Time dependent genetic analysis links field and controlled environment phenotypes in the model C4 grass Setaria

Baxter I[1]

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Plenary One, CSIRO Discover Centre Theatre, September 19, 2016, 9:00 AM - 10:30 AM

Phenotyping has become the rate-limiting step in using large-scale genomic data to understand and improve agricultural crops. In collaboration with a large consortium of labs, we have used the Bellwether Phenotyping platform for controlled-environment plant growth and automated, multimodal phenotyping to study how plant biomass traits change temporally in response to water availability. We have also conducted parallel field experiments, allowing us to compare insights derived in both controlled and field environments. We have analyzed two independent genetically structured populations of *Setaria* sp.: an interspecific *S. italica* x *S. viridis* recombinant inbred line population and to two grow outs of a *S. viridis* natural diversity panel. We developed Plant Computer Vision (PlantCV) as an open-source, platform independent quantitative image analysis community resource and have used it to quantify height, biomass, water-use efficiency, color, plant architecture, and near-infrared traits. Using height as a model trait we have shown that the contribution of individual genetic loci change dynamically throughout development and the reduction of growth observed in water limited environments is a consequence of delayed progression through the genetic program. I will discuss our efforts to integrate field data and our attempts to extend the analysis to new traits and populations.

Biography

Ivan's research uses high-throughput elemental profiling to measure the elemental composition of plant tissues including soybean seeds and corn kernels. These data are used to perform genetics and modeling to understand how the interactions of elements, genes and the environment determine the elemental composition of plants and allow plants to adapt to different environments.

Rapid end-to-end deployment of phenotyping capabilities: opportunities and challenges

Xavier Sirault[1], Jose Berni-Jimenez[1], Warren Creemers[1], Peter Kuffner[1] and Geoff Buckmaster[1]

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Plenary One, CSIRO Discover Centre Theatre, September 19, 2016, 9:00 AM - 10:30 AM

Global pressure to increase cereal crop yield to feed a projected 9.7 billion people in 2050 has resulted in a race to developing high throughput phenotyping techniques and methods in view of identifying the genes that will underpin “the next green revolution” in major crops. Although a number of phenotyping capabilities have emerged across the globe, we feel that a number of them have drifted towards acquiring the latest or biggest hardware phenotyping technologies rather than addressing the real challenge of high throughput plant phenotyping: extracting information and value from the data collected on a large scale.

In this talk, we will present lessons learnt firsthand from 8 years of active Research & Development in the field of phenomics, via the establishment of the Australian Plant Phenomics Facility in Australia. We will reflect on a number of points which we feel are critical for empowering the research community and industry sector, in particular, the development and distribution of fit-for-purpose technologies associated to scalable end-to-end software solutions deployable in cloud environments. We will conclude by offering a vision on how the national facility will contribute to the Australian innovation ecosystem by introducing phenoSMART™, a science gateway for phenomics research.

Improving NUE: A case for good phenomics

Garnett T[1,2]

[1]The Plant Accelerator, The University of Adelaide, [2]The Australian Center for Plant Functional Genomics

Session 1: Intersection between controlled environments and phenomics, CSIRO Discover Centre Theatre, September 19, 2016, 11:00 AM - 12:30 PM

Improved nitrogen use efficiency (NUE) in crop plants has the potential to significantly reduce fertilizer application costs and increase crop yield. It is therefore important to develop efficient screening methods for improved NUE. NUE is a complex, multi-component trait and screening for NUE in field trials poses the challenge of low heritability and high environmental interaction. Phenotypic screenings in controlled environments offer the advantage of focusing on individual components of NUE while controlling aspects of nitrogen (N)-availability, water application and climate conditions. One of the major restrictions to N uptake early in the season in southern Australia is lack of water, which restricts N mobility in soil and hence N uptake. In results to be presented, the nitrogen response of wheat varieties was investigated incorporating water stress early in the season and at flowering with the aim of better understanding the interaction between these two important factors restricting grain crop yields. Ten wheat varieties were grown on a Lemnatec high throughput phenotyping platform with three N levels and four water stress treatments. Water stress treatments were: well watered; well watered then water stressed from flowering; water stressed initially then well watered from flowering; and water stressed throughout. Plants were grown on to maturity to assess grain yield response. In terms of biomass there were large differences in N response between varieties and major interactions with water stress. The shoot growth response of the varieties varied in total biomass and also in the timing of growth. Grain yields likewise showed major differences in N response between varieties. There were good correlations between non-destructive measurements of biomass and grain yields but this differed between water stress treatments. In terms of developing a reliable, controlled environment method for screening NUE in cereals the results are promising.

Biography:

Trevor is currently Director, Technology Development at the Plant Accelerator, lead node of the Australian Plant Phenomics Facility. Apart from phenotyping generally his research focuses on improving nitrogen use efficiency in crops.

Phenotyping transpiration efficiency: linking trait dissection to genetics

van Oosterom E[1], Chenu K[2], McLean G[3], Deifel K[1], Sulman R[4], Hammer G[1]

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Session 1: Intersection between controlled environments and phenomics, CSIRO Discover Centre Theatre, September 19, 2016, 11:00 AM - 12:30 PM

High-throughput phenotyping has become a limiting factor for trait selection in breeding programs, in particular for the many agronomically relevant traits that can express significant genotype × environment × management (G×E×M) interactions. Here we describe a phenotyping platform for transpiration efficiency (TE, biomass production per unit water use), a trait of interest to breeders because of its potential to increase crop productivity in water-limited environments. The phenotyping platform integrates high-throughput screening for TE of large numbers of genotypes in small lysimeters with a system of large lysimeters for detailed studies on selected genotypes. High-throughput screening of mapping populations provides insights into the genetic control of TE through the identification of quantitative trait loci (QTL), whereas detailed studies on selected genotypes with contrasting QTL and TE allow quantification of the function and effects of selected QTL. Incorporating this knowledge into predictive crop growth simulation models can capture the implications of changes in TE or its component traits on grain yield and G×E×M interactions across the target production environments. The integration of high-throughput phenotyping within this larger multi-disciplinary approach ensured that the design of the phenotyping platform was based on specific needs.

Biography:

Erik van Oosterom is a crop physiologist at QAAFI at the University of Queensland. His research aims to link phenotypic expression of physiological traits to their underpinning genetic control mechanisms and incorporate this knowledge into APSIM crop simulation models to improve their predictive capabilities for applications in plant breeding.

ENVIRATRON—a Plant Research Facility for a Changing Climate

Imberti H[1]

[1]*Percival Scientific, Inc.*

Session 1: Intersection between controlled environments and phenomics, CSIRO Discover Centre Theatre, September 19, 2016, 11:00 AM - 12:30 PM

Researchers face the monumental task of predicting plant performance and tolerance as Earth's climate changes. To address this challenge, a team of researchers from Iowa State University along with industry partner Percival Scientific are developing an "Enviratron"--an advanced, high-throughput phenomics facility to study the factors that impact plant growth. A series of growth chambers permits the control of multiple environmental variables at a time: temperature; light duration, quality and quantity; wind; humidity; carbon dioxide levels; and water potential. Precision control over the growing environment makes it possible to identify which variables have the largest impact on plant phenotype. The layout of the facility and environmental chambers is designed to accommodate an automated rover with a robotic arm. The rover is outfitted with an array of sensing and imaging equipment to track plant health at many points throughout the lifetime of the plant, thus allowing the rover to non-destructively collect data while the plants remain undisturbed in the environment. The result is a facility that can predict plant performance in response to looming challenges such as heat and drought stress. The Enviratron project is the next step in solving tomorrow's threats to agriculture and food security.

Biography:

Henry Imberti is the Senior Vice President of Engineering at Percival Scientific, Inc. where he has worked since 1988. He has been a member of NCERA-101 for 23 years in which he served as the vice-chair in 2013 and the chair in 2014.

Extracting valuable traits from a plant phenotyping platform requires model-assisted dissection of the phenotype

Cabrera-Bosquet L[1], Prado S[1], Grau A[1], Fournier C[1], Wei-Chen T[1], Coupel-Ledru A[1], Welcker C[1], Tardieu F[1]
[1]*INRA*

Session 2: Phenomics facilities and technologies, CSIRO Discover Centre Theatre, September 19, 2016, 1:30 PM - 3:00 PM

While phenotyping platforms have emerged as promising tools, methods are still lacking for extracting information usable in either genetic analyses or in modelling. We have developed a suite of methods to measure light interception, radiation-use efficiency (RUE), growth sensitivity to water deficit and water-use (WU) in thousands of plants in a high-throughput phenotyping platform. Different models were interfaced to calculate (i) the spatial distribution of incident light, as experienced by hundreds of plants in a glasshouse, by simulating sunbeam trajectories through glasshouse structures every day of the year, (ii) the amount of light intercepted by plants (I_{PPFD}) via a functional–structural model using 3D reconstructions of each plant placed in a virtual scene reproducing the canopy in the glasshouse, (iii) RUE calculated as the ratio of plant biomass to $I_{PPFD,}$ (iv) the sensitivity of growth to drought, calculated as the ratio of leaf area expansion rate to soil water potential and (v) WU calculated as the response of plant transpiration to local evaporative demand. The inputs of these models were (i) plant images taken every 30° every day for each plant for estimating leaf area, biomass and architecture, (ii) plant transpiration obtained by sequential pot weighing, corrected for plant weight and (iii) environmental data collected every 15 min in 8 sites of the greenhouse. These methods were tested at the PhenoArch plant phenotyping platform (http://bioweb.supagro.inra.fr/phenoarch), during six experiments with panels of 1680 maize (*Zea mays* L) hybrids or lines grown in different seasons (contrasting light and evaporative demand) and at two soil water potentials. Each of the studied traits displayed a large genotypic variability, involving a large range of sensitivities of growth and transpiration to soil water status and evaporative demand (high GxE interaction). By calculating "hidden variables" encapsulating spatial and temporal environmental variations such as RUE or responses of growth and transpiration to evaporative demand and water deficit, we have identified heritable physiological traits usable in genetic analyses and crop modelling that are currently used in field studies, thereby opening up the way for large-scale genetic analyses of the components of plant performance.

Biography

Llorenç Cabrera-Bosquet is a research engineer at INRA-LEPSE in Montpellier, France. He obtained a PhD in Plant Ecophysiology from the University of Barcelona and CIMMYT where he studied the use of stable isotopes to assess plant performance and stress adaptation in different cereal species under controlled conditions and in the field. Since September 2013 he is the technical coordinator of the PhenoArch high-throughput plant phenotyping platform where he develops and combines tools and methods to characterize the environmental conditions as sensed by individual plants and to estimate plant growth, architecture and transpiration, with the final aim to extract valuable traits that can be used in crop modelling and genetics. He is also the technical coordinator across the French Plant Phenotyping Network.

Lightweight field phenotype platforms

Jimenez-Berni J[1]

[1]HRPPC

Session 2: Phenomics Facilities and Technologies, CSIRO Discover Centre Theatre, September 19, 2016, 1:30PM – 3:00 PM

Abstract to come

Assessing nitrogen use efficiency and water street interactions in wheat

Hansen N[1]

[1]*University of Adelaide*

Session 2: Phenomics Facilities and Technologies, CSIRO Discover Centre Theatre, September 19, 2016, 1:30PM – 3:00 PM

Abstract to come

Australia: Cropatron imaging in glasshouse

Kuffner P[1]

[1]HRPPC

Session 2: Phenomics Facilities and Technologies, CSIRO Discover Centre Theatre, September 19, 2016, 1:30PM – 3:00 PM

Abstract to come

The high-throughput phenotyping and genetics of photosynthetic traits

Harbinson J[1]

[1]*Wageningen University.*

Session 3: Sensing systems and image-analysis, CSIRO Discover Centre Theatre, September 19, 2016, 3:30 PM - 5:30 PM

Photosynthesis is a complex physiological process whose improvement is a route to improving crop yields. Its properties, or traits, display considerable natural variation, but the genetic basis of this is not at all well understood, though the genes coding for the structural components of photosynthesis, such PSI and PSI, are well known. The absence of a genetic foundation for our understanding of photosynthetic variation not only limits our ability to breed improved photosynthesis but reflects how little we know about the regulation of photosynthesis at the genetic and molecular level. In order to begin to build a better genetics of photosynthesis we built a photosynthetic phenotyping system based on chlorophyll fluorescence. Designed to work with arabidopsis and similarly small plants, this can measure up to 1440 plants multiple times per day. We have been using this system with various mapping populations of arabidopsis, brassica, Solanum and Beta and we whave been successful in identifying QTLs that give rise to variability in photosynthetic traits. Particularly under stress conditions, where phenotypic variation is typically greater than under more permissive conditions, QTL identification has proven to be rather easy. Identifying the causal genes underlying these QTLs is, perhaps not surprisingly, proving to more difficult but we have had some success. In my talk I shall describe the phenotyping system, the basic results we have obtained with it, and path from QTLs to causal genes.

Holistic and Component-based Automated Plant Phenotyping Analysis using Visible-Light Images

Das Choudhury S[1]

[1]*University of Nebraska-Lincoln*

Session 3: Sensing systems and image-analysis, CSIRO Discover Centre Theatre, September 19, 2016, 3:30 PM - 5:30 PM

Extracting meaningful numerical phenotypes from plant images remains a critical bottleneck in automated plant phenotyping. We classify image-based phenotyping approaches into: holistic and component-based. Holistic analyses consider the whole plant as a single object and measure its attributes, whereas component-based phenotyping analyzes individual parts of a plant, e.g., leaves and stems. Two novel holistic phenotypes are introduced: bi-angular convex-hull area ratio and plant aspect ratio. *Bi-angular convex-hull area ratio* is defined as the ratio of the area of the convex-hull of the plant when viewed from the side at a particular angle and the convex-hull of the same plant when viewed at a rotation of 90°. It provides information about temporal change in phyllotaxy, i.e., the arrangement of leaves around a stem. *Plant aspect ratio* is defined as the ratio of the height of the bounding rectangle of the plant from the side-view and the diameter of the minimum enclosing circle in the top-view. It characterizes canopy architecture that is generated by the crop accessions in the field. A leaf-tracking algorithm is introduced to study the temporal variation of component-based phenotypes, i.e., leaf-count, stem-height, leaf-size and leaf-curvature in maize using our newly introduced benchmark dataset called Panicoid Phenomap-1.

Biography:

Sruti Das Choudhury received M.Tech in Computer Science and Application from the University of Calcutta, INDIA, and PhD in Computer Science Engineering from the University of Warwick, UK, in 2009 and 2013, respectively. Presently, she is working as a Postdoctoral Research Associate in the UNL, USA, on Image-Based Plant Phenotyping.

Non-destructive estimation of light energy distribution between photosystems

Murakami K[1], Matsuda R[1], Fujiwara K[1]

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Session 3: Sensing systems and image-analysis, CSIRO Discover Centre Theatre, September 19, 2016, 3:30 PM - 5:30 PM

Light energy absorbed by a leaf drives photosynthetic electron transport. In higher plants, the photosynthetic electron transport chain is anchored by photochemical reactions that occur at two types of photosystems (i.e. PSII and PSI). These photosystems represent different light absorption spectral distributions. Since the electron transport occurs in series, an imbalanced energy distribution between PSII and PSI should lower photosynthetic light use efficiency (e.g. Hogewoning et al. 2012). Furthermore, our recent paper suggests that sunlight and mixture of blue and red LED light, which is widely used for the measurements of the leaf photosynthetic rate, can induce the imbalance depending on the energy distribution property of a leaf (Murakami et al. 2016). The property of a leaf is different among species and light environments during the leaf growth, and therefore should be evaluated as an important photosynthetic characteristic. In the present study, we constructed a mechanistic model for the energy distribution between PSII and PSI. This model is capable of non-destructive evaluation of the energy distribution property of a leaf based on measurements of chlorophyll fluorescence and P700 absorbance. Several latest results will be introduced.

Biography:

Keach Murakami received B.S. and M.S. degrees in agricultural engineering from The University of Tokyo, in 2012 and 2014. He majors in the photosynthetic electron transport of a leaf in response to the spectrum of light and its modeling in Ph.D.

Australia Deep learning for phenotype-genotype classification

Nemin S[1]

[1]*Australian National University*

Session 3: Sensing systems and image-analysis, CSIRO Discover Centre Theatre, September 19, 2016, 3:30 PM - 5:30 PM

Plant phenotyping by measuring the plant observable characteristics, such as shape, size and growth rate, is a key to study the interactions between phenotypes, genotypes and the environmental conditions. Considering the rapid growth of phenotype-genotype experiments, there is an ongoing interest in automating the plant phenotyping frameworks. To this end, incorporating computer vision and machine learning techniques into the framework is highly desirable, as this allows faster phenotyping, which can potentially leads to analysing more experiments with larger amount of data.

Recently, deep learning using Convolutional Neural Network (CNN) has shown great success in image recognition and classification. One of the advantages of deep learning that makes it so popular is its distinct feature manipulation. While handcrafted features are mostly used in other techniques, deep learning offers built-in capability for feature learning and hierarchical feature extraction. This means, the obtained features are specific to the problem and thus can be useful in automatic phenotyping for genotype classification.

The mentioned deep learning technique using CNN is able to capture good features for each individual plant image. However, as the plant growth and variations over time are also key components in plant phenotyping, there is a need to include the dynamic temporal behaviour of plants into the deep learning framework as well. To this end, Recurrent Neural Network (RNN) as a type of artificial neural networks that uses internal memory to process sequential information can be used. Using CNN for feature extraction and RNN for temporal information is a powerful tool for image/video classification and we are investigating their potentials in facilitating study of plant phenotype-genotype interactions.

May light phylloclimate help phenotyping?

Chelle M[1]

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Plenary Two, CSIRO Discover Centre Theatre, September 20, 2016, 9:00 AM - 10:35 AM

High-throughput phenomic advances will need to occur across scales of phenotyping platforms to sustain and improve crop yields. To achieve such objectives, one stumbling block is the knowledge of the environment, which drives the growth, and the development of each individual plant. Indeed, errors or uncertainties in the description of this effective local environment may generate bias, (i) when phenotyping various genotypes in the same location as well as (ii) when comparing indoor and field phenotyping results, leading to misunderstanding of genotype x environment interactions. Such bias depends especially on the plant architecture.
Phylloclimate corresponds to the physical environment actually perceived by each individual aerial organ of a plant population. Its characterization may be a way to limit this bias, in comparison with meso- or micro-climate. Focusing on light phylloclimate simulation, I will present some results on plant phenotyping in growth chambers, from the characterization of effective light variables to their possible use to improve phenotyping platforms. Finally, I will discuss the role of light phylloclimate and the use of function-structure plant models in the complex dilemma between indoor and field phenotyping.

Biography:
Michaël Chelle is research director at INRA, France. He is senior scientist in bioclimatology with a strong focus on 3D modelling (mainly for radiation) and has a liking for interdisciplinary approach, as shows his scientific background (engineering degree in agronomy, 1992; MS and PhD in computer science applied to physics, 1997; Accreditation to Supervise Research (HDR) in plant science, 2008). He has developed research on the physical environment perceived by individual plant organs (phylloclimate) and on its interaction with plant and pathogens functioning. He has led the team of plant ecophysiology at INRA Grignon until this year. His current research focus on the response of foliar fungal pathogen to leaf temperature as well as modeling the fluorescence radiance going out vegetation. In 2015, he has been nominated deputy scientific delegate to the digital transformation at INRA headquarter. Last, since 2013, he has represented Europe in the board supervising the Function-Structure Plant Modeling (FSPM) workshop series, where phenotyping questions clearly arise.

Genes, phenes and machines: as well as ways to bridge the gap between lab and field

Poorter H[1]

[1]*Plant Sciences, IBG2*

Plenary Two, CSIRO Discover Centre Theatre, September 20, 2016, 9:00 AM - 10:35 AM

In the first half of this talk we will pay attention to some of the new developments in the phenotyping research at Forschungszentrum Jülich, with particular emphases to (a) novel devices for seed phenotyping, to determine plant and soil water content, to measure root distribution in soils and finally the characterisation of sun-induced fluorescence from airplanes and satellites. (b) We will then inform about recent developments in phenotyping networks in Germany (DPPN), in Europe (EMPHASIS) and globally (IPPN).

In the second half, we discuss how representative plants grown under controlled conditions are for those growing in the field. A meta-analysis showed that lab-grown plants had faster growth rates, higher N concentrations, and higher SLA. They remained smaller, however, because lab plants are grown for much shorter time. We compared glasshouse and growth chamber conditions with those in the field and found that the ratio between the daily amount of light and daily temperature (photothermal ratio) was consistently lower under controlled conditions, especially for Arabidopsis. This may strongly affect a plant's source:sink ratio and hence their overall morphology and physiology.

Plants in the field also grow at higher plant densities. A subsequent meta-analysis showed that a doubling in density leads on average to 34% smaller plants with strong negative effects on tiller or side-shoot formation but little effect on plant height. We found the r^2 between lab and field phenotypic data rather modest (0.26). Based on these insights, we discuss various alternatives to facilitate the translation from lab results to the field, including options to apply growth regimes closer to field conditions.

Designing soils

Young I[1]

[1]*University of Sydney*

Session 4: Current Research in Controlled Environments and Phenomics, CSIRO Discover Centre Theatre, September 20, 2016, 11:00 AM - 12:30 PM

Abstract to come

Root growth analysis using X-ray Computed Tomography in controlled environments

Gerth S[1], Claußen J[1], Wörlein N[1], Uhlmann N[1]

[1]*Fraunhofer Development Center For X-ray Technology*

Session 4: Current research in controlled environments and phenomics, CSIRO Discover Centre Theatre, September 20, 2016, 11:00 AM - 12:30 PM

Recently, the non-destructive observation of root growth using X-ray CT is prominently in the focus of research. Thus, it is possible to reconstruct the 3D volume information of objects using X-ray projections from different points of view.
Including the method of X-ray computed tomography in nowadays greenhouses, allows a high throughput root phenotyping. Depending on the quality of the measurements and the throughput for phenotyping, a robust and automated data segmentation algorithm is needed. We present results of such a segmentation algorithm and the influence of measurement time and data quality on the results.
The genotypes Mo17 and B73 of Maize were grown in a tube with 9 cm in diameter and 40 cm in height and scanned regularly. The scanning geometry used is the axial 3D-CT, where a conical X-ray beam projects the pot on a flat 2D image detector. The spatial sampling frequency of this setup is about 85 µm using a high-power tube.
First we will present, how to design a sensor seamlessly integrated in a conveyor belt system. Additionally, the tradeoff for high throughput phenotyping will be discussed. To demonstrate the data quality of the automated root segmentation, the growth of two different maize genotypes will be shown. A detailed discussion about the influence of measurement time, soil and watering for the segmentation algorithm will be presented as well as the difference between automated and manual usage of the algorithm.
We will compare the development of the root system of MO17 and B73 Maize analyzing the total segmented root length and the surface diameter distribution.

Biography:

Stefan Gerth finished his PhD about the self organisation of polymer chains at the solid liquid boundary in 2012 at the University of Erlangen-Nürnberg. Directly afterwards he started at the Fraunhofer development Center for X-ray technology to apply X-ray computed tomography in the field of root phenotyping.

Zegami - a new tool for visualizing phenotypic data sets

Berger B[1], Sainsbury G[1], Garnett T[1]
[1]*Australian Plant Phenomics Facility - The Plant Accelerator*

Session 4: Current research in controlled environments and phenomics, CSIRO Discover Centre Theatre, September 20, 2016, 11:00 AM - 12:30 PM

High-throughput phenotyping facilities, such as The Plant Accelerator, generate large phenotypic datasets, with thousands of images. These data sets are often too large and overwhelming for plant scientists to work with and make sense of. Zegami is an easy to use interactive tool, which allows users to browse their image collections, create graphs and plots on the fly and search for subsets of images. Users can use the functionalities to detect outliers, find patterns within the data and explore novel phenotypic traits. Importantly, plant scientists can come up with new questions to further explore in collaboration with statisticians. All datasets generated at The Plant Accelerator will be uploaded to Zegami for user access and public access, once datasets have been published.

Biography:
Bettina Berger is the Scientific Director of The Plant Accelerator, the University of Adelaide's node of the Australian Plant Phenomics Facility. Bettina worked at The Plant Accelerator since its opening in 2010 and focuses on the development of high-throughput phenoytping protocols to study plant performance in controlled environments.

Automated phenotyping for improved nitrogen use efficiency in wheat

Nguyen G[1], Vakani J[1], Joshi S[1], Maphosa L[1], John U[2], Hayden M[2], Mason J[2], Spangenberg G[2], Slater T[2], Kant S[1]

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Session 5: Current research in controlled environments and phenomics (continued), CSIRO Discover Centre Theatre, September 20, 2016, 1:15 PM - 2:45 PM

Amongst strategies to improve nitrogen use efficiency (NUE) in crops, targeted, rapid cycle breeding for efficient varieties is one of the most effective. To achieve this, comprehensive, cost-effective, and high-throughput phenotyping is needed to identify favourable genotypes and the genes underlying NUE traits. Here, we report an automated phenotyping protocol to screen wheat genotypes for improved NUE. Wheat plants were grown in Plant Phenomics Victoria's automated controlled environment facility at Horsham. Three week old plants were loaded onto the system, supplied with five relative nitrogen (N) levels; 5, 10, 15, 20 and 25 mM weekly, and grown until maturity. Plants were imaged twice per week using the LemnaTec Scanalyzer 3D to obtain visible images of a top and three side views (0, 120 and 240^{o}), and hyperspectral images from one side. Wheat plants were highly responsive to different N regimes, with 5 and 20 mM N identified as low and optimum N levels, respectively, to screen wheat genotypes. Projected area from visible images and several hyperspectral indices were highly correlated with fresh and dry biomass, and leaf area. Results demonstrate the automated high-throughput phenotyping system can be used to efficiently screen wheat genotypes for improved NUE under glasshouse conditions.

Biography:

Surya Kant is senior research scientist at Agriculture Victoria. Surya has worked as research associate at University of Guelph, Canada (2006-2011) and two post-doctorates, Ben Gurion University, Israel (2002- 2006) and Faculty of Agricultural, Israel (2000- 2002). Surya graduated from the Haryana Agricultural University, India. Published over 30 research articles.

High-throughput phenotyping platform for nodal root angle in sorghum

Singh V[1]

[1]*The University of Queensland*

Session 5: Current research in controlled environments and phenomics (continued), CSIRO Discover Centre Theatre, September 20, 2016, 1:15 PM - 2:45 PM

Water availability is an important abiotic stress that can severely affect agricultural production. The angle of the first flush of nodal roots is a key determinant of spatial water acquisition of mature sorghum plants and could therefore be an important trait in breeding for drought tolerance. However, application of nodal root angle in molecular sorghum breeding programs has been limited due to the lack of an effective phenotyping platform. The aim of this study was to develop a high-throughput phenotyping platform for rapid and non-destructive digital measurement of nodal root angle of sorghum seedlings. The phenotyping platform comprises of 500 custom made soil-filled root chambers and a high-throughput imaging box. Each root chamber consists of two transparent perspex plates of 50 × 40 cm, separated on three sides by 3 mm thick rubber that are positioned in steel tubs. The imaging box contains two cameras to image both sides of each chamber and lights to enhance the efficiency of image processing. This low cost high-throughput phenotyping platform can be used in most glasshouse environments, and its high-throughput capability makes it an effective tool for application in molecular breeding programs.

Biography:

Dr Vijaya Singh works focuses on the crop physiological basis of adaptation to abiotic stress (drought and heat) in summer cereals. The aim is to link the phenotypic expression of key physiological traits to the underlying genetic control mechanism.

Light competition within dense plant stands under different light qualities

Shibuya T[1], Kishigami S[1], Endo R[1], Kitaya Y[1]
[1]Osaka Prefecture University

Session 5: Current research in controlled environments and phenomics (continued), CSIRO Discover Centre Theatre, September 20, 2016, 1:15 PM - 2:45 PM

Light competition and subsequent growth of dense plant stands were evaluated under light with different red:far-red ratios (R:FRs). The plant stands containing cucumber seedlings with different mutual shading degrees were prepared, and were grown under light with normal R:FR (similar to that of sunlight, = 1.2) or high R:FR (= 11). Under normal R:FR light, differences in shading degree within individuals became non-significant within 2 days, whereas under high R:FR light, differences were preserved throughout the experimental period. This indicates that the unequal competition for light exists between neighbors under high R:FR light. The initial shading degree and dry-matter accumulation of the seedlings during the experimental period were positively correlated under high R:FR light but not under normal R:FR light, indicating that the initial dominance of light interception by individual seedlings is likely to affect their subsequent growth under high R:FR light. The seedlings that had lost out to neighboring seedlings could not climb over the neighbors under high R:FR light, probably because of insufficient stimulation of shade-avoidance responses. The knowledge from this study that light quality affects plant growth by altering the competitive interactions among plants will provide guidance for optimizing the light conditions.

Biography:

Toshio Shibuya is an Associate Professor at Osaka Prefecture University. Dr. Shibuya received a Ph.D in Horticultural Engineering from Chiba University in 1999. He is interested in environmental control of physiological and ecological plant responses in the horticultural production.

Model-Assisted Targeting of Phenotyping Platforms

Hammer G[1] & Chapman S[2]

[1]University of Queensland & [2] CSIRO

Session 6: Field Phenotyping, CSIRO Discover Centre Theatre, September 20, 2016, 3:00 PM – 5:00 PM

Abstract to come

High resolution field phenotyping: exploiting rice genetic diversity

Coe R[1]

[1]*International Rice Research Institute*

Session 6: Field phenotyping, CSIRO Discover Centre Theatre, September 20, 2016, 3:00 PM - 5:30 PM

The key to increasing rice yields by 25% over the next 25 years will be harnessing natural genetic diversity. A major step towards discovering novel alleles for important phenotypes has been the release of the full genome sequence of 3,000 rice accessions (The Rice 3000 Genomes Project 2014). Similar progress has not been made with phenotyping due to the cost and lack of methodologies with which to measure a range of diverse traits in such a large number of accessions. To address this issue we have been collaborating with the High Resolution Plant Phenomics Centre (HRPPC) on the construction of a prototype phenotyping platform capable of high resolution phenotyping in the field. Equipped with a range of proximal remote sensors, the platform moves autonomously above the surface of a crop canopy, acquiring images from which a diverse range of crop traits can be nondestructively measured. The sensors include Light detection and ranging (LiDAR) devices together with RGB, thermal and a hyperspectral imaging cameras. The system is being trailed on paddy grown rice inside a screen house. We discuss the development and current status of the system together with future applications for field phenotyping and contribution to rice research.

Biography:

Robert Coe is a scientist working jointly between the C4 Rice Centre at IRRI and the ARC Centre of Excellence For Translational Photosynthesis in Australia. He is leader of the C4 Rice Centre Phenomics Group, part of a multinational research team working towards improving the efficiency of photosynthesis in rice.

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The development of a field-based forage phenomics platform

Badenhorst P[1]
[1]*Department of Economic Development, Jobs, Transport and Resources*

Session 6: Field phenotyping, CSIRO Discover Centre Theatre, September 20, 2016, 3:00 PM - 5:30 PM

A forage phenomics platform is being established to allow non-destructive, high throughput evaluation of forages, in both controlled environments and the field. This forage phenomics platform uses multiple surveillance platforms, including the PhenoRover (ground vehicle), PhenoBlimp (tethered stationary aerial device), PhenoCopter (unmanned aerial vehicle). Imaging technologies implemented from one or more surveillance platform, including normalised difference vegetation index (NDVI), multi-spectral camera imaging and infra-red based thermal imaging. Protocols and screening methods are being established for key forage traits, including morphological characteristics, yield, nutritive value estimates and abiotic and biotic stress responses. Initial assessment of the correlations between actual biomass yield and NDVI, in spaced-plant and sward ryegrass field trials, have shown significant positive correlations with a correlation coefficient up to 0.94. The integration of georeferenced, semi-automated NDVI, canopy height and canopy temperature measurements into our perennial ryegrass field screening procedures has allowed for the weekly assessment of biomass yield and abiotic stress tolerance. Development of a data management system and analysis framework has allowed for semi-automated data storage, image processing and data analysis.

Biography:
Pieter Badenhorst has a Bachelors Degree in Science (AnimalBiotechnology), Honors Degree in Science (Genetics), Masters Degree in Science (Molecular Genetics) and Doctor of Philosophy degree in Molecular Plant Breeding. He leads the Biosciences Research team in Hamilton, Victoria and specialises in forage breeding and advanced phenomics.

Field phenotyping of sorghum breeding plots through proximal sensing.

Potgieter A[1], Watson J[1], Jordan D[1], Hammer G[1], Chapman S[2], Laws K[3], Mclean G[3], George-Jaeggli B[1], Holland E[2], Elldridge M[1]

[1]University of Queensland, [2]CSIRO, [3]QDAF

Session 6: Field phenotyping, CSIRO Discover Centre Theatre, September 20, 2016, 3:00 PM - 5:30 PM

Monitoring and capturing physiological and phenological traits within sorghum breeding trials is time consuming and costly. For example, the current method for estimating tillering involves manually counting or scoring head and tiller number across thousands of plots, and over multiple trials. Despite being highly valuable, this information often proves too costly to collect and thus relies on subsampling of plots. The advent of sensing technologies has advanced operators' ability to evaluate crop vigour over fields in different environments, in terms of both cost and time. These advancements have significant potential for sorghum breeders, where the measurement of phenotypic traits like plant height, crop yield, crop cover and photosynthetic capacity are important in enhancing efficiencies in genotypic selection and thus breeding of new commercial hybrids with improved traits. This study outlines the application and ability of proximal sensing technologies to enhance plant-breeding research outcomes. Specifically, we describe the design of a high throughput (HTP) software pipeline to capture, manipulate and analyse BIG DATA collated from proximal sensors on-board a phenotyping platform. We discuss preliminary results from the use of high-resolution spatial characterisation of time-sequence data, obtained from hyperspectral, distance and thermal sensors. Application of such an approach across breeding fields will enhance phenotyping capabilities and hence the ability to accurately discriminate LAI, dry-biomass, chlorophyll content and likely crop yield responses among genotypes. The deployment of these methods into breeding programs will result in faster delivery of commercial hybrids with more specific adaptation to environments, where traits like leaf area index and chlorophyll content are useful to increase yield.

Biography:

Dr Andries Potgieter, is Senior Research Fellow at UQ, where he currently lead and mentor a team of researchers making significant advances in the areas of seasonal climate forecasting, proximal sensing and quantitative eco-physiological systems modelling with applications in the development of predictive cropping systems across Australia broad cropping region.

Turning photons into food: A global analysis of energy inputs to farming without sunlight

Bugbee B[1]

[1] *Utah State University*

Plenary Three, CSIRO Discover Centre Theatre, September 21, 2016, 9:00 AM - 10:30 AM

Every year agriculture feeds more people with less land. Food quality and safety have increased. Automation has increased and human labor has decreased, resulting in lower food costs but a steady increase in the use of fossil fuels. All of our energy inputs to agriculture are miniscule, however, compared to the energy input from sunlight. We celebrate our achievements in making local lettuce available in the darkest month of the year but this requires supplementing sunlight with electric light. Our ability to convert electricity into photosynthetic photons has doubled since 2006, leading some protagonists to proclaim that we no longer need sunlight. Assuming an electric cost of $0.10/kWh and our most efficient electric lights (8 moles of photons/kWh), the economic value of summer sunlight in mid-latitudes is $700,000 per hectare over a 100 day growing season. The equivalent of winter sunlight during the darkest 50 days of the year at 45° North Latitude is worth about $40,000 per hectare. These values drive the comparative costs of indoor/outdoor food production. Here I analyze the economic and environmental trade-offs of using sunlight vs. electric light to grow food. Natural photons from sunlight are still the gold standard but electric light becomes increasingly important as sunlight dims in northern latitudes in the winter. The more sunlight we capture in photosynthesis the smaller our carbon footprint.

Biography:

Dr. Bugbee's career has been guided by the idea that teaching is the highest form of understanding. Over a 34 year career he has mentored 33 graduate students. Six of his students are now on the faculty at other universities.

He is internationally known for his research with NASA. He and his students developed a dwarf variety of wheat that has been used in studies on the Space Station and he is currently studying the use of fiber optics for growing plants in space.

He recently gave a TEDx talk entitled: "Turning water into food."

Pushing the Limits of Urban Agriculture

Lefsrud M[1]
[1] *McGill University*

Plenary Three, CSIRO Discover Centre Theatre, September 21, 2016, 9:00 AM - 10:30 AM

Field based agriculture offers a cheap, efficient and reasonably reliable means of producing food, but it is limited by seasonal changes, location availability and weather patterns. Comparatively, urban agriculture offers a modern twist on the traditional challenge of ‘growing food where people live’. Current research in controlled environments has created a range of hospitable environments in the form of shade houses, greenhouses, container agriculture, and indoor agriculture. All of these technologies offer benefits but also have limitations. More specifically, research is required for LED lighting, water recovery, nutrient control systems, combined heat and CO_2 generation, cooling, growing system design, automation and consumer acceptance. Highlighted in this presentation will be an overview of Urban Barns, an indoor agricultural company based in Montreal.

Biography:

Dr. Lefsrud, an Associate Professor at McGill University leads the Biomass Production Laboratory. His B.Sc. and M.Sc. is in Agricultural and Bioresource Engineering and his Ph.D. is in Plant Physiology. His research program deals with the development of bioprocesses and improvements in plant growth environmental energy usage.

Traitcapture: NextGen Software and Hardware for Scaling from Seeds to Traits to Ecosystems

Brown, T[1]

[1]*Australian National Univeristy*

Session7: CE's and Phenomics: new horizons, CSIRO Discover Centre Theatre, September 21, 2016, 11:00 AM – 12:30 PM

Addressing environmental management and food production challenges of the 21st century requires exponential increases in our ability to understand and model ecosystem and agricultural processes.
Lab approaches enable accurate measurement of the genetic and environmental basis of yield and fitness traits. Field data enables modelling of how genotype/environment interactions scale from plot to ecosystem.
High-throughput lab phenomics can precisely phenotype thousands of plants under simulated climates. Genome-Wide Association Studies can dissect how traits emerge as interactions between genes and environment. In the field, new technologies (UAVs, sensor networks, etc.) and cloud computation enable 3D time-series monitoring of the environment at unprecedented resolutions. Unfortunately, such high-density data is extremely hard to manage, visualize and analyze and there is a lack of data standards and open source software tools; all of which limits adoption and wider usability of the phenomics approach.
TraitCapture is an open-source high-throughput phenotyping system combining multispectral lighting and environmental controls for simulating regional and climate-shifted conditions in growth chambers with real-time phenotyping of 2,000 plants.
The Phenomic-Environmental-Sensing-Array is a field site at the National Arboretum in Canberra, combining traditional and "NextGen" monitoring (weather, sensor networks, precision dendrometers, time-series UAV flights, LiDAR, and hyperspectral, thermal and gigapixel-resolution time-lapse). Phenomic and environmental data, combined with tree genomic data, allow us to examine how microclimate variation, environment and genetics shape phenotype.
EcoVR is a software tool for visualizing complex geospatial time-series datasets in virtual reality. EcoVR allows users to combine 3D landscape data layers (UAV and gigapixel imaging, LiDAR, etc) with environmental data (mesh sensors, hyperspectral, thermal, etc) to layer time-series data onto the individual trees and the landscape.
All software tools are web-based, open-source and work with both lab and field datasets.

Identification of traits contributing to salinity tolerance in Arabidopsis thaliana

Panzarova K[1], Awlia M[2], Nigro A[3], Fajkus J[1], Julkowska M[2], Tester M[2], Trtílek M[1]

[1]PSI (Photon Systems Instruments), Drasov, Czech Republic, [2]King Abdullah University of Science and Technology (KAUST), Division of Biological and Environmental Sciences and Engineering (BESE), Thuwal, 23955-6900, Saudi Arabia, [3]Institute of Plant and Microbial Biology, University of Zurich, Switzerland

Session 7: CE's and phenomics: new horizons, CSIRO Discover Centre Theatre, September 21, 2016, 11:00 AM - 12:30 PM

Advances in genome sequencing need to be accompanied by reproducible and efficient high-throughput phenotyping approaches to facilitate the discovery of new genes underlying enhanced plant performance. Soil salinity poses a great challenge for modern-day agriculture with most breeding efforts focusing on salinity tolerance using shoot-ion exclusion as the key phenotype.
To enhance our understanding of the early plant responses to salinity, we designed a protocol based on using phenotyping system developed at Photon Systems Instruments (PSI, Czech Republic). Growth, morphology and photosynthetic activity determine overall plant performance collectively. Therefore we established methodology based on automated integrative analysis of photosynthetic performance, growth analysis and colour analysis at the onset and during early phase of salinity stress responses of nine *Arabidopsis* accessions cultivated under controlled conditions. The imposition of plants to 100 mM NaCl in the soil-water rapidly affected photosystem II operating efficiency, reduced growth dynamics and dynamically changed colour index of plants. Selected photosynthetic performance- related parameters were clustered with relative plant growth rates into traits corresponding to early and late changes in response to salt stress and natural variation in the quantified traits was characterized. Our analysis enabled the categorization of changes in phenotypic traits upon imposition of stress, which can be used as markers for early or late salt stress responses, and provide insights into the underlying processes of plant salinity tolerance.
This work presents an integrative approach, which allows simultaneous analysis of different phenotypic traits, may improve our knowledge of plant performance and stress response dynamics, and lead to the identification of desirable target genes contributing to crop improvement.

Biography:

Klára Panzarová (Šimková) is plant biologist with expertise in plant stress physiology, chlorophyll fluorescence imaging and imaging technologies used for automated plant phenotyping. After PhD with Klaus Apel and post-doc at ETH Zurich in Switzerand, she moved to Photon Systems Instruments (PSI), where she works as chief scientist.

Semi-transparent photovoltaic glass (STPVG) greenhouses for protected cropping

Kamal Alameh[1], Mikhail Vasiliev[1], John Hall[2], Folco Faber[3] and Victor Rosenberg[2]
[1]Edith Cowan University, [2]ClearVue Technologies, 3 Apex Greenhouses (Australia)

Session 7: CE's and phenomics: new horizons, CSIRO Discover Centre Theatre, September 21, 2016, 11:00 AM - 12:30 PM

The continual increase in world population and the limitations of conventional agricultural practices demand new cost-effective, safe, secure and sustainable food production approaches and facilities. Semi-transparent photovoltaic glass greenhouses (STPVG), incorporating innovative energy-harvesting, water sanitising, nutrient recycling and microclimate control technologies, can significantly increase crop yields and quality whilst reducing energy, water and agrochemical requirements.
A basic 4m x 4m glass greenhouse demonstrator was developed at Edith Cowan University, WA, in collaboration with ClearVue Technologies, and is being characterised and compared with conventional glass greenhouses in terms of electricity generation, insulation and microclimate control.
The glass greenhouse demonstrator integrates semi-transparent photovoltaic glass panels that pass most of the visible light through enable selective control of light radiation to maximise crop yield, while producing and storing electricity for functions such as water filtration and irrigation, heating and air conditioning, all in a closed environment.
The glass panels comprise spectrally-selective optical structures and inorganic nano-particles incorporated into a polyvinyl butyral (PVB) interlayer that is fixed between two sheets of clear glass. They convert Ultraviolet (UV) and Infrared (IR) components of sunlight into electricity whilst allowing visible light to pass through the glass. The panels produce around 35 watts of electricity per square metre of glass and have superior insulation properties compared to conventional glass, thus enabling substantial reduction in heating, cooling and lighting costs.

Adding Far-red Radiation to Sole-source Lighting for Specialty Crops

Runkle E[1], Park Y[1], Meng Q[1]
[1]*Michigan State University*

Session 8: Advanced in LED lighting: technologies and applications, September 21, 2016, 1:30 PM - 3:30 PM

An increasing number of high-value specialty crops are being commercially produced in controlled environments under sole-source lighting. New facilities are primarily installing light-emitting diodes that emit narrowband red (R, 600-700 nm) and blue (B, 400-500 nm) radiation and sometimes also broadband white. We are investigating the merits of adding far-red (FR, 700-800 nm) radiation to decrease the phytochrome photoequilibrium (PPE) to produce crops with higher-quality attributes. In one series of experiments, ornamental seedlings were grown under a PPFD of 96, 128, or 160 $\mu mol \cdot m^{-2} \cdot s^{-1}$ with various intensities of FR radiation to emit a total photon flux density of 160 to 224 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and R:FR ranging from 1:0 to 1:1. Plant height and leaf area decreased by approximately 35-40% and 15-30%, respectively, as the PPE increased from 0.69 to 0.88. At the same PPFD, the addition of FR that increased leaf size led to an increase in shoot dry weight of shade-avoiding crops such as petunia but not in the shade-tolerant impatiens. In lettuce, adding 30 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of FR to 180 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of B+R increased shoot dry weight and leaf length by up to 44% and 66%, respectively. The merits of including FR radiation in sole-source lighting will be discussed.

Biography:

Erik Runkle is a professor and extension specialist in the production of floriculture and specialty crops grown in controlled environments

Genetic mapping of high-dimensional phenotypes.

Alexander Ivakov [1], Riyan Cheng [1], Justin Borevitz[1] and Robert Furbank[1]

[1] Australian National Univeristy

Session 8: Advanced in LED lighting: technologies and applications, September 21, 2016, 1:30 PM - 3:30 PM

Genome-wide association mapping is a powerful technique to discover and dissect the genetic basis of natural variation in agronomic traits. By efficiently collecting data on more and more phenotypes, modern phenomics approaches enable genetic mapping studies at an unprecedented scale. However, the methods used for genetic mapping have remained the same and largely focus on one single, one-dimensional trait at a time. This is inadequate for traits that are inherently highly-multivariate and where a single aspect carries little meaning or information. Here we propose a machine learning approach to mine high-dimensional datasets for distinct, multivariate phenotypes that maximise the QTL effect at each individual locus. In this way the analysis discovers both novel genes as well as novel phenotypes determined by them. We demonstrate the use of the method to map high-dimensional representations of leaf shape, as well as hyperspectral reflectance spectra obtained using imaging techniques in Arabidopsis thaliana

Supplemental LED Effects on Growth and Phytonutrients of ‘Outredgeous’ Lettuce

Mickens M[1], Skoog E[1], Massa G[1], Wheeler R[1]

[1]*NASA Kennedy Space Center*

Session 8: Advanced in LED lighting: technologies and applications, September 21, 2016, 1:30 PM - 3:30 PM

Growing plants in space will be an essential part of sustaining astronauts during long-range missions. To drive photosynthesis, light-emitting diodes (LEDs) are becoming superior because of their efficiency, longevity, small size, safety, and wavelength versatility. Isolating the effects of certain wavelengths on plant growth when combined with white light is attracting attention. In order to optimize crop production/quality aboard the International Space Station (ISS) and beyond, this study has aimed to configure novel “light recipes.” By using white light as a background to maintain normal growth, the addition of monochromatic wavelengths will provide a clearer understanding of how each part of the visible spectrum effects plant growth when provided by LEDs. Under six treatments of White (W) LEDs, W + blue (B), W+ green (G), W + red (R), W + far red (FR), and B+G+R+FR LEDs without WLEDs, this investigation is assessing differences in biomass, morphology, chlorophyll, and the synthesis of key phytonutrients in lettuce. A space diet consisting of plant-derived anthocyanin, lutein, zeaxanthin, potassium, magnesium, and vitamin K is paramount to improving astronaut health. The crop responses to each treatment are currently being evaluated to select an LED combination that would optimize both plant yield and nutrient content.

Biography:

Matthew Mickens is a native of Durham, NC. He received a B.S. in Agricultural Science, a M.S. in Environmental Science, and a Ph.D. in Energy and Environmental Systems, with a dissertation on synthesizing luminescent phosphors for white LEDs. He is now investigating optimal light recipes for growing plants in space.

Optimizing LED spectra for photosynthesis, C-partitioning and export in greenhouses

Lanoue J[1], Leonardos E[1], Grodzinski B[1], Kholsa S[2], Hao X[3]

[1]University Of Guelph, [2]OMAFRA, [3]Agriculture and Agri-Food Canada

Session 8: Advanced in LED lighting: technologies and applications, September 21, 2016, 1:30 PM - 3:30 PM

In Canada, controlled environment growth facilities, such as greenhouses equipped with supplemental lighting are essential for year-round production of crops. Supplemental lighting allows for the increase in photosynthetically active radiation (PAR) during low light months as well as optimization of the day length which can increase production throughout the year. Historically commercial greenhouses have used high pressure sodium (HPS) and/or high intensity discharge (HID) lighting but there is a growing trend towards the further refinement of light emitting diodes (LEDs) as more energy efficient alternatives.
Increased quality and yield in selected high-value crops, including tomatoes, forces us to re-examine how the spectral qualities of LED-luminaries can be optimized to best effect photosynthesis, C-partitioning and actual rates of translocation during tomato production cycles. We will present new evidence for a direct effect on 14C-export kinetics with LEDs of differing spectral composition. The implications of these findings for the future design of LEDS for commercial production will be discussed.

Biography:

Jason Lanoue is a graduate student at the University of Guelph under the supervision of Dr. Bernard Grodzinski. He is currently working on optimizing the spectral qualities of LEDs for photosynthesis, C-partitioning and export in vegetative greenhouse tomatoes.

Effect of CO2, Temperature, and Water Deficit on Petunia Flowering

Mills S[1], Moon Y[1], Waterland N[1]

[1]*West Virginia University*

Session 9: Controlled environments: temperature, CO2, humidity, air circulation and plant responses, CSIRO Discover Centre Theatre, September 21, 2016, 4:00 PM - 5:30 PM

Changes in climate, including increases in atmospheric CO_2, temperature, and water deficit, present a challenge to agriculture. These three environmental factors, among other factors, play significant roles in plant growth and development. In order to cope with environmental stress plants utilize morphological and physiological mechanisms to survive and mitigate the stress. The goal of this research was to investigate the effects of elevated CO_2, temperature and water deficit stress on the growth, flower development, and expression of genes that are involved in stress response pathways. Petunias were grown in growth chambers at two levels of CO_2 (400 and 800 $\mu mol \cdot mol^{-1}$), two temperature regimes (21/18 and 28/25 °C day/night), and two water regimes (0.15 and 0.30 m^3/m^3). The moisture levels of the growing media were maintained by an automated irrigation system. Growth index, flowering time, size of the corollas, number of flowers per plant and flower longevity were examined. Gene expression patterns, using quantitative real-time PCR, of selected genes involved in stress responses, floral development, hormone synthesis, photosynthesis and respiration were also examined to understand the impact of environmental stress on morphological/physiological changes at the molecular level.

Biography:

Sarah Mills is pursuing a Master's of Science in horticulture under Dr. Nicole Waterland at West Virginia University. She is investigating, 1) the effects of elevated CO2, temperature, and water deficit on floral development of petunia, and 2) the effect of temperature on floral development and fruit quality of blueberries.

Comparing Key Light Ratios for Plant Growth and Development

Both A[1], Wallace C[1]

[1]*Rutgers University*

Session 9: Controlled environments: temperature, CO2, humidity, air circulation and plant responses, CSIRO Discover Centre Theatre, September 21, 2016, 4:00 PM - 5:30 PM

Recent advancements in light-emitting diode (LED) technology have provided excellent opportunities to precisely control the spectral output that impacts plant growth and development. Plant scientists often use light ratios to compare different light sources. For example, based on the average plant response to photosynthetically active radiation, the red:blue ratio can be used to assess the effect a particular light source may have on plant production. However, the scientific literature does not provide conclusive definitions of the key wavebands that are used to calculate these ratios. For example, red light is sometimes identified as light with a wavelength of 660 nm, and other times as all light across the 600-700 nm waveband. As a result, the calculated light ratios can have very different values. We used a spectroradiometer to evaluate a range of light sources and different lamp models (sunlight, INC, CFL, MH, HPS, and LED). Spectral data was used to calculate various light ratios based on differing definitions of the key wavebands. The calculated ratios included red:blue, red:green, green:blue, and red:far-red. The results demonstrate the importance of standardized definitions for key wavebands and hopefully contribute to an easier interpretation of the reported light ratios once these definitions are universally applied.

Biography:

Dr. A.J. Both is an Extension Specialist in Controlled Environment Engineering at Rutgers University. Dr. Both's research includes engineering and crop production projects in growth chambers, greenhouses and high tunnels. His research interests include greenhouse environment control, hydroponic vegetable production, supplemental lighting, and energy systems.

The temperature response of dry matter and sugar accumulation in grapevine berries

Greer D[1]

[1]*Charles Sturt University*

Session7: CE's and Phenomics: new horizons, CSIRO Discover Centre Theatre, September 21, 2016, 11:00 AM – 12:30 PM

The aim of this work was to compare the ripening process in three grapevine cultivars; *Vitis vinifera* L. cv. Chardonnay, cv. Merlot and cv. Semillon, in response to temperature and quantify the response. The vines were grown in controlled environment conditions. Phenology of budbreak and flowering dates were compared across the three cultivars as well as shoot growth in standard growth conditions. In the late stage of ripening, the three cultivars were exposed to five different temperature regimes, with the day temperature ranging from 20 to 40°C, and berry attributes and the ripening processes were followed in each variety. Budbreak and flowering dates varied, with Semillon vines the earliest to develop and Merlot the last. Shoot and bunch growth also varied, with Chardonnay vines with very long shoots and small bunches whereas Semillon and Merlot vines had similar shoot lengths but much longer bunches. Temperature had little effect on the berry expansion process in all varieties, partly because expansion may have been completed. However, there were marked effects of temperature on the accumulation of both dry matter and sugar in all varieties but also marked differences in response. There was a general accordance between the temperature responses for both rates of dry matter accumulation and rates of ripening. Application of the temperature response to field-grown Semillon vines accurately predicted the seasonal progression of ripening, independently vindicating the intrinsic nature of the temperature-dependent response of the berry ripening process. To conclude, the rate of ripening in all three grapevine cultivars was a curvilinear function of temperature. Chardonnay berries could be classified as cool-season since rates were highest at 25°C and the rates declined markedly at higher temperatures. Semillon and Merlot could be classified as warm-season because the rates of ripening for Merlot appeared to maximise at 40°C and beyond while Semillon was optimal at 35°C, for both processes. The study also vindicates the use of controlled environments to establish the temperature-dependent functions, which can be readily up-scaled to field conditions.

Extreme palaeo-atmosphere experiments on living fossil plants in controlled environment chambers

McElwain J[1]

[1] *University College Dublin*

Plenary Four, CSIRO Discover Centre Theatre, September 22, 2016, 9:00 AM - 10:30 AM

The gas composition of the atmosphere has varied dramatically throughout Earth history. Atmospheric evolution is influenced by and has driven changes in plant evolution yet despite many decades of research uncertainties remain regarding how atmospheric CO_2 and O_2 have changed through geological time. Mass balance models and palaeontological proxies indicate that the great tropical coal swamps of the Carboniferous were exposed to O_2 concentrations as high as 35% but were characterized by CO_2 concentrations as low, or lower, than those of the modern day. Vertebrate extinction boundaries have been associated with episodes of sub-modern ambient O_2 (~13%) and extremely elevated CO_2 (> 2000 ppmV), yet all model and proxy estimates of palaeoatmospheric conditions are subjected to large error ranges. We use an experimental palaeontological approach to interrogate existing understanding of atmospheric evolution and to improve estimates of palaeo-atmospheric CO_2 concentrations from fossil plants. This talk will explore how simulated palaeo –atmosphere experiments in controlled environment chambers have been used to develop new palaeo-atmosphere proxies and test existing methods and assumptions on atmospheric evolution. Leaf phenotypic, carbon isotopic and ecophysiological responses of 'living fossil taxa' to extreme palaeo-atmosphere treatments will be discussed in order to gain better insights into plant-atmosphere interactions over the past 400 million years. Methodological and technical challenges associated with this research will also be explored.

Biography:

Professor Jennifer McElwain is a research leader in Earth system science and plant biology. She is an Associate Professor of University College Dublin's School of Biology and Environmental Science, member of UCD's Earth Institute and Director of the Programme for Experimental Atmospheres and Climate (PEAC) facility. Over the past 20 years her research and teaching have focused on the development and use of palaeobiological proxies to understand the evolution of Earth's atmosphere and climate on multimillion year timescales and how fluctuations in both have influenced large scale patterns in plant evolution and ecology throughout Earth history. Controlled Environment Chamber experiments are used in her research programme to calibrate palaeobiological proxies and investigate plant-atmosphere interactions.

Genomic and environmental dissection of complex plant traits

Borevitz, J[1]

[1] *Australian National University*

Plenary Four, CSIRO Discover Centre Theatre, September 22, 2016, 9:00 AM - 10:30 AM

Traits are phenotypes that are heritable and thus can be predicted from the genotype of the seed. They are the result of major genes and polygenic background variation which interact with the environment. Through Genome Wide Association Studies in dynamic controlled environments with high resolution phenotyping we can dissect the causal genetic variation and background effects to enable digital breeding of climate ready crops. I will present results from Arabidopsis thaliana as a model.

Searching for the regulatory processes underlying plant growth traits by integrative analyses of 'omics data

Mathew G. Lewsey[1], Mark Zander[2], Siddhartha Jain[3], Carol S. Huang[2], Ronan C. O'Malley[2], Shelly Trigg[2], Renee Garza[2], Ziv Bar-Joseph[3] & Joseph R. Ecker[2,4]

[1] La Trobe University, [2] The Salk Institute for Biological Studies, [3] Carnegie Mellon University, [4] Howard Hughes Medical Institute

Session 10: Controlled environments: novel applications, CSIRO Discover Centre Theatre, September 22, 2016, 11:00 AM - 12:30 PM

We are investigating the processes that underly hormone-regulated growth in Arabidopsis seedlings at the systems level. We do so using a range of 'omic approaches that include mapping gene expression, protein-DNA interactions and protein-protein interactions by high-throughput sequencing. The goal of this research is to link genome regulation to control of growth phenotypes, ultimately permitting targeted optimisation of plant traits. We have generated models that integrate our diverse datasets and are testing their predictions experimentally. Initial studies have focused on the function of two hormones, jasmonate and ethylene, during seedling growth in the dark. This mimics early growth of a seedling through the soil. We have identified extensive interaction between hormones at points of gene expression control. Furthermore, our integrative analyses have predicted novel regulators of hormone-responsive growth.

Plant characterisation using advanced sealed environment technology

Michael Stasiak[1], Carsten Richter[2], Per Lyssa[3], Mike Dixon[1]

[1] *Controlled Environment Systems Research Facility, University of Guelph,* [2] *Conviron,* [3] *Intravision Group AS*

Session 10: Controlled environments: novel applications, CSIRO Discover Centre Theatre, September 22, 2016, 11:00 AM - 12:30 PM

Building on technological advancements in growth chamber technology (Guelph BlueBox), a hardware collaboration between the University of Guelph's Controlled Environment Systems Research Facility, Conviron and Intravision Lighting has resulted in the development of a sealed environment chamber capable of high resolution measurement of whole plant photosynthesis and evapotranspiration. By precisely manipulating the environment conditions within the chamber, detailed plant/environment responses to light (intensity and quality), carbon dioxide concentration, vapour pressure deficit and temperature can be easily obtained. Plant environment response is unique between plant species and there are often notable differences between cultivars developed for improved growth characteristics such as drought, insect and disease tolerance. These differences can be demonstrated in time periods considerably shorter than a typical field season, allowing for improved analytical throughput for phenotypic characterization. Tomato, pepper and lettuce whole plant characterizations will be shown.

Maintaining Relationships in Closed Environments: Plant/Microbe Mutualisms

Stutte G

[1]*Kennedy Space Center*

Session 10: Controlled environments: novel applications, CSIRO Discover Centre Theatre, September 22, 2016, 11:00 AM - 12:30 PM

Controlled environment technology developed to support growth of plants on long duration space missions can be used to increase the quality, composition and yield of culinary and medicinal plants grown in closed environments. Controlled environments allow conditions to be modified for the induction/suppression of environmentally modulated in genomic, phenomic and metabolic pathways. Environmental stress, controlled or uncontrolled, induces the production of secondary metabolites and often reduces the yield. Given the value of many secondary metabolites as components of functional food, sensory quality and medicinal plants, its imperative to minimize the impacts of environmental stress when inducing secondary metabolite production. Several plant/microbe interactions have been shown to develop mutualisms that provide a bioprotective, and growth promoting effect to the host plant while simultaneously increasing the concentration of bioactive phytomolecules. A series of ground (Murge) and space flight (SyNRGE) experiments have investigated the role of microgravity on plant microbe interactions in space. A NanoCube plant growth chamber was designed and built (SyNRGE Plant Growth Chamber, SPGC) that compatible with the NanoLab on the International Space Station and two flights have been performed, and symbiotic bacteria and fungi returned to Earth. The stability of functionality mutualism is being assessed.

Biography:

Gary Stutte works in the area of space agriculture and controlled environments and has been principal investigator on four space flight experiments to the International Space Station. He is interested developing technology for long-duration space missions, the role of plant/microbe mutualisms on system stability and production of biological active phytochemicals.

Energy consumption in controlled environments: supplemental lighting and CO2 systems

Harbick K[1], Albright L[1], Mattson N[1]

[1]*Cornell University*

Session 11: Controlled environments: novel applications (continued), CSIRO Discover Centre Theatre, September 22, 2016, 1:15 PM - 2:45 PM

Annual energy consumption, cost, and carbon footprints are compared in simulation for two controlled environments: plant factory and traditional greenhouse. Energy consumed for heating, ventilating, and air conditioning (HVAC) as well as supplemental lighting are included in the models. CO_2 supplementation and its effects on energy are also modeled. In the greenhouse case, supplemental lighting is controlled to a consistent daily light integral (DLI) of Photosynthetically Active Radiation (PAR) using Light and Shade System Implementation (LASSI). In the plant factory model, lighting power is sized according to photoperiod and DLI requirements. Building HVAC loads and system responses are computed using the ASHRAE heat balance method with a one hour time-step. Both environments are simulated in several different climates using Typical Meteorological Year (TMY) data sets. In each simulation, energy consumption, cost, and carbon footprints are shown to be significantly higher in the plant factory environment compared to the greenhouse.

Biography:

Kale Harbick conducts research in the CEA group at Cornell, focusing on environmental control algorithms and modeling energy consumption in controlled environments. Previous work included crater detection for Mars landers and autonomous helicopters at NASA-JPL, energy efficiency programs in K-12 schools, and teaching physics, computer science, and energy management.

Integration of Management Tools for Controlled Environment Research Facilities

Leonard J[1]

[1]*The Ohio State University*

Session 11: Controlled environments: novel applications (continued), CSIRO Discover Centre Theatre, September 22, 2016, 1:15 PM - 2:45 PM

Information management has become a time-consuming, overwhelming challenge for managers of controlled environment research facilities. Managers report negative impacts due to difficulties in organizing data, in optimizing costly research space, and in effectively communicating information with stakeholders.

Managers currently employ a disparate variety of tools to manage data with many struggling to build customized spreadsheets. Disturbingly, some managers rely on random paper records and report storing mission critical data in their head, creating the potential for catastrophic data loss. Commercial greenhouse software focuses primarily on shipping logistics and inventory and fail to address tools such as pest management and equipment maintenance. While some products do include space planning, the application to institutional sized facilities is not ideal.

Development of a web-based application, addressing the unique space and data management challenges of controlled environment research facilities, offers the opportunity to integrate management tools into an accessible centralized platform. The application can utilize an API to stream live environmental data from greenhouse/growth chamber control programs and lends itself to integration with phenotyping systems.

Biography:

Joan Leonard is Program Manager for the Arts and Sciences Plant Growth Facilities at The Ohio State University. With over 30 years of practical experience at research controlled environment facilities, Ms. Leonard supports a wide range of research including the Arabidopsis Biological Resource Center

Comparing supplemental and sole-source lighting for bedding plant seedling production

Lopez R[1], Randall W

[1]*Michigan State University*

Session 11: Controlled environments: novel applications (continued), CSIRO Discover Centre Theatre, September 22, 2016, 1:15 PM - 2:45 PM

In order to produce high-quality seedlings, a photosynthetic daily light integral (DLI) of 10 to 12 mol·m^{-2}·d^{-1} must be delivered with supplemental (SL) or sole-source lighting (SSL) in greenhouses or indoor high-density multilayer environments, respectively. Therefore, our objective was to compare seedlings grown under low greenhouse ambient light (AL; 6 mol·m^{-2}·d^{-1}) to those grown under AL plus SL or SSL (DLI of ≈10.5 mol·m^{-2}·d^{-1}). Seedlings were placed under AL plus SL from HPS lamps or LED arrays (*PPF* of 70 µmol·m^{-2}·s^{-1}) in the greenhouse for 16-h or under SSL from LED arrays (*PPF* of 185 µmol·m^{-2}·s^{-1}) in a growth room for 16-h. Root and shoot dry mass, stem diameter, relative chlorophyll content, and the quality index of most species were generally greater under SSL and SL. In addition, height of geranium, petunia, and marigold was 5% to 26%, 62% to 79%, and 7% to 19% shorter, respectively, for seedlings grown under SSL compared with those under AL and SL. Seedlings grown under SSL were of similar or greater quality compared with those under SL; indicating that LED SSL could be used as an alternative to traditional greenhouse seedling production. Observations of ice nucleation and its progression in spikes using infrared video thermography

Biography:

Roberto is a professor and Controlled Environment Extension Specialist at Michigan State University. His research focuses on energy-efficient production of specialty crops in high tunnels, greenhouses, and multi-layer indoor environments. His group investigates how light (quantity, quality, and duration) and substrate temperature influence crop timing, rooting, quality, and subsequent performance.

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POSTER ABSTRACTS

Poster 1

Advantages of LED grow light with a far-red enriched spectrum

Bochenek G[1], Fälström I[1]

[1]*Heliospectra AB*

The red to far-red ratio has significant effects on plant germination, architecture, flower development and biochemical reactions. It is also reported that FR admixture can increase the efficiency of photosynthesis.

LED grow lights are often designed to target maximal electrical efficiency. The electrical efficiency of FR LEDs is lower than compared to diodes of other colour. Yet, their use in grow lights may be justified if benefits from enhanced plant growth performance balances efficiency reduction of the lamp.

We investigated growth performance of basil, dill and lettuce grown in LED light regimes without FR or containing moderate levels of far-red (R:FR ratio 5:1 -3:1). Light intensity levels in the experimental units were adjusted to compensate for the fact that photosynthetic active spectrum spans beyond 700 nm and a small proportion of FR wavelengths is used in photosynthesis, as well as for higher energy consumption by the lamp with FR diodes. The preliminary results show that stem and leaf elongation caused by moderate doses of FR improves light interception by plant canopy and efficiently stimulates biomass accumulation. Plants grown with FR light had “more natural” appearance. The results indicate that there is an advantage of using FR in a closed environment.

Biography:

Grazyna Bochenek works as a researcher for Heliospectra AB where she is involved in development of grow light regimes and assessment and design of light environment for specific crop requirements. She holds PhD in plant sciences from University of Gothenburg.

Poster 2

Proposed Product Information Label for Lamps used in Horticulture

Both A[1], Wallace C[1]
[1]*Rutgers University*

For many years, electric lamps have been used to supplement sunlight for the production of horticultural crops. The recent advancements in light-emitting diode (LED) technology and the surge in consumer adoption have also created significant interest and excitement among growers. LED lamps hold the promise of energy savings and allow for easier manipulation of the generated light spectrum. Many manufacturers and suppliers jumped at the opportunity to provide the horticultural industry with novel LED systems. However, growers have had a hard time comparing LED systems due to insufficient independent or verifiable research data regarding both lamp performance as well as their impact on plant growth and development. In an attempt to provide unbiased lamp performance data, we are proposing a simple product label that contains key operating specifications that growers can use to compare lamps available from different manufacturers and distributors. Our proposed label is specifically designed for an easy assessment of a particular light source used for horticultural applications. It lists information about efficacy, photon flux output in key wavebands, the normalized photon flux across the 300-900 nm waveband, and the photosynthetically active radiation distribution across a fixed measurement plane below the lamp.

Biography:

Dr. A.J. Both is an Extension Specialist in Controlled Environment Engineering at Rutgers University. Dr. Both's research includes engineering and crop production projects in growth chambers, greenhouses and high tunnels. His research interests include greenhouse environment control, hydroponic vegetable production, supplemental lighting, and energy systems.

Poster 3

Comparison of LED and HPS Supplemental Lighting for Seedling Production

Craver J[1], Lopez R[2]

[1]*Purdue University*, [2]*Michigan State University*

One common means of providing supplemental lighting (SL) for the production of ornamental seedlings (plugs) in the greenhouse is through the use of high-pressure sodium (HPS) lamps. However, high-intensity light-emitting diodes (LEDs) have recently emerged as a potential alternative. The objectives of this study were to 1) quantify the effect of SL source on seedling quality; and 2) evaluate the nutrient uptake of seedlings under different SL sources. Seeds of six annual bedding plant species were sown in 128-trays and placed under light treatments consisting of 1) 70 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of SL from HPS lamps; 2) 70 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of SL from LED toplights; or 3) no SL (ambient). Seedlings were evaluated for various quality attributes as well as macro- and micronutrient content. Overall, seedlings produced under HPS lamps or LED toplights were comparable in quality. However, seedlings produced under SL were of higher quality than those under no SL. Nutrient uptake was occasionally higher for plants grown under HPS lamps compared to LED toplights, but results varied based on species. While these results display little difference in seedling quality based on SL source, they confirm the benefits gained from the use of SL for seedling production.

Biography:
Joshua Craver is a graduate student at Purdue University working under the direction of Dr. Roberto Lopez. His research currently involves both supplemental and sole-source LED lighting applications within the field of floriculture.

Poster 4

LEDs and photoreceptors: Red and Blue Lights

Farokh Tehrani P[1]

[1]*Azad University, Science and Research Branch*

Plants, as sessile and photosynthetic organisms, have to adjust their growth and development in response to the environment. Light is recognized as the most prominent environmental factor modulating the process. We study the effects of red and blue lights on seed germination, anatomical and ultrastructural features, and the expression of CRY1 and HY5 genes in oilseed rape (*Brassica napus* L.). In the laboratory, the seeds germinate under various light emitting-diode (LED) treatments: white (control), red and blue light. Seed germination percentage increases significantly under red light. As exposure to blue light increases, the expressions of CRY1 and HY5 increase, but hypocotyle length is inhibited. In greenhouse experiment, potted plants are grown under blue and red lights. The shoot length, plant biomass, stem diameter, leaf area and thickness, SPAD number, and stomata frequency increase in blue light treatments. Palisade parenchyma cells are rectangular in the leaves of the same treatments. Chloroplasts have fewer starch under blue light and grana thylakoids decreases.

Biography:

Pegah Farokh Tehrani is a visitor at CSIRO Canberra. She finished her PhD at Azad University, Science and Research Centre in Tehran, Iran. Her research interests are photobiology, photosynthesis, cell, and development.

Poster 5

Vegetable transplants physiological responses under supplemental and sole-source LED lighting

Hernández R[1], Kubota C[2]

[1]North Carolina State University, [2]The University of Arizona

Vegetable transplants in North America are a high value crop. This research summarizes the physiological responses of cucumber, tomato, and pepper transplants to LED light quality under supplemental and/or sole-source lighting on three research phases: (1) Effect of different supplemental blue (B) and red (R) photon flux ratios under varied solar daily light integrals (DLI). (2) Comparison between supplemental B or R LED and HPS lighting. (3) Plant responses under a full range of B:R photon flux ratios in sole-source lighting. (1) For tomato and peppers there were no differences in growth and morphology between the different supplemental LED treatments regardless of solar DLI. For cucumber, the increase of B PF decreased leaf area and growth rate under low solar DLI. (2) Cucumber transplants under 100% B and HPS had 46% and 61% greater hypocotyl length than plants under 100% R, respectively. Pepper transplants under HPS had 160% greater leaf-curling than under 100% B. (3) Under sole-source lighting, cucumber seedlings decreased hypocotyl length, leaf area and dry mass with the increase of B PF. For tomatoes, dry mass and leaf area increased with the increase B PF up to the 50% and then decreased from 50% to 100%.

Biography:
Ricardo Hernández is an Assistant Professor at NC State University in the Department of Horticultural Sciences, his research areas are controlled environment and horticultural energy. Chieri Kubota is a Professor at The University of Arizona in the Controlled Environment Ag Center, her research focuses on plant physiology under controlled environment

Poster 6

PHYA and PHYB regulate adventitious rooting response to dark-light transitions

Kreiser M[1], Cohen J[1], Gardner G[1]

[1]*University of Minnesota*

Adventitious rooting can be induced without exogenous hormones in some species by transitioning plants from dark to light environments. We are investigating the role of light quality and plant photoreceptors in this process, employing Heliospectra L4A Series 10 LED lamps that allow for precise control of light quality, intensity, and photoperiod. Etiolated wild type *Arabdiopsis* seedlings exposed to red, white, or blue light for one week produced significantly more adventitious roots than seedlings that were kept in continuous darkness or exposed to far red light only. Phytochrome B (*phyB)* mutants produced significantly more adventitious roots than wild type in response to red or white light treatments, but also produced very few adventitious roots under dark conditions. Phytochrome A (*phyA)* mutants and *phyAphyB* double mutants produced significantly fewer roots than wild type under all light treatments tested. These results suggest that PHYA and PHYB regulate adventitious rooting in response to dark-light transitions, with PHYA being required for adventitious for adventitious root formation and PHYB functioning as an inhibitor. These findings have implications for better understanding and potentially improving adventitious rooting in horticulturally important species, which is often a bottleneck to propagation and production.

Biography:

Molly Kreiser is a graduate student at the University of Minnesota pursuing a PhD in Plant Biological Sciences. Her research focuses on the role of auxins in adventitious root formation and improving vegetative propagation of horticulturally important plants.

Poster 7

The Photosynthesis Action Radiation (PAR) Curve of Lettuce plants

Lefsrud M[1], Reddy S[1], Wu B[1]

[1]*Mcgill University*

Light emitting diodes (LEDs) in controlled environment food production is becoming more important as LED efficiency increases. Moreover, the environmental factors that directly impact photosynthesis including temperature, humidity, light, CO_2 concentration and nutrient source are controlled through the computer-based, automated control. The electricity expense of lighting systems, however, are still high since light is the driving factor limiting plant growth and yield. Current, horticultural lighting companies have been using the McCree curve as the focus of all LED lamps with wavelengths of blue (430 to 460 nm) and red (630 to 680 nm) spectrum and ratios of these two wavelengths to optimize plant production.
Our research group is investigating the photosynthetically active radiation (PAR) curve of lettuce plant using narrow spectrum filtered light emitting diodes (LEDs) under controlled conditions. These experiments are focusing on the plant response across the full PAR curve with light intensity of 30 μmol $m^{-2}s^{-1}$ with a bandwidth of 10 nm. Our results are showing that the spectrum photosynthetic responses are not always maximized with these two wavelengths alone and additional wavelengths below 630nm holds more potential to maximize horticultural plants under LED lighting.

Biography:

Dr. Lefsrud, an Associate Professor at McGill University leads the Biomass Production Laboratory. His B.Sc. and M.Sc. is in Agricultural and Bioresource Engineering and his Ph.D. is in Plant Physiology. His research program deals with the development of bioprocesses and improvements in plant growth environmental energy usage.

Poster 8

Effects of Daily Light Integral and Carbon Dioxide on Microgreens

Allred J[1], Mattson N[1]

[1]*Cornell University*

Microgreens are young, tender and edible crops harvested shortly after emergence of the first true leaf. CO_2 enrichment is often used in greenhouses to reduce the need for supplemental lighting, but little information is available on the response of microgreens to both light and CO_2. Our objective is to evaluate the effects of varying daily light integral (DLI) and CO_2 enrichment on the growth and nutritional characteristics of microgreens. Three species, mizuna (*Brassica rapa*), arugula (*Eruca sativa*) and mustard ‘Garnet Giant’ (*Brassica juncea*) received a combination of four DLI (3, 6, 9 & 12 moles/m^2/day) by four CO_2 (400, 600, 800 & 1000ppm) treatments in controlled environment chambers. Treatments were assessed for their effects on plant height, fresh weight (FW), dry weight (DW), total flavonoids and phenolics. For all three species, FW and DW significantly ($P \leq 0.001$) increased as a function of increasing DLI and CO_2 with greatest FW and DW at 12 moles/day and 1000ppm CO_2 respectively. A statistically significant interaction exists between DLI and CO_2 where the benefit of CO_2 decreases as DLI increases. For mustard ‘Garnet Giant’, average fresh weight under 6 moles/m^2/day at 1000ppm CO_2 was equal to average fresh weight under 12 moles/m^2/day at 400ppm CO_2.

Biography:

Jonathan Allred is an M.S. student in Horticulture Biology with a focus in Biological and Environmental Engineering and Economics at Cornell University in Ithaca, New York. Jonathan got his B.S. in Plant Science at Cal Poly Pomona in Pomona, California in 2013. He wishes to pursue his PhD in CEA.

Poster 9

Carbohydrate partitioning and berry ripening in grapevines under decreased CO2 conditions

Miss Zelmari Coetzee[1,2], Dr Rob Walker[1,3], Prof Alain Deloire[1,2], Dr Simon Clarke[1,2], Dr Suzy Rogiers[1,4]

[1] The ARC Training Centre for Innovative Wine Production, [2] National Wine and Grape Industry Centre, [3] CSIRO Agriculture, [4] NSW Department of Primary Industries

To assess if the loading of sugar and potassium into grape berries are dependent on each other, an experiment was conducted in environmentally controlled chambers to reduce berry sugar import by lowering the atmospheric CO_2. In addition, the potassium import was manipulated through two levels of soil fertilisation. The berry pericarp was analysed to determine the concentration of these two metabolites in relation to each other within the grape berry.

The carbon assimilation rate was decreased ~35% by reducing the atmospheric carbon concentration by ~30%. Despite this decrease, the berry sugar concentration on a dry mass basis did not differ between the atmospheric treatments. The berry potassium concentration was, however, higher in the reduced atmospheric CO_2 treatments and coincided with a decrease in the root starch and potassium concentrations, specifically when the K^+ fertilisation was increased. These findings indicate that sugar and K accumulation into the berry are not necessarily correlated and that there is flexibility in the accumulation of metabolites when growing conditions are modified. These findings also point to the possibility of the relocation of carbohydrates from storage reserves to the grape berries under reduced photosynthetic conditions and increased potassium fertilisation.

Poster 10

Natural ventilation augmented cooling (NVAC) greenhouse: design and field trials.

Lefsrud M[1], McCartney L[1]

[1]*Mcgill University*

Traditional greenhouse designs use exhaust fan, row misting and fan and pad ventilation systems to decrease inside air temperature and provide fresh air to the crop. However, these temperate greenhouse designs are unable to maintain proper environmental conditions in tropical locations. Traditional tropical greenhouse designs rely solely on natural ventilation and convection which makes them suitable for only the most heat-tolerant crops. A potential solution is a natural ventilation augmented cooling (NVAC) greenhouse. A NVAC greenhouse is an open roof design, improved by coupling natural ventilation with an unconventional misting system. The misting system is located in the rafters of the greenhouse sprays a mist of water into the rising warm air. The newly cooled air flows down onto an added inside roof and collapses into the lower space of the greenhouse. This effect cools the air and enhances air movement in the greenhouse without using fans. Prototypes of the design have been built in Quebec and Barbados. When the misting system is operating, air movement within the greenhouse is increased to ~1 m/s at plant level, relative humidity is similar to outside conditions and the temperature inside the greenhouse is between ~2 C below outdoor conditions.

Biography:

Dr. Lefsrud, an Associate Professor at McGill University leads the Biomass Production Laboratory. His B.Sc. and M.Sc. is in Agricultural and Bioresource Engineering and his Ph.D. is in Plant Physiology. His research program deals with the development of bioprocesses and improvements in plant growth environmental energy usage.

Poster 11

Application of High Throughput Plant Phenotyping in Natural Resources Management

Mazis A[1], Hiller J[1], Morgan P[2], Stoerger V[3], Awada T[1,4]

[1]School of Natural Resources, University of Nebraska-Lincoln, [2]Environmental Division, LICOR Biosciences, [3]Department of Agronomy and Horticulture, University of Nebraska-Lincoln, [4]Agricultural Research Division, University of Nebraska-Lincoln

High throughput plant phenotyping is increasingly being used to assess morphological and biophysical traits of economically important crops in agriculture, under controlled environment or in the field. In this study, we assess the potential application of this technique in natural resources management, namely the characterization of woody plants regeneration, establishment and growth, under water stress and nutrient manipulations. This is important in our efforts to better understand the impacts of climate variability and change on forest ecosystems.

Three woody species were selected for this study, *Quercus prinoides*, *Quercus bicolor* and *Betula papyrifera*. Seeds from these species were collected from trees growing at the edge of their natural distribution in Nebraska, Missouri and Iowa, USA. Seeds were germinated in the greenhouse and were transferred to the Lemnatec^{3D} High Throughput platform facility at the University of Nebraska-Lincoln. Seedlings subjected to water and nutrient manipulations are being imaged twice or three times a week using four cameras (RGB, Fluorescence, IR and Hyperspectral), throughout the growing season. Traditional leaf to plant levels ecophysiological measurements are being concurrently acquired to assess the relationship between these two techniques. These include gas exchange (LI 6400 and LI 6800, LICOR Inc., Lincoln NE), chlorophyll content, optical characteristics (Ocean Optics USB200+), water and osmotic potentials, leaf area and weight, plant nutrients and carbon isotope ratio.

In the poster, we will present results on the potential application of high throughput phenotyping techniques for the three species, characterized with different growth habits and plant architecture, their responses to water and nutrient manipulations, and the relationship between imaging and traditional ecophysiological techniques.

Biography:

Anastasios Mazis works as Graduate Assistant in University of Nebraska-Lincoln. In 2015 he graduated with B.Sc. from Aristotle University of Thessaloniki, Greece, Department of Agriculture. Since 2016, he is pursuing his M.Sc. in University of Nebraska-Lincoln in the area of Applied Ecology under the guidance of Dr. Tala Awada. His study revolves around plant phenomics, ecophysiology, plant adaptation and forest ecology

Poster 12

Automated phenotyping for abiotic stress tolerance in lentil

Javid M[1], Joshi S[1], Slater T[2], Kant S[1]

[1]Agriculture Victoria, Grains Innovation Park, 110 Natimuk Road, Horsham, Vic 3400, [2]Agriculture Victoria, AgriBio, Centre for AgriBioscience, 5 Ring Rd, Bundoora, Vic 3083

Lentil yield in low rainfall areas is limited due to several abiotic stresses. High-throughput phenotyping protocols would speed-up breeding lentil varieties tolerant to abiotic stresses. Three individual phenotyping assays for water stress, boron toxicity and salt stress were developed at Plant Phenomics Victoria's high-throughput plant phenotyping facility located at Horsham. Three different lentil genotypes were used for each assay, with three watering regimes, four boron levels, and four salt (NaCl) levels. Plants were imaged, a top view and three side views (0, 120 and 240 °), three times per week. Destructive harvesting was conducted during vegetative growth, with high correlations recorded between projected area from visible images and manually harvested fresh and dry biomass. Significant varietal responses were observed for each abiotic stress treatment. For water stress, PBA Ace showed higher projected area compared to PBA Jumbo2 and Northfield. While for boron stress, ILL2024 had higher projected area than PBA Flash and PBA Blitz. While CIPAL1504 showed higher projected area than ILL2024 and Nugget in the salinity treatment. The phenotyping protocols established are efficient at identifying genotypes tolerant to abiotic stresses and will be useful to accelerate crop breeding efforts in the improvement of lentil.

Biography:

Surya Kant is senior research scientist at Agriculture Victoria. Surya has worked as research associate at University of Guelph, Canada (2006-2011) and two post-doctorates, Ben Gurion University, Israel (2002- 2006) and Faculty of Agricultural, Israel (2000- 2002). Surya graduated from the Haryana Agricultural University, India. Published over 30 research articles.

Poster 13

Adding value to germplasm collections through advanced phenotyping technologies.

Norton S[1], Murray K[1], Slater T[2], **Kant S[1]**, Mason J[2], Spangenberg G[2]

[1]Agriculture Victoria, [2]Agriculture Victoria

Genebanks are tasked with the preservation of the wide diversity of agricultural species that cover cultivated, landrace, progenitor and wild relative genepools. Researchers and plant breeders evaluate and use these valuable genetic resources to develop more productive varieties that have greater adaptability under the current and changing conditions expected in the future. Traditionally, many genebanks phenotype material in the field whilst they are being grown for seed production, manually recording a limited range of plant architecture related characteristics, and responses to any biotic/abiotic stress parameters if they occur. The challenge for genebanks is to make use of new and emerging genotyping and phenotyping platforms to better characterise their collections, which will enable plant breeders to more effectively pinpoint material to develop new varieties. The Australian Grains Genebank is currently investigating field based, and controlled environment high throughput phenotyping systems to screen germplasm for a range of biotic and abiotic agricultural traits of interest to the next users of material. With the advent of new high resolution, high throughput phenotyping technologies, genebanks can more accurately measure plant architecture, development and function, non-destructively, on more material, more efficiently, leading to improved information for breeding outcomes.

Biography:

Surya Kant is senior research scientist at Agriculture Victoria. Surya has worked as research associate at University of Guelph, Canada (2006-2011) and two post-doctorates, Ben Gurion University, Israel (2002- 2006) and Faculty of Agricultural, Israel (2000- 2002). Surya graduated from the Haryana Agricultural University, India. Published over 30 research articles.

Poster 14

Adaptive Data Processing for More Reliable Plant Water Usage Information

Ling P[1], Boucherle H[2]

[1]The Ohio State University, [2]The Ohio State University

Inexpensive, reliable ways to measure plant water use on short temporal scales are desirable for a better understanding of plant water use efficiency. Apart from acquiring better instrumentation, often at higher costs, new data mining methods may be a way to extract more reliable data from a low cost system. In this study, different time-averaging methods were applied to the data from a custom built weighing lysimeter system to determine the maximum amount of reliable water use information that could be determined. The relationship between data reliability and temporal resolution were examined based on error analyses, and an adaptive data averaging algorithm was proposed to optimize the temporal resolution and number of reliable data points obtained from the data set. The results were evaluated against the data collected using a precision laboratory balance in two separate month-long tests. The adaptive data averaging method increased the amount of reliable data points by 20 to 34 percent, while keeping error at a significantly reduced level. This paper aims to increase the obtainable information from a typical low-cost weight measurement system with a larger random noise level.

Biography:

Dr. Peter Ling is a horticultural engineer specializes in sensing and control for controlled environment plant production. Dr. Ling is an Associate Professor of Department of Food, Agricultural and Biological Engineering, The Ohio State University, and an Extension Specialist of the State of Ohio, USA

Poster 15

Yield assessment of perennial ryegrass using aerial NDVI measurements

Pieter E. Badenhorst[1], Andrew Phelan[1], Luke Pembleton[2], German Spangenberg[2]
[1]Biosciences Research, DEDJTR, Hamilton, [2]Biosciences Research, DEDJTR, Bundoora.

Current assessment of non-destructive yield in forage breeding programs rely largely on the visual assessment by experts, who would categorize biomass to a discrete scale. This method has inherent pitfalls as it can generate bias between experimental repeats and between different experts. The method is also time-consuming and would be impractical on large scale field trials. A method has been established to allow for a rapid, non-destructive assessment of biomass yield of forages using aerial based normalised difference vegetation index (NDVI) imaging technologies. This method uses aerial surveillance platforms, including the PhenoBlimp (tethered stationary aerial device, delivering measurements from variable elevated positions) and PhenoCopter (radio-controlled mobile aerial device, delivering measurements from variable elevated positions) that deploy a modified GoPro Hero 4 camera with an IRPro NDVI-7 lens. NDVI measurements can be extracted at 1cm resolution using Pix4D, allowing for the quantitative NDVI measurement of single plants. NDVI data can then be calculated and processed for single plants, rows or plots based on user defined georeferenced areas in QGIS software.

Biography:

Pieter Badenhorst has a Bachelors Degree in Science (AnimalBiotechnology), Honors Degree in Science (Genetics), Masters Degree in Science (Molecular Genetics) and Doctor of Philosophy degree in Molecular Plant Breeding. He is currently leading the Biosciences Research team in Hamilton, Victoria, focusing on forage breeding and advanced phenomics.

Poster 16

Field phenotyping of diverse wheat varieties for nitrogen use efficiency

Nguyen G[1], Panozzo J[1], Spangenberg G[2], Kant S[1]

[1]Agriculture Victoria, Grains Innovation Park, 110 Natimuk Road, Horsham, Vic 3400, [2]Agriculture Victoria, AgriBio, Centre for AgriBioscience, 5 Ring Rd, Bundoora, Vic 3083

Developing robust phenotyping approaches to evaluate the nitrogen (N) status in plants will help in breeding crop varieties with improved nitrogen use efficiency (NUE), as well as reduce environmental pollution and N input cost. A split-plot field experiment was conducted, with 15 diverse wheat varieties and three N treatments; 0, 80 and 160 kg N ha^{-1}. Two optical instruments, Crop Circle and SPAD chlorophyll meter were used to determine normalised difference vegetation index (NDVI) from crop canopy and chlorophyll content from single leaves. The sensors in both instruments capture spectral reflectance from leaves at visible and near infrared wavelengths, which is associated with canopy greenness and N status in plants. Vegetative and grain N were estimated by near infrared reflectance spectroscopy. The data indicated that there was a significant interaction between N treatments and varieties, where application of 80 kg N showed the highest NUE index. Significant positive correlations were observed in all wheat varieties for NDVI and chlorophyll content, shoot N content, grain N, shoot biomass and grain yield. The research shows the applicability of utilising sensor based techniques to study NUE improvement in wheat under field conditions.

Biography:

Surya Kant is senior research scientist at Agriculture Victoria. Surya has worked as research associate at University of Guelph, Canada (2006-2011) and two post-doctorates, Ben Gurion University, Israel (2002- 2006) and Faculty of Agricultural, Israel (2000- 2002). Surya graduated from the Haryana Agricultural University, India. Published over 30 research articles.

Poster 17

Phenotyping wheat with delayed leaf senescence and enhanced fructan content

Joshi S[1], Choukimath A[1], Chen T[2], Panozzo J[1], Mason J[2], Spangenberg G[2], Kant S[1]

[1]Agriculture Victoria, Grains Innovation Park, 110 Natimuk Road, Horsham, Vic 3400, [2]Agriculture Victoria, AgriBio, Centre for AgriBioscience, 5 Ring Rd, Bundoora, Vic 3083

Cytokinins are known to delay leaf senescence and higher fructan levels improve biomass accumulation. Transgenic wheat plants were produced for expression of a chimeric *Isopentenyltransferase* (*IPT*) gene, which encodes a key enzyme in cytokinin biosynthesis, and chimeric *Sucrose 1-fructosyltransferase* (*1-SST*) and *Fructan 6-fructosyltransferase* (*6-SFT*) genes encoding enzymes involved in fructan biosynthesis in wheat. Two different promoters *AtMYB32* and *TaRbcS* from *Arabidopsis thaliana* and wheat, respectively, were used to drive transgene expression. Four gene cassettes; *AtMYB32::IPT*, *TaRbcS::1-SST*, *TaRbcS::1-SST:6-SFT* and *AtMYB32::IPT-TaRbcS::1-SST* were transformed in wheat via *Agrobacterium*-mediated transformation. Phenotypic screening of transgenic and non-transgenic sib-null wheat lines was conducted with well-watered and water stress treatments under controlled environmental conditions. Phenotypic and physiological observations recorded included chlorophyll level, phenology, leaf senescence and seed yield. Selected transgenic and sib-null wheat lines were tested under field conditions with irrigated, rainfed and rain limited (rainout shelter) treatments, at Horsham during 2014 and 2015. Transgenic lines had similar phenology to sib-nulls and no significant differences were observed for grain quality traits. Some transgenic lines showed better performance than their respective sib-nulls such as improved crop canopy biomass, chlorophyll index, shoot biomass, tiller number, 1000-grain weight and grain yield, delayed leaf senescence and lower canopy temperature.

Biography:

Surya Kant is senior research scientist at Agriculture Victoria. Surya has worked as research associate at University of Guelph, Canada (2006-2011) and two post-doctorates, Ben Gurion University, Israel (2002-2006) and Faculty of Agricultural, Israel (2000- 2002). Surya graduated from the Haryana Agricultural University, India. Published over 30 research articles

Poster 18

An automated high-throughput phenotyping platform at Plant Phenomics Victoria, Horsham

Kant S[1], Joshi S[1], Nguyen G, Slater T[2], Mason J[2], Spangenberg G[2]

[1]Agriculture Victoria, Grains Innovation Park, 110 Natimuk Road, Horsham, Vic 3400, [2]Agriculture Victoria, AgriBio, Centre for AgriBioscience, 5 Ring Rd, Bundoora, Vic 3083

Recent advances in high-throughput phenotyping systems and non-destructive imaging technologies provide opportunities for the automated and simultaneous analysis of plant growth, vigour, morphology and physiology during 'whole of lifecycle'. Agriculture Victoria has established Plant Phenomics Victoria (PPV), Horsham, which is a controlled environment facility to speed-up improvements of different crop species, including cereals, pulses, oilseeds and forages. This facility consists of a state-of-the-art glasshouse and Scanalyzer 3D imaging system with visible and hyperspectral imaging, automated watering and weighing, and a conveyor system with 600 plant carriers. Visible imaging allows digital colour images from top and side views at any angle from 0-360°. Significantly high correlations were observed between projected area from visible images and manually harvested fresh and dry biomass in wheat, lentil, chickpea and fieldpea. Hyperspectral imaging in the wavelengths of 550-1,700 nm, enables the evaluation of several growth indices and the estimation of biochemical composition and photosynthetic machinery of the plant. Different growth indices correlated well with fresh and dry biomass, leaf area and chlorophyll content. The estimation of anthocyanin, protein, starch, sugar and other biomolecules is being undertaken. Various agronomic traits tested in the PPV facility includes nitrogen use efficiency, and drought, boron and salinity tolerance.

Biography:

Surya Kant is senior research scientist at Agriculture Victoria. Surya has worked as research associate at University of Guelph, Canada (2006-2011) and two post-doctorates, Ben Gurion University, Israel (2002- 2006) and Faculty of Agricultural, Israel (2000- 2002). Surya graduated from the Haryana Agricultural University, India. Published over 30 research articles.

Poster 19

Image-based Automated Vegetative-Stage Dynamic Phenotyping Analysis of Maize Plants

Das Choudhury S[1]

[1]*University of Nebraska-Lincoln*

We introduce our benchmark dataset called Panicoid Phenomap-1, which comprises images of 40 genotypes of panicoid grain crops captured by visible light camera once daily for 26 days using Lemnatec Scanalyzer high-throughout plant phenotyping facility at the University of Nebraska-Lincoln, USA, to facilitate vegetative-stage temporal phenotyping analysis. Image-based Phenotyping analysis is classified as: holistic and component-based. Holistic analysis considers the whole plant as a single object, whereas, component based analysis measures the attributes of plant parts, e.g., leaf-count, stem-height and leaf-curvature. Two newly introduced holistic phenotypes are bi-angular convex-hull ratio and plant aspect ratio. Bi-angular convex-hull ratio is the ratio of the area of convex-hull of the plant at sideview 0° and the area of convex-hull at sideview 90°. Plant aspect ratio is measured as the ratio of height of the bounding rectangle of a plant at the sideview and the diameter of the minimum enclosing bounding circle at the topview. Bi-angular convex-hull ratio provides information about phyllotaxy, i.e., the arrangement of leaves on stem, while plant aspect ratio enables to characterize plants by its nature of canopy architecture due to genetic variation. Experiments are performed on Panicoid Phenomap-1 dataset to demonstrate the significance of these phenotypes on maize plants.

Biography:

Sruti Das Choudhury received PhD in Computer Science from the University of Warwick, UK, in 2013, and M.Tech in Computer Science and Application from the University of Calcutta, India, in 2009. Presently, she is working as a postdoctoral research associate on plant phenotyping analysis at the University of Nebraska-Lincoln, USA.

Poster 20

Multi-spectral, three dimensional high throughput phenotyping system (MS3D-HTPS)

Lozano-Claros D[1], Whelan J[1], Deng D[1], Elton D[1], Trtilek M[2], Jenkins M[1], Custovic E[1]
[1]La Trobe University, [2]Photon Systems Instruments

The MS3D-HTPS is a compact low cost system designed to develop a comprehensive, multi-dimensional phenotypical model. It allows for specific hypothesis related to genotypic and/or environmental effects to be tested. The system integrates several imaging techniques that allow for the dissection and measurement of individual parameters of plants, namely, morphology and growth dynamic.
The hardware consists of a 1 x 3.5 m size rack system with an adjustable height tray to accommodate different size plants. The ceiling within the system houses ten panels each containing arrays of LEDs to cover a broad range of wavelengths, and a single downward facing RGB camera. Additional to this ceiling structure is an array of ten cameras, five on each side of the system. The total light intensity can be set as high as approximately 2000 $\mu mol\ m^{-2}\ s^{-1}$ allowing for intense daylight conditions to be emulated.
The user interface is designed for ease of use and allows researchers to emulate different seasonal and diurnal conditions. Through the use of advanced image and mesh processing algorithms vital information pertaining to plant traits can be extracted. The mesh for analysis is generated using commercially available software (Pix4Dmapper) and the images generated by the RGB cameras within the system. This information is cross correlated with growth chamber temperature and humidity data.

Biography:

Diego Lozano-Claros is a PhD candidate at La Trobe University, Melbourne. He is investigating and developing an automatic phenotyping system by using several image processing techniques and machine learning technology. He is an Electronic Engineer from Surcolombiana University and obtained a master of telecommunication and networking at La Trobe University.

Poster 21

Quantitative evaluation of respacing in lettuce production under electric lighting

Kubota C[1]

[1]*The University Of Arizona*

Respacing seedlings is a common practice to enhance leafy crop productivity in controlled environment. In this study, using available lettuce growth and morphology data under electric lighting, various scenarios of respacing were theoretically evaluated and compared with other light-energy saving strategies such as improving lamp photon efficiency or targeted lighting. Respacing effectively reduced electricity consumption, especially when respacing was conducted twice. In contrast, increase in labor cost with respacing was small (<1 cent per plant per respacing), compared with the large saving in electricity (>50% saved with two respacings). Electricity and total production costs (not including capital investment) were the lowest with targeted lighting: \$0.65-\$1.15 kg^{-1} and \$6.75-7.27 kg^{-1} (fresh weight basis) in this study, respectively. When targeted lighting was employed, the sensitivity of production costs to lamp photon efficiency was lesser than that in the reference case without employing any energy saving strategies. However, respacing also significantly increased the potential annual yield of a given size of production area. For example, annual lettuce yield was increased by 2.32 times by respacing twice over a production cycle in the present analysis. Depending on the production priority and market price, appropriate strategies need to be selected to maximize the profit.

Biography:

Dr. Chieri Kubota is a professor in the School of Plant Sciences and Controlled Environment Agriculture Center (CEAC) at the University of Arizona. Her research program focuses on the development of science-based technology in the area of controlled environment agriculture (CEA) including greenhouse and indoor facilities.

Poster 22

Computational and experimental studies for improved climate uniformity in greenhouses and vertical farm systems

Kacira M[1], Zhang Y[1]

[1] The University of Arizona

Controlled environments have played important role in field of agriculture, allowing the grower to have more control on the climate conditions surrounding the crops. Failure to maintain suitable consistent conditions leads to decline in both quality and quantity of plants and the uniformity of production. Proper climate control strategies are needed to keep these factors uniform in the greenhouse within acceptable ranges to guarantee high quality and yield. Interactions of environmental variables both in greenhouse and vertical farm systems are complex involving a number of physical and chemical properties of matter that are challenging to model realistically. Our research focus on developing methods of understanding these complex phenomena within controlled environments. We have developed and validated 3D Computational Fluid Dynamics (CFD) models to study the aerodynamics of greenhouse and indoor plant production systems to improve climate uniformity which can offer design recommendations for system manufacturers, growers, system operators. This poster presentation briefly introduces CFD modeling approach, discusses steps in pursuit of good practice in CFD model development and application, and then discusses research results with examples of evaluating design features on climate uniformity (i.e. based on air temp., RH, VPD, and air velocity and flow patterns) within a naturally vented high pressure fogging system integrated greenhouse, a bioregenerative life support system based greenhouse prototype, and an indoor vertical farm based crop production system.

Poster 23

It's a gas – planned changes to refrigerant legislation and how it may affect CEs

Stephen Andrews[1]

[1]Sainsbury Laboratory, University of Cambridge, United Kingdom

The European Union 2014 F Gas Regulations came into force on 1st January 2015. The previous version of the regulations contained requirements based on the size of the refrigerant charge, the 2014 regulations take more account of the Global Warming Potential (GWP) of the refrigerant and the requirements are now based on the GWP CO_2 equivalent Tonnes. In addition the 2014 regulations also place restrictions on the use of some refrigerants based on their GWP. From 2018 there will be a significant phase down in the amount of HFCs placed on the market, including from 2020 the banning of some high GWP refrigerants in new equipment. It is unclear at the moment what effect the significant reduction in the amount of GWP CO2 equivalent Tonnes allowed to be traded will have on the availability of refrigerants with a GWP of 2500 or more over the coming years. Some CEs are currently being sold which utilise these refrigerants, should potential purchasers still consider buying them? What are the alternatives? How will existing equipment using high GWP refrigerants be supported? Who has the answers to these and other questions?

Poster 24

Can the use of Valoya G2 Far Red LED supplementary lights reduce vernalisation time for Winter Wheat Cereal plants from 8 weeks to 4?

Barry Robertson[1]

[1]John Innes Centre Norwich Norfolk United Kingdom.

This experiment came out of a conversation between myself, Matthew Gilroy of Conviron UK and Lars Aikala CEO Valoya LED lighting systems.
We discussed the effects light wave length on vernalisation of Winter Wheat, Lars suggested the use of Far Red light would have an effect. Valoys G2 units were used as they contain Far Red in their design.
The experiment used an Adaptis A1 1000 reach in CER and Valoya G2 LED light unit. In junction with Serya Ghosh a PHD research student at JIC alongside JIC project leaders developed a Fast Breeding experimental programme designed and inspired by Dr Lee Hickey Research Fellow (Winter Cereals per breeder) at The University of Queensland designed the programme.
The experiment compared four areas. The standard JIC vernalisation CER with the Conviron/Valoya vernalised plants. Glasshouse growing compared with CER fast breeding environment.
Fast Breeding environmental conditions resulted in no difference in tillering times or number of heads produced whether the plants came from the JIC conventional vernalisation CER or the FR lit CER.
JIC standard Glasshouse conditions the plants did benefit from the exposure to Valoys Far Red G2 LED lights but the results were mixed due to external environmental conditions.
Further study is needed to see why Valoys G2 LEDs in vernalising Winter Wheats showed an effect in glasshouses but not in the fast breeding programme.