic properties. This allows the analysis of ecophysiological questions in basic research. In plant breeding, it is possible to do screenings of genetic lines (mutants or transgenics) in the Arabidopsis-model as a pre-selection in the process of the development of improved crop plant lines.

A crop plant imaging station equipped with a crane system is being set up in a greenhouse. Plants are automatically transported into the measuring station. The transport process can include a weighing and watering step. Inside the measuring unit, the biomass of plants like rapeseed, sugar beet, maize, or barley can be measured non-invasively. All steps are connected to a database, which allows following the development of individuals and populations. Comparisons of genetically different populations as well as various environmental scenarios are enabled. Phenotyping of crop plants under biotic or abiotic stress can be performed.

O14

Plümer, Lutz, T. Rumpf, C. Römer

Advanced machine learning methods for early detection of weed and plant diseases in precision crop protection

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Early detection of plant diseases and weeds is vital for precision crop protection. Early date of prediction has significant influence on the extent and effectiveness of fungicide and herbicide applications. In the DFG Research Training Group GRK 722 (Use of Information Technologies for Precision Crop Protection) hyperspectral reflectance and fluorescence data have been used for the pre-symptomatic prediction of plant diseases, namely Cercospora leaf spot, leaf rust, and powdery mildew. Hyperspectral signatures contain relevant information about the occurrence of pathogens even at a very early stage. Much the same is true of early weed detection. Shape parameters derived from bispectral images have an enormous potential for the early identification of weed in crop, the interpretation of such signals, the extraction and selection of significant features and the design of robust classifiers, however, are major challenges from a machine learning perspective. The signal noise ratio is demanding. Classes are not easily separable. Feature spaces are highly dimensional, in contrast to a limited number of test samples. Advanced machine learning methods such as ensemble based learning and support vector machines have proved their ability to cope with these challenges. Based on experiments in GRK 722 we will present some instructive examples integrating modern sensor techniques with advanced machine learning methods and discuss potential and challenges of this approach. It turns out, however, that a single approach does not provide satisfactory results. The problem specific extraction and selection of relevant features together with task oriented classification methods is necessary for robust identification of weed and pathogens at the earliest possible date.

O15

Post, Joanna, Goldbach, H., Schmidt, K.

CROP.SENSe.net – Networking sensor technology R&D for crop breeding and management

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The current challenges faced by crop breeding and management include increased demand for food from a growing world population, changing dietary needs, increasing cultivation of biomass crops as an energy source and global changes due to climate change. Maintaining an increasing production rate, achieved over the latter half of the 20th century, is thus an emerging problem. Crop research and crop breeding need to provide both qualitative and quantitative improvements in the production of "food, feed, fibre and fuel" crops within a relatively short space of time. Primary crop production must be the supporting technology for a "knowledge based bioeconomy" to ensure resource resilience, yield security and yield stability.

The recent rapid development of non-destructive sensors and robotics, and the ability of computers to analyse the complex data sets generated, offers new opportunities for non-destructive detection of external characteristics (morphology and growth dynamics) and internal characteristics (biochemical, physiological and genetic) of individual plants and populations. Effective use of sensors could accelerate breeding methods, reduce experimental resource requirements and enable multiple, simultaneous and objective data to be collected and analysed. Development and use of non-destructive methods for qualitative and quantitative assessment of plant characteristics in breeding and the improvement of primary plant production are also the significant steps required to open up the so-called phenomics bottleneck so as to keep pace with advances in genotyping and enable more precise and resource efficient crop management.

CROP.SENSe.net is a novel breed of network, bringing together new research ideas and producing synergies and solutions not possible by traditional single subject research. Partners, across 35 research projects, are working together to develop and improve non-destructive sensor technologies and methods for their application, deployment and implementation in improving food, feed, fibre and fuel crops by high throughput phenomics, deep phenotyping and precision farming.

CROP.SENSe.net uses a wide array of sensor technologies almost over the entire range of electromagnetic radiation such as visible and multispectral analysis, infrared technologies, γ-radiation, wideband radar, TeraHertz and sub-THz scanners, CT and magnetic resonance spectroscopy and others, as well as headspace analysis for volatile indicators of plant (stress) reactions. Merging data (signals) from different sensors will gain synergistic and additional information of plant status. Intelligent data evaluation will enable analysis of spatial information on plant status over time on the same plants.

This presentation will provide an overview and some preliminary results from this 5-year BMBF-funded National Competence network.

O16

Bürling, Kathrin, M. Hunsche, G. Noga

Differentiation between N-deficiency and leaf rust (*Puccinia triticina*) in wheat (*Triticum aestivum*) by means of UV laser-induced fluorescence spectral measurements

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In the context of precision agriculture several non-destructive approaches e.g. fluorescence, reflectance, and thermal-imaging measurements have been tested and adopted for the fast and early detection of individual stresses such as diseases and mineral deficiency. Despite of considerable advances, a reliable discrimination between biotic and abiotic stresses on basis of non-destructive techniques remains a challenge. Earlier experiments have proven that ratios between blue, green, red and far-red fluorescence peaks are very sensitive to stress events due to changes in the content of chlorophyll and secondary metabolites which emit blue fluorescence. Amongst others, plants might accumulate specific compounds such as salicylic acid and phenylpropanoid as key substances in plant disease resistance. On the other hand, levels of nitrate influence phenol and lignin production as both are reduced in wheat shoot by high nitrate levels. Moreover, both nitrogen-deficiency and pathogen infection are accompanied by changes in chlorophyll content. Based on this background information, we hypothesised that a differentiation between moderate N-deficiency and early leaf rust (Puccinia triticina) infection in wheat might be accomplished by means of UV laser-induced fluorescence spectral measurements. For the experiments, plants of the winter wheat (*Triticum aestivum* L. emend. Fiori. et Paol.), cultivar Ritmo, were grown under controlled environmental conditions. Emerging plants were provided with either a full Hoagland nutrient solution or with a deficiency solution containing 30% of the N-amount of the full-supply-solution. Twenty days after sowing, pathogen inoculation was done on the youngest fully developed leaf (2nd from top). Fluorescence measurements (370 - 800 nm) were carried out by using a compact fibre-optic fluorescence spectrometer with a nanosecond time-resolution and operated with the boxcar technique (IOM GmbH, Berlin, Germany), from two to four days after inoculation. Thereafter, peak positions were determined and ratios of amplitudes, half-bandwidths, and amplitudes to half-bandwidths calculated. According to our results, several ratios showed a clear difference between infected and non-infected leaves, irrespective of nitrogen treatment. Moreover, the amplitude ratio F451/F522 was the most sensitive parameter to distinguish between the four treatment groups: N-full supply (A), N-deficiency (B), N-full supply + leaf rust infection (C) and N-deficiency + leaf rust infection (D). On day three after inoculation, one day before the first weak chlorotic spots became visible, values of this ratio were as follows: (A) 3.8, (B) 3.6, (C) 3.2, and (D) 3.0. In summary, measurements of fluorescence spectra open up promising perspectives for a reliable differentiation between leaf rust and N-deficiency in cereals.

O17

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Hyperspectral imaging and image analysis for the detection and differentiation of sugar beet diseases

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Fungal crop diseases affect the spectral properties of diseased plants in different ways. Therefore, hyperspectral imaging techniques have a high potential as a non invasive diagnostic tool in plant protection. Pixel-wise mapping of spectral signatures allows detailed detection of diseased tissue on the leaf level or diseased areas within field sites. Disease-specific spectral signatures of sugar beet leaves with *Cercospora* leaf spots, sugar beet powdery mildew and beet rust, respectively, have been evaluated, collected in a spectral library and compared to characteristic spectral signature of healthy sugar beet leaves. Under controlled conditions, reflectance spectra from diseased and healthy sugar beet plants were investigated on the leaf and on canopy level. Multi-temporal measurements were recorded using an imaging line scanner spectrometer. Significant differences between the disease-specific spectra were detected in the visible range and in the near-infrared range. Based on the specific spectral signatures, sugar beet leaves with three leaf diseases were differentiated by automatic classification using the spectral angle mapper. In addition, several hyperspectral vegetation indices commonly used in remote sensing science were tested for their suitability in disease detection and identification. Both, automatic classification methods and vegetation indices afforded a good differentiation between healthy and diseased sugar beets. Classification methods were more sensitive in distinguishing between the sugar beet diseases.

O18

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Improving wheat disease detection with hyperspectral data using data reduction techniques

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In the past decade the agricultural area used for wheat cultivation in Germany remained more or less stable, while the yield rates of wheat could be increased. This was possible thanks to the cultivation of high-yielding varieties and the generally intensive usage of agrochemicals with significant environmental impact. The demand of sensor-based decision support in agriculture is rapidly growing since agricultural treatments like the application of pesticides can be realized in a site-specific way if spatially explicit information on the within-field heterogeneity is given. Airborne hyperspectral data has proven to be suitable for wheat disease detection and may deliver fast and precise spatial information of pathogen infections within entire fields. But, however, the entire spectrum is not needed for discrimination between healthy and stressed crops due to irrelevant and/or redundant information in some spectral bands. For a definition of an optimal sensor system for crop stress detection, it is necessary to know which spectral wavelengths at which spectral resolution are affected by stress impact. This study focuses on the improvement of the detectability of diseased wheat stands by reducing hyperspectral data to spectral bands relevant for this purpose. An agricultural area, cultivated with a wheat cultivar vulnerable to leaf rust (*Puccinia recondita*) and 4 hectares in size, was divided into six subplots, alternating with no fungicide application and common fungicide application to cause a variety in disease severities. The different plot types could be well differentiated and classified using spectral angle mapper (SAM) and support vector machines (SVM). Two different feature selection approaches were tested to reduce the hyperspectral data, i.e. the Bhattacharyya distance with a feature forward search strategy and a wrapper approach. The original dataset as well as datasets reduced to several band combinations as selected by the feature selection approaches were classified and compared to in-field sampled stress severities. The results demonstrate that a reduction of the original data to few hyperspectral bands increases the classification accuracy of both classifiers. Thus, the detection of wheat infected by leaf rust could be improved, which allows a derivation of more reliable information for agricultural practice.

O19

Nutter, Forrest W., Jr., N.S. Holah, S.K. Eggenberger

Developing integrated GPS, GIS, and satellite remote sensing technologies to locate the epicenters of plant disease foci

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One of the most critical decisions that must be made (in near real time), is whether or not the discovery of a new biotic threat within a crop was the result of a deliberate introduction (bio-crime), or the result of a natural event (e.g., long-distance transport via weather-related events). It was our hypothesis that the use of high resolution satellite imagery, coupled with GPS and GIS can be used to develop forensics tools to answer such questions. The specific objective of this study was to determine if we could accurately locate the exact GPS coordinates where point sources of soybean rust were deliberately introduced into soybean field plots. Satellite imagery (IKONOS) was obtained during the growing season and the epicenters of soybean rust disease foci were detected by generating image intensity contour maps, (ii) developing a kriging method, and (iii) developing a transect method. Of the three methods, contour map method had the highest accuracy (within 1.7 m) and precision (± 1.3 m) in locating the actual soybean rust epicenters. We propose that high resolution satellite imagery can be developed and used to:

(i) Look for anomalies in other fields of the same crop within each 10 x 10 km image scene,

(ii) Detect and map crop canopy anomalies (such as primary and secondary disease foci),

(iii) By applying various spatial analyses. Determine if crop anomalies are due to a natural or deliberate introduction,

(iv) Use satellite imagery to direct sample collection for pathogen isolates within and among disease foci.

In conclusion, high-resolution satellite imagery, when coupled with GPS and GIS tools, accurately and precisely determine the GPS coordinates where soybean rust was deliberately introduced into soybean plots.

O20

Walgenbach, Martin[1], M. Dörpmund[1], Cai Xiang[2], J. Vondricka[1], R. Lutz[1], P. Schulze Lammers[1]

Construction and investigation of a field sprayer with direct nozzle injection of plant protection products

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Direct injection systems for plant protection products (PPP) are developed to increase precision in application, prevent the operator from contact with the chemical agents and to protect the environment against harm. They can be divided by their injection points of the PPP in the Pipes, which cause different response times until the spray mixture exits the nozzle. For sensor-based spraying of PPP, a fast reacting injection device is required to be able to apply on-the-go.

A prototype field sprayer with direct nozzle injection based on a standard sprayer is constructed for real-time site-specific application of PPP. The response time of the injection device is less than 230 ms. The application rates of the PPP are to be changed independently from the droplet size of the spray mixture at the nozzles.

The interactions in the hydraulic system for the PPP between temperature, viscosity and pressure are studied. Prototypes of ball valves for metering of the injection are investigated and a controller is set up. A field programmable gate array (FPGA) and a PID controller running on a real-time computer are used for valve control by a pulse-width modulated (PWM) signal. The amount of PPP injected by the valves ranges from 0.1 to 150 mls^{-1} and the viscosity from 1 to 800 mPa·s.

Pressure in the hydraulic system is kept constant and metering of the injection is enabled by changing the opening time of the valve. The accuracy of the injection is investigated. Variations in viscosity and pressure need to be compensated by the controller. After finishing spraying the residues in the pipes are pushed back to the tank by pressurized air and a cleaning procedure starts. In laboratory experiments this is investigated.

A standardisation of PPP-formulations would help to eminently reduce the complexity of the control system.

O21

Andersson, Kim Johan, H.S. Midtiby, R.N. Jørgensen

Novel precision targeting system for laser weeding of dicots

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Not presented because of illness

O22

Giles, D. Ken[1], A.J. Hewitt[2,3], R. Connell[3], Z. Czaczyk[4]

Drift reduction characteristics of pulse-width modulated spray control

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Not presented

O23

Kempenaar, Corné, P.O. Bleeker, F.K. van Evert, J. Hemming, A.T. Nieuwenhuizen, E.J. Pekkeriet, R.Y. van der Weide, J.C. van de Zande

Variable rate application of pesticides in potato and tulip

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Precision agriculture technology offers opportunities to optimize weed control site specifically. The optimization of weed control takes place at the level of grids within the crop or field, or at the level of individual plants in the crop. The size of grids in site specific weed control strategies is roughly between 1 and 100 m^2. Individual plant treatment takes place at a smaller scale and higher resolution, at the level of several cm^2. Though important steps have been made with R&D of site specific weed control strategies during the past two decades, the use of these strategies in current agriculture is still limited.

Every site specific weed control strategy consists of (1) a sensing unit for detection of site-specific variation in weed, soil and/or crop conditions, (2) a decision making unit that translate sensor readings into need and intensity of treatment, and (3) an actuator or implement unit that carries out the weed control. To be successful in practice, the strategy must be competitive with current methods and strategies in terms of costs, efficacy and ease of use. Several projects at Wageningen University & Research Centre are aimed to further develop site-specific weed control methods and strategies, focusing on sensor optimization, decision algorithms, actuators and integration of the different units. In this paper, we address decision algorithm development in four projects: (1) plant detection in crop rows and plant specific mechanical control, (2) plant specific mechanical control of *Rumex obtusifolius* in grassland, (3) site specific dosing of soil herbicides, (4) site specific dosing of potato haulm killing herbicides and (5) site specific dosing of fungicides in potato and tulip. Most attention in the presentation will be given to project 3, 4 and 5.

In project 3 doses are adjusted to site specific conditions to a scale of ca 30 m^2. Soil maps with spatial variation in soil organic matter are the basis for site specific dosing of soil herbicides. Dosing algorithms that relate soil organic matter to dose were determined in greenhouse experiments. Adjusted doses are applied with injection sprayers or conventional sprayers carrying spray booms wider than 24 m. Efficacy date under field conditions are not yet available. Potential reductions are 10 – 20%.

In projects4 and 5 doses are also adjusted to a scale ca 30 m^2. Nearby sensing of crop biomass is used to determine spatial variation within the crop, and is the basis for site specific dosing of the potato haulm killing herbicides. Dosing algorithms that relate crop biomass to minimum lethal doses were determined under field conditions. The strategy has been tested in more than 20 potato fields over four years. On average, a reduction of nearly 50 % was obtained for potato haulm killing herbicides, while efficacy remained good. In project 5 reductions of about 25% in fungicide use were obtained (tested on 3 crops only).

In projects 1 and 2, algorithms for detection of specific plants were developed. Highlights of these projects will be briefly addressed (see also abstract of Nieuwenhuizen et al.).

O24

Gude, Johanna, L. Damerow, P. Schulze Lammers

Weeding by laser application

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One of the main aims of precision crop protection is to reduce the chemical amount of pesticides, in particular the herbicides. The thermal weed control is an efficient alternative to herbicides and physical treatment. Already known as a thermal weed control method are the flame-scarfing technology and the application of hot water or hot foam. The intention of this project is to depress the weeds in crops and to achieve a diminished competition between weeds and crops.

The first experiments should help to detect the biological and technical parameters of laser and plant. To test typical and morphological different weeds in crops, one monocotyledonous (*Alopecurus myosuroides*) and one dicotyledonous (*Anthemis arvensis*) were sowed in small pots. The cultivation has proceeded under constant conditions in the greenhouse. The application experiments took place in the Fraunhofer Institute of Laser Technology in Aix-la-Chapelle. Two types of laser were available in the institute, an Ytterbium-Fibre-Laser and a CO_2-Laser. The two lasers were able to vary power [kW], spot diameter [mm] and residence time [ms]. Thereby it was possible to test different experimental series with diverse biological and technical parameters: plant species, growth stage, point of application, type of laser, power, spot diameter and residence time.

After the application the treated weeds were rated for 3 weeks and, in some cases, observed by different microscopes, a thermal and a high-speed-camera.

First experiments proved that weeds were damaged by laser radiation. Thereby, because of the high laser precision, it is very important which point of application is focused. The highest output was achieved by attacking the growing centre or the stem basis. Most of the weeds being attacked in the growing centre died immediately after treatment, at the latest 4 days after. Different experimental series relating to the diverse parameters were tested. The intention of these tests is to detect the best combination of parameters relating to the lowest energy input and at the same time the highest depression of the weeds.

In addition we have to work on a combination between the laser application and the detection of weeds. At the best it is possible to create an autonomous working unit for the application on field.

O25

Dammer, Karl-Heinz

Variable rate growth regulation in winter rape in autumn by a camera controlled field sprayer

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In northern Europe winter rape is sown in late summer. In this time before seeding the soil is often characterised by low moisture due to the water consumption of the preceding crop, low precipitation, wind or high temperatures. Under these conditions the germination is disturbed. According to the water content of the soil the germination time could be locally different within the field. At the same time different growth stages of the crop occur within a heterogeneous plant stand.

In autumn farmers usually spray fungicides as growth regulators. For instance azole-fungicides sprayed in late September or October protects the rape plants against fungal diseases and inhibits the growth. The shortening of the plants resulted in a higher freezing resistance while winter. But in areas of the field with small late germinated plants a restraint of the growth is not wanted. These plants should growth further on.

The coverage level can be used for characterising heterogeneous rape fields in autumn and for adapting the dosage of pesticides. In a heterogeneous rape field (35 ha) in autumn 2009 a variable rate application of Folicur® was performed according to the coverage level. After binarysation of the red and infrared images the coverage level was automatically detected by camera vision. The 3-chip-CCD camera was mounted on the three-point linkage of the tractor. The field sprayer was controlled by the camera vision system using special software. There was a saving of around 22% of the fungicide/growth regulator product. In December, before the crop went into the vegetative rest, growth differences were not so distinct compared with the time of application.

Adapting the application amount of the pesticide according to plant parameters could help to optimise the input in means of production and to reduce the input of pesticides into the environment.

O26

Olatinwo, Rabiu O.[1], R.C. Kemerait, Jr.[2], J.O. Paz[1,3], G. Hoogenboom[1]

The TSWV risk calculator: a weather-based assessment tool for managing risk of tomato spotted wilt of peanut in Georgia, United States

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Tomato spotted wilt disease of peanut (*Arachis hypogaea* L.) caused by Tomato spotted wilt virus (TSWV), a member of the genus Tospovirus (family Bunyaviridae) is responsible for several million dollars worth of crop loss in the southeastern United States annually. The initiation of spotted wilt infection and subsequent spread of the virus in peanut field during the growing season relies on favorable weather conditions. Following the first report of spotted wilt in 1986, a multidisciplinary research effort at the University of Georgia led to the development of a TSWV risk index based on on-farm survey and field experiments data. However, due to inter-annual weather variability, there is a need for weather information in the index to accurately determining tomato spotted wilt risk. The goal of this study was to improve the accuracy of the TSWV risk index by incorporating weather information for a reliable assessment of spotted wilt risk at the beginning of the season. The specific objective was to develop a weather-based TSWV risk index based on identified agronomic, cultural, and environmental factors. Historical on-farm survey data from peanut fields in Georgia from 1999 to 2005, and the corresponding meteorological data obtained from the Georgia Automated Environmental Monitoring Network (AEMN: www.georgiaweather.net) were analyzed. The best model identified accounted for 61% of the variation in spotted wilt intensity. The model combines agronomic, cultural, and environmental factors in predicting TSWV risk in Georgia. A web-based risk tool developed from the model equation is currently being optimized. A fore knowledge of potential TSWV risk based on the calculator may be useful in mitigating the risk of tomato spotted wilt epidemics. An optimized and accurate TSWV risk calculator would help growers make important management decisions in reducing crop loss.

O27

Overstreet, Charles[1], E.C. McGawley[1], M. Wolcott[2], D. Burns[3], E. Burris[4], G.B. Padgett[5]

Using verification strips to define nematicide response areas to the Southern root-knot and reniform nematodes in cotton in the Alluvial soils of the mid-South, USA

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The Southern root-knot nematode (*Meloidogyne incognita*) and reniform nematode (*Rotylenchulus reniformis*) are serious pests of cotton in many fields along rivers such as the Mississippi River in the mid-South regions of the U.S.A. These alluvial soils are quite variable in soil texture at the surface and within the soil profile. The use of apparent electrical conductivity (ECa) is now widely utilized to help measure this textural variability within a field. Although nematodes such as Southern root-knot are generally associated with sandy soils, the damage caused by them can be reduced as soil texture changes. Verification strips are rows that are treated with a nematicide (usually 1,3-dichloropropene at 28 L/ha at least 10 days prior to planting) or left untreated through the various soil zones within a field as determined from ECa. These strips are repeated two-eight times within a field. The yield of resulting from each treatment is compared within soil zones to determine where the fumigant was efficacious. The responses to the fumigant have ranged from -125 to 650 kg ha of cotton lint in various soil zones. Soil zones that had the lowest ECa values generally gave the greatest response to the fumigant (av. 365 kg ha of cotton lint over the untreated). Additionally, fields that were predominately infested with Southern root-knot nematode gave higher average responses to the fumigant than fields either infested with reniform alone or combined with Southern root-knot (260 kg/ha compared to 170 kg/ha of cotton lint over the untreated). The use of verification strips has been shown to be an effective method of determining where nematodes are causing yield losses as well as the areas that are non-responsive to the application of the fumigant.

O28

Zeuner, Thorsten

Use of Geographic Information Systems in crop protection warning service

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One of the important aims of the German Crop Protection Services (GCPS) is to reduce spraying intensity and to guarantee an environmentally friendly crop protection strategy. ZEPP is the central institution in Germany responsible for the development of methods in order to give the best control of plant diseases, so far more than 20 met. data -based models were developed and introduced into practice. This study shows that it is possible to obtain results with higher accuracy for the models by using Geographic Information Systems (GIS). The influence of elevation, slope and aspect on met. data were interpolated with GIS and the results were used as input for forecasting models. The results of interpolation are saved in a grid over Germany. At the moment the area of Germany (357.050 km^2) is represented by ca. 570 met. stations, that is one met. station each 626 km^2. A grid cell is 1 km wide which means that after interpolation each square kilometer of Germany is represented by a virtual met. station (= grid cell). Multiple Regression method is used to interpolate temperature and relative humidity. A comparison between real temperatures and interpolated temperatures showed results with high accuracy. The coefficient of determination in all cases ranged between 96 and 99%. Interpolated met. data are made available for disease forecasting models. Absolute differences of forecasted and recorded dates for late blight first occurrence were three days, which must be regarded as a highly accurate result. Currently additional disease forecast models are adapted and validated to this method.

Abstracts

III Poster presentations (in alphabetical order)

P1

Andújar, Dionisio[1], A. Escolà-Agustí[2], J. Dorado[1], C. Fernández-Quintanilla[1]

Using ultrasonic sensors for weed detection

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A new approach is described for automatic assessment of weed biomass and height in wide-spaced crops. An ultrasonic sensor was mounted on the front of an ATV vehicle, pointing straight downward to the ground. The control system sequentially registered and georeferenced the echoes reflected by the various leaf layers or by the ground. Preliminary measurements taken on bare ground with vegetation patches of various lengths, heights and densities suggested that this procedure may be adequate to detect, quantify and classify weed patches. Resulting echograms showed clear differences in patch characteristics. The weed detection system was further evaluated in maize fields in the early spring (with weeds at the 2-to-6 leaves growth stage), pointing the sensor to the inter-row area. For static measurements, 180 sampling points with different densities of pure and mixed stands of *Sorghum halepense*, *Xanthium strumarium* and *Datura stramonium* were assessed. Immediately after the measurements, the sample areas were harvested, determining weed height, density, biomass and cover. Results showed good relationships between sensor readings and various weed parameters. For dynamic measurements, a 2-ha field with a heterogeneous distribution of *S. halepense*, *D. stramonium* and *D. ferox* was assessed using the ultrasonic sensor and a DGPS receiver mounted on the front of a tractor. Actual geopositioned measurements of weed biomass and height confirmed the good relationship between these data and sensor readings.

P2

Balsari, P.[1], G. Doruchowski[2], P. Marucco[1], Ard T. Nieuwenhuizen[3], M. Tamagnone[1], J.C. van de Zande[3], M. Wenneker[4]

Evaluation of a crop identification system and an environmentally dependent application system in apple orchards

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Within the European ISAFRUIT project a Crop Adapted Spray Application (CASA) system for precision crop protection has been developed. The system consists of three parts. First part is the Crop Health Sensor (CHS), the second part is the Crop Identification System (CIS), and the third part is the Environmentally Dependent Application System (EDAS). The CIS system consists of an array of six ultrasonic sensors that measures the width and density of the fruit tree canopy that is travelled alongside. This enables the automatic adjustment of spray dose according to the canopy characteristics, deviating from the required nominal dose. When no canopy is detected by the sensor array, the spray nozzles are turned off, and therefore minimizing unwanted spray drift. In addition to the CIS system, the EDAS software layer determines based on RTK-GPS position in the orchard, e.g. close to the sides of the orchard, or close to waterways or wells, whether the coarse or fine droplet nozzles are selected for spraying by the EDAS system automatically based on RTK-GPS. The sensor and positioning systems that have been combined in the CASA sprayer should minimize the environmental load of spraying crop protection chemicals in fruit tree orchards.

The CIS system and the EDAS system were tested in seasons 2008, 2009 and 2010 for their performance in apple orchards in Italy, Poland and the Netherlands. The performance was measured in terms of spray deposit, spray drift, biological efficacy and residue on fruit. In Italy, the volume applied with CIS activated (435 L/ha) was halved with respect to the nominal volume of 850 L/ha, with comparable spray deposition on leaves. The measurements in Poland showed that using drift reducing nozzles and reduced airflow on the outer rows of the orchards did not cause significantly lower deposition on the leaves of these trees. The field trials in the Netherlands showed that secure calibration of the crop identification sensors is required. Drift, deposition, residue and efficacy data of year 2010 experiments are still under analysis.

The combination of precision crop sensors and position in orchard was valuable to maintain efficacy and reduce environmental load when spraying fruit orchards.

P3

Basi, Sabin[1], M. Hunsche[1], G. Noga[1], L. Damerow[2], P. Schulze Lammers[2]

Potential use of a monodroplet generator as an alternative application device for a precise weed control

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With the objective of exploiting alternative options for minimizing the herbicide use contrasting to the conventional application technology, while increasing the required biological efficacy, a pneumatic droplet generator has been constructed to produce monodroplets of herbicide solution aiming a target-oriented weed control. Principally, the device works by pneumatic pressure generated with nitrogen gas. A solenoid valve controlled by an impulse generator regulates the pressure, breaking liquid jet exiting from the nozzle, and discharging a single droplet. Excess gas is exhausted through the vent, dampening the pressure so that no more droplet discharges. As shown in our experimental studies, the application device delivers the required amount of herbicide consistently and accurately. As integrative part or the tests, parameters such as the effect of impulse width for controlling the gas flow through solenoid valve, vent opening, pressure, and composition of liquid affecting surface tension of the herbicide have been evaluated. Increase in the impulse width, vent closer or orifice size raises the droplet volume. Decreasing the surface tension of the liquid with a surfactant, had an effect of reducing the volume and the pressure required for droplet formation. With an optimum adjustment of the parameters impulse width, exhaust vent, orifice size, and the pressure, the droplet generator can successfully be used to deliver droplet volumes as low as 0.05 µl to 2.5 µl. Apart from monodrops, the device can also be used to deliver the required volume in the form of jet streams too. Delivery efficiency of the device has been tested with model weeds characterized by hydrophobic or hydrophilic leaf surfaces. The effect of height, volume of herbicide droplets and surfactants has been studied with regard to droplet retention. In general, the selected surfactants had a positive effect on retention capacity owing to reduced surface tension of the herbicide formulation, while droplet volume and height of application had a negative effect. In the upcoming experiments, interaction between generated droplets and plant surface with regard to the biological efficacy will be evaluated. The use of the equipment could be extended for other purposes also, such as, fungicide, insecticide or micro-nutrient application.

P4

Berdugo, Carlos A., U. Steiner, E.-C. Oerke, H.-W. Dehne

Evaluation of physiological effects of fungicides in wheat by infrared thermography

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In addition to fungicidal effects, some fungicide classes like Qo-inhibitors have been reported to induce positive physiological modifications in crops. Physiological effects may be detected by destructive methods such as preparations of enzymes and pigments. An excellent alternative to destructive methods is the use of imaging techniques, which give the possibility to have an early detection of changes caused by several factors such as biotic and abiotic stresses. Near-range infrared (IR) thermography is a non-destructive method which allows the recording of the temperature of plant surfaces depending on differences in transpiration rate. The effects of four fungicidal groups on the leaves and ears senescence of wheat were studied in a disease free environment under greenhouse conditions. Fungicides were applied at two growth stages (GS), first when the flag leaf ligule was visible (GS 39), and when the emergence of inflorescence was completed (GS 59). The green leaf area duration (GLAD) was assessed as a percentage of green area of the leaf blade of the uppermost three leaves. Digital thermal images were obtained using a Varioscan 3201 ST (Jenoptic Laser, Jena, Germany) at four growth stages (GS 75, 80, 85 and 90). Differences in transpiration rate among treatments were confirmed by IR-thermal images; significant differences were detected regarding the temperature of leaves and ears between fungicide-treated and untreated plants. At GS 75 and 80, differences in leaf and ear temperature were significant. In contrast, no significant differences in the ear temperature were detected among treatments at GS 90. Fungicides increased GLAD when compared to untreated wheat plants. This difference was more evident at the flag leaf than at F-1 and F-2. Additionally, this increment was higher when strobilurin and carboxamide fungicides were used as compared to the treatments with an azole or spiroxamine. A direct relation was found between GLAD and transpiration rate, due to the fact that plants with longer GLAD had a lower temperature of leaves and ears. Remote recognition of physiological changes in plants whit thermal images is an accurate alternative in order to detect the effects of fungicides on plant senescence.

P5

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Developing Sweedy - a robot for weed control in swedes (*Brassica napus* ssp. *rapifera*)

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Rutabaga or swede (*Brassica napus* ssp. *rapifera* Metzg) is a root vegetable rich in vitamin C used for both fodder and human consumption in Norway. One of the tasks in the project Change in production methods for swede – new measures and strategies for cost-effective weed control (2009 - 2011) was robotic weed control. The sub-tasks of the robotic weed control were to develop machine vision for intra-row weed detection and a tool suitable for intra-row and close-to-crop weeding in rutabaga.

Machine vision

The first version of the software was based on images from a farmer's field with seeded rutabagas in SE Norway. The images were recorded in June 2009 when crop had 2 - 4 true leaves, simultaneously with the manual, time-consuming weeding and thinning operation. Two xenon lamps were mounted on a hand-pulled wagon together with a digital SLR. Nadir view images 0.75 meter above soil surface were sampled continuously in the crop row with a resolution of 10 pixels mm^{-1}. The main weed species were the annual dicotyledons *Chenopodium album* L. and *Vicia* ssp. The strategy was to identify the crop plants using their leaf geometry and assuming all non-crop leaves to be weed leaves. A safety region around the crop leaves was also defined. Processing time was about 10 - 15 images $second^{-1}$.

Intra-row weeding tool:

The intra-row weeding tool under development is based on a commercial printer head. The width of the tool is 64 mm and has 16 "nozzles" (15 µm opening). The intended application resolution is 4 mm. The challenge is its precision when application distance is more than 10 cm. The planned active ingredient is commercially available and gives no toxic residues. It is expected to be accepted in organic as well as conventional farming.

Test platform:

For indoor and outdoor tests, a vehicle moving on rails was build. We will test the integration of imaging, machine vision and the software to target intra-row weed pixels with this platform at a field of seeded rutabagas in June 2010. The concept is applicable for other row crops as well.

P6

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HydroSense: Weed mapping by using ground-based sensing systems in cotton in Greece

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Not presented

P7

Chojnacki, Jerzy

Effect of changes of liquid static pressure on entomopathogenic nematode viability

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Entomopathogenic nematodes are used in organic agriculture as a biological pest control agents. The nematodes mixed with liquid are applied onto plants or into soil by the means of sprayers. During this application, the nematodes might be pumped multiple times through the hydraulic installation of the sprayers. The nematodes flow from the sprayer tank through the pump, valves, agitator or overflow pipe, and then return into the tank. This process might potentially kill them. The cause of nematode destruction can be changes of liquid static and dynamic pressure inside the installation. The aim of the experiments was to determine if the changes of liquid static pressure could be the cause of the entomopathogenic nematodes damage inside the sprayer. The material used in the experiments, were nematodes *Steinernema feltiae* and *Heterorhabditis megidis*. To determine the extent of damage to living organisms in the conducted experiments a nematode relative viability was used. The relative viability is a percentage of number of living organisms in the total number of nematodes. There were compared the relative viability in samples of liquid which were taken before the experiment with from with relative viability in samples which were taken after treatment in the experiment. All specimens with nematodes were kept for 24 hours at a temperature of 18°C. This time was established in such a way that nematodes which were negatively affected by pressure but had not died could be dead. In the experiments, samples of nematodes in water were placed into a pipe. In the pipe, liquid was pressurized by a pump. Experiments were performed with timed intervals of the pressure treatment. In order to find a strong signal of the extent of nematode damage in the experiments, pressures were set at 21 and 53 MPa. The values of pressure frequency interruptions were changed from 1.08 to 3.33 Hz. The differences of nematode relative viability in liquid samples before and after pressure treatment were observed. Conclusion In the experiments, no influence of the change of static pressure on the relative viability of entomopathogenic nematodes was found.

P8

Coelho-Netto, R.A.[1], F.W. Nutter, Jr.[2]

Moko disease of banana: Use of GPS and GIS tools to map disease risk

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Moko disease of banana, caused by the bacterial pathogen *Ralstonia solanacearum*, causes a lethal disease of banana in many parts of the world, but is especially devastating to the subsistence farmers in the Amazon region of Brazil. The coupling of GPS and GIS technologies with disease survey data regarding the prevalence and incidence of plant disease has tremendous potential for deriving new spatial information regarding disease risk. An extensive survey to detect the presence (prevalence) and incidence of Moko disease in subsistence farms growing banana was carried out in 2001 and repeated in 2003. Inspection of GIS maps showing the presence/absence of Moko disease at subsistence farm locations in the Amazon River Basin and the locations of subsistence farms subject/not subject to periodic flooding revealed prevalence maps for Moko disease were nearly identical to GIS maps for farms subject to periodic flooding. Chi-square analysis was then performed at the farm scale and plant scale to determine if the risk for Moko disease was associated with periodic flooding. At the farm scale, the prevalence of Moko disease in 2001 was 30/53 in periodically-flooded farms, but only 1/55 in subsistence farms not subject to periodic flooding (ŧ2= 39.59, p≤ 0.0001). In 2003, Moko disease was present at 14/18 subsistence farms subject to flooding versus 2/17 in non-flooded farms (ŧ2=15.35, p ≤ 0.0001). Higher incidence (risk) for Moko disease was also associated with subsistence farms subject to periodic flooding at the plant scale (in 2001, ŧ2= 446.31, p≤ 0.000, and in 2003, ŧ2=202.49, p≤ 0.0001).

The use of GPS and GIS tools in this research project led to the discovery of a new mechanism for long distance dispersal of the causal organism, *Ralstonia solanacearum*. The conceptual model for long distance dispersal by river water is plausible due to the practice of cutting Moko-infected plants near ground level and leaving infested debris where it was cut. Periodic flooding then removes bacterial cells from the debris and transports these bacterial plumes over long distances. Spatial dependence of Moko-infected subsistence farms at distances exceeding 200 km has been detected using k-function spatial analyses.

P9

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Residual disposal and cleaning of direct injection systems for pesticide application

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Over the past years an increasing awareness on environmental issues contributed to precision plant protection becoming an important area of research in agricultural science. In practice, precise pesticide application will not only save the environment but it will also increase the efficiency of active ingredients. Therefore, research has been done on direct injection systems for agricultural pesticide application which keep the pesticide and carrier (water) separate while metering and mixing them on demand within the pipeline before entering the nozzle.

The objective of this work was to evaluate and characterize the cleanability and cleanliness of a direct injection system for pesticide application. Since the sprayer is still under construction, cleaning experiments were carried out on a test bench. Results from cleaning experiments were also supposed to highlight potential problems that might as well occur to the real sprayer. The 21 m sprayer will be equipped with 42 direct injection units, one for each nozzle. Each direct injection unit will carry a mixing chamber and three fast reacting dosing valves, allowing the operator to inject three different pesticides at the same time.

Although the intended cleaning procedure includes both pressurized air to push the pesticide back into the pesticide tank and water for subsequent rinsing, first laboratory tests focused on cleaning effects of air only, beginning with a general assessment of the cleanability of different materials. Instead of real pesticides, save-to-use PVP solutions were selected to contaminate the hydraulic system in a controlled manner. The degree of cleanness was determined gravimetrically.

Questions to be answered through first laboratory tests were:

- How does the choice of tubing material affect the cleaning result?
- How much of excess pesticide can be removed from a boom section by pressurized air?
- How are the residues distributed along the boom section?
- How much air do we need to push a relatively high amount of pesticides out of the pipes?

PTFE was, as expected, the material most cleanable followed by PVC and stainless steel or glass. Pressurized air could remove more than 90 % of the simulated pesticide from a boom section. There was a strong non linear gradient of residues along the boom section.

P10

García-Torres, Luis, D. Gómez-Candón, J.J. Caballero-Novella, M. Gómez-Casero, J.M. Peña-Barragán, M. Jurado-Expósito, F. López-Granados

Use of SARI® software for remote images processing in precision crop protection

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This works aims to show the capabilities of SARI® software in precision crop protection, as follows: a) Sectioning and assessment of weed infestations at a “micro-image”/ “micro-plot” level; b) Implementing a weed-crop competition/ bio-economic model; and c) Developing site-specific herbicide prescription maps. The software SARI has been developed to achieve precision agriculture strategies through remote sensing imagery. It is written in IDL® and works as an add-on of ENVI®. It has been designed to divide remotely sensed imagery into “micro-images”, each corresponding to a small area (“micro-plot”), and to determine the quantitative agronomic and/or environmental biotic (i.e. weeds, pathogens) and/or non-biotic (i.e. nutrient levels) indicator/s of each micro-plot. The microplot length and height is arbitrarily defined as multiple of the image spatial resolution. SARI calculate for each microplot diverse indicators, such as the integrated pixel digital values (IDV) and the percentage of pixels (%PI) with a DV≠0, and classify the microplots in arbitrarily defined classes based in these indicators. Spatial patches aggregation of biotic/ non-biotic factors and their corresponding pesticide/ fertilizer variable rates application prescription maps can be achieved through SARI from remote images and complementary ground-taken data. Examples of SARI functioning over real weed infestations captured in remote images will be displayed.

P11

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A farmer's point of view on within-field variation

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Farmer's knowledge has received little attention yet within precision farming research. However, considering the experience farmers gain throughout seasons and years of intensively working the land, their knowledge may form a suitable source for mapping within-field variation. The study presented here, characterizes and examines spatial knowledge arable farmers have of their fields and explores whether this knowledge is a suitable entry to map within-field variation of soil parameters.

A combination of in-depth semi-structured interviews and field work were applied to capture spatial knowledge of five farmers. Each participating farmer selected a field for further inquiry. The farmer divided the field into homogeneous units and described the soil characteristics of the units. In addition he provided information on the field history, current and past management of the units, yield performance, weed density, nematode occurrence as far as possible. Five soil samples per unit where taken at a random but geo-referenced location and analysed for macronutrients, soil pH, texture and soil organic matter. Results of the soil analysis of units within a field were statistically compared using ANOVA to test on significance.

The results of the interviews show that farmers have extensive knowledge of their fields and furthermore, all farmers in this study apply this knowledge intuitively, as far as technically and economically feasible, during field operations such as soil tillage, application of herbicides and nitrogen and phosphate fertilization. Although some of the farmers used GPS for steering guidance, none of the participating farmers had logged their spatial knowledge or spatial variable practice in any way. Historic land use and geomorphology are reflected in within-field variation of the soil. The results of the soil analysis on organic matter content, clay fraction and fertility showed that overall the knowledge of the farmer formed a suitable starting point to map within-field variation. It is thus regarded an important information source, also for highly automated precision farming systems. The participatory approach is likely to foster increased awareness and implementation of precision farming techniques.

P12

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Multitemporal and multisensoral investigations of canopy symptoms in sugar beet fields caused by *Heterodera schachtii* and *Rhizoctonia solani*

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The characteristically clustered occurrence and low level of mobility of *Heterodera schachtii* and *Rhizoctonia solani* in the soil and the induction of symptoms in the sugar beet canopy make them perfect targets for precision agriculture tools. A field site with natural infestation of *H. schachtii* and *R. solani* was investigated in 2009 with handheld and aerial hyperspectral sensors. At several sample points ground truth data, in particular incidence and severity of pest and disease were collected and geo-referenced. Reflectance measurements obtained from the flight campaigns (AISA, HyMap) and the hand held spectroradiometers were highly correlated with symptoms caused by the beet cyst nematode or *Rhizoctonia* crown and root rot. The results generated in this study, demonstrate that remote sensing in combination with geographic information system technologies can be used as a tool for the detection and mapping of symptoms caused by beet cyst nematode and *Rhizoctonia* crown and root rot. Significant correlations between ground truth and hyperspectral vegetation indices were found. Furthermore, a supervised classification with Spectral Angle Mapper of leaf symptoms induced by the organisms resulted in a classification accuracy of 78% and 62% for the first and second flight campaign, respectively.

P13

Hozayn Mahmoud Abdalla, Mahmoud

Allelopathic potential of 16 flax varieties against burclover (*Medicago polymorpha* L.) weed

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Allelopathic crops may play an important and useful role in minimize lot of problems in agriculture production as pollution of agriculture environment, unsafe agriculture production specially to human and animal, depletion of crop diversity, soil sickness and unavailability of mineral nutrition. To evaluate the allelopathic potential of a plant, germination seed of a test plant are often exposed to whole plants, seeds, plant extracts, or isolated allelochemicals of the aggressive species. In this study, sixteen varieties of flax (7 local, i.e., Sakha-1, Sakha-2, Sakha- 3, Sakha-4, Giza-8, Giza -9, Giza 10 and nine imported i.e., Mayak, Tekka, Alba, Ariana, Letoania-5, Letoania-7, Letoania-9, Fyking and Blanka) were selected to evaluate their allelopathic potential against burclover (*Medicago polymorpha* L.) that cause great damage to flax production in Egypt. Fifty seeds of each variety individually and 50 seed of each Variety plus 25 seed of burclover (together) were planted in the Petri dishes 12 cm in diameter. The germination percentage varied from 36-100% and from 4.44 - 100% individually and with the grass seeds, respectively. According germination %, the flax varieties can be divided to resistant varieties which their percentage of germination varied from 83-100 with Burclover (Sakha-1, Giza-8, Giza -9, Giza 10, Alba and Ariana) and moderate varieties which their germination percentage varied from 61 - 71% (Sakha-4, Mayak and Tekka) and sensitive varieties which their percentage of germination less than 50%. Also, it can be noted that there are some varieties have negative effect on burclover germination as Giza-10, Mayak, Lituania-5, Lituania-7, Tekka and Sakha-2. It could be concluded that flax varieties can be cultivated to adversely affect the germination of the burclover weed without affect on germination of it. We need extensive studies to make an allelopathic map for different crop varieties may be to use as a practical indicator for precision crop protection.

P14

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Estimation of weed pressure in cereals using digital image analysis

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Lack of automatic weed monitoring is a bottleneck for operational site-specific weed control. Weedcer is an algorithm developed for automatic estimation of weed pressure in cereals based on red-green-blue images. It was developed and tested with images acquired in Norwegian cereals seeded at the normal row spacing of the region, 0.125 m.

Images were acquired in spring for spring cereals and autumn for winter wheat. Images were acquired about 0.5 m above the soil surface with a camera mounted vertically on a mobile platform. To ensure even illumination, external flash was used. Each image covered approximately 0.06 m^2 (0.2 m × 0.3 m) and the image resolution was ca 0.25 mm $pixel^{-1}$. The algorithm uses adaptive thresholding for optimal separation of soil and plants regardless of soil conditions and crop colour. Weed leaf candidates are identified based on shape, size, colour and texture. The shape descriptors include roundness, elongation and a set of Fourier features. The candidates are then classified by a support vector machine (SVM) which has been trained on a manually classified, independent data set based on images from 2007 and 2008.

The classifier was tested on two datasets. Test set A consists of randomly selected images from 2007 and 2008. Test set B consists of manually selected images from 2007, 2008 and 2009. Test set B covered a large span of soil conditions, weed and crop densities. We built separate classifiers for spring and winter cereals. Results are given for ground cover. Test set A had 84.0% correct classification of weed vs. spring cereal with 10.9% false positives (cereal classified as weed) and 5.1% false negatives (weed classified as cereal). Test set B had 79.2% correct classification, 6.7% false positives, 14.0% false negatives.
The results for winter wheat were better. Test set A had 91.0% correct classification, 4.5% false positives, 4.4% false negatives. Test set B had 91.7% correct classification, 1.1% false positives, 7.1% false negatives.

P15

Keller, Martina, C. Gutjahr, M. Weis, R. Gerhards

Response of weed coverage to herbicide dose as an integral part of a decision support system for precision weed management

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Precision weed control takes into account the spatial heterogeneity of weed distribution within fields. This spatial heterogeneity can be detected and classified with bi-spectral cameras and suitable classification algorithms. With this technique the coverage of different weeds can be measured with high spatial resolution. In order to adjust herbicide applications to the information provided by the bi-spectral cameras a decision component - commonly referred to as decision support system - is crucial.

A decision support system requires further inputs such as yield loss functions, the estimated yield without any weed competition and the expected price for the crop. This decision component decides whether and what to spray to optimize profit, to minimize seed bank buildup and the risk of resistance development. Furthermore, the amount of applied herbicide could be varied depending on weed coverage. Dose-response curves have been proposed as a part of such decision systems to adjust the applied dose to the weed densities in the field. Dose-response curves estimate weed response - often measured by dry matter - to varying herbicide doses.

In this work dose-response curves of frequently used herbicides were determined for important weeds (*Alopecurus myosuroides*, *Echinochloa crus-galli*, *Galium aparine* and *Chenopodium album*) in the greenhouse under controlled conditions to obtain data for future modeling of a decision support system. Because weed coverage provides a good estimate for yield loss, the response to different doses was measured as coverage determined with the bispectral cameras. Additionally, dry matter was measured. Linear regression between coverage and biomass as dry matter was calculated.

The results showed highly significant correlations between coverage and dry matter. Estimated dose-response curves were similar for coverage and coverage estimated by dry matter via linear regression. Thus, coverage is a suitable response parameter for dose-response experiments. Furthermore, already published dose-response curves based on dry matter can be used for modeling. The whole data set is accessible online.

P16

Kuhlmann, H., Florian Schölderle

A multisensorsystem for the generation of a rectangular formation of sugar beet plants – approach for the longitudinal drive and the turn-around

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In precision farming the number of agricultural machines, that are positioned by sensors or steered position-based, is increasing. The aims of the use of information about the position are workload reduction, site-specific steering, yield-documentation and the automation of processes. Economical and ecological reasons require a site-specific and adequate application of pesticides and fertilizers. In agricultural research, the treated areas are downsized to a plant-specific application.

Another way of weed control is the use of alternatives to the treatment by herbicides. One approach – an increase of the efficiency of mechanical hoeing – is aimed by the DFG-project 'Position steered seed deposition for the generation of longitudinal and lateral rows in sugar beet cultivation', a cooperation of the Institute of Agricultural Engineering and the Institute of Geodesy and Geoinformation (University of Bonn). The aim is to enable drives of a tractor with a conventional mechanical hoe in longitudinal and lateral direction by the generation of a rectangular plant formation. The inter-row as well as the intra-row areas can be weeded.

For the average density of about 100000 plants per hectare an adjustment of the plant distance is required from 45cm x 20cm to 30cm x 30cm. To achieve an efficient degree of weed control and an economic acceptable yield loss by damage, violence and spillage of plants, 2cm standard deviation of plant position (distance plant-to-plant, position at the seed pattern) must be satisfied. Because of roll-effects in the furrow and biological variations 1cm standard deviation is required for the seed deposition position.

To guarantee that requirement over the whole duration of seeding and the whole area, a multi-sensor system is used, consisting of a RTK-GPS-receiver, a velocity sensor and a yaw-rate sensor in combination with a special computer for data acquisition and processing. For the estimation of position a Kalman-filter is used, that enables a high frequency of data acquisition and processing and is real-time capable.

The problem of position estimation can be divided into two parts:

- Longitudinal drive of seeding
- Turnaround, start of the following seeding run

This article will present the approach for the longitudinal drive and calculated simulations of the position estimation for the turnaround.

P17

Mahlein, Anne-Katrin, R. Zito, A. Taheri, E.-C. Oerke, J. Hamacher, C.A. Berdugo

Multi-sensoral detection of physiological changes in cucumber leaves during pathogenesis of CMV, CGMMV, and powdery mildew

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The development of plant diseases is associated with biophysical and biochemical changes in host plants. Various sensor methods have been used and assessed for their suitability as alternative diagnostic tools under greenhouse conditions. Cucumber leaves were inoculated with cucumber mosaic virus (CMV), cucumber green mottle mosaic virus (CGMMV), and the powdery mildew fungus *Sphaerotheca fuliginea*, respectively. Changes in photosynthetic activity, spectral reflectance and transpiration rate of infected leaves were assessed during disease development by the use of non-invasive sensors. The photosynthetic activity of healthy and diseased cucumber plants was measured by chlorophyll fluorescence and compared to the actual chlorophyll content. In addition, SPAD-values were measured to assess the chlorophyll content. Hyperspectral imaging data were analyzed using spectral vegetation indices. As an indicator of plant vitality, the normalized difference vegetation index (NDVI), the pigment specific simple ratios (PSSRa; PSSRb) and the anthocyanin reflectance index (ARI) were calculated to detect spatial and temporal changes in cucumber leaves. Digital infrared thermography was used to visualize spatiotemporal changes in leaf temperature related to transpiration during pathogenesis. The maximum temperature difference within a leaf was suitable for the discrimination of healthy leaves and cucumber leaves inoculated with CGMMV and *S. fuliginea*, even before visible symptoms appeared. For CMV-inoculated leaves, however, this difference was only evident at early stages of symptom development. The results from this study suggest that each pathogen has a characteristic influence on the physiology and vitality of cucumber plants, which can be measured by a combination of non-invasive sensors. Further investigations under controlled and field conditions have to prove whether non-contact measurements of physiological changes in plants may become an alternative to destructive methods and allow an early detection of changes caused by biotic stressors. Furthermore, the combination of sensors seems to be promising as a diagnostic tool.

P18

Nordmeyer, Henning, O. Richter, N. Sandt

Modelling spatio-temporal weed population dynamics for site specific weed control

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Many agronomically important weeds are spatially aggregated in distribution. Often a stability of weed patches could be observed. This is due to heterogeneity in soil and environmental factors and to weed biology. The concept of site-specific weed control takes into account this variability. Weed population simulation models provide the possibility to estimate the effect of different weed control strategies. Site specific weed control considering economic thresholds is a promising strategy for reducing herbicide use. A mathematical model embedded in a cellular automate with an extended Moore-neighbourhood has been developed to study spatial dynamics of different weed populations.

The model was applied to several weed species, *Apera spica-venti*, representative for a grass weed, as well as *Stellaria media*, representative for a broad-leaved weed. Different scenarios of site-specific weed control were simulated over different time periods. Sensitivity analysis and plausibility assessment were carried out. This approach also allowed for the consideration of the dependence of weed dynamics on habitat characteristics. By means of this cellular automation, the spatial spread of weed species can be modeled under consideration of heterogeneous distribution of soil properties on a field. Validating the model, the actual spatial distribution of weed species is compared with the results of simulation taking into account the soil properties and starting from a series of different initial weed distributions. Based on the actual distribution infestation forecasts for the following years are presented. The use of this model for site specific weed control is discussed. The model provides the ability to predict the spatial and temporal dynamics of different weed species under consideration of different control strategies and soil properties. The prognoses can be used to determine the potential for herbicide savings. The possible population increase is still underestimated by the model. If detailed knowledge about the population biology, dispersion dynamics and soil properties is available, the model may be a helpful tool for the development of site specific weed control strategies.

P19

Páez, Francisco, V.J. Rincón, J. Sánchez-Hermosilla

Methodological proposal for three-dimensional modeling of tomato plant in greenhouse and the optimization of spray application by computational fluid dynamics (CFD) techniques

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The three-dimensional model of plant is useful to know geometrical parameters, biomass indices and studies of the interaction between the vegetation and the environment. The aim of this work was to develop a 3D model of a tomato plant in greenhouse type "raspa y amagado" in their different growth stages for its use in simulations of spray using CFD techniques, developing a methodology to simulate the process of spray pesticides in greenhouses, in order to develop a tool to optimize the pesticide deposition on the plant and to reduce the doses employed. Consequently, the risks for the environment and human health will be lower due to our Mathematical-Physical model based on CFD. This model is able to simulate the effect of operational variables of a treatment over the effectiveness (for instance pressure, spray angle, type of nozzle…). A magnetic 3D digitizer (Polhenus FASTRAK) was used to take the plant data in greenhouse, being 101.7 cm the optimal working distance to achieve an error lower than 1.5cm. In order to study the accuracy of 3D model, a three-dimensional representation was firstly compared with a real image. Secondly, the estimated values of height and width were compared with real values. The values of TRV (Tree Row Volume) were compared, being the errors in most cases lower than 8%. After that, the corrected estimated LAI (Leaf Area Index) was compared with the average real LAI, getting errors lower than 4.5% for most stages of the analyzed plant. The three-dimensional model of plant provides a good estimation of the plant biomass. Finally, a spray simulation on the 3D model was done, allowing quantifying the fluid fraction retained by the plant, with no need to carry out field trials and with low cost.

P20

Pahlavanravi, Ahmad

Crop combination and crop diversification in Jiroft watershed

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Not presented

P21

Pinto, Francisco, U. Rascher

Remote sensing of photosynthetic efficiency using sun-induced chlorophyll fluorescence signal obtained by a hyperspectral imaging method

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The aim of this project is to provide a better understanding of spatial distribution and behavior of light and photosynthesis at canopy or vegetation scale by recording the hyperspectral signature using a novel high-performance hyperspectral imaging method. The use of imaging hyperspectroscopy offers the advantage of simultaneous acquisition of spatially co registered images in many spectrally contiguous bands, and thus would allow us to make a 2D mapping of photosynthesis performance at canopy level.

Four different phenotypes of sugar beet and four of barley were cultivated under normal conditions in the experimental field Klein-Altendorf from Bonn University. Hyperspectral images were acquired in different vegetation stages in order to observe differences in the photosynthesis performance. Important information about photosynthetic related processes and structural factors were calculated using indexes from the reflectance of the leaf, e.g. Photochemical Reflectance Index (PRI), Chlorophyll Index (CI), Water Index (WI), etc. We also aim to detect and quantify passively the signal of sun-induced chlorophyll fluorescence in photosystem II (Fs) emitted under natural light conditions using the Fraunhofer Line Depth (FLD) principle. Fs has shown evidence that can be correlated with photosynthetic efficiency and stress induced limitation of photosynthetic electron transport. Conventional methods to determine photosynthesis status (PAM, spectroscopy, IRGA) were performed as well at leaf level to observe whether the retrieved Fs and the different indexes are correlated with photosynthetic efficiency.

In this poster, preliminary results corresponding to the pre- process of the hyperspectral images are presented. Reflectance for each pixel was calculated and thus different vegetation idices could be estimated at the level of a single leaf. The next steps in this work will be the retrievement of the Fs from the spectral signature.

P22

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Evaluation of *Streptomyces* species for the biological control of rhizome rot disease in Indian turmeric plantations

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Turmeric (*Curcuma longa* L.) belongs to the family Zingiberaceae is an important commercial spice crop in India and consider the best in the world in terms of quality. Moreover, it has been reported that turmeric has antimicrobial and anticancerous activities; besides, biopesticidal and biofungicidal properties are well documented. Among the turmeric diseases, rhizome rot disease caused by *Pythium graminicolum* f.sp. *aphanidermatum* and *Fusarium oxysporum* at different stages of the rhizome is a serious problem in turmeric plantations in Tamil Nadu, Karnataka and Kerala states of India. In order to control the disease, the soil with a contact fungicide Mancozeb (2.5 g/l) and a systemic fungicide, Carbendazim (1 g/l) solution is drenched around the plant at fortnight interval. Seed treatment is also recommended in which baby rhizomes are soaked in Mancozeb and Carbendazim along with a wetting agent like Triton AE. As soil treatment with chemical fungicide harm the soil micro biota and pollute the environment, alternate control strategies are the need of hour. In this scenario, biological control can be a viable alternate or supplement for chemical control for the management of soil borne pathogens. Although, few biocontrol agents such as *Trichoderma harzianum*, *Bacillus subtilis* and *Pseudomonas fluorescens* are recommended for the control of turmeric rhizome rot, no attempt was made so far using *Streptomyces* spp. as biocontrol agent. Therefore, the present investigation was taken up. The results showed that the population density of *Streptomyces* spp. in turmeric soils was found to be more in Tamil Nadu than in Karnataka followed by Kerala states. Further the population density was correlated with the soil nutrient status. About 30 isolates of *Streptomyces* spp. were obtained from soil samples using starch-casein agar medium. All these isolates were purified, screened and characterized for their antifungal activity. Dual culture studies, morphological interaction and antibiosis indicated that the antagonistic properties of the test antagonist on *P. graminicolum* and *F. oxysporum*. The disease severity was considerable reduced in the field after two applications of a carried based bioformulation containing *Streptomyces* spp. at two month intervals. The similar trend was recorded in which rhizomes were dipped with the culture filtrate containing the above antagonist before planting. The study revealed that both these two pathogen's growth was suppressed significantly and it was found to be of potential antagonist against turmeric pathogens.

P23

Sabah, Razi

First study of thrips in Feva bean in Sdid Okba at Biskra

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Not presented

P24

Sadighi, Hassan

The use of GIS in determining the environmental/agricultural land potentials: Case study of Varamin area in south of capital, Tehran, Iran

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P25

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Spectroradiometric measurements to assess Tristeza-diseased citrus plants

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The Citrus tristeza closterovirus (CTV) is one of the main causes of loss and destruction of citrus groves across the world. Detecting promptly the virus outbreaks and determining how the infection has developed in time and space, since its first report, is of utmost importance to support a monitoring programme. The aim of the present study is to acquire, process and investigate the spectral signatures of CTV-infected and CTV-free plants.

In Apulia region (Southern Italy) two preliminary trials were conducted under controlled conditions and in the open field. In the first trial Mexican lime (a universal CTV indicator) plants were grown under a greenhouse in optimum nutritional and temperature conditions. Half of the plants were inoculated with a local CTV-quick decline isolate (IAMB-Q 109). Approximately 20 days after the inoculation, the spectral reflectance signatures were acquired from the leaves of the whole lot by a spectroradiometer (325 - 1075nm), connected to a plant probe-leaf clip under artificial light. The inoculated plants were tested by DAS-ELISA and were found CTV-positive.

For the second trial four commercial groves ('Precoce di Massafra' clementine and 'Navelina' orange) were identified in the CTV outbreak area. Based on molecular testing results (DTBIA, RT-PCR), leaf and canopy spectral signatures were acquired from 14 CTV-free and 14 CTV-infected plants in each plot. Infected plants were showing different chlorosis and declining stages.

In both trials the spectral characterisation showed a difference in Reflectance values between CTV-positive and CTV-negative plants, thus highlighting the potential of spectroradiometric measurements to discriminate the different stress conditions and suggesting the possible use of satellite optic sensors for large-scale disease monitoring.

P26

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Spatial distribution of Fusarium head blight and associated mycotoxins in wheat

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Fusarium Head Blight (FHB) is one of the most important diseases in small grain cereals and often is caused by a complex of *Fusarium* species. Some of these species are able to produce one or several mycotoxins. Understanding the spatio-temporal dynamics of the pathogens and the metabolites they produce is a prerequisite for representative sampling for the assessment of Fusarium-infected kernels and their mycotoxin contamination, and for effective management of FHB in wheat. The spatial distribution of the disease and associated mycotoxins was examined in wheat fields in Western Germany at harvest using geo-referenced sampling of 42 samples in a 20 x 20 m grid. Results were mapped and analysed with a geographic information system (GIS) as well as with the program SADIE® (Spatial Analysis by Distance Indices).

Fusarium avenaceum (FAVE), *F. culmorum* (FCUL), *F. graminearum* (FGRA) and *F. poae* (FPOA) were identified as FHB pathogens in a field near Aldenhoven (D) in 2007. The frequency of infected kernels had an aggregated pattern for total *Fusarium* infection and FAVE, and was random for FGRA and FPOA. The severity of *Fusarium* infection, i.e. the amount of Fusarium DNA in wheat flour measured by quantitative PCR, also showed non-regular spatial distribution within the field, with FGRA exhibiting an almost random pattern. The trichothecene mycotoxins deoxynivalenol and nivalenol had a random and an aggregated pattern, respectively; the contamination with zearalenone was limited to one focus within the field resulting in a high index of aggregation. Random and aggregated patterns of fungal infections necessitate a high number of subsamples per field for representative assessment of mycotoxin contamination in the field.

P27

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Mapping spatial variability of soil organic carbon on the field scale via airborne hyper-spectral images

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The level of soil organic carbon (SOC) is not only a criterion of good agricultural practice and a crucial factor for preserving soil fertility; it also influences the incidence of pests and the efficacy and fate of pesticides. Yet, many arable soils reveal a considerable spatial heterogeneity of SOC contents at the field scale. This is known in principle, but it has not been quantified for most fields due to the considerable workload associated with traditional soil sampling and lab analyses. Therefore, minimally or non-invasive sensors have gained growing interest. In this study, we analyzed the influence of SOC on the accuracy and quality of an airborne hyperspectral sensor. Within a HyMap flight campaign in August 2008 we took randomized surface soil samples of four arable fields; two of them with bare soil (n = 44, n = 30, respectively), and two with plant remains (n = 100) and straw residues (n=30). Sampling points were geo-referenced with a DGPS receiver. HyMap is an aircraft-mounted hyperspectral sensor which provides 126 spectral bands between 450 nm and 2500 nm. A nominal spatial resolution of 4 m was achieved. The respective spectra were selected using ENVI 4.7. For statistical analyses the Partial Least Square Regression (PLSR) algorithm was performed using the chemometric software OPUS 6.0. The quality of the prediction models was estimated by calculating the coefficient of determination (R^2) and the root mean square error of cross validation (RMSECV). The prediction accuracy was highest for the bare soil (R^2 = 0.8 – 0.9; RMSECV = 0.0625), followed by the fields with plant remains and straw residues (R2 = 0.6 – 0.7; RMSECV = 0.088). Our results reveal that a successful prediction of SOC via hyperspectral imaging is possible, but the quality depends on the amount of vegetation or straw cover. For bare soils, this technique provides a valuable tool to create high quality and high resolution SOC maps.

P28

Schmidt, Kai

Analysis of (hyper-)spectral signatures

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Spectral reflectance techniques have been commonly used in remote sensing research for several decades. While the resolution of sensor technology has increased drastically, the analysis of the information is somewhat insufficient. The challenge is to link the technical sensor information to a classification of the sensed object. With known objects, such as plants, the spectral signatures show diverse and complex trajectories and characterise different physiological and biochemical conditions of the crop. Instead of using specific wavelengths for analysis, taking into account the complete information of a spectral signature is seen as an advantage. Therefore a new algorithm based on additive double Weibull functions is introduced. The model is applicable to the wavelength range from visible light (VIS) to near infrared (NIR) and up to short wave infrared (SWIR). It includes sufficient accuracy and reduces the complex sensor information to a few model parameters. The model is easily fitted to sensor data resulting in an individual parameter vector for each object. Regression analysis shows both an adequate exploitation of the data and no parameter redundancy. Using the approach for the analysis of leaf diseases on sugar beets requires a two-step procedure. The pathogens used were Cercospora beticola, Erysiphe betae and Uromyces betae. In the first step the model is fitted to the data, taken by a spectral reflectance sensor of healthy and infested leafs. The resulting parameter vectors are then further analysed by discriminance analysis. The second step assigns the parameters taken from the regression model to different classes, allowing not only a separation between healthy and infested leafs at early stages, but also a diagnosis of the single pathogen at later stages. The technique introduced here exploits the complete technical information and resolution provided by spectral reflection sensors. The data are compressed to secondary model parameters. The model is open for statistical analysis, is broadly applicable and has a high potential to classify and separate sensor signals. It is seen as a new analysis technique that also supports the classical analysis procedures.

P29

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Sensor and application technology for precision weed management - weed sensors, GIS, sprayer

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In order to meet the heterogeneous distribution of weeds and weed species within agricultural fields with a feasible selective application of herbicides three basic requirements must be given:

1 Knowledge about the small-scale distribution and species composition of weeds within agricultural fields. Camera based weed detection techniques in combination with digital image analysis have the power to distinguish between crops and weeds and the discrimination of weed species. Knowledge based image analysis systems are used for the weed discrimination by means of characteristic contour and shape parameters. The results of the image analysis show high identification rates between 75% and 98% depending on factors like type of crop, growth stage of weed and crop, selected parameters and classifier for identification.

2 For the visualisation and documentation of the detected weed distribution within the field GIS-software is needed. By combining decision algorithms and the information about weed species distribution and weed density GIS-software can be used for the calculation of herbicide application maps which can be implemented by herbicide sprayers.

3 Application systems with the potential of high resolution and fast adaptation of variation of herbicide, herbicide combination and the dose rate of the active ingredients subjected to weed density and weed species composition.

In order to use the full advantages of site-specific weed control, the three above mentioned process steps have to be optimized and combined in order to build up a fast and precise system for site-specific herbicide application. The aim of this contribution is to show technical solutions for the process steps and their adoption to practical use.

P30

Tomkiewicz, Dariusz

A plant-based sensor for monitoring plant biological condition

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Introduction Progress in contemporary electronics have made possible to use plant-based sensors that continuously monitor some aspect of plant biological condition. Plant-based sensor have potential to provide more accurate and timely information on crop bio-responses to environmental stress and could overcome limitations of traditional monitoring methods which focus only on monitoring parameter of ambient air and soil.

Objectives During the research a tested hypothesis was formulated that information provided by impedance spectroscopy is correlated with plant environmental stress. Another goal of the research was to develop an impedance sensor that can collect data directly from crop in real time and send them to associated control systems.

Methodology Experiments were performed on two sets of tomato plants (*Lycopersicon esculentum* Mill.). The tomato plants were started to grow in a horticultural laboratory. Plants were preselected and placed to plastic pots. Both sets of the plants grow in hydroponics. The grow medium (ground) consisted of pearlite. One set of plants was fed with continuous solution flow with all necessary nutrients, the second set was watered only by continuous distilled water flow. The impedance sensor consisted of electrodes that were placed inside of tomato stalk and an electronic sensor unit. Digital to Analog Converter (DAC) of the electronic sensor play a role of frequency generator. The frequency generator was connected to electrode. The frequency generator allows for a plant stalk to be excited with a frequency sweep with a user-defined start frequency, frequency resolution, and number of points in the sweep. In addition, the device allows the selection of the peak-to-peak voltage value of the output sinusoidal signal. The response signal after passing the tomato plant is recorded by Analog to Digital Converter (ADC) of the sensor. The recorded data are processed with the use of 1024 points Discrete Fourier Transformation (DFT) algorithm. The DFT algorithm returns both a real and imaginary data-word at each frequency point along the sweep. The impedance magnitude and phase are easily calculated for a farther analysis.

P31

Tomkiewicz, Dariusz

A neural network classifier for counting insecticidal nematodes on digital images

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Introduction Insecticidal nematodes are a component of many biological pesticides used in plant protection, specifically in organic agriculture. In order to define the quality of biopesticides, it is necessary to determine the concentration of nematodes in a liquid. Average concentration of nematodes in one litre of liquid should be between 500 000 to 1 500 000 larvae. Nowadays the nematodes concentration in liquid is counted by a human expert, by means of a microscope. The process of counting nematodes is very burdensome and long-lasting.

Objectives During the research there was a tested hypothesis that an automatic classifier based on computer image analysis methods and artificial neural network can count nematodes much more quickly and more precisely than a human expert. The classifier has to discriminate between insectivorous nematodes and other objects on the image like dirt, light spot etc. The neural network was utilized as a classifier due to its data fusion ability. An Optimal Brain Surgeon method (OBS) was applied together with neural network for optimal nematodes features selection and for optimization of the neural network structure.

Methodology The neural networks were successfully used for pattern recognition and classification of data sets. The neural networks have abilities to learn from examples without a priori information about the system structures or parameters and to data fusion. The problem of the feature selection for a neural network classifier is reduced to the problem of the input layer optimization, i.e. selection of such inputs, which changed, produce the biggest output error (change of error function) during training and eliminate those inputs, which produce small change of output error. The neural network structure optimization is a complex problem. One of the most popular methods of optimization of the neural network structure is the OBS method. The type of neural network utilized in experiments was built as a multilayer perceptron with an input layer, a single hidden layer with biases and an output layer. Neurons in the hidden layer had hyperbolic tangent activation functions, the neuron in the output layer had a linear activation function. The software application was created in LabView environment.

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