# TROPAG

INTERNATIONAL TROPICAL AGRICULTURE CONFERENCE

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BRISBANE CONVENTION & EXHIBITION CENTRE

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# Oral Abstracts

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## 100

## Why animal-source foods need to be part of the global food security and nutrition agenda

**Dr Lawrence Haddad**

*Global Alliance for Improved Nutrition (GAIN), Switzerland*

A number of recent reports on diets and food systems have generated a great deal of divisive debate about the role of animal source foods in the human diet. The media have latched on to these debates and have, in some cases, accentuated the divides. This presentation will emphasise not division, but inequality. It is the inequality in what people eat that needs to be addressed. Many people eat far too much animal sourced food: too much for their health and too much for the planet's environmental health. But many also eat too little animal sourced food—these foods are rich sources of micronutrients that are essential for young infant and child growth and are not available in other affordable foods for these populations who tend to be low income. So a nuanced approach to animal sourced foods is needed. Those who eat too much for their good health and who put necessary stress on the planet's environmental resources should eat less and those who are undernourished with very monotonous diets would benefit from eating more. This presentation explores this contested terrain and aims to improve clarity in the policy space surrounding animal source foods.

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## 101

## Small holder farmers and science of tomorrow

**Dr Usha Barwale Zehr**

*Mahyco, Dawalwadi Jalna, India*

Small Holder farmers in India have benefited from the scientific advances be it the high yielding varieties of Green revolution or the most recent revolution with the use of Bt cotton leading to livelihood improvement. The small holder farmers in India will continue to feed the nation and more under several environmental constraints which require rededicated effort in agricultural sciences. Application of new science to agriculture is critical be it New Breeding Technologies, greater focus on soil health, water use efficiency and more. Farmers are also constrained by what they have access to, where their inputs come from and where they will go to market their harvest. Indian farmers are using mobile phones in large numbers, from basic to smart phones and with relatively cheap access to data, are using these devices to share information. Digital platforms which provide information on weather, soil health, carbon status, predict yield, financial transactions or market opportunities in addition to the genetic improvements are being delivered to farmers in local languages and impacting their decision making and improving lives. Policies around new innovation must be clear to deliver the benefits of these advances to the farmers. These innovations are shaping the future of science for small holder farmers and may even entice the youth to continue to farm.

## 102

### Transformational adaptation in agriculture under climate change

**Prof Mark Howden**

*Australian National University, Canberra, Australia*

The accelerating pace of climate change is becoming more evident year by year. Many of the first and most severe impacts are on tropical agriculture with evidence of falling crop yields, decreases in livestock productivity and increased climatic disruptions affecting both on-farm operations and value chains. Most of the impacts are unfortunately negative. This is already affecting farmers and farming communities via economic, institutional, social and psychological stresses and is likely impacting on sustainable natural resource management. Unfortunately, increasingly negative changes appear to be likely, with projections of widespread and substantial negative future impacts of climate change on tropical agriculture. There are many potential adaptations to climate change, covering options ranging from incremental to transformational change each with different risk vs return profiles. There is an increasing focus on transformational change as a result of acknowledgement of the scale of potential future changes. Agriculture has undergone many transformational adaptation processes in the past in response to technological, institutional, social and sometimes climatic factors. This presentation will summarise what we might (or might not) have learnt from these past changes, many of which (in glorious hindsight) have not been well designed or implemented. It will then posit some pathways forward for transformational climate adaptation.

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## 103

### Transforming agricultural biosecurity

**Assoc Prof Grant Hamilton**

*School of Earth, Environmental and Biological Sciences, Queensland University of Technology, Brisbane, Australia*

Issues such as ending hunger, and protecting and promoting sustainable use of ecosystems form the core of the Sustainable Development Goals. These issues are directly impacted directly by our biosecurity systems. There is an urgent need to transform these systems, and we now have the tools to do this. The use of improved remote sensing capabilities, new platforms to carry these sensors, advanced analytics such as Machine Learning, and visualisation, all provide us with the opportunity to detect problems early and target responses more quickly and more efficiently. Part of the solution is to translate the advances from other fields into biosecurity. There is a need now to move beyond traditional practices, and to work with partners to develop these tools and methodologies to transform biosecurity to ensure the sustainability of agricultural industries and the environment.

## 104

## Agricultural systems research: A transformative approach to sustainable intensification

**Prof Daniel Rodriguez**

*The University of Queensland - QAAFI, St Lucia, Australia*

The recent increase in the number of undernourished and the rise of the conflict-food insecurity-migration nexus (da Silva and Shenggen, 2017), issues a clear warning signal that achieving the UN Sustainable Development Goals (SDGs) by 2030 will require significant transformations of our agricultural systems, and a new focus on research for- and in-transformational approaches. Even though significant incremental gains in food production have been made over the last 20 years, protracted conflicts (da Silva and Shenggen, 2017), structural constraints, limited availability of resources, and expected increases in food demand (Frelat et al., 2016; Rodriguez et al., 2017), are shedding doubts on our capacity to meet the SDG targets using business as usual approaches. Here is proposed that these are complex problems within our food – social – political systems, requiring transformational approaches, that address multiple interlinked constraints (Garnett et al., 2013) to produce non-marginal gains in our food systems; and that agriculture has a significant role to play to address some of the underlying causes (Petersen and Snapp, 2015).

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## 105

## Transforming landscapes through irrigation

**Dr Matthew Harrison**[1], Professor Holger Meinke[1,4], Mr Melle Nikkels[1,2,3], Dr Saideepa Kumar[1] and Dr Sahar Shahpari[1]

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Globally, irrigated agriculture comprises some 20% of cultivated land and accounts for 40% of all global food production[1]. Water provision through irrigation can increase crop biomass production, provide drought resilience, attract price premiums for niche crops, and can allow for growing multiple crops within the same year. At the landscape scale, installation and effective utilisation of irrigation infrastructure and water is conducive to transformational changes in agricultural productivity. The Green Revolution in Asia relayed on irrigation to reduce the continent's levels of undernourishment from 24% in 1991 to 14% in 2012[2]. Nonetheless despite perceived potential for large-scale agricultural intensification, contemporary irrigation schemes no longer command the unequivocal support they once did. Public policy debates now concern trade-offs between the economic potential of irrigation and prevention of adverse environmental and societal impacts[3]. Indeed, peer-reviewed literature increasingly recognises water systems as both natural and social, being shaped by the coupled dynamics of human-water interactions. There have been also repeated calls for forward-looking, adaptive decision frameworks to help deal with future uncertainties[4]. This, invariably, combined with contested goals for the future we aspire to, lends significant ambiguity to water infrastructure planning[3]. Here, we examine how irrigation systems can be designed and managed at the landscape scale to be adaptive to futures that are shaped largely by unforeseeable human-water interactions. We explore how coupled human-water interactions and dynamic adaptive pathways can be used holistically to facilitate decisions on the design and management of irrigation infrastructure.

[1]World Water Assessment Programme (UNESCO WWAP) 2019. Available: http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/facts-and-figures/all-facts-wwdr3/fact-24-irrigated-land/ [Accessed 17 October 2019]

[2] Pingali, Prabhu (2012) Green Revolution: Impacts, limits and the path ahead. *Proceedings of the National Academy of Sciences of the United States of America.* 31: 12302-12308.

[3] Nikkels, Melle; Kumar, Saideepa and Meinke, Holger (2019). Adaptive irrigation infrastructure – linking insights from human-water interactions and adaptive pathways. *Current Opinion in Environmental Sustainability* 40: 37-42.

[4] Walker WE, Haasnoot M, Kwakkel JH (2013) Adapt or perish: a review of planning approaches for adaptation under deep uncertainty. *Sustainability* 2013, 5:955.

## 106

## Food systems failure: Can we avert future crises?

Dr Kiah Smith[1]

[1]*School of Social Science, Brisbane, Australia*

Can 'sustainable intensification' provide a foundation from which to address structural inequalities in the global food system? This presentation argues that understanding systemic failures and structural inequalities of the current global food system must preclude any analysis of the potential, success or failure of 'sustainable intensification' approaches. Using the food crisis of 2008 as a reference point, I discuss the multiple social, environmental and political failures of industrial agriculture, neoliberal economic and trade policy regimes, and a host of new (and not-so-new) global structural conditions. Instead of 'feeding the world' as promised, producing more food through Green Revolution technologies and Green Growth policies has not solved the problems of inequitable access, rising costs, over-reliance on fossil fuels, poor labour conditions, insufficient nutrition, and distorted trade relations. Instead, food insecurity, hunger and malnutrition have increased; rural poverty persists; livelihood options for the rural poor have decreased; and environmental degradation linked to unsustainable food production and consumption practices shows few signs of slowing. These problems are exacerbated in the context of decreasing agricultural productivity and the uneven distribution of climate change impacts. In light of continued emphasis on increasing food production (itself a contested assessment of the food security dilemma), a critical framework is presented here that centres questions about who benefits and who is disadvantaged. The capacity for 'sustainable intensification' to reorient the global food system towards justice and food security for people and ecological systems needs to be more central in debates about its transformative potential.

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## 107

## Farming systems analysis for problem-solving in the R4D context

Dr Sarina Macfadyen

*Australian Centre for International Agricultural Research, Australia*

There is a long history of farming system research in "research for development" projects that have helped to address a range of agricultural production issues. Farming systems analysis recognizes that any farm can be considered a linked set of natural, social, and designed elements that are intensively managed by humans. A farming business also sits within a household and broader community that can provide opportunities and constraints for agricultural production. Understanding the interactions between these different components are needed to quantify the costs and benefits of potential changes in practice at the whole-farm level. A farming systems analysis (FSA) approach can also be used to inform more transformative changes to farming systems that may be required in the future. I have conducted a stocktake of recent projects supported by the Australian Centre for International Agriculture Research (ACIAR) that have involved farming systems research in some form. There is potential for future projects to use FSA to address issues of sustainability in farming systems that are seeking to intensify or diversify production, and for informing strategies for scaling of agricultural innovations that are appropriate and equitable for smallholder farmers. I will present some ideas about how FSA could be used in future projects to address ACIAR objectives.

## 108

### In vitro approaches for papaya crop improvement

**Dr Puthiyaparambil Josekutty**, Mark MacLaughlin, Candy MacLaughlin, Marion MacLaughlin, Ian MacLaughlin

*Skybury Coffee Pty Ltd*

*Carica Papaya* L., commonly known as 'papaya' or 'pawpaw' is a tropical fruit that is tasty and highly nutritious. Papaya also claims several medicinal and industrial uses. Papaya cultivation in Australia is mostly confined to the tropical regions of Queensland, Western Australia and Northern Territory, although very limited production exists in some subtropical pockets.

Major challenges for commercial production of papaya in Australia are (i) limited number of genotypes that are sought after cultivars and (ii) prevalence of major diseases such as *Phytophthora* rot, black spot and Papaya Sticky Disease. Papaya's limited genetic variability makes it very difficult to achieve crop improvement through conventional breeding. Therefore, in the past five years Skybury farm heavily invested into in vitro research leading to accelerated papaya crop improvement. This paper will discuss the conversion of Skybury's papaya plantation from a highly variable, seedling plantation to a very uniform, 100% clonal plantation; development of PSD free papaya lines through in vitro breeding, mutation breeding, as well as somaclonal selection program which has yielded excellent new commercial Skybury papaya lines in a short period of time.

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## 109

### The use of cryobiotechnology to conserve plant genetic resources: Opportunities and challenges

**Dr Raquel Folgado**[1]

[1]*The Huntington Botanical Gardens, San Marino, USA*

The genetic resources of plant species (e.g. the diversity of genetic material) are available in natural or field populations. However, twenty percent of the world's plants are threatened with extinction due to many reasons such as deforestation, developmental activities and changes in agricultural practices. Gene banks have been created in many countries to store the maximum diversity, mainly in seed collections or clonal field collections. Since the maintenance of field collections is often costly and risky, the cryobiotechnological tools can help to preserve them by using techniques like in vitro culture and plant cryopreservation. Those innovative techniques have been successfully applied to many crops and some wild species, but more research is needed to better understand the tolerance to cryopreservation of the plants. Likewise, investigations that lead to optimization of the tissue culture systems for endangered plant species, will allow to include new plants into gen banks. Cryobiotechnological tools are applied at The Huntington Botanical Gardens (San Marino, USA) to develop tissue culture systems from initiation to rooting of plantlets. Once the micropropagation is well optimized, cryopreservation protocols being developed, mainly using shoot tips as plant material. In vitro shoots obtained from ex vitro buds are used as donor plants, and they are acclimated using osmotic or cold stresses before the shoot tips dissection. The case studies include avocado and wild species such as aloes, agaves, magnolias, and other endangered species, and the final goal is to obtain more efficient methods to assure the long-term preservation of plant genetic resources.

## 110

## Tissue culture for the collection, conservation and multiplication of elite coconut germplasm

**Prof Steve Adkins**[1], Mr Mike Foale[1], Dr Julianne Biddle[1], Dr Sisunandar Sisunandar[1], Dr Quang Nguyen[1]

[1]*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), St Lucia, Australia*

Grown on 12 million hectares across 90 countries, coconut (*Cocos nucifera L.*) is one of the world's most valued palm crops. This species contributes directly to the income for 20 million small-holder farmers and dependents, providing food, health benefits, structural products as well as aesthetic beauty to the landscape. Apart from coconut water and sugar, beneficial oil products have been increasingly acknowledged worldwide, becoming a most attractive functional food in recent years. In addition, special coconut varieties, which have delicious buttery endosperm or a flavoursome water, are also attracting considerable attention. However, coconut productivity has been constrained by several factors, including those of advanced age, extreme weather events, the wide spread incidence of phytophagous insects as well as lethal diseases. There is now a significant requirement for producing new palms, from a wide range of elite genotypes, on a large scale, to replace the old, unproductive palms and to meet the increase in demand for the new commodities in an expanding market. Since the traditional method for propagation is uneconomical as it is highly demanding of fruit, tissue culture is rapidly becoming an important way of producing seedlings with desirable traits. For the creation of such material wild populations in remote locations can be sourced for their unique yield, disease and pest resistance traits, then transported as embryos (embryo rescue and culture) to the research station, then conserved (cryopreservation) and made available for selection and incorporation into new genetic lines, prior to rapid clonal multiplication through tissue culture (somatic embryogenesis).

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## 111

## Developments in banana tissue culture in Australia

**Mrs Sharon Hamill**[1]

[1]*Department of Agriculture and Fisheries, SCMC Nambour, Australia*

The Australian banana industry has for almost a century recognised the damage that pests and diseases can inflict on its industry and since early last century the banana producing States and Territories have implemented a series of biosecurity strategies designed to restrict disease movement. Banana tissue culture has supported those strategies for the past almost forty years, and is relied upon in numerous ways to prevent or mitigate disease impact. This presentation describes how banana tissue culture is used in Australia in biosecurity, in farm management and in research to prevent entry or spread of disease. Banana tissue culture is used to gain access to improved cultivars in Australia. Current improvement strategies such as mutation breeding will be described. Examples will discuss the use of tissue culture for quarantine cultivar imports and in germplasm collections and how banana tissue culture helps industry to elude the impact from Australia's most damaging banana diseases including Banana Bunchy Top Virus, black Sigatoka and Fusarium Wilt.

## 112

## Micropropagation of recalcitrant Persea americana rootstock cultivars

**Dr Jayeni Hiti-Bandaralage**[1], Dr Alice Hayward1, Mr Chris O'Brien1, Prof Neena Mitter[1]

[1]*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), St Lucia, Australia*

Avocado is a treasure throve of nutrients and grant many health benefits. Currently new planting practices (2-3 times more plants per hectare) are adopted to increase production. Being planted as a grafted tree, rootstock propagation is the first step in propagation. Seedling rootstocks exhibit high genetic variation, hence associated with unpredictable field performance. Elite rootstock propagation is critical to maintain genetic stability influencing product quality and farm management practices. Rooting cuttings is only possible through a complex, lengthy and expensive method called 'Frolich and Platt method'. Growers wait over 3-6 years to obtain plants and pay high prices due to this difficulty in rootstock propagation.

Tissue culture (TC) has demonstrated high potential in propagation for economically important plants. However, avocado is highly recalcitrant to TC conditions, thus couldn't be propagated through industrial TC. For the first time in the world, at the University of Queensland, Queensland Alliance for Agriculture and Food Innovation, a successfully shoot-tip culture based high throughput TC technology has been established for avocado. Various parameters have been optimised to identify best conditions for all stages; initiation, shoot induction, multiplication, in vitro hardening, root regeneration and acclimatisation. Large number of plants (↑2000) have been acclimatised with 97% survival. Over the last 2 years, TC rootstocks grafted with 'Hass' are evaluated in commercial orchards to compare with grafted conventional rootstocks (nursery clonal & seedling rootstocks). The technology developed has a great impingement on both Australian and global avocado industry by meeting timely supply of high demand for clonal avocado plants.

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## 113

## Enhancing product development by use of double haploid

**Dr Usha Zehr**[1]

[1]*Maharashtra Hybrid Seeds Company Pvt. Ltd.*

Delivering improved seeds has been critical for the seed industry to enhance farmers productivity and income. Delivering these products in a time sensitive manner creates great value for the seed companies. Plant breeders have used all tools available to them for making genetic gains in the shortest possible time. Use of molecular markers, predictive breeding and double haploids have helped advance material faster. Developing an efficient protocol for double haploid production is the first step towards obtaining high number of plants. The uncertainty with growing season, as a result of more unpredictable weather events, getting new products to market faster gives one more way we can work on climate resilient crops and sustain the growth and profitability that is needed on the farm.

## 114

### Let them eat meat? A solution or a problem for a sustainable healthy future?

**Dr Lawrence Haddad**[1]

[1]*Global Alliance for Improved Nutrition (GAIN), Switzerland*

There are few foods that humans eat that cause as much emotional response as meat. There is much debate about the human health benefits and costs of different kinds of meat consumption for different groups of people in different countries. There is also much debate about the net greenhouse gas emissions of tending different kinds of animals on different types of land in different kinds of production systems. The presentation will attempt to unpack some of these issues as a contribution to injecting some nuance into a polarised debate and should therefore help identify policy solutions for sustainable development in different contexts.

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## 115

### The quest for policy and public expenditure opportunities to support implementation of sustainable smallholder livestock and aquaculture interventions

**Prof Robyn Alders**[1], Dr Johanna Wong[1], Dr Ben Quayle[1], Dr Scott Moreland1, Dr Hannah Reed[2], Dr Belinda Richardson[2], Prof David Heymann[1]

[1]*Centre for Global Health Security and Chatham House, Fullerton, Australia,* [2]*Bill and Melinda Gates Foundation, Seattle, USA*

The number of people living with chronic hunger has risen for the third consecutive year to over 820 million in 2018 while incomes for men and women smallholder farmers are not increasing in line with SDG2 targets. Animal-source food and income from livestock and aquaculture production can play a significant role in enhancing diet quality and quantity in resource-poor settings where monotonous cereal-based diets are common. However, achieving financially, environmentally and socially sustainable smallholder animal (ruminant and poultry) and aquaculture systems, that are also gender- and nutrition-sensitive, has proven challenging. By analysing existing, multi-sectoral policy environments we aim to develop a decision tool that will help guide participating Governments and donors like the BMGF in future agriculture investments intended to enable countries to better meet their national plans and Sustainable Development Goal targets; and to enhance the social license to operate smallholder animal enterprises.

Project activities include: macro and micro policy mapping at global, regional and national levels; collation and analysis of policies made and implemented by the public sector in collaboration with private sector partners (commercial and smallholder enterprises) across the agricultural, environment, health, trade and transport sectors. Detailed case studies are being compiled with Bangladesh in South Asia and Nigeria in Sub-Saharan Africa to identify policies that are exemplars, or that create bottlenecks and constraints to inclusive, sustainable animal and aquaculture production. Roundtable discussions with senior representatives are being conducted in each case study country. This presentation provides an opportunity for participants to contribute to this policy discussion.

## 116

## Facts and myths: Livestock and the environment

**Dr Mario Herrero**

*Commonwealth Scientific and Industrial Research Organisation, Brisbane, Australia*

Livestock play a critical role in providing humanity with multiple benefits including incomes, food, employment and social status. The livestock sector is large, it maintains the livelihoods of over 1.1 billion people directly or indirectly, and has a significant land and resource use footprint. As part of this footprint, it is deeply connected with land use, biomass appropriation, water and nutrient and biogeochemical cycles. In many instances, the sector contributes to the depletion and deterioration of natural resources. The growing demand for animal-sourced foods calls for the sector to be closely monitored and regulated, or to reduce demand to ensure that these environmental pressures are kept within a safe operating space.

Livestock systems are heterogeneous, as are the solutions to maintain livestock within sustainability boundaries. Publicly, the sector as a whole has been often vilified as a single polluting entity, causing more harm than benefit. This has led to a confusing image and to a series of facts and myths that are explored in this paper. The livestock sector in many instances plays beneficial roles, both social and environmental, and with sound research and policy can also mitigate many of its negative environmental impacts. This paper discusses these options, as well as the rational of having or not livestock as part of sustainable and healthy diets.

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## 117

## Success example: The potential for livestock methane mitigation

**Prof Richard Eckard**[1]

[1]*The University of Melbourne, Parkvillle, Australia*

Livestock production globally is facing the dual challenges of increasing productivity to feed a growing world population, while also reducing its emissions of the greenhouse gases methane and nitrous oxide. Following the 21st Council of Parties Paris Agreement, an increasing number of companies, industries and states have set targets for achieving carbon neutrality of their industries and supply chains by 2050. Recent research has shown significant reductions in enteric methane from ruminants are possible. These technologies include: grazing tropical legumes containing secondary compounds like tannins (e.g. Leucaena, Lotus); supplementing livestock diets with oil (e.g. cotton seed, cold pressed canola seed), rumen modification (e.g. methane inhibitors, early life programming), breeding and animal management. Options for significant abatement on farm are still limited, particularly in extensive and subsistence livestock systems where regular contact with animals may be limited. Initially, livestock producers may need to make extensive use of offsets using soil and tree carbon to reduce their net emissions. This presentation will explore profitable and practical options currently available for significant reductions in enteric methane in the short-term, emphasising the research still required for both large and small scale livestock systems to achieve carbon neutrality by 2050.

## 118

## Productivity – intensification – animal welfare: Synergies or trade-offs?

**Dr Rebecca E Doyle**[1,2], Dr Cecile Godde[3], Dr Barbara Wieland[2], Prof Cathy M Dwyer[4], Dr Kristina Rosel[2,5], Dr Johanna F Lindahl[2,6], Dr Silvia Alonso[2], Dr Delia Grace[2]

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Globally, animal source food production and consumption is rising fast. Reducing or eliminating livestock products is one proposed strategy to help keep within/return to planetary boundaries. However, this may not improve human welfare and nutrition, nor animal productivity and welfare. Excluding animal welfare from this discussion excludes a crucial element of sustainable production. We propose that considering the welfare of animals as a part of both strategies is key to creating genuinely sustainable animal production systems.

Adding a welfare dimension could change recommendations on consumption. In high income countries, animal welfare concerns could be used as a broader strategy for a more 'respectful' use of animal products, including increasing the quality of (and price paid for) animal source foods and reducing wastage. In the case of sustainable intensification, particularly in low- and middle-income countries, focusing on animal welfare strategies including improved monitoring and management, effective feed and water provision, early interventions and preventative health care, and providing behavioural opportunities all have productivity and efficiency benefits.

A focus on animal welfare can be inclusive of all sizes and styles of animal production, and can apply to both extensive and intensive management systems. Small-scale production, where animals are precious household assets with multiple layers of value, but where resources are often constrained, may benefit significantly from a welfare focus. This presentation will share examples of where and how animal welfare can be and is being used for more sustainable animal production solutions.

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## 119

## Informing tomorrow's livestock science: Opportunities to transform food systems in tropical developing regions

**Dr Anna Okello**[1]

*[1]Australian Centre for International Agricultural Research, Bruce, Australia*

As the global demand for livestock products grows, so too does the debate around the sector's long-term sustainability. Nowhere is this issue more prevalent than in Low- and Middle-Income Countries (LMICs) where livestock – and their products – are critical sources of both income and nutrition for smallholder farmers and their communities. It is well recognised that tropical regions provide an enormous opportunity to build on current baseline efficiencies, for example through adapting improvements in genetics, nutrition, health and husbandry currently applied in intensive systems elsewhere in the world. However, the mixed farming systems that dominate smallholder landscapes in many tropical regions may also offer the greatest opportunity for transformational – rather than incremental – changes that promote their important societal and nutritional contributions whilst mitigating negative impacts of livestock production described elsewhere in the world. If so, what does 'sustainable intensification' of tropical livestock systems look like to 2030 and beyond, and what is the role of research in demonstrating how this can be achieved?

## 120

## Australia-Africa Universities Network: Providing sustainable solutions to challenges jointly facing Australia and Africa

**Prof Kadambot Siddique**[1]

[1]*The University of Western Australia, Perth, Australia*

The Australia Africa Universities Network (AAUN) established in 2012, as the only consortium of universities spanning Australia and Africa, has the objective to inject new vigour into the academic relationships between the two continents. With the purpose of working together to find innovative, long lasting solutions for critical issues concerning both continents, the consortium has identified four areas of focus: Food & Nutrition Security, Public Health, Education and Mining & Development.

AAUN is establishing, high calibre partnerships in research and academia and has begun mutual research capacity building in order to bring positive improvements to areas of focus. AAUN has secured vital relationships and teamwork with international agencies and business to help us to achieve our mission. As a means of further engagement with these strategic associations, and in order to cultivate new ones, AAUN has set to work on a comprehensive knowledge sharing portal via its website that offers intelligence and advisory services for government institutions, the corporate sector and media on Africa-Australia relationships and research.

AAUN has established 56 research projects and teams, each of them including several AAUN members, along with associated institutions and individuals where that can extend critical capacity. These teams are continuing communities of scholars, working together across disciplinary and international borders. The catalyst for these developments is our Partnership and Research Development Fund, with an annual competitive round of applications and awards. While small, these seed investments have delivered success in a majority of cases, and proceed with publications, external grants and impact.

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## 121

## Delivering market requirements: Product profiling with market foresight for bean value chains in East Africa

**Mr Jean Claude Rubyogo**[1], C.M. Mukankusi[2], R Chirwa[3], B.F. Amsalu[4], S.T. Nkalubo[5], T Shiferaw[4]

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Common Beans (*Phaseolus vulgaris*) is a multipurpose foodstuff in east, central and southern Africa. Since the year 2000, the Pan Africa Bean Research Alliance (http://www.pabra-africa.org/) bean breeding program, has aimed at increasing bean grain productivity of major market-demanded bean types based on grain colour, size and shape. However, as beans become increasingly more commercially oriented, with high value and attracting differentiated rural and urban consumers with varied product preferences. PABRA is reorganising its breeding to focus on evolving consumer-preferred traits such as palatability, cooking time, bronzing, canning quality and lack of flatulence while continuing to increase genetic gains and productivity to incentivize farmers and other value chain actors in bean markets. This requires increasing efficiency and precision in breeding and anticipating the growing and ever-changing consumer demand in terms of both numbers of consumers and their choices, as well as the changing bean production environment. In order to deploy this innovative approach, PABRA has embarked on designing products targeting specific and prioritised product profiles by using foresight of consumers' demands and their implications on bean cropping and other value chain components. Early results from the use of new improved varieties in Ethiopia and Uganda indicate that approach is creating good market opportunities for small holders. It is transforming beans from a mere food security crop to a higher value one that is attracting multiple private and public investments along the value chain in the bean business corridors.

Key words: Common bean, foresight, product profiles, consumer demand

## 122

# Public-private breeding transition in sorghum in Australia and lessons for sub-Sahara Africa

**Prof David Jordan**[1]

[1]*The University of Qld - QAAFI, Warwick, Australia*

The last decade has seen a period of dramatic change in plant breeding in Australia with the commercialization of a range of crop improvement programs which were previously bred by the public sector. This has raised questions about the role of the public sector in breeding and pre-breeding activities and the nature of its future interactions with the private sector. In sub-Sahara Africa similar changes are occurring in a number of crops and additionally efforts are being made to give public funded breeding a more product-driven commercial focus. In this presentation I will discuss the transition from public to private sector breeding in sorghum in Australia. This transition occurred slowly over a period of 50 years. During this time the public and private contributions have remained at similar relative levels but the nature of their contributions have changed substantially. The presence of the public program has been instrumental in enhancing and retaining private sector research investment in Australia and addressing problems that would not warrant private sector investment. With close to 100% of sorghum hybrids containing public germplasm but with few hybrids based entirely on public lines, we argue that the combination of the two systems has delivered superior outcomes for Australian sorghum growers than would have been the case if either sector had operated alone. It is likely that experience gained during this transition may provide useful insight for other crops in Australia and sub-Sahara Africa.

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## 123

# Introducing market-led approaches into postgraduate plant breeding education programmes in Africa

**Prof Shimelis Hussein**[1], Prof P Tongoona[2], Prof. P Kimani[3], Dr. N Yao[4], Dr. R Chirwa[5], Mr. J.C. Rubyogo[6], Dr. V. Anthony[7], Prof. G. Persley[8]

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Crop genetic improvement is one of the key strategies for transforming African agriculture. However, the adoption rate of improved varieties in sub-Saharan Africa (excluding South Africa) is below 35%, compared with above 60% in Asia and 80% in South America. The low uptake of modern crop varieties in sub-Saharan Africa is partly due to a lack of suitability of many new plant varieties to meet the needs and preferences of the farmers and other actors such as processors, retailers and consumers in the value chain. The new varieties may also fail to meet the current and changing market demands. Therefore, the next generation of plant breeders should be trained to undertake demand-led breeding (DLB), focusing on the needs and preferences of the value chains, the marketplace and the stakeholders in the region. This paper presents implementation of the DLB curricula in Africa through various training workshops and postgraduate plant breeding education programmes; hitherto involving 400 alumni from the public and private sectors. Further, the paper highlights lessons drawn from consultations with DLB alumni for learning and scaling up DLB in Africa. The paper concludes that DLB education is a key element for plant breeders to develop high performing market preferred varieties and seed supply systems, for economic development in Africa.

Keywords: demand-led plant breeding, market preferred varieties, sub-Saharan Africa

## 124

## Africa's plant breeders and their variety portfolio for farmers and markets: Opportunities and challenges

**Dr Nasser K Yao**[1], Prof Paul Kimani[2], Prof Hussein Shimelis[3], Dr Jean Claude Rubiogo[4], Prof Pangirayi B Tongoona[5], Dr Roland Chirwa[6], Dr Vivienne Anthony[7], Prof Gabrielle Persley[8]

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A detailed survey involving over 150 active plant breeders in Sub-Saharan African countries has been undertaken during 2019 to identify promising new varieties that have either recently been released or are in late stage development. The purpose of the study is to characterize and promote the portfolio of public varieties that are on track to serve African smallholder farmers, their value chains and emerging markets. Data are being collected on the number and characteristics of the new crop varieties in the development pipeline, their benefits and performance attributes for farmers, processors and consumers, and the approach being taken to achieve seed scaling and distribution to farmers. The study will be used to support African breeders to demonstrate and communicate the valuable attributes of their varieties, encourage opportunities to match improved varieties with market demand, catalyze connections with private sector seed organizations and encourage investment in production and distribution of quality seeds to farmers. This paper provides an overview of the data and conclusions from the study. It pinpoints the need for continuing professional development and capacity strengthening in 1) creating development, variety positioning and marketing strategies, 2) seed production and distribution opportunities because of low seed availability, and 3) licensing frameworks to encourage partnerships with seed scaling organizations. It also discusses the opportunities and challenges and draws the road map toward achieving higher rate of variety adoption in farmer's fields while informing the development of a training curriculum for breeders on best practices in making and communicating variety performance claims.

Keywords: Sub-Saharan Africa, variety portfolio, plant breeding, seed scaling-up, capacity building

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## 125

## Demand led breeding

**Prof Gabrielle Persley**[1]

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Building support for plant breeding in Africa and increasing public and private investment is by creating business cases for target crops that will generate high performing varieties that meet emerging market demands. The aim is to use this evidence base to influence African policy makers, governments, investors and international development agencies to increase investment in demand-led approaches in plant breeding and support the transformation of small holder agriculture in Africa.

Policy research is being undertaken to develop an innovative methodology that can easily be used by breeders and R&D professionals to create compelling business cases that attract public and private investment in plant breeding. The methodology will use quantitative data and other evidence on the range of benefits from the development of new crop varieties that respond to market demand and lead to increases in genetic gains, productivity and profitability of crops.

A framework is being developed that draws upon best practices and expertise from leading organizations in this field from both the private and public sectors worldwide. This includes experiences in the funding of plant breeding within Australia on key domestic and export crops, and critical analysis of the benefits and return on investment ensuing for farmers, their value chains and the environment. The new approach for making the case for increasing investments in demand led plant breeding will be introduced to the breeding, policy and investment community via a series of publications and workshops developed in partnerships with plant breeders and policy makers in Africa.

## 126

## Successfully facilitating agricultural investment in northern Australian landscapes

**Professor Allan Dale**[1]

[1]*CRC for Developing Northern Australia, Hermit Park, Australia*

There is a strong bilateral and bipartisan aspiration in the *White Paper on Developing Northern Australia* to secure the expansion of agriculture through new investment. Despite this approach, agricultural development investment remains tentative. To lift investment, significant Commonwealth, State and Northern Territory solutions to key policy, regulatory and regional development challenges need consideration, analysis and negotiated resolution. Key risks facing new investors (as well as the communities where development can occur) include the need to resolve conflicting societal aspirations for northern Australian landscapes, significant knowledge and data limitations, complex regulatory and tenure challenges, and workforce and infrastructure limitations. There are significant environmental challenges to be mitigated, and the effective involvement and empowerment of local Traditional Owners within the development process is particularly important.

The Cooperative Research Centre for Developing Northern Australia (CRCNA) is focusing strategic effort on exploring key issues constraining development in key or priority development regions in each jurisdiction by partnering with the Commonwealth, State and Territory Governments to explore the issues at hand. The work aims to propose innovative policy, process, regulatory and other solutions to facilitate agricultural development, while achieving environmental and social outcomes which help maintain our nation's market advantage. By deeply engaging key development stakeholders to help collectively identify issues and solutions, it is hoped this case study-based approach will identify new pathways to achieve positive development outcomes and explore improved approaches to the way these risks are understood and managed.

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## 127

## A situational analysis for developing a rice industry in northern Australia

**Prof Robert Henry**[1]

[1]*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Brisbane, Australia*

Rice is a major global crop. Production in Australia has been largely in the south. Several attempts have been made to establish a rice industry in northern Australia. This study aims to learn from previous experience and define a path for development of a sustainable industry in northern Australia. Rice is a native plant in the north bringing the problem of indigenous pests and diseases. In addition to the production of domesticated (Asian) rice, the options of producing native rices or rices with attributes derived from the native rices are being explored. Production constrains are being defined in terms of the availability of suitable rice varieties, rice agronomy, rice processing infrastructure and transport and storage for each of the jurisdictions WA, NT and QLD. Northern Australia has the potential to produce novel high value rice products that target consumers in Australia and internationally.

## 128

## Northern beef industry emerging market, supply chain gap analysis & sector capacity baseline study

**Dr Chris Chilcott**[1]

[1]*Commonwealth Scientific and Industrial Research Organisation (CSIRO), Berrimah, Australia*

With an ongoing interest in developing northern Australia, we undertook a beef situation analysis to assist the Cooperative Research Centre for Developing Northern Australian in tailoring their investment decisions. The northern beef industry is dominated by rangeland enterprises that include family farms, indigenous pastoral enterprises and large corporate interests. The analysis was a whole of supply chain examination of current practices, strategies and plans. It included consultation with producers, industry groups, research organisations and government departments. The competitive advantages of the northern beef industry are its adapted production systems, low cost base and geographic positioning that allows it to take advantage of south-east Asian markets. However, the inherent low productivity, high capital costs and over reliance on a small number of markets make it vulnerable to market shocks. We found that the industry faces challenges in maintaining profitability and the ability to translate research to practice to enhance productivity its social license to operate. The review makes recommendation under four themes: There is an ongoing need for research and develop for profitability and productivity gains for the top businesses; There is a need to improve the translation of proven R and D to farm practice for the majority of the northern Australian beef industry; There is a need to support and develop business cases for economic enabling infrastructure to allow the northern Australian beef industry to remain competitive and intensify production, and; There remains some regulatory reform and derisking required to support investment in the industry and allow diversification.

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## 129

## Preparing the way for growth in aquaculture in Northern Australia: Industry priorities and vision 2028

**Prof Dean Jerry**[1,2], Prof Kyall Zenger[1,2], Associate Professor Jan Strugnell[1], Dr Amy Dietrich[1], Rob Bell[3], Roger Barnard[3], Dr Simon Irvin[4], Dr Greg Coman[4], Kylie Penehoe[5], Michael Davis[5], Kim Hooper[6], Jo-anne Ruscoe[7], Dr Jennifer Cobcroft[1]

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The Australian Government aspires to double the aquaculture industry from present values to $2 billion by 2027. Currently, ~18% of Australian aquaculture value comes from northern Australia. Aquaculture in northern Australia has the potential to increase primary production, regional employment, industry and infrastructure investment, and gross regional product (GRP). In response to this opportunity, the Cooperative Research Centre for Developing Northern Australia (CRCNA) commissioned a situational analysis of the northern Australia aquaculture industry. The goal is to develop a realistic, inclusive, industry supported Vision to 2028, including a plan for the industry and the CRCNA to inform and guide future investment.

Data was collected from stakeholders from across northern Australia through an online survey and regional forums. The main challenges identified by stakeholders to aquaculture expansion, included the availability and retention of skilled labour, regulatory burdens and the cost of power. However, each sector had nuanced views, with barramundi producers indicating market competition in the top three challenges, while power ranked much lower. For the tiger prawn farming sector, absence of selective breeding programs, access to broodstock, and specific pathogen free (SPF) broodstock were the key challenges; while in pearl production, environment risks, oyster health and transport costs ranked highly. Aquaculture has also been identified as a key sector for engagement of Aboriginal and Torres Strait Islander people in agribusiness in northern Australia, where there is natural cultural alignment and resource access.

## 130

## Northern Australia forestry situational analysis project

**Mr Mick Stephens**[1]

[1]*Timber Queensland, Kedron, Australia*

With support from the CRC for Developing Northern Australia, this project links industry, state department and academic partners and stakeholders to identify opportunities, explore potential policy, investment and other solutions to challenges, plus assess sector wide research priorities facing the northern forestry and forest products industry.

The industry, which has significant growth potential, includes the substantial areas of native forest on state-owned and private tenure including Indigenous owned land, particularly in East Arnhem Land and Cape York, as well as plantation forests for pulp, timber and sandalwood production.

To date the project has highlighted greater native forest resource security, from private or state owned resources, as necessary to provide confidence for downstream processing businesses to invest, grow and supply demand for solid wood products in northern Australia, as well as some specific export markets (e.g. Asia). This can provide sustainable local employment, including in remote indigenous communities, but will require business model, training and skill development support.

There is also potential to expand plantations with innovative practices such as silvopastoralism, combining forestry and livestock production, to generate better overall returns. Mine site revegetation can also add value to existing extensive mining land-use activities through revegetation with productive forestry (e.g. timber, bioenergy).

The final project report will be completed in November 2019, it is intended that the consortium of key research partners from the project will form an industry development alliance with a life beyond the project, to assist with the on-going growth and development of the industry.

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## 131

## Business on country: Land-use diversification on the Indigenous estate

**Mr Ricky Archer**[1]

[1]*North Australian Indigenous Land and Sea Management Alliance Ltd, Darwin, Australia,* [2]*Cooperative Research Centre for Developing Northern Australia, Hermit Park, Australia*

Despite ownership and native title interests in large areas of land, adjacent rivers and seas in northern Australia, Indigenous people remain marginal participants in the commercial economy. Historical and contemporary determinants of low levels and quality of economic participation remain intractable, and recent policy in northern development has done little to address Indigenous interests, except to reiterate perceptions of Indigenous lands and culture as barriers to orthodox development (NTG 2014; Australian Government 2015; Russell-Smith et al. 2019).

The Northern Australia Indigenous Land and Sea Management Alliance ( NAILSMA) and the Cooperative Research Centre for Developing Northern Australia (CRCNA) have collaborated on a study to identify ways to support Indigenous landowners and their communities to become active participants in northern development; in ways that genuinely advance their interests. The project builds on the work of Indigenous leaders from across northern Australia to construct a framework for proactively considering land use options and, where the best available information and analysis identifies the most favourable opportunities to attract external investment (NAIEP 2013).

In this paper, we consider the present state of the Indigenous estate, including the nature and condition of lands and natural resources, current uses and their socioeconomic and biophysical implications, and the economic development aspirations of landowners and their communities. We identify gaps and barriers to realisation of those aspirations, and, as context for other parts of the study, look for pathways to avoid or overcome barriers.

NAIEP *2013* An Indigenous prospectus for participating in the sustainable development of north Australia. North Australian Indigenous Experts Forum on Sustainable Economic Development. Second Forum. Kakadu National Park, Northern Territory, Australia 30 April - 2 May 2013. Report to the *Northern Australia Ministerial Forum. North Australia Indigenous Land and Sea Management Alliance, Darwin.* 78 pp.

Northern Territory Government 2014 Submission by the Northern Territory Government to the Joint Select Committee on Northern Australia Inquiry into the Development of *Northern Australia. February 2014. Northern Territory Government, Darwin.15 pp.*

*Russell-Smith J, James G, Pedersen H & Sangha KK (Eds.) 2019* Sustainable land sector development in northern Australia: Indigenous rights, aspirations and cultural responsibilities. *CRC Press, Baton Rouge. 226 pp.*

## 132

## Transformational wheat agronomy: Success from system synergy

**Dr John Kirkegaard**[1], Dr James Hunt[2], Dr Julianne Lilley[1], Dr Lindsay Bell[3]

*[1]Commonwealth Scientific and Industrial Research Organisation (CSIRO), Canberra, Australia, [2]LaTrobe University, Melbourne, Australia, [3]Commonwealth Scientific and Industrial Research Organisation (CSIRO), Toowoomba, Australia*

In 2008, as Australia emerged from the Millenium drought, and with the spectre of climate change upon them, Australian wheat farmers and researchers were challenged to develop strategies to maintain the wheat yield increases necessary to sustain production and profit. By adopting a systems agronomy approach, rather than a focus on any individual technology, new systems emerged that could capture, store and use water more efficiently both at the paddock scale and across the farm. Combinations of improved crops sequence, summer fallow management, slower developing wheat cultivars sown earlier using no-till, and modified in-crop agronomy to maintain harvest index, significantly improved crop yield and water-use efficiency. At farm scale, starting the sowing program earlier using this strategy had a multiplying effect across the farm as more crops could be sown in their optimum window. On mixed farms, earlier sown crops also provided options for grazing during the vegetative phase (dual-purpose crops), at no cost to grain yield, further improving the profitability, flexibility and reducing the risk of the farm business. The involvement of growers in the research from the outset, and the farmer-to-farmer interactions meant that adoption and impact was rapid. This research provides an example of incremental transformation, where no single technology alone drives large yield improvement, but the synergies between several innovations within a system can generate significant improvement. The first agricultural revolution and several examples since reinforce this important message, yet arguably we currently fail to structure and manage research to capture these transformative changes.

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## 133

## Delivering traits for improved adaptation to future climates

**Dr Greg Rebetzke**

*Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia*

Increasing climate variability is as great a concern as increasing air temperatures forecast with climate change. The challenge for breeders is in identifying and selecting traits now that are genetically correlated with environments into the future and/or difficult to manage away from their breeding nurseries. We report on studies targeting constitutively-expressed traits (e.g. increased rates of spike and grain-filling and increased coleoptile length) to establish their value proposition for increasing grain yield in future environments. The work supports the potential for higher rates of grain-filling and longer coleoptiles as traits where genetics are available now in pre-emptive selection in breeding programs. Further, there is not expected to be any cost associated with these traits in grain yield or quality, or in cooler, wetter seasons.

## 134

# Combining trait physiology, crop modelling and molecular genetics to improve wheat adaptation to terminal water-stress targeting stay-green and root traits

**Dr Jack Christopher**[1], Dr Cecile Richard[1], Dr Karine Chenu[1], Dr Mandy Christopher[2], Valeria Paccapello[2], Dr Andrew Borrell[3], Dr Lee Hickey[4]

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Terminal drought stress is currently a major constraint in many wheat production regions. This is predicted to worsen with future climate change. The stay-green phenotype allows crops to remain green and photosynthesize for longer after anthesis, potentially improving yields in terminal drought environments. Root systems with greater root length density at depth can contribute by increasing access to deep soil moisture late in the season.

To study the genetics of root and stay-green traits in wheat, a multi reference parent nested association mapping (NAM) population was developed. Using the "speed breeding" system of rapid generation advance, over 1500 recombinant inbred lines (RIL) were generated in approximately 18 months. Genome-wide association mapping (GWAS) using a novel whole-genome NAM method (WG-NAM) identified genetic regions associated with the target traits.

High-throughput techniques were developed and used for the NAM lines to (i) phenotype seedling roots in controlled conditions, and (ii) objectively characterize novel stay-green traits for hundreds of genotypes in standard yield plots in the field. NAM lines were phenotyped for yield and stay-green traits at multiple water-stressed and non-stressed environments during 4 seasons. Particular traits were associated with superior adaptation to certain environments.

Many lines with adaptive root and stay-green traits exhibited superior yield to the reference parent in relevant target environments and 54 such lines have been provided to commercial Australian wheat breeders for cultivar development.

This combination of technologies is increasing understanding of physiological adaptation to water-limited environments in wheat and helping accelerate genetic progress.

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## 135

# Increasing heat tolerance in wheat to counteract recent and projected increases in heat stress

**Dr Najeeb Ullah**[1], Dr Behnam Ababaei[1], Dr Karine Chenu[1]

*[1]The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Rockville, Australia*

The frequency of heat shocks during grain filling of wheat crops across the Australian wheatbelt has significantly increased over the last 30 years. These post-flowering heat events significantly reduce wheat yields with a relatively greater impact on grain size than number. A controlled environment study was conducted to assess the impact of post-flowering heat on wheat recombinant inbred lines SB062 and SB003. Plants were submitted to 7-day heat shock (33/21°C day/night temperature) at different periods during the grain filling. Heat shock significantly accelerated leaf senescence, with a greater impact on older leaves and for mid post-flowering stresses. Overall, the tolerant line (SB062) could maintain leaf greenness longer than the sensitive one (SB003), especially when submitted to heat stress. Further, heat shock during early-to-mid grain filling reduced the grain size and weight. While the impact on developing grains was significant in SB003, no significant effect of post-flowering heat was observed on leaf senescence nor on grain size in the tolerance line SB062. Delayed leaf senescence appeared to play a role in maintaining grain size under heat stress. The research findings will assist improving crop models for post-flowering heat effects and developing techniques for screening heat tolerant wheat lines. Increased post-flowering assimilate production through sustained leaf greenness could improve the performance of wheat crops in increasingly warmer environments.

## 136

## Tracking a major gene increasing wheat biomass and yield in hot environments

Dr Pauline Thomelin[1], Dr Julien Bonneau[2], Dr Chris Brien[1], Dr Radoslaw Suchecki[1], Dr Ute Baumann[1], Prof Peter Langridge[1], **Dr Penny Tricker[1],** A/Prof Delphine Fleury[1]

*[1]School of Agriculture, Food and Wine, The University of Adelaide, Glen Osmond, Australia, [2]School of BioSciences, The University of Melbourne, Melbourne, Australia*

Wheat productivity is severely reduced by high temperatures. Breeding heat tolerant cultivars could be achieved by identifying genes controlling variation and using these to select superior genotypes. Here, we report the positional cloning of *qYDH.3BL*, a quantitative trait locus (QTL) on bread wheat chromosome 3B associated with yield stability under hot conditions. The QTL was constitutively expressed in deep soil, with the positive allele associated with an increase in grain yield, thousand grain weight, early vigour and plant biomass under elevated temperatures. We fine mapped the QTL interval to a region containing twelve predicted genes. Of those, one gene showed contrasted gene expression and sequence polymorphism among parental lines and near-isogenic lines. This gene is homologous to *Seven In Absentia (SINA)* genes, a family encoding E3 ubiquitin ligase proteins involved in the ubiquitin pathway for the degradation of target proteins. Near isogenic lines carrying the positive allele at *qYDH.3BL* under-expressed *TaSINA* at an early developmental stage and had increased biomass, grain number and size following heat stress. A sequence variation in the promoter region of *TaSINA* would explain contrasted gene expression. A survey of worldwide distribution indicates the positive allele haplotype became widespread from the 1950s through the CIMMYT wheat breeding programme but was, to date, selected for only in Mexico and Australia.

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## 137

## New advances in phenotyping technologies

Dr Coe Robert[1,4], Dr Michael Schaefer[1,4], Dr Tim Brown[2,4], Dr Bettina Berger[3,4], **Dr Xavier Sirault[1,4]**

*[1]CSIRO Agriculture & Food, Canberra, Australia, [2]Australian National University, Canberra, Australia, [3]The University of Adelaide, Adelaide, Australia, [4]Australian Plant Phenomics Facility, Adelaide, Australia*

Since 2008, the Australian Plant Phenomics Facility has been at the forefront of advances in plant phenotyping. Founded with a focus on innovation through multidisciplinary collaboration, the APPF has developed capabilities driving discoveries in global agricultural research. Drawing on the experience of collaborating with leading agricultural research in Australia, we highlight the application of phenotyping technologies for measuring and quantifying plant traits in wheat research and breeding programs. We then describe the imbalance between innovating in phenomics and delivering impact to our industries: the transition from engineering with a focus on technology discovery and sensor integration for measuring new traits, to simple, scalable, accessible solutions is in fact extremely challenging. At the heart of the issue is impact – if the full potential of plant phenomics is to be realised, then functional, scalable capabilities addressing real-world industry problems are ultimately needed. Central to our strategy is engagement with the Research community as well as Industry in order to understand the real needs and challenges faced by each community of users, so that the APPF may bring its expertise, not just its technology, to bear. We highlight some of the ways in which we continue to contribute to capability development but also call for a rethink on how to innovate within this space.

## 138

## Matching technology with need

**Mr Chad Simpson**[1]

[1]*E.E Muir & Sons Pty Ltd, Bundaberg, Australia*

As an agronomist working on Australia's largest avocado orchard, there was many challenges faced in the production and processing of the fruit. Looking for tools and more accurate data that could be used to make operations more efficient and aid in increased orchard health, better production processes, more accurate yield estimates and more efficient application of nutrients was hard to find. Many research projects produced outcomes that were not needed or understood and generally unable to be used by the end user.

From my first interaction with leading technology I saw that there was something there that could be used to streamline some activities but developments needed to be made to understand the full potential and benefits of this technology.

The key role that I saw for myself within this project was to ensure the research was "Keeping it real". Allowing the research group to understand what the end user could use to achieve increased orchard health, better production processes, more accurate yield estimates and more efficient application methods.

Although there needs to be research done that is in its infancy, there still needs to be the focus on where this will end up and a goal that can be achieved from data gathered. Involvement of end users in all research even in its infancy is key to achieving a commercial outcome.

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## 139

## Forward estimation of mango crop load and harvest timing based on in-field machine vision and handheld spectroscopy

**Prof Kerry Walsh**[1], Dr Zhenglin Wang[1], Mr Anand Koirala[1], Mr Nicholas Anderson[1]

[1]*Central Queensland University, North Rockhampton, Australia*

Forward estimation of crop load and timing of harvest maturity is important for both harvest resourcing and marketing decisions. The application of in-field machine vision and handheld spectroscopy is showcased within a farm management system for forward estimation of mango crop load and harvest timing. Imaging rigs were deployed on farm vehicles, and an image pipeline developed to process images and display results to a farm map. A YOLO based architecture was customised to the task of panicle and fruit detection in canopy images, providing rapid and accurate results. Panicles were detected by stage of development, feeding to heat sum development models for fruit maturation, and complemented by in-field handheld spectroscopy for non-invasive fruit dry matter assessment to forward predict optimal harvest timing. Fruit above a minimum size were detected and counted, with comparison to the estimates from other technology (by collaborators) and from the packhouse. Fruit size was estimated on tree using a time of flight camera to complement RGB imaging, allowing estimation of camera to fruit distance. Fruit lineal dimensions were converted to fruit mass based on fruit allometrics, specific to cultivar. The technologies of real time fruit detection and camera to fruit distance also enable provide the foundation for harvest mechanisation. The technology is most effective with the new high density, narrow canopy architectures, given visibility of fruit.

## 140

## Efficient and detailed orchard maps: Flowers, fruit, ripeness, canopy light interception and yield

**Dr James Underwood**[1], Dr Suchet Bargoti[1], Dr Alex Wendel[1], Ms Madeleine Stein[1], Mr Fredrik Westling[1], Mr Samuel Orn[1]

[1]*The University of Sydney, Australia*

As part of the recently completed Rural RnD4P research programme featured in this symposium, The University of Sydney conducted research on the use of robotic ground vehicles to map commercial orchards, to provide data to growers to support farm management decisions.

The major research themes for the USYD component were flower and fruit yield and ripeness estimation and mapping for mangos, and light interception modelling for avocados towards automated pruning decision support. Although the primary focus was on mangos and avocados, the outcomes are also relevant to the broader industry, with potential applications to a variety of other crops.

A ground vehicle robot was provided in-kind, pre-equipped with a wide range of sensors including lidar, colour, thermal and hyperspectral cameras, soil sensors, and accurate positioning devices. Data were obtained from farms in Queensland over the three years of the project, and processing methods were developed and evaluated.

An efficient system was developed to scan and map orchards with very high resolution, while remaining efficient to scan whole orchard blocks. The processing methods that were developed proved to be cable of yield mapping and total yield estimation (with error rates between 0 and 6% for mangos), flower mapping, mango ripeness mapping, and avocado light interception modelling.

This presentation describes the system and the resulting data that can be obtained on commercial farms.

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## 141

## The appropriate use of UAVs and Lidar for mapping tree crop canopy structure and health

**Ms Dan Wu**

[1]*Remote Sensing Research Centre and Joint Remote Sensing Research Program, The University of Queensland, Australia*

For horticultural tree crops, canopy structure metrics such as leaf area, canopy height, crown area and crown volume have been closely related to tree health and productivity - both yield and quality. Whilst on-ground visual evaluations of these parameters is currently the commercial accepted practice, this method is labour intensive, time inefficient, subjective to the visual observer and difficult to scale across entire orchards. Remote Sensing technologies have been evaluated as an alternative for collecting these metrics but commercial-scale validation and subsequent adoption is limited. Dan will discuss the appropriate methods to collect and process Lidar data and drone imagery and present results on horticultural canopy structure mappings from these data.

## 142

## Exploring the potential of high resolution satellite imagery for yield prediction of avocado and mango crops

**Dr Moshiur Rahman**[1], Professor Andrew Robson[1], Surantha Salgadoe[1], Professor Kerry Walsh[2], Dr Mila Bristow[3]

*[1]Applied Agriculture Research Centre (AARSC), University of New England, Armidale, Australia, [2]Institute of Future Farming Systems, Central Queensland University, Rockhampton, Australia, [3]Department of Primary Industry and Resources, Northern Territory Government, Darwin, Australia*

Accurate pre-harvest yield estimation of high value fruit tree crops provides a range of benefits to industry and growers. Currently, yield estimation in Avocado *(Persea americana)* and Mango *(Mangifera indica)* orchards is undertaken by a visual count of a limited number of trees. However, this method is labour intensive and can be highly inaccurate if the sampled trees are not representative of the spatial variability occurring across the orchard. This study evaluated the accuracies of high resolution WorldView (WV) 2 and 3 satellite imagery and targeted field sampling for the pre-harvest prediction of yield. Stratified sampling technique was applied in each block to measure relevant yield parameters from eighteen sample trees representing high, medium and low vigour zones (6 from each) based on classified normalised difference vegetation index (NDVI) maps. For avocado crops, principal component analysis (PCA) and non-linear regression analysis were applied to 18 derived vegetation indices (VIs) to determine the index with the strongest relationship to the measured yield parameters. For mango, an integrated approach of geometric (tree crown area) and optical (spectral vegetation indices) data using artificial neural network (ANN) model produced more accurate predictions. The results demonstrate that accurate maps of yield variability and total orchard yield can be achieved from WV imagery and targeted sampling; whilst accurate maps of fruit size and the incidence of phytophthora can also be achieved in avocado. These outcomes offer improved forecasting than currently adopted practices and therefore offer great benefit to both the avocado and mango industries.

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## 143

## National scale mapping of horticulture tree crops in Australia

**Mr Craig Shephard**

*The University of New England, Australia*

Australia's horticulture tree crop growers and their industry now have easily accessible spatial information available, thanks to an interactive, online web map—the **Australian Tree Crop Rapid Response App**. Built by the Queensland Land Use Mapping Program (QLUMP) the map displays the location and extent of all commercial avocado, macadamia and mango orchards.

The success of the mapping showcases the value of science and innovation within horticulture industries. This is a result of collaboration between government, universities and industry—that combines industry and government data interpreted with imagery to map and classify the location and extent of tree crops. A citizen science 'Land Use Survey' app also enabled experts to contribute to better inform the mapping.

The map was successfully applied in the response to Tropical Cyclone Debbie which severely impacted the mango industry, however the potential applications for the map are not limited to post-natural disaster monitoring. Knowing the distribution and extent of orchards has the power to greatly inform decision-making at farm and industry level, including biosecurity preparedness.

Importantly the mapping adheres to national standards for commodity level land use mapping, supported by the Australian Collaborative Land Use and Management Program. Privacy concerns are acknowledged and respected as no personal information is collected as part of the land use mapping process nor contained within the land use datasets.

Using web-based GIS technology was a key enabler for the project, opening the spatial data to anyone, anywhere, on any device. No GIS? No worries!

## 144

## Management of cattle exposed to high environmental temperatures

**Dr Terry Mader**[1], Dr John Gaughan

[1]*Mader Consulting, LLC, GRETNA, USA*

Increasing awareness of animal welfare has become a high priority in food production systems involving domestic livestock. Under normal working conditions, management practices are constantly being evaluated to insure that optimum levels of animal comfort are maintained. However, during periods of adverse weather, optimum conditions for animal comfort as well as animal performance are often compromised. Animals experiencing heat stress show greater rectal temperatures, increased respiration rates, decreased feed intake, decreased milk production, and other health problems. During prolonged periods of heat stress lower conceptions rates are observed in breeding livestock. In addition, animals reared in confinement are often compromised, due to limitations in air movement and an increase in radiant heat load from surrounding surfaces and/or other animals. Economic losses from reduced performance of livestock experiencing severe environmental stress likely exceed losses associated from livestock death by 5- to 10-fold. Alternative feed, supplementation, and feeding programs need to be considered for livestock challenged by adverse environmental conditions. Use of additional water for consumption and cooling or sprinkling, shade, and/or alternative livestock handling strategies need to be considered to help livestock cope with heat stress. For animals reared outside, strategies that increase animal space, waterer space, and environmental buffers, need to be employed to minimize stress. Our current knowledge base suggests that ample opportunities exist for livestock producers to minimize impact of environmental stress on food producing animals, however, a greater understanding of animal responses to weather challenges is needed to help animals cope with adverse and changing climatic conditions.

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## 145

## Nutritional strategies to mitigate effects of high environmental temperature

**Assoc Prof John Gaughan**[1], Prof Terry Mader[2]

[1]*The University of Queensland, Gatton, Australia,* [2]*The University of Nebraska, Lincoln, USA*

Reducing fluctuations in dry matter intake (DMI) during periods of hot weather is a primary goal in intensive cattle production. This is important in terms of productivity and there are also potential health benefits in reducing DMI fluctuations (e.g. lower risk of acidosis when cattle come back on feed). Another goal is to manage cattle so that they return to full feed as soon as possible after a heat event i.e. the recovery period. During periods of high heat load intensively fed cattle naturally reduce DMI as a means of reducing metabolic heat production, which allows them to better cope with high environmental temperatures. Numerous nutritional strategies have been used in an attempt to mitigate the effects of high ambient temperature on feedlot cattle. A common approach in the feedlot sector has been the use of 'heat load rations'. These usually have a higher fibre content which is thought to reduce metabolic heat production, and thereby reduce the decline in DMI associated with increased environmental heat load. In the fairy sector the use of slowly fermentable grains has been explored. In addition there have been numerous studies using dietary supplements. These include the use of supplements such as betaine, yeasts, vitamin E, selenium, cobalt, monensin, and fats and oils. There is however some conjecture on the usefulness of sudden changes in rations. There are some new insights as to when dietary changes should be made, and how this may help recovery of cattle.

## 146

## Metabolism and endocrinology of cattle in high environmental temperatures

**Dr Gene Wijffels**[1], Dr Megan Sullivan[2], Dr Stephen Anderson[3], Ms Sally Stockwell[1], Ms Suzie Brisoce[1], Mr Russell McCulloch[1], Dr Judy Cawdell-Smith[2], Dr John Gaughan[1]

*[1]CSIRO Agriculture and Food, St Lucia, Australia, [2]School of Agriculture and Food Sciences, The University of Queensland, Gatton, Australia, [3]School of Biomedical Sciences, The University of Queensland, St Lucia, Australia*

Close-to-market weight grain fed cattle experience high heat loads during summer. There are health, welfare and production impacts on these high value animals. Two cohorts of 600 kg Black Angus steers (n=12) were subjected to heatwave conditions during a thermal challenge in climate chambers. Frequent blood sampling enabled a detailed description of the metabolic and endocrine trajectories during high heat load and recovery in feedlot cattle.

In high heat load ruminants, blood flow is diverted from the major organs impacting metabolic rate and cellular functions. The metabolic rate will slow with falls in the thyroid hormone plasma concentrations. Insulin and the adipokines gave an indifferent response. The high heat load cattle were hypoglycaemic and oxidising fatty acids. Liver involvement was evidenced by the build-up of bilirubin in plasma, and reduced release of cholesterol and ALP. Thermal challenge saw markedly increased plasma creatinine and urea implicating reduced glomerular filtration; although the kidneys were working to retain chloride ions to balance the loss of bicarbonate from the increased respiration rate.

As heat load reduced during recovery, rumen temperature and respiration rate normalised and feed intake gradually returned. Plasma glucose levels increased also. With increased blood supply to the organs, there was a rise in liver enzymes into the blood, although liver function had not fully restored during the recovery period; plasma bilirubin concentrations were still high, and ALP and cholesterol levels low. Twelve days after the thermal challenge, most blood parameters had returned to normal and the steers had gained weight.

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## 147

## Physiological adaptations of pigs under high environmental temperatures

**Dr Jeremy Cottrell**[1]

*[1]The University of Melbourne, Australia*

With increasing global temperatures and incidence of sub-tropical and tropical pork production, the management of heat stress (HS) is a subject of increasing concern. Furthermore modern genotypes are derived from temperate European stock and are susceptible to increased environmental heat loads. Adaptive responses to HS include reductions in feed intake, however pair feeding studies have shown that this can only partly explain reductions in growth rates. Other adaptive responses include thermal panting to increase evaporative heat loss and blood flow redistribution to increase peripheral radiant heat loss to the environment. Under sustained environmental heat these buffering pathways have physiological consequences for the pig, contributing to reduced growth rates. Evaporative panting results in a loss of carbon dioxide to the environment. This can result in respiratory alkalosis, however usually this is actively buffered against at an metabolic unknown cost. Likewise, redistributing blood flow to the periphery results on a concurrent reduction in blood flow elsewhere. This precipitates damage to organs in the GIT, in part by increasing oxidative stress. However there is emerging evidence that the damage is more widespread. The aims of this presentation are to review some of the ways that HS influences pig physiology.

## 148

## Nutritional strategies to mitigate heat stress in pigs

**Prof Frank Dunshea**[1]

[1]*The University of Melbourne, Parkville, Australia*

Pigs are comparatively less heat tolerant than other livestock which creates a challenge for pig producers during summer. Based on a changing climate causing an increase in the severity, frequency and duration of heat waves these issues surrounding heat and pig production are only going to increase. This is particularly so given that future expansion of the pig industry are likely to be in tropical regions such as South-east Asia and Latin America. Efforts by the pig to dissipate excess body heat come at a cost to health and divert energy away from growth, compromising efficient pig production. Management of heat stress requires multiple strategies, and recent research is improving the understanding of the application of nutritional strategies to ameliorate the effects of heat stress. In particular the use of feed additives or feed supplements is an important, flexible and economical method to alleviate heat stress and the intensive nature of pig production lends itself to the inclusion of dietary supplements. Some specific examples include antioxidants, betaine, plant-derived poylphenols and chromium which have been proved effective in mitigating against heat stress in pigs. The aim of this presentation is to summarise recent advances in the nutritional management of heat stress in pigs.

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## 149

## Nutritional strategies to mitigate heat stress in chickens

**Assoc Prof Eugeni Roura1, Assoc Prof Chiara Palmieri**[1]

[1]*The University of Queensland, St Lucia, Australia*

Climate change in the tropical and subtropical regions of our planet seems to be impacting the frequency and severity of high environmental temperatures and heat stress in chicken production systems. In addition, modern fast-growing broiler lines are characterised by increased susceptibility to heat stress which negatively impacts on the birds' welfare causing high mortality rates, and results in economic and productivity losses of the affected flocks. Classical nutritional approaches to help chicken broilers coping with heat stress include high energy - high fat diets. However, in light of recent evidences, the degree of unsaturation of dietary fats during a heat stress episode seems to be critical. In particular, a polyunsaturated fat profile (such as in soybean oil) may increase mortality in broilers under heat stress. In addition, the protein balance of the diet is equally important. While birds coping with heat stress seem to benefit from a low crude protein diets, the requirement of some essential and non-essential dietary amino acids may need to be reviewed. Other dietary supplementations with a positive performance impact in chickens under heat stress include GABA and betaine. Furthermore, hyperventilation has been associated with an increased oxidative metabolism requiring additional supplementation with antioxidant vitamins (C and E). In contrast, little evidence has been found to support the use of dietary supplements of electrolytes and organic acids. Finally, initial evidences suggest that some phytochemicals may improve heat stress resilience, and this hypothesis warrants further investigation.

## 150

## Can we create a sustainable functional food market using Australian native plant foods?

**Dr Mridusmita Chaliha**

*ARC Training Centre for Uniquely Australian Foods, The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Australia*

There is a global demand for natural ingredients from plant sources with multi-functional properties for application in the food and nutraceutical industries. Australian bush foods have unique nutritional and health properties providing considerable potential to grow existing value chains within the Global Functional Foods market which is worth more than US $ 130 billion.

Australian endemic plants have been used by the Indigenous communities for centuries as food and medicine. These plants are nutrient-dense, climate-resilient and biologically unique. The potential to harness the diversity of crops in tropical, sub-tropical, temperate and arid regions of the country, and the economic, health and social benefits flowing back into Aboriginal and Torres Strait Islander communities are significant.

Kakadu plum *(Terminalia ferdinandiana, KP)* is one such Indigenous plant that has been used by the Indigenous Communities for their dietary and health needs. Market analysis indicate a 10% growth per annum in the future for all KP products both nationally and internationally. Demand drivers for high-volume, high production industries are mostly in the nutraceutical, supplement and pharmaceutical industries, requiring consistent quality and reliable supply. In response to these market opportunities there is a need to identify and improve the existing value chains to be able to improve their efficiency.

The current CRC-NA project aims to improve the quality of the KP supply and value chains to address issues of inconsistencies in quality and reliable supply. Outcomes will empower Indigenous communities by ensuring Indigenous ownership of KP production and control of supply chains.

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## 151

## Integration of Aboriginal culture and history through bush food enterprises

**Ms Madonna Thomson**

*Jagera Daran, Nyanda Aboriginal Cultural Tours and Bush Food Experience, Australia*

Abstract not available at time of publication

## 152

## Australian cuisine and traditional food flavours

**Dr Heather Smyth**

*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Centre for Nutrition and Food Sciences (CNAFS), Australia*

Australia boasts as one of the richest biodiverse regions in the world. From Kangaroos to Kakadu plums and Quolls to Quandongs, these distinctive plants and animals have been consumed by the Australian Aboriginal population for many thousands of years. Apart from perhaps macadamia nuts, these richly biodiverse and flavourful foods are almost entirely absent from the modern western diet but are highly deserving of pride-of-place in Australian food culture.

For the global food industry, Australian native plants present a novel opportunity in terms of flavour and dietary diversification. Extracts and ingredients made from indigenous plants are rich in bioactive components which can add value to mainstream foods as either natural flavourants, colourants, anti-browning agents, for health-value fortification or to act as preservatives which extends product shelf life. Food manufacturers are able to completely replace health-averse synthetic food additives with formulations of plant extracts, while also enhancing the biodiversity of mainstream consumer food products.

Our research seeks to increase opportunities for Indigenous Australian ingredients in mainstream foods so that a branding point-of-difference can be achieved for Australian food companies while supporting sustainable livelihoods on-country.

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## 153

## Nutritional value of Australian traditional foods and diet diversification from a global perspective

**Dr Michael Netzel[1], Professor Michael Rychlik[1,2],** Dr Olivia Wright[3], Associate Professor Yasmina Sultanbawa[1]

*[1]Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Coopers Plains, Australia, [2]Technical University Munich (TUM), Munich, Germany, [3]School of Human Movement and Nutrition Sciences, The University of Queensland, St. Lucia, Australia*

Australian native plant food and non-native fruits and vegetables grown in the 'unique' Australian environment can have exceptional nutritional and functional properties. Many of these 'foods' are still underutilised but have the potential for wider availability and commercialisation. As a basic requirement for this, their nutritional composition (including anti-nutrients and phytochemicals) must be determined and assessed. Compositional data of nutrients, vitamins (e.g. vitamin C and folates) and phytochemicals (e.g. polyphenols and carotenoids) of selected Australian grown (native and non-native) fruits as well as native fruits from other countries will be presented. Furthermore, their potential (nutritional) 'value' in the context of a diverse and healthy diet will also be discussed.

## 154

## Influence of traditional South African food preparation methods on functional compounds

**Prof Dharini Sivakumar**[1]

[1]*Tshwane University of Technology, Pretoria West, South Africa*

Prof Dharini Sivakumar has been awarded National Research Chair in DST-NRF SARChI Chair in Phytochemical food network to improve nutritional quality for consumer by the NRF/DST in 2016. She initiated the programme on African Indigenous Food at the Tshwane University of Technology in 2016. Her research group has developed a modified atmosphere packaging to market Nightshade, Chinese cabbage and Amaranthus leaves in fresh form. Currently her research group have developed different functional food products for food diversification programmes. She has six PhD students investigating the impact of different cooking methods on functional compounds and anti-diabetic effects. She has published 95 research articles in higher impact factor journals, seven book chapters and her H-Index is 30. Recently she was awarded The Australia-Africa Universities Network – Partnership and Research Development Fund 2019 jointly with A/Prof. Yasmina Sultan Bawa. She has research collaborations in the UK, Italy, Canada, Australia, France and Germany.

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## 155

## Designing meal plans for the foodservice sector using traditional Australian foods

**Dr Olivia Wright**[1,2,3], Dr Michael Netzel[2,3], Associate Professor Yasmina Sultanbawa[2,3]

[1]*School of Human Movement and Nutrition Sciences, The University of Queensland, Brisbane, Australia,* [2]*Queensland Alliance for Agriculture and Food Innovation, Brisbane, Australia,* [3]*Centre for Nutrition and Food Sciences, Brisbane, Australia*

A summary of the current literature around Australian native plant foods and their potential for diversifying dietary patterns will be presented. This will be in the context of shining a spotlight on the new Australian Research Council (ARC) Training Centre for Uniquely Australian Foods. Planned work for improving the nutrient profile of Australian and international dietary patterns through incorporation of Australian bush tucker will be discussed, highlighting the important collaborations with indigenous communities to develop nutritious and sustainable, value-added products. Mechanisms to incorporate uniquely Australian foods into meal plans in the foodservice sector will be considered.

## 156

## Wastes to profits – delivering advanced bioproduct technologies for agriculture

**Mr Doug McNicholl**

*Meat and Livestock Australia, Australia*

Australia's animal industries produce significant quantities of wastes from on-farm production, intensive feed and processing sectors. The management of these wastes is a significant cost for these industries exceeding $100-200 million per year. Emerging technology and innovative business models adapted from other parts of the world present industry with the opportunity to convert waste cost into in excess of $100 million per annum revenue opportunity by converting wastes from the red meat, dairy, pork and municipal industries into valuable products. Doug will provide insight to the drivers of innovation and the key technical, economic and social barriers to overcome in order to unlock this waste to revenue opportunity for Australian animal industries.

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## 157

## Energy and feed products from waste: Applying the circular economy to agricultural industries

**Dr Paul Jensen**

*Advanced Water Management Centre, The University of Queensland, Brisbane, Australia*

Agricultural industries are amongst the largest organic waste producers both in Australia, and globally. However, agricultural industries are also large consumers of energy, nutrient and water resources. This simultaneous supply and demand paradigm has shifted the focus of waste management from "treatment" to "value-add and recycling".

Existing value-add technologies have focused on waste-to-energy, where anaerobic digestion (AD) is a mature commercial technology used to produce biogas and subsequently renewable energy. There are thousands of installations globally and ↑100 full-scale installations in Australia representing ↑$100 million in infrastructure. Appropriate selection, design and integration of AD technologies is essential to ensure effective and economical waste management. However, there remain many areas where AD is still not applied, either due to the cost or due to challenging nature of the waste. Next generation AD technologies address these challenges through novel waste pre-treatments, innovative reactor designs or process enhancing additives.

However, waste-to-energy processes such as AD only utilise some components within organic waste, nutrients, minerals or metals remain available. Single-cell protein (SCP) processes are potentially disruptive waste-to-feed technologies of the future. SCP are edible unicellular microorganisms such as algae, yeasts, bacteria or fungi and can contain ↑60% crude-protein. SCP are emerging as potential supplement/substitute for protein-rich foods for human consumption or animal feeds – depending on the source of waste, the production process and the specific properties of the SCP. When considering broader environmental impacts, SCP may represent efficient low-cost, low-energy protein production and contribute to a sustainable feed base in some agricultural industries.

This presentation presents the development and integration of such next generation waste-to-value technologies for agriculture.

## 158

## Low cost and flexible production of biofuels and biochemicals

**Dr Darryn Rackemann**[1]

[1]*Queensland University of Technology, Brisbane, Australia*

Mercurius Biorefining (formerly Biofuels) was founded in 2009, with the mission to produce bio-chemicals and drop-in fuels through novel applications of existing technologies. The company has patented the Renewable Acid Hydrolysis Condensation Hydrotreating (REACH) technology, which allows for divergent product streams using various biomass feedstocks.

Abundant biomass resources are available in regional areas. The proposed development route involves targeting distributed satellite sites to produce an energy dense intermediate product from available sources of biomass that can be transported to a centralised processing facility for final refinement. This approach along with the novel liquid catalytic technology allows for lower cost biomass collection and conversion to a biocrude product that is easy to transport. The higher capital required for upgrading to the final fuel products can be leveraged from existing or proposed bio-refineries, like Northern Oil is building in Gladstone, to reach the necessary economies of scale for conversion into diesel and jet fuel or other valuable chemicals for domestic and international use.

The presentation will explore the strategies employed using the Mercurius technology to produce both fuels and chemical products and detail the progress made towards the pilot scale development and pathway to commercialisation.

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## 159

## How synthetic biology will transform the Australian biotechnology industry

**Assoc Prof Claudia Vickers**[1, 2]

[1]*CSIRO, Brisbane, Australia,* [2]*Australian Institute for Bioenginnering and Nanotechnology, The University of Queensland, Brisbane, Australia*

Synthetic biology (SynBio) is driving a revolution in bioengineering, which in turn is accelerating development of a sustainable bioeconomy. SynBio applies classical engineering principles to bioengineering, including the use of modular plug-and-play componentry and high-throughput automated design-build-test-learn cycles. This facilitates the design and construction of novel nucleic acid-encoded parts, devices, machines, and even whole organisms. SynBio provides advantages of precision, predictability, sophistication, control, and speed relative to classical genetic engineering. A BioFoundry provides the physical and virtual environment to facilitate this industrialisation of bioengineering. We have recently established Australia's first accessible BioFoundry with the aim of bringing the sustainable bioeconomy to you – faster, better, and cheaper.

## 160

## Mapping biomass resources in Queensland

**Ms Kelly Bryant**[1], Mr Phil Norman[1]

[1]*Department of Environment and Science, Queensland Government, Brisbane, Australia*

The Australian Biomass for Bioenergy Assessment (ABBA) is an Australia-wide assessment of biomass resources and biomass resource supply chains. The project aims to:

1) Develop a public, national data base of biomass resources
2) Highlight the opportunities for the use of biomass resources across Australia
3) Support bio-industries to get more value from organic material, often destined for landfill, by improving access to information and data.

The project collects and publishes information about the location, amount, current usage and projected future demand of all types of biomass across Australia. This includes residues and wastes from the agricultural, forestry, horticultural, livestock and food processing industries as well as organic wastes from urban sources.

It also collects information about relevant infrastructure such as transport networks, and existing users or producers of biomass. The information presented in a centralized location online – the Australian Renewable Energy Mapping Infrastructure platform (https://nationalmap.gov.au/renewables/) – where it can be viewed by anyone with an interest in biomass. This data is publically accessible, interactive and requires no special software or specialist to interrogate the information.

Potential bioenergy project investors, other biomass purchasers, current and future energy users and electricity providers, and policy makers can use this data to guide the early decision making process on biomass resources and availability by location and volume.

The ABBA project is one of the actions supporting the Queensland Government's Bio futures 10-year Roadmap and Action plan.

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## 161

## Lignocellulosic biomass as a bioeconomy platform – industry perspectives

**Alex Baker**

*Leaf Resources Ltd, Australia*

Circular bio(based)economies have set drivers focusing on lignocellulosic biomass as a platform chemical feedstock to produce intermediates for industry to take further along the low carbon renewable value chain.

As part of this, biorefineries are regarded as a cornerstone of a bioeconomy and can be deployed and integrated to transform biomass to usable useful chemicals.

Additionally biorefineries provides local economic opportunities to local workers, farmers, and support and service industries.

Discussion from an industry perspective will look at the technology, project commercialisation opportunities and challenges.

## 162

## Trees for food security: How is it stacking up in Eastern Africa?

**Prof Catherine Muthuri[1],** Dr. Athanase Mukuralinda[1], Mr Charles Galabuzi[2], Mr Wondwossen Gebretsadik[3], Dr. Clement Okia[1], Dr. Jean Damascene Ndayambaje[4], Dr. Kiros Hadgu[1], Dr. Fergus Sinclair[1]

*[1]World Agroforestry Centre (ICRAF), Nairobi, Kenya, [2]National Forestry Resources Research Institute - NAFORRI, Kampala, Uganda, [3]Ethiopia Environmental Forestry Research Institute- EEFRI, Addis Ababa, Ethiopia, [4]Rwanda Agricultural Board-RAB, Kigali, Rwanda*

Smallholder farmers contribute to over 75% of the food supply in Eastern Africa and play a pivotal role in addressing sustainable agricultural intensification for food and nutritional security. Increasing tree density and diversity in farming landscapes is a cornerstone of system intensification leading to more resilient livelihoods at scale. The trees for food security project (T4FS) aimed at improving food security and smallholder livelihoods through the widespread adoption of appropriate agroforestry practices in key agroecologies in Ethiopia, Rwanda and Uganda. The project integrated supply of quality germplasm and tree management with value chain development, better water management and new approaches to govern livestock management. The program embedded agroforestry research within development initiatives of the target countries for enhanced buy-in, wide scale adoption and sustainability. Scaling best practices was facilitated using a combination of co-learning approaches such as participatory assessment of best fit options, networks of farmer participatory and controlled trials, dissemination activities, modelling, training, capacity building and curriculum development. Climate smart agroforestry practices (e.g. biomass transfer, high value fruit and timber farming, climber bean farming) were tested across a range of contexts with very promising findings and farmer appreciation. Appropriate value chains mainly on fruits, timber and tree nurseries were validated and tailored financial options identified. Given the various project benefits realized after the two-phase investment period, the program is now focusing on monitoring and evaluation to track performance and measure impact of the major achievements realized to date to help inform future investment by different research and development partners.

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## 163

## Fostering sustainable agricultural intensification in Eastern and Southern Africa: Agronomic, institutional and policy enablers

**Dr Paswel Marenya[1],** Dr Bedru Beshir[2], Dr Domingos Dias[3], Mr Charles Nkonge[4], MS Tima Munthali[5], Dr Drake Mubiru[6], Dr Pascal Rushemuka[7], Dr John Sariah[8]

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The Sustainable Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa (SIMLESA) was a research and development program implemented between 2010 and 2019 by national agricultural research institutes in seven countries across Eastern and Southern Africa. The national agricultural institutes were brought together in an international, multidisciplinary collaboration funded by the Australian Centre for International Agricultural Research (ACIAR). The technological focus was on testing and piloting locally adapted conservation agriculture methods appropriate for smallholder farmers, to support sustainable agricultural intensification. The social science focus was on characterizing the maize-legume cropping systems, market analysis, and determining effective policy and value chain interventions to enable conservation agriculture-based sustainable intensification in eastern and southern Africa. As a result of applying the agronomic methods tested under the SIMLESA program, farmers recorded average yield improvements of 10% across the region (and up to 37% in moisture-limited lowland locations within countries). Potential labour savings of up to 56% were observed. By 2018, about 480,000 farmers had adopted at least two components of the recommended practices on an average of 0.4 ha (43%) of their maize fields. Multi-year socio-economic and agronomic data from more than 5,000 households in 508 villages and 40 trial sites across 10 agro ecologies have been curated and are publicly available. The experiences from the SIMLESA program highlight the value of transnational collaboration in agricultural research. Lessons on the key institutional innovations needed to drive smallholder farming towards sustainable agricultural intensification have been documented.

## 164

## Sustainable intensification in the Eastern Gangetic Plains: Key to food security and livelihood improvement of smallholders

**Dr Thakur Tiwari[1],** Dr Mahesh Gathala[2], Dr Apurba Chowdhury[3], Dr Renuka Shrestha[4], Dr Sanjay Kumar[5], Dr Ujjwal Kumar[6], Dr Saiful Islam[7], Mr Mamunur Rashid[8], Dr Mazharul Anwar[9], Dr Illias Hossain[10]

*[1]International Maize and Wheat Improvement Centre, Kathmandu, Nepal, [2]International Maize and Wheat Improvement Centre, Dhaka, Bangladesh, [3]Uttar Banga Krishi Vishowvidhyalaya, Coochbehar, India, [4]Nepal Agriculture Research Council, Kathmandu, Nepal, [5]Bihar Agriculture University, Purnea, India, [6]Indian Council of Agriculture Research, Patna, India, [7]International Maize and Wheat Improvement Centre, Dhaka, Bangladesh, [8]RDRS, Rangpur, Bangladesh, [9]Bangladesh Agriculture Research Institute, Rajshai, Bangladesh, [10]Bangladesh Wheat and Maize Research Institute, Rajshahi, Bangladesh*

The Eastern Gangetic Plains (EGPs) has the potential to become a major contributor to South Asian regional food security, despite the world's highest concentration of rural poverty and a strong dependence on agriculture. A regional project entitled 'Sustainable and Resilient Farming Systems Intensification (SRFSI), managed by CIMMYT with over 20 partners with ACIAR/DFAT funding was launched in May 2014 to sustainably reduce the poverty.

A total of 436 farmer-participatory on-farm trials comparing the performance of three conservation agriculture based sustainable intensification (CASI) technologies like Zero/Strip till as base (ZT/ST) over the conventional tillage (CT; T1) practices were conducted across eight districts in northwest Bangladesh, Bihar and West Bengal in India, and eastern Terai of Nepal for two consecutive years i.e. 2015/16 and 2016/17. The three CASI treatments comprised a "partial CASI" option (T2: at least one crop in the cropping system established with ZT management) and two "full CASI" options (T3 and T4: all crops established with ZT/ST management; in T3 rice was direct seeded (DSR) while in T4, it was unpuddled transplanted (UPTR)). Multicriteria assessment showed an increase in rice equivalent system yield (RESY) by 4%, gross margin by 19-20%, input water productivity by 7-9% and energy productivity by 13-14% while decrease in requirements for irrigation water, energy, labor and the production cost by 15-17%, 10-11%, 32-38% and 15-18% respectively, and reduction in $CO_2$ equivalent emission by 8-13% in full CASI over CT. CASI has shown great promise for food security and livelihood improvement at small scale.

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## 165

## Sustainable intensification in rice production and processing chains (Laos and Cambodia)

**Dr Jaquie Mitchell[1],** Prof Shu Fukai[1]

*[1]The University of Queensland, St Lucia, Australia*

Traditionally, rice in Laos and Cambodia is grown by several million smallholders managing subsistence-oriented production. Sustainable intensification in rice production has been limited by the lack of irrigation water, lack of suitable varieties and labour availability. Irrigated rice areas where double cropping can be reliable have increased in recent years but are limited to about 15% of the total rice area. However, success in rice intensification particularly in Cambodia has been attributed to the development of varieties tolerant to biotic and abiotic stress, and the introduction of quick maturing photoperiod insensitive varieties. The introduction of direct seeding particularly broadcasting has become common with labour shortage and high labour cost. However, this change in crop establishment method has resulted in major weed problems, and the challenge is now to develop integrated weed management system for sustainable intensification. Use of seed drill appears promising for weed control and also reduced lodging.

Lack of labour availability has also resulted in a shift to combine harvesting. The introduction of combine harvesters and associated use of artificial grain dryers has resulted in a more marketable commodity. Milling quality, particularly head rice yield, has increased with timely harvest during ripening and proper grain drying. Mechanization reduces the cost of production, and hence rice can be marketed more readily. In Cambodia where mechanization is more advanced, rice export has increased sharply in recent years. The presentation will address recent research results on sustainable intensification in rice production and processing chains in these countries.

## 166

## Assessments of lowland rice-based farming systems and prospects for future research and development priorities

**Dr Van Touch[1],** Rebecca Cross[1], Clemens Grünbühel[2], Peter Ampt1, Try Yorn[3], Robert John Martin[1], Floris Van Ogtropa[1], Daniel K. Y. Tan[1]

*[1]The University of Sydney, Sydney Institute of Agriculture, School of Life and Environmental Sciences, Sydney, Australia, [2]Stockholm Environment Institute, Bangkok, Thailand, [3]Meanchey University, Banteay Meanchey, Cambodia*

Projections of global demand for rice is expected to increase globally at the rate of 1.5% per year (or 48.5% by 2050). The crop production increase must be done sustainably from existing farming land due to the reductions in availability and quantity of resources. Having more local studies enhances our understanding of different farmer characteristics and behaviour, socio-economic conditions and other essential constraints faced by individual farmers. This is needed for fine-tuning farming systems research which will lead to a profitable and sustainable increase in farming production. This study aims to understand and assess the lowland rice-based farming systems in Northwest Cambodia, and examine options to enhance rice production, profitability and sustainability. Farmer surveys were conducted using the CommCare Mobile Acquired Data (MAD) system and 524 farmers were interviewed. The survey identified farmers' key constraints on crop production, their knowledge gaps and limitations and the rice yield gaps which exist in Northwest Cambodia. Agricultural research and development priorities should be focused on crop establishment method, sowing window, weed and nutrient management strategies, overall soil health improvement, crop rotations and cover crops that can improve cropping systems, profitability and sustainability. An increase in understanding of farmer behaviour, adoption constraints and barriers, together with other essential interaction at the local level is also crucial when aiming to promote improved farming innovations.

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## 167

## Outcomes of agroforestry and monocropping - Comparison and assessment

**Dr Nguyen La[1]**

*[1]ICRAF Vietnam, Hanoi, Viet Nam*

Agroforestry is considered as a solution for improving livelihoods of smallholder farmers and reducing land degradation. However, the upscale is required objective assessments and appropriate solutions.

Five agroforestry options established in 2014 in Northwest Vietnam include Macadamia+coffee+soybeans, Acacia+mango+maize+forage grass, Acacia+longan+coffee+soybeans+forage grass, Teak+plum+coffee+soybeans and *Docynia indica*+forgare grass, were used to evaluate the annual income, cumulative profit, multi-year return on investment and efficiency on soil erosion control compared with traditional monocropping systems such as mono-maize and mono-*Docynia indica*.

Mono-maize provides annual income. However, tends to decrease. Break-even point of mono-*Docynia indica* happened in the year 4th after planting. Depend on agroforestry options, the break- even presented in the year 2nd to year 4th. The cumulative profit of mono-maize and mono-*Docynia indica* for five-year study were 1196 and 875 USD ha-1, respectively. Meanwhile, five agroforestry options were provided the cumulative profit from 29 to 10,000 USD ha-1. Five-year return on investment of monoculture maize and *Docynia indica* were 5% and 7%, respectively. Agroforestry options gave the value of 0.001%, 5%, 8%, 12% and 28% for Macadamia+coffee+soybeans, Acacia+mango+maize+forage grass, Acacia+longan+coffee+soybeans+forage grass, Teak+plum+coffee+soybeans+forage grass and Sontra+forage grass, respectively.

The effectiveness on soil erosion control in agroforestry options are clear, decreasing from 53% in the second year to 98% in the fifth year after establishment compared to mono-maize.

The analysis results show that agroforestry options provided attractive income for farmers only 2nd or 3rd year after establishment and reduce soil loss. However, higher investment cost is required, and appropriate supports are needed for wider application.

## 168

## Understanding early orchard productivity in macadamia

**Dr John Wilkie**[1], Helen Hofman[3], Hanna Toegel[5], Jarrad Griffin[2], Carola Parfitt[2], Dr Benjamin Toft[4]

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Macadamia is a recently domesticated, underdeveloped tree crop, grown in subtropical and tropical locations throughout the world. Macadamias are vigorous and grow to be large trees at maturity and tend to be grown in large tree, low density orchard systems, in order to delay canopy management interventions and orchard crowding.

A range of temperate tree crops, including apples, are grown in intensive small tree, high density orchard systems. These systems are characterised by optimised light relations, detailed tree training and defined tree architectures, and effective vigour management systems such as dwarfing rootstocks. These intensive systems also tend to be highly productive.

Our work is investigating the potential for intensive orchard systems to improve productivity in macadamia. A long term planting systems trial was established at the Bundaberg Research Facility in 2014 to understand the effects of tree density (313, 556, 1000 and 1482 trees per hectare), tree training (conventional and central leader) and cultivar ('A203' and '741') on orchard productivity and the physiological factors underlying productivity. Our results suggest that early orchard yield in macadamia is limited by total orchard light interception and flower raceme production.

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## 169

## Genomics and the macadamia orchard of the future

**Dr Catherine J Nock**[1], Ms Kirsty S Langdon[1], Dr Abdul Baten[1,2], Dr Ramil Mauleon[1], Dr Craig M Hardner[3], Dr Katie O'Connor[3], Associate Professor Bruce Topp[3], Professor Graham J King[1]

*[1]Southern Cross University, Lismore, Australia, [2]Agresearch, Palmerston North, New Zealand, [3]University of Queensland, St Lucia, Australia*

The application of genomics has transformed selective breeding and agricultural productivity. Until recently, sequence data for the tree nut macadamia were limited in comparison to other horticultural crops. The first macadamia genomic data, collected at Southern Cross University in northern NSW Australia in 2011, were used to develop genetic markers and a reference chloroplast genome sequence. These tools have been applied in subsequent research and have enhanced our understanding of macadamia including: population structure of the main progenitor species *M. integrifolia*, Australian wild origins of domestication in Hawaii, evidence of gene flow from crop to wild germplasm and significant variation in the capacity for self-fertilisation between cultivars. Ongoing research aims to characterise population structure on a large diversity collection in order to identify novel variation underrepresented in domesticated germplasm and to guide the prioritisation of wild populations for conservation. The genome of macadamia cultivar '741' has been sequenced, assembled and anchored to genetic linkage maps. Availability of a chromosome-scale, annotated macadamia genome sequence will enable the identification of DNA markers and genes underlying economically important traits such as pest and disease resistance, quality and yield. An understanding of the location and distribution of trait loci is crucial for breeders to accelerate the development of new varieties. Genomics is expected to shape the macadamia orchard of the future.

## 170

# Benchmarking and farm economics of Australian macadamia production: What makes a modern orchard productive?

**Mr Shane Mulo**[1], Mr Grant Bignell[1], Mrs Ingrid Jenkins[1], Mr Jeremy Bright[2], Dr Geoff Slaughter[3]

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The Australian macadamia industry has a strong focus on improving productivity and quality in order to remain globally competitive. Farm performance is measured for approximately 60% of the national industry through collection and analysis of seasonal data including yield, quality and planting metrics and, in some instances, costs. Farm performance is benchmarked through confidential comparison and reporting of individual farm results relative to groups of similar farms. These comparisons are based on a range of criteria including location, farm size, tree age, management structure and use of irrigation.

Productivity typically varies significantly between both farms and seasons. Relating farm productivity to seasonal observations provides insight into the impact of potentially limiting factors including weather, pests, diseases and agronomic conditions. Benchmark data further provides objective, long-term indicators of typical farm business performance across industry. Analysis of practices shared by high performing farms provides insight into current industry best practice and the relative value of its application. These data have informed decision making for growers, investors, processors, consultants, researchers, accountants, funding bodies and other agencies.

Yield, quality and cost data underpin economic models used to forecast cash flows for a wide range of farm business scenarios. In addition to supporting investment, these forecasts have informed evaluation of industry research including breeding, pest management, disease management and crop forecasting.

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## 171

# Extending a breeding information management system to combine international data for global performance predictions

Cameron Peace[1], **Craig Hardner**[2], Sook Jung[1], Taein Lee[1], Dorrie Main[1]

*[1]Department of Horticulture, Washington State University, USA [2]University of Queensland, Queensland Alliance for Agriculture and Food Innovation, Brisbane, Australia*

The Breeding Information Management System (BIMS) supports breeders to efficiently manage and use data for program decision-making. Initially created as part of the RosBREED program, BIMS provided a system to manage pedigree, phenotypic, and genotypic data from a breeding program. As breeding programs have begun to use information on large-effect trait loci and genome-wide predictions for selection of parents, seedlings, and advanced selections, BIMS is being extended to incorporate new types and amounts of genetic data. Horticultural tree crop breeding programs tend to be locally focused and there has generally been limited evaluation of the suitability of advanced selections across a broad range of target commercial environments. We propose to extend functionality of the publicly funded Tripal BIMS to support the evaluation of environmental stability of germplasm on a global scale, initially for horticultural crops. Our hypothesis is that a particular phenotype of an individual is a sample of its response to the environment to which it has been exposed, and SNP genotyping can track replicated genomic segments across otherwise unconnected germplasm trials. Our vision is that data from different sources can be compiled into an anonymous database that individual users can interact with to input genotype and phenotypic data and output performance predictions across the range of environments in the dataset.

## 172

## Improvement of citrus cultivars through introgression of wild germplasm

**Dr Jose Chaparro,** María Belen Besilla

University of Florida, USA

Interspecific hybridization has played a pivotal role in the development and breeding of citrus fruit. Molecular marker and genomic sequencing data indicate that most commercial citrus fruit types including but not limited to sweet orange, grapefruit and lemons arose through interspecific hybridization. The novel phenotypes were stabilized through via apomixis, a type of asexual propagation. Interspecific hybridization has also been used extensively in Citrus rootstock and scion breeding programs.

Modern global commerce is allowing the worldwide sourcing of agricultural products for retail sale. This is also facilitating the spread of pests, pathogens and other invasive species.

When compared to annual crops, the breeding of perennial tree crops is hindered by long generation times, large space requirements and outcrossing nature. The long generation times prevent the rapid turnover of generations limiting the number of generations that breeders can evaluate. Their large size requires that trees be grown at lower planting densities, increasing the amount of land needed and the costs of associated with growing out populations.

The rapid pace of new pest and pathogen introductions, and the biological constraints of working with a woody perennial argue for a proactive focus on the development of novel germplasm and specifically the use interspecific hybridization to increase the genetic diversity available to plant breeders. Our experience with interspecific hybrids in citrus is consistent with the utility of interspecific hybrids for generating useful genetic variation. In this presentation we will discuss our experience with the use of *Poncirus trifoliata* and *Eremocitrus glauca* in citrus breeding.

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## 173

## Breeding macadamia cultivars for orchards of the future

**Dr Mobashwer Alam[1], Ms Katie O'Connor[1],** Dr Ben Hays[2], Dr Craig Hardner[2], Dr Bruce Topp[1]

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*[2]The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Brisbane, Australia*

Macadamias are the iconic bush nut native to the eastern rainforests of Australia and have been cultivated for their high-quality kernel around the world. Conventional methods of breeding for new varieties is time-consuming and labour intensive. There are three main stages involved: parent selection, progeny evaluation, and multi-location trials of elite selections. Consequently, it takes 24-36 years to release a new variety. Long juvenility, poor correlation of young and mature tree yield, and large tree size are the key reasons for slow variety release, and inefficient orchard productivity and management. Therefore, a new focus in macadamia breeding is developing early producing low vigour varieties to increase production efficiency in our orchard systems. We also attempted to accelerate the Australian industry-funded breeding program for faster release of varieties. We investigated the use of genomics and marker-assisted selection methods for future identification of candidate varieties and to reduce the selection cycle. Through genome-wide association studies, we identified SNP (Single Nucleotide Polymorphism) markers associated with nut weight, kernel weight, percentage of whole kernels, and trunk circumference. Genomic best linear unbiased prediction (GBLUP) models have achieved moderate prediction accuracies (~0.6) for yield and yield stability over four years. The implementation of genomics-assisted breeding will allow the selection of elite individuals at the seedling stage, hence will save at least 40% of the total cost of the progeny evaluation stage. Experiments are in progress to validate these results in a separate population, which will allow implementing the model in future breeding confidently.

## 174

## Genome editing in poultry: Opportunities and impacts

**Dr Tim Doran**[1], Dr Kristie Jenkins[1]

[1]*Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia*

The most recent breakthroughs in the generation of genetically engineered birds have come from the use of primordial germ cell (PGC) culture. PGC culture has been used for gene targeting (Schusser *et al*, 2013) and precision genome engineering (PGE) (Park *et al*, 2014). Our development of direct injection technology (Tyack *et al*, 2013) circumvents the need to establish PGC cultures for the strain or species of bird in which the genome modification is desired. Similar to the PGC culture approach direct injection takes two generations to obtain a fully modified bird.

We have successfully coupled CRISPR technology with direct injection to generate chimeric G0 roosters which have been subsequently used to generate germline engineered G1 birds. In addition to our direct injection approach we have also developed another method which generates targeted modifications in birds in a single generation. This method called sperm transfection assisted gene editing (STAGE) delivers the CRISPR machinery via transfected sperm (Cooper *et al*, 2016). Using this approach we have generated germline edited birds and in a few instances mosaic birds. The edits generated using this approach are mostly single nucleotide changes and occasionally insertions, however the base pair deletions often reported with CRISPR activity were not observed.

Both methods provide an alternative to PGC cultures which is important in agricultural and model Avian species for which PGC cultures have not been successfully generated. We are applying this technology to improve health, welfare, productivity and food safety of chickens and their products.

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## 175

## Selecting for behavioural traits in animals – what could we change and should we?

**Dr Jill Fernandes**[1], Professor Alan Tilbrook[1], Associate Professor Dominique Blache[2]

[1]*The University of Queensland, St Lucia, Australia,* [2]*The University of Western Australia, Perth, Australia*

Humans have been selecting for behavioural traits in animals for over 10,000 years. How much of this selection was driven by the pressures of the domestic environment, and how much of it was driven by human will...and does it matter? With the recent explosion of capabilities in gene editing, which behaviours could we likely change in the near future, and when should we consider the modification of behavioural traits in animals to be ethically justified on the grounds of better animal welfare? Agricultural policy scientist Dr Jill Fernandes of The University of Queensland will walk us through a series of thought experiments to explore the fascinating albeit 'messy' ethics of 'messing' with animal behaviour.

## 176

## Castration free swine through gene editing of porcine KISS1

**Dr Tad Sonstegard**[1], Dr. Kyra Martins[1], Julio Mateo[1], Jon Bostrom[2], Dr. Paula Rodriguez[2], Dr. Felipe Ongarrato[2], Dr. Daniel Carlson[2], Dr. Clay Lents[3]

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The goal of this work was to use genome editing methodology to develop and characterize a castration free (CF) trait for commercial deployment in the swine industry. Post-partum castration is a management practice to avoid boar taint in pork products derived from male animals and is associated with some animal well-being production mandates in certain geographies. The pre-partum solution in development here relies on site-directed nucleases (SDNs) designed and optimized to enable precise genetic changes to truncate the coding sequence of porcine kisspeptin (KISS1). The proteins encoded by KISS1 and its receptor, GPR54, are indispensable for initiating release of gonadotropins that influence onset of sexual maturation and reproduction. Parental stocks derived from two commercial lines of swine under genome selection were chosen as target genetics to allow potential testing of feed efficiency performance of CF swine. The SDN deployment was done by microinjection of in vivo fertilized embryos collected from Duroc and Yorkshire cull sows. Treated embryos were transferred into 11 recipients, which resulted in births of 58 piglets. A total of 34 piglets were mosaic for KISS1 knockout along with 2 non-mosaic knock-outs. These animals have been entered into a phenotype characterization system to monitor growth, gonad development, and reproductive hormone levels (FSH, LH, Steroids, Progesterone, Skatole, Androstenone) during the period from birth to adult age. We expect the recessive phenotype of KISS1 induced genetic castration will be the same as humans with the syndrome for Hypergonadotropic Hypogonadism, where an animal remains in a potentially reversible, yet pre-pubertal and infertile state due to the lack of signaling from GPR54. The age of our piglets is still too young to determine this similarity in phenotype or the proper timing for fertility rescue; however, the data packet from phenotyped cohort will be presented and discussed to reveal how the edits are affecting growth and development.

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## 177

## Naturally polledTM–improving the welfare of dairy cattle

**C. Ramage**[1], S. Ashworth[2], T. Sonstegard[3]

*[1]Rautaki Solutions Pty Ltd., Melbourne, Victoria, Australia; [2]Total Livestock Genetics Pty Ltd., Camperdown, Victoria, Australia; [3]Acceligen, St. Paul, MN USA*

Genome editing represents a highly specific and efficient tool for animal improvement with the potential to rapidly generate useful novel phenotypes/traits, correct known defects within elite genetic resources and support animal welfare. The approach is more precise, targeted and expeditious than traditional breeding and transgenic approaches.

Recently, gene editing technology was used to produce polled cattle, eliminating a controversial animal welfare issue while retaining elite dairy production genetics. Dehorning or disbudding is the process of removing or stopping the growth of horns in livestock. Breeding polled (hornless) livestock removes the need to dehorn or disbud livestock or trim their horns.

Genetic selection for polled cattle is considered the most effective means to avoid the need for dehorning. However, the inheritance pattern of the polled or horned condition is relatively complex, and in some breeds (especially dairy breeds) the horned phenotype is prevalent, and this provides a major constraint in the use of genetic selection. As such, advances in genome editing and its application to animal improvement programs offers a solution to this issue.

This presentation will explore the use of genome editing for polled and discuss some of the challenges faced in navigating a pathway to market under an environment of uncertainty.

## 178

# Differences in thermoregulatory responses between Dorper and second cross lambs to heat stress challenges

**Ms Aleena Joy[1],** Professor Frank R Dunshea[1], Professor Brain J Leury[1], Dr Kristy DiGiacomo[1], Prof Iain J Clarke[1], Mr Minghao Zhang[1], Ms Archana Payyanakkal[1], Dr Richard Osei-Amponsah[1,2], Dr Surinder Singh Chauhan[1]

*[1]University of Melbourne, Dookie College, Australia, [2]University of Ghana, Legon, Ghana*

We compared the thermotolerance of Dorper (D) and second cross (SC) (Poll Dorset x Merino/Border Leicester) lambs by assessing physiological and biochemical responses. After acclimatization, 4-5-month-old lambs of each breed were exposed to either thermo-neutral (18-21°C, 40-50% RH, n=12/group) or cyclic heat stress (HS) (28°- 40°C; 40-60% RH, n=12/group) for 2 weeks in climatic chambers. The HS involved exposure to temperatures of 38°- 40°C between 0800 and 17.00 h daily; otherwise the temperature was maintained at 28°C. Elevated temperature increased rectal temperature (P↓0.01), respiration rate (P↓0.01) and skin temperature (P↓0.01) in both breeds, (data for 12.00 and 16.00h pooled), but to a lesser extent in D than in SC lambs (P↓0.01). The HS increased (P↓0.01) water intake to a greater extent in SC than in D lambs and HS reduced (P↓0.05) food intake in SC lambs but not in D lambs. There were no treatment effects on blood glucose and lactate levels in either breed. Significant effects of breed (P↓0.01) and treatment (P↓0.01) were observed in blood creatinine levels, being higher in SC lambs. Higher pH (P↓0.01) and lower pCO2 (P↓0.01) were recorded under HS in both breeds. Among blood electrolytes, Cl-, Na+ and base excess were significantly (all P↓0.01) reduced under HS, with no breed differences. In conclusion, the attenuated physiological responses to HS in Dorper lambs indicates better adaptation of this breed to high environmental temperature.

Keywords: Adaptability, physiological responses, thermotolerance

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## 179

# A study on DNA methylation from bovine tail hair and liver tissues

**Dr Loan To Nguyen[1],** Dr Elizabeth Ross[1], Professor Ben Hayes[1]

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DNA methylation occurs predominantly on the cytosine nucleotide in CpG dinucleotides. In humans, the methylation states of CpG sites changes with age and can therefore be utilized as an accurate biomarker for aging. In cattle, biological age prediction based on methylation status could provide key information for genetic improvement programs. For instance, this could help to avoid the difficultly of recording chronological age (time since birth) in large animal populations for association studies. Additionally, comparing chronological age with biological age (based on methylation status) can provide important information about the stress an animal has been under during it's lifetime. However, relatively little is known about DNA methylation patterns in livestock. We aimed to gain a better understanding of genome wide DNA methylation in cattle, in order to ultimately derive age predictions from methylation patterns. To achieve this goal, we apply a combination of different techniques including long-read Nanopore sequencing, reduce representation bisulfite sequencing, whole genome bisulfite sequencing (coverage ↑ 30x) and Human Methylation EPIC array (↑ 850K methylation sites) to study genome-wide bovine DNA methylation patterns. Six tail hair and two liver tissue samples from cattle with known chronological age were selected and used for all four approaches. The set of CpG sites generated will now be used to perform age prediction analyses. Furthermore, high resolution DNA methylation maps of bovine tail hair and liver can also provide critical insights for further epigenome studies.

## 180

## The inside and out of folate in strawberries and avocados

**Dr Michael Netzel**[1], Ms Caroline Dumler[2], Ms Nadine Weber[2], Ms Lisa Striegel[2], Professor Michael Rychlik[1,2], Dr Hung Hong[1], Dr Tim O'Hare[1]

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[2]*Technical University Munich (TUM), Munich, Germany*

Folate, an important B-group vitamin, is considered a critical vitamin in many countries, with folate deficiency being associated with neural tube defects in newborns. Strawberries and avocados are considered a healthy, tasty snack by many consumers, and may potentially be an important dietary source of natural folates, depending on variety and growing environment. A selection of Australian grown strawberry varieties and breeding lines, as well as commercial avocado cultivars, were screened for their folate content and vitamer profile by stable isotope dilution assay. Total folate content ranged from 69-170 µg/100 g fresh weight (fw) for strawberries and 76-196 µg/100 g fw for avocados, which was well above the values in the Australian Food Composition Database (39 µg/100 g fw for strawberries and 90 µg/100 g fw for avocados, respectively). Furthermore, folate concentration in the outer strawberry tissue was found to be 1.7-fold higher than the inner tissue of the fruit, whereas the inner avocado tissue had 1.4-fold higher folate than the outer green edible tissue. 5-Methyltetrahydrofolate, the biologically active form in humans, was the principal vitamer present. With these high folate concentrations, a punnet (250 g) of Australian-grown strawberries or 200 g of Australian-grown avocados would deliver the FSANZ recommended dietary intake (RDI) for folate (400 µg dietary folate equivalents/day/adult). Furthermore, the differences between outer and inner tissue could indicate that flatter, longer strawberries may have greater potential to accumulate folate than fruit with a more spherical shape, whereas more folate could be accumulated in a rounder-shaped avocado.

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## 181

## Zeaxanthin-biofortified popcorn for eye health

Dr Tim O'Hare[1]

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Zeaxanthin is one of only two dietary carotenoids accumulated in the human macula. A key role of zeaxanthin is to protect the eyes' photoreceptors from damage induced by blue light. Photoreceptor damage can lead to macular degeneration, which is the leading cause of blindness in Australia. Unfortunately, zeaxanthin is fairly rare in our diet. Popcorn (*Zea mays* var. *everta*) is a good dietary source of zeaxanthin, but the creation of zeaxanthin-biofortified popcorn potentially allows less popcorn to be consumed for an increased dietary dose of zeaxanthin.

As zeaxanthin is an orange pigment, breeding for zeaxanthin gives popped kernels a naturally buttery colour, unlike standard popcorn which is virtually white. The creation of naturally buttery-coloured popcorn potentially negates the practise of adding artificial butter-colourants, while also providing an excellent source of dietary zeaxanthin.

The action of popping involves a combination of high-temperature and high-pressure, sufficient enough for starch to liquefy, and for the tiny beads of moisture within starch bodies to reach an extremely high pressure. Eventually, the kernel pericarp can no longer withstand this pressure, and an explosion occurs, resulting in butterfly-shaped popcorn. These extreme conditions, however, lead to an approximate 50 % decline in zeaxanthin concentration following popping, and a gradual further 25 % reduction over the next 24 hours. Consequently, in order to optimise zeaxanthin intake, popcorn should be eaten as soon as possible after popping. Zeaxanthin-biofortified popcorn provides an additional dietary source of zeaxanthin, potentially reaching a sector of the community more prone to low zeaxanthin intake.

## 182

## Folate in durian and other tropical exotics

**Prof Michael Rychlik**[1], Dr. Michael Netzel[2], Dr. Lisa Striegel[1]

*[1]Technical University of Munich, Freising, Germany, [2]Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Coopers Plains, Australia*

Folates are a group of water-soluble vitamins the intake of which is considered to be well below dietary recommendations. This particularly applies to countries, which do not fortify staple foods. However, mandatory fortification with folic acid is still under discussion due to potential risks for some parts of the population. Therefore, there is an emerging search for natural folate sources. Besides green vegetables available in developed countries, there is an additional variety of other promising sources from regions with a high biodiversity of edible plants. For evaluating these natural folate sources, accurate methods for folate analysis and assessing their bioavailability are required. In this presentation, the use of stable isotopes to achieve this goal will be presented as well as recent results on durian and other tropical exotic fruits as promising folate sources from different parts of the world known for their high biodiversity. Our analyses revealed durian to be the fruit with the highest folate content of up to 440µg/100 g fresh weight [1] followed by yellow passion fruit, longan fruits, papayas, mangos, jack fruits, and feijoa.

Reference: [1] Striegel L, Chebib S, Dumler C, Lu Y, Huang D, Rychlik M. Durian Fruits Discovered as Superior Folate Sources. Front Nutr. 2018;5:114

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## 183

## Super-sweet purple sweetcorn: Breaking the genetic link

**Mr Apurba Lal Ray**[1,2]

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Purple-pericarp supersweet sweetcorn currently does not exist as a horticultural product. Purple pericarp comprises the outer layers of the kernel, with the purple pigment being produced by anthocyanin. Unlike the aleurone layer which can also be pigmented, the pericarp is maternal tissue. Although standard purple sweetcorn based on mutations such as sugary1 (su1) and sugary enhancer (se1) are in existence, the development of purple supersweet sweetcorn based on the widely used shrunken2 (sh2) gene mutation is much more challenging. This is because there is an extremely close genetic linkage between the supersweet shrunken-2 mutation and the anthocyanin biosynthesis gene, anthocyaninless-1 (a1). As distance between these two genes is only 0.1cM, the development of purple supersweet sweetcorn depends on breaking this close genetic link, which occurs at a very low frequency of 1 in 1000 meiotic crossovers. To make this possible, we crossed a white supersweet variety (a1a1sh2sh2) with a purple-pericarp Peruvian maize (A1A1Sh2Sh2) to obtain an initial heterozygous hybrid (A1a1Sh2sh2). The hybrid seed was sown and subsequently self-pollinated to produce seed segregating for the double recessive homozygote, sh2sh2 (1 in 4). These kernels present a visually distinctive phenotype, characterised by the seed's shrunken appearance. Approximately 2760 sh2sh2 seeds were separated and resown. Due to the low frequency of linkage breakage, the majority of these plants (~99.9%) produced supersweet white cobs (a1a1sh2sh2). Three plants (0.1%) however, produced supersweet purple cobs (A1a1sh2sh2), due to a single low-frequency linkage break. These cobs will form the basis for a purple-pericarp supersweet sweetcorn breeding program.

## 184

## Filling the void – boosting the nutritional value of blueberry

**Dr Richard Espley[1],** Mr Blue Plunkett[1], Dr Catrin Guenther[1], Dr Andrew Dare[1], Mr Declan Lafferty[2,3], Dr Nick Albert[2], Dr Tony McGhie[2], Janice Turner[4], Dr Lisa Jones[5], Ella Grierson[2], Dr Kathy Schwinn[2], Dr Kevin Davies[2], Prof Andrew Allan[1,3], Prof Laura Jaakola[6]

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Eating fresh fruit and vegetables as part of the daily diet is one way to achieve a longer healthy life. With advances in understanding the genomics and genetics of crop plants, there is an opportunity to enhance important consumer traits such as appearance, flavour, health, storage and convenience. The key compounds in fruits and vegetables that benefit health are vitamin C, vitamin A and flavonoids, including anthocyanins. Anthocyanins provide many of the red, blue and purple colours of fruit. These colour compounds been measured as a healthy dietary component and are perceived as healthy by consumers. Therefore, anthocyanin concentration is a key target for fruit improvement. In many fresh plant products, the health-providing compounds, such as anthocyanins, are mainly located in the skin. Fruit skin makes up less than 10% of a fruit, leaving a large volume of flesh ready for 'improvement'.

As an exemplar for this, we are using *Vaccinium* species to create a novel, anthocyanin-rich berry. Blueberry has deeply pigmented skin but colourless flesh, while its close relative, bilberry, has deeply pigmented skin and flesh, containing higher concentrations of anthocyanins. We are applying hybridisation techniques to blueberry and bilberry to produce hybrid berries with coloured flesh and up to five times the phytochemical content of normal blueberry to create an attractive new fruit for consumers. Transcriptomics and metabolomics will create knowledge on why different fruit tissues amass different concentrations of anthocyanin. This will inform strategies to create new fruit types with elevated anthocyanin across a range of crops.

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## 185

## Soil and foliar Zn fertiliser application as strategies of agronomic biofortification for sweetcorn grown in soils with varying Zn status

**Mr Zhong Xiang Cheah[1],** Dr. Stephen Harper[2], Dr. Tim O'Hare[3], Prof. Dr. Michael Bell[1,3]

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The effectiveness of soil and foliar Zn fertiliser applications are often studied from the perspective of improving yields in sweetcorn and maize. However, few studies have examined the effectiveness of these strategies from a biofortification context, targeting increased Zn concentration of sweetcorn kernels to improve human dietary intake. Our study found that as soil Zn status increased there was poor efficiency of translocation of Zn into kernels. Whilst foliage Zn concentration more than doubled, as did whole plant Zn uptake, there was only a 30% increase in kernel Zn concentration. Although the increase in kernel Zn concentration was significant, it was not large enough to translate into beneficial outcomes for human health. Preliminary results have showed that foliar Zn application at correct timings (approximately one week after pollination) significantly improved kernel Zn concentration of plants grown with otherwise adequate Zn supply, and could potentially be a more efficient strategy of delivering high Zn content in diets. The effectiveness of soil Zn fertilisation in improving sweetcorn kernel Zn concentration of plants grown in soils with low Zn status is currently been investigated.

## 186

## Food tampering – what we can learn from strawberries

**Ms Clare Hamilton-Bate**[1]

[1]*Freshcare Ltd, Sydney Markets, Australia*

Like many aspects of life and business, supply chain integrity is very often taken as a given. Supply chains are designed to be timely, efficient, practical and cost effective. Whilst risk factors are considered, supply chains are rarely designed in consideration of intangible threats such as the malicious tampering experienced by the Queensland Strawberry Industry in September 2018.

The malicious tampering of Queensland strawberries and the resultant disruption to the strawberry and wider fresh produce sector is sadly not an isolated incident. Similar incidents have occurred and continue to occur, in many sectors of the fresh produce industry, both domestic and international, over an extended time period.

A Queensland Government funded project used a stepped approach to deliver a detailed supply chain review, and provide recommendations for enhanced supply chain integrity and, associated risk management and mitigation strategies for the Queensland Strawberry Industry.

The lessons learnt, project findings and recommendations, providing valuable insight to far wider than the Queensland strawberry industry alone.

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## 187

## Supply chain integrity – managing food safety and food fraud risks

**Ms Margaret Balfour**[1]

[1]*Integrity Compliance Solutions, Murarrie, Australia*

Food fraud is often discussed in the food manufacturing sector but has had little attention in the primary industry sectors. Or have they? Often overlooked but significant cases of food fraud have occurred globally in the fruit, herb, spice and meat sectors. This presentation will review some relevant cases and highlight the decision-making tools available to industry that can be used to identify where the risks lie and what action could or should be taken. Challenges of the future in agriculture are addressed by considering the causes, trends and ways to stay ahead of the curve to minimise risk to your business and brand.

## 188

## Innovative technologies to mitigate microbial food safety risks in fresh produce

**Dr Sukhvinder Pal Singh**[1]

[1]*NSW Department of Primary Industries, Ourimbah, Australia*

Fresh horticultural produce related foodborne illnesses outbreaks have increased around the world, and despite the adoption of good on-farm and postharvest practices, microbial contamination of fresh produce can still occur. Non-thermal plasma (NTP) has recently emerged as an innovative option for killing/inactivating a broad range of microorganisms such as bacteria, moulds, yeasts and viruses. The reactive oxidizing species present in the NTP can inactivate and/or eliminate microbial pathogens on the produce surfaces leading to improved food safety and decay control. This presentation will provide an overview of the NTP technology, its potential applications in postharvest horticulture and barriers to commercialization. The technology has great potential to be a rapid, chemical-free, dry, environmentally friendly, and effective antimicrobial solution for food safety and decay control. Adoption of this technology will minimise microbial contamination, mitigate postharvest losses and reduce the amount of postharvest chemicals and water used, resulting in improved environmental health and sustainability.

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## 189

## A biocontrol option to control a foodborne pathogen, using Campylobacter bacteriophages to control Campylobacter in poultry

**Dr Nalini Chinivasagam**[1], Ms Wiyada Estella[1], Mr Samuel Cockerill[1], Mr Lance Maddock[1], Mr. David Mayer[1], Dr. Craig Billington[2], Ms Aruni Premaratne[2], Dr. Lu Liang[3], Dr. Phillipa Connerton[3], Professor Ian Connerton[3]

[1]*Department of Agriculture and Fisheries Queensland, Dutton Park, Australia,* [2]*Institute of Environmental Science and Research, Christchurch, New Zealand,* [3]*University of Nottingham, Loughborough, United Kingdom*

*Campylobacter* is a leading cause of foodborne illnesses both in Australia and internationally and is a commensal in poultry. There is a need for environmentally friendly options to support the current farm management strategies that address food-safety. The use of bacteriophages provides a safe biocontrol option. A collaborative study by the Department of Agriculture and Fisheries (QLD), the University of Nottingham (UK) and the Institute of Environmental Science and Research (NZ) is in progress. *Campylobacter* bacteriophages were sourced from Queensland poultry farms and following extensive screening, suitable candidates to be used in cocktails were identified. This followed an on-farm proof of concept study on a small sample of chickens, using selected cocktail candidates, to provide an understanding for practical application. The trial demonstrated a 2-log reduction of *Campylobacter* in the caeca of treated birds (compared to control) ($P \downarrow 0.05$). Another important finding of this study was the absence of bacteriophage resistance, a concern with phage therapy. Work at ESR has addressed approaches to select and adapt bacteriophage cocktails to particular hosts, which included screening against NZ and Australian hosts. This approach enabling the formulation of high performing bacteriophage cocktails for Australian and international markets. Work in the UK is exploring the understanding of the host-bacteriophage relationships to ensure safety to meet regulatory requirements and support potential scale-up options. In summary, the work in progress via international collaborations is aimed at delivering a safe biocontrol option that can meet both commercial and regulatory needs aiming at controlling on-farm *Campylobacter.*

## 190

## Technologies that improve food safety and compliance

**Mr Keith Gemmell**[1]

[1]*Safe Food Production Qld, Brisbane, Australia*

Blockchain, Internet of Things, API's, Machine Learning, Artificial Intelligence and big data are all emerging technologies that will impact on food safety systems in the coming decade. These technologies have the ability to transform businesses, consumers and regulators expectations of this system, including not only how information is collected and stored but how it is shared and leveraged to strengthen these systems. The challenges, however, are how to manage the increase in the variety, velocity and volume of the information, how it should be interpreted and by who. In this talk, we will explore some of these components how they fit together and what it may mean for business, consumers and regulators.

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## 191

## Taking food safety to a new level - the application of genomics and big data

**Prof David Burt**[1]

[1]*University of Queensland, Brisbane, Australia*

The concept of "farm to fork" is very familiar, where food products are traced throughout the supply chain, providing the means to track and remove foodborne infections. Genomics and big data analytics are playing their part in this battle against foodborne pathogens. This can start with the selection and breeding of resistant crops and livestock breeds able to actively reduce the burden of pathogens in our food. The precision and speed of selective breeding can be increased by the application of genome-wide tools. in addition, genomics helps to understand the details of host-pathogen interactions, providing other routes to control infection. Traditionally pathogen detection has been based on methods that require live culture but in recent years advances in genomics have changed that with metagenomics approaches able to identify pathogens (bacteria, viruses, fungi or parasites), trace the origin of outbreaks, and define potential drug targets and treatments to halt the spread of infections to the general population. Comparative genomic studies of wild plant and animal species are also revealing novel resistance mechanisms towards pathogens that may be applied to domesticated crops and livestock breeds. These and other problems are of interest to the "Genome Alliance in Australasia" (GAiA), a community with significant skills and resources for the study of diverse plant, animal, fungal and microbial species, including access to national collections, technologies, informatics, links to national and international organisations. The aspirations of GAiA are ambitious to answer global challenges that affect us all in human health, food security and the environment.

## 200

# Tropical livestock for wealth in developing countries

**Alfred De Vries**

*Bill & Melinda Gates Foundation*

The Agriculture Development program at the Gates Foundation strives to empower smallholder farmers with the tools and technologies they need to boost productivity, farm income and food quality. We partner with governments, local NGOs and businesses to give farmers better access to the markets, distribution networks, and the inputs they need.

Our investments in livestock started in 2012. The reasons for including livestock in the program were:

- 60% of people in extreme poverty own livestock
- livestock often their most important asset
- 30-40% of Agricultural GDP
- important source for high quality nutrition
- opportunity to empower women
- enormous potential for yield improvement

Most animals in developing countries have health challenges and very low yields (~10 times lower compared to other countries), resulting in low farmer income, poor resource efficiency, high GHG emission intensity and high consumer prices.

The major constraints for higher productivity are in animal health, genetics and feed quality. To address these constraints, we have made investments in new technologies, products and delivery systems. Examples in genetics are genomic selection, sex sorted semen and artificial insemination for dairy cows and buffaloes. Important investments in poultry genetics are in the delivery of locally adapted chicken with 5-10 times more egg production. Other promising investments are in digital platforms that link farmers to the formal market as well as to financial services.

These technologies help to overcome barriers for successful farming in tropical countries, but much more innovation and investments are needed to give every farmer the chance of healthy and productive livestock.

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## 201

# Engineering crops for resistance to disease and tolerance to environmental stress

**Pamela Ronald**[1]

[1]*University of California, Davis, United States*

A major goal for food and agricultural research is to increase the resiliency of agricultural systems to adapt to rapid changes and extreme conditions. Prof. Ronald will describe how genetic approaches are being used to generate the next generation of crops that will help farmers thrive in these challenging conditions.

Her laboratory at UC Davis studies genes that control resistance to disease and tolerance of environmental stress. Together with her collaborators, she has engineered rice for resistance to disease and tolerance to flooding. Ronald will describe isolation of a rice immune receptor, its similarity to animal immune receptors and the microbial molecule that binds to and activates the rice immune receptor. She will describe isolation of the Sub1A gene and the development of a flood tolerant rice variety (known as 'Sub1' rice) produced by the International Rice Research Institute that was cultivated by over six million farmers in India and Bangladesh in 2017. Under submerged conditions, these 'Sub1' varieties have enhanced yield and can prevent total crop failure.

## 202

## Recent advances in predicting stomatal behaviour

**Prof Belinda Medlyn**[1]

[1]*Western Sydney University, Penrith, Australia*

The finding that empirical models of stomatal conductance can be interpreted in terms of optimal stomatal theory has opened up a wide range of new avenues for research into stomatal behaviour. In this talk I will review recent advances in optimal stomatal theory, describing new model developments and how they help us predict stomatal responses to light, drought and heat. I will survey how stomatal behaviour varies within and across native plants. I will also discuss how these advances may help us improve predictions of stomatal behaviour in crops.

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## 203

## Leaf 3D imaging and modelling to increase crop photosynthesis and water-use efficiency

**Prof Margaret Barbour**[1], Mr Richard Harwood[1]

[1]*The University of Sydney, Brownlow Hill, Australia*

Plant scientists typically study photosynthesis, respiration and transpiration using models that ignore the complex internal structure of a leaf, treating it as a single point-source or sink for water and CO2. But key leaf processes depend sensitively on fine-scale 3D anatomical features, including diffusion of CO2 through the leaf (which strongly limits photosynthesis), light scattering and self-shading by chloroplasts (which enhance and reduce photosynthesis, respectively), and water movement through leaf tissues (which affects water-use efficiency). A number of researchers have suggested that engineering optimal internal anatomy of a leaf offers unexplored potential to improve photosynthetic productivity and water-use efficiency of economically important crops. However, until recently 3D models have been restricted to simple geometric shapes because of a lack of imaging techniques and limited computing power. New imaging and modelling techniques are currently being developed to overcome these technical limitations, which will allow in *silico* experiments with different leaf anatomies. These opportunities will be explored in wheat and chickpea.

## 204

### Improving light use efficiency in C4 plants by increasing electron transport rate

**Dr Maria Ermakova**[1], Robert T Furbank[1], Susanne von Caemmerer[1]

*[1]ARC Centre of Excellence for Translational Photosynthesis, Australian National University, Canberra, Australia*

C4 plants play a key role in world agriculture and strategies to manipulate and enhance C4 photosynthesis have potential for major agricultural impacts. The C4 photosynthetic pathway is a biochemical CO2 concentrating mechanism that requires the coordinated functioning of mesophyll and bundle sheath cells of leaves. Chloroplast electron transport in C4 plants is shared between the two cell types and provides resources for CO2 fixation therefore underpinning the efficiency of photosynthesis.

Using the model monocot C4 species Setaria viridis (green foxtail millet) we could demonstrate that cytochrome (Cyt) b6f complex regulates electron transport capacity and thus CO2 assimilation at high light and saturating CO2. Overexpression of the Cyt b6f in both mesophyll and bundle sheath cells results in higher electron throughput and allows better light conversion efficiency in both photosystems. Importantly, higher Cyt b6f content in leaves provides higher rates of C4 photosynthesis without marked changes in Rubisco or chlorophyll content. Our results demonstrate that increasing the rate of electron transport is a viable strategy for improvement of light conversion efficiency in C4 crop species like maize and sorghum.

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## 205

### High-throughput phenotyping tools to test whether leaf-level photosynthesis traits are measurable at the crop level

**Dr Barbara George-Jaeggli**[1,2], Dr Andries Potgieter[1], Ms Xiaoyu Zhi[1], Mr Sean Reynolds Massey-Reed[1], Dr James Watson[1], Ms Marnie Lamprecht[1], Prof Scott Chapman[1,3], Mr Kenneth Laws[2], Ms Colleen Hunt[2], Prof Andrew Borrell[1], Prof David Jordan[1], Dr Erik van Oosterom[1], Dr Alex Wu[1], Prof Graeme Hammer[1]

*[1]University of Queensland, QAAFI, Warwick, Australia, [2]Department of Agriculture and Fisheries, Agri-Science Queensland, Warwick, Australia, [3]CSIRO Agriculture Flagship, St Lucia, Australia*

In the absence of water limitation, radiation use efficiency (RUE), which quantifies how much biomass can be accumulated per unit of light intercepted by a crop canopy, determines its productivity. Various leaf- and canopy-level characteristics contribute to RUE. A recently developed model linking leaf-level biochemical traits to a crop development and growth model allows us to predict which of those characteristics have the greatest impact on crop yield. However, these predictions are difficult to test without being able to measure the individual leaf characteristics or canopy RUE itself across a diverse set of genotypes. Furthermore, many of the inputs used in the cross-scale model have not been parameterised for a C4 crop such as sorghum.

We are using UAV- and tractor-based sensor platforms and targeted data analysis pipelines that combine 2-D spectral information with 3-D point cloud data to estimate leaf and canopy traits associated with RUE in sorghum. Canopy traits include leaf area index, plant height, light interception and light distribution, leaf angle, biomass. Examples of leaf-level traits we are targeting are stomatal conductance (as a surrogate for photosynthetic rate), chlorophyll content and biochemical photosynthetic parameters, such as maximum Rubisco carboxylation (Vcmax) and electron transport rate (Jmax).

Using these high-throughput methods we hope to be able to a) ascertain whether there is significant variation among diverse genotypes for traits associated with leaf-level photosynthesis traits and b) test whether the leaf-level characteristics scale up to differences in productivity at the canopy level.

## 206

### New tools can easily detect photosynthetic diversity in wheat

**Dr Gonzalo Estavillo**[1], Dr Viridiana Silva-Perez[5], Dr Joanne De Faveri[2], Dr Anthony Condon[1], Dr Richard Poire[3], Dr Robert Furbank[1,4]

*[1]CSIRO Agriculture & Food, Canberra, Australia, [2]CSIRO Data61, Atherton, Australia, [3]The Australian National University, Australian Plant Phenomics Facility, Canberra, Australia, [4]The Australian National University, ARC Centre of Excellence for Translational Photosynthesis, Research School of Biology, Canberra, Australia, [5]Agriculture Victoria, Horsham, Australia*

There is an urgent need to increase the rate of gains in wheat yield potential (YP) to meet future demands. Increasing crop biomass by enhanced photosynthesis is a logical avenue to maximize YP. However, there is little known about how much variation for photosynthetic traits is present in wheat and their genetic control. Here we present evidence of a significant diversity in wheat photosynthetic traits and the development of new tools to measure photosynthesis more effectively in multiple organs. First, gas exchange measurements detected diversity of wheat photosynthetic traits with high heritability in multiple environments. We then developed a new, higher-throughput technique, using predictions from hyperspectral leaf reflectance to investigate genetic diversity in both the capacity and efficiency of wheat photosynthesis on selected lines from a MAGIC population and on sets of recombinant inbred lines derived by crossing high-yielding parents. We also used an affordable, hand-held chlorophyll fluorescence spectrometer to detect genetic diversity of photosynthetic traits in both modern and pre-breeding wheat cultivars. Finally, we measured the response of the electron transport rates (ETR) required for photosynthesis to changes in irradiance by monitoring the quenching of chlorophyll fluorescence of ears detached from field plots of high-yielding wheat lines. This chlorophyll fluorescence based screening detected significant differences in ETR response curves of ears among wheat genotypes. We will discuss the suitability of these tools for screening of photosynthetic traits and their potential uses in a pre-breeding context.

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## 207

### Integrative leaf photosynthesis-to-crop yield modelling to help accelerate yield improvement

**Dr Alex Wu**[1], Prof Graeme Hammer[1], Mr Al Doherty[1], Prof Susanne von Caemmerer[2], Prof Graham Farquhar[2]

*[1]ARC Centre of Excellence for Translational Photosynthesis, Centre for Crop Science, Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Brisbane, Australia, [2]ARC Centre of Excellence for Translational Photosynthesis, Division of Plant Sciences, Research School of Biology, The Australian National University, Canberra, Australia*

Enhancing photosynthesis is widely accepted as critical to advancing crop yield. However, yield consequences of photosynthetic manipulation are confounded by feedback effects arising from interactions with crop growth, development dynamics and the prevailing environment. Modelling provides a means to improve understanding of likely yield consequences and guide photosynthetic enhancement efforts to help accelerate yield improvement. Here, we developed a cross-scale modelling capability that integrates leaf photosynthesis with crop field performance in a manner that addresses the confounding factors. The model was parameterised at the leaf photosynthesis level and crop-level simulations validated using data on crop biomass and yield for wheat and sorghum from diverse field experiments. Consequences for yield were simulated for major photosynthetic enhancement targets related to leaf $CO_2$ and light energy capture efficiencies, and for combinations of these targets. Predicted impacts showed marked variation and were dependent on the photosynthetic enhancement, crop type and environment, especially the degree of water limitation, the most significant factor in dryland cropping. The importance of interdependencies operating across scales of biological organization was highlighted, as was the need to increase understanding and modelling of the photosynthesis–stomatal conductance link to better quantify impacts of enhancing photosynthesis.

## 208

## Modelling orchard light environment

**Dr Neil White**[1,2]

*[1]Department of Agriculture and Fisheries, Toowoomba, Australia, [2] Queensland Alliance for Agriculture & Food Innovation, The University of Queensland, Australia*

The Small Tree High Productivity Initiative seeks to intensify orchard production through higher density plantings. Structural plant modelling is being employed to help understand orchard canopies to provide earlier results than planting systems trials alone. While the goal of crop modelling in most instances is focussed on determining yield in relatively simple and homogeneous crops such as wheat, maize, sorghum, here we need to try and understand how to deal with long-lived, complex canopies where there are significant changes in canopy structure brought about by active management of canopy shape to capture optimal amounts of light.

While Radiation Use Efficiency approaches from crop modelling may hold for each configuration of canopy, the changes that occur as the tree grows means that applying this for novel canopy architectures would need continuous recalibration. This presentation considers the costs and benefits of detailed light modelling and examines a methodology to compare diverse tree architectures at the orchard level. This method provides a way to rank the performance of canopy shapes relative to an industry standard using the concept of Effective Leaf Area. This is the canopy leaf area weighted by the proportion of above canopy radiation for a given location and time of year.

This method allows for any shape to be considered and simulation performed in a timely manner so that candidates for field trials can be prioritised. In the next round of this project, further information about pruning responses and partitioning between fruit and vegetative growth will be collected to enable developmental management models to be run.

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## 209

## Using virtual plants to understand how fruit trees grow

**Dr Inigo Auzmendi**[1], Dr John D. Wilkie[2], Dr Jim S. Hanan[1]

*[1]Queensland Alliance for Agriculture and Food Innovation (QAAFI), The University of Queensland, St Lucia, Australia, [2]Department of Agriculture and Fisheries (DAF), Queensland Government, Wollongbar, Australia*

Apple orchards have experienced a significant increase in productivity in the last 50 years through modifying training systems, tree size and planting densities. Some tropical and subtropical fruit and nut trees could benefit from following a similar approach. Field experiments replicating those carried out in apple might not suffice, because not all species behave in the same fashion. Also, variability might obscure the results of our treatments, since growing orchards under optimal conditions, i.e. no water or nutrient stress, pests or diseases, might be difficult to implement. Improved understanding of how trees grow could be a more efficient approach to increase productivity than trial and error. However, vegetative and fruit growth as well as light interception interact, and separating these factors in the field is not straightforward. Virtual plants or functional-structural plant models simulate the growth of individual organs in the canopy replicating physiological functions and tree architecture. These computational models have been employed for integrating several factors to simulate and understand tree growth. We implemented a virtual macadamia that combined sub-models of light interception, photosynthesis, potential growth of individual organs and inter-organ competition for carbon. Tree canopy architecture measured in the field was used to simulate growth during one season. Our virtual experiments showed how planting density, tree size and shape affected growth and yield at tree and orchard level. It increased our understanding of and supported our hypotheses, and helped to interpret results of field experiments. Our conclusions can be useful for designing future field experiments and orchards.

## 210

## Robotic sensing and acting in protected cropping systems

**Dr Chris Lehnert**[1]

[1]*Queensland University of Technology, Brisbane, Australia*

In this presentation, I will discuss the potential for new methods in robotic sensing and acting aimed at solving problems in the protected cropping industry and what it might look like in the future. In particular, this work will discuss robotic harvesting of indoor crops which offers an attractive solution to reducing labour costs and may lead to new methods for managing crops such as selective harvesting, sorting at the point of pick and better yield estimating. However, robotic harvesting is a particularly challenging task that requires integrating multiple systems such as robotic sensing and dexterous grasping. This presentation will outline a novel method for robotic sensing aiming to tackle challenges encountered in cluttered and unstructured agricultural environments. The method is demonstrated within simulation and on a real robot for a challenging scenario of robotic harvesting in a highly occluded and unstructured environment. We believe this method is a step towards having robots that can operate autonomously in challenging occluded and unstructured environments such as protected cropping systems.

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## 211

## Simulating bee pollination for horticultural applications

**Assoc Prof Alan Dorin**[1]

[1]*Monash University, Melbourne, Australia*

We depend on wild and managed bees for the pollination of a third of fruits, vegetables and nuts for human consumption. Consequently, the details of the interactions between bees and flowers are of utmost concern to growers and seed producers. However, due to the increasing variability of our climate, the loss of bees' natural habitat, the use of pesticides and the industrialisation of agriculture, the interactions between bees and our flowering crops are changing in complex ways. Traditional field trials are one approach helping to establish how these changes are impacting on food production, but these techniques are time-consuming, season-limited, and susceptible themselves to the same rapid and dynamic disruptions the ecosystems are subject to. Instead, we propose an iterative experimental approach, in which detailed computer simulations that predict how best to run field trials, are repeatedly informed by field observations and field trial outcomes. The simulations account for bee species' unique perceptual, behavioural, physiological and morphological characteristics, and realistically model the bees' foraging environments, including open fields, protected crops, and natural ecosystems. We explain how our simulations work, and provide case studies detailing the results of experiments with planting layout to boost pollination. These models lead to improved plant/pollinator interaction management. They have the potential to boost yield, quality, and shelf-life for a variety of crops, to raise food security generally, and to improve the sustainability of our farm and natural ecosystem management practices.

## 212

### From real-time precision mapping to robotic actuation - examples from vegetable and tree crops

**Prof Salah Sukkarieh**[1]

[1]*University of Sydney, Sydney, Australia*

In this talk I will present our work on using low-cost autonomous mobile platforms for the horticulture industry. The technology presented is targeted at delivering low-cost solutions to all growers – giving them access to the technology for their complete cycle of operations. I will present some of the key technologies in making the platform robust for different conditions as well as the farmer interface mechanisms. The presentation will also show results of the platforms in action, within vegetable and tree crop applications to map out individual crops and their features, providing on-demand crop intelligence for farmers. The presentation will also show results of automated crop manipulation activities using robotic tools on the autonomous platform in real time.

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## 213

### The relevance of dominance to genomic selection in breeding clonally propagated plant species

**Dr Christian Werner**[1], Dr Chris Gaynor[1], Dr Gregor Gorjanc[1], Dr Dan Sargent, Alessandra Lillo[2], Prof John Hickey[1]

[1]*The Roslin Institute, University of Edinburgh, Edinburgh, United Kingdom,* [2]*Driscoll's Genetics Ltd., East Malling Enterprise Centre, United Kingdom*

Genomic selection (GS) has the potential to fundamentally revolutionize breeding for quantitative traits in plants. It can enable better use of resources in breeding programs and increases in genetic gain per unit time. We investigated different strategies to implement GS for a trait representing yield in clonally propagated plant species that exhibit diploid genome structure or diploid-like recombination during meiosis, such as a strawberry. Stochastic simulations were used to evaluate genetic gain, changes in genetic variance and inbreeding over 40 years of breeding. The simulated individuals were highly heterozygous, and different degrees of dominance were applied in order to examine the impact of non-additive genetic effects on the accuracy of GS. The GS strategies were compared to a conventional breeding program using phenotypic selection. Cost effectiveness was analysed by constraining all breeding programs to approximately equal annual operating costs. Our results demonstrate that genomic selection of new crossing parents can be disadvantageous under high dominance degrees when selection is based on genomic estimated breeding values (GEBV). However, when genomic optimal cross selection was used to identify the best subset of crosses among all combinations in a half diallel scheme, GS significantly outperformed phenotypic selection regardless of the degree of dominance.

## 214

## Breeding low emitting ruminants: Predicting methane from microbes

**Dr Suzanne J Rowe[1],** Dr Melanie Hess[1], Dr Larissa Zetouni[1], Dr Sharon Hickey[2], Dr Rudiger Brauning[1], Mrs Hannah Henry[1], Dr Holly Flay[5], Juliana Budel[6], Brooke Bryson[4], Dr Peter Janssen[3], John McEwan[1]

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The greatest source of global anthropogenic methane ($CH_4$) emissions is from ruminant livestock. Multiple mitigation strategies in livestock are currently being explored. Of these breeding for lower $CH_4$ emitting ruminants has the advantage of being permanent and cumulative and universally applicable to all classes of livestock. Here, we show that methane emissions can be predicted by the complex community of microbiota sampled from rumens enabling evaluation of systems and individuals. Furthermore, there is evidence that the microbial community is controlled not only be the feed substrate but also by the host itself and that selecting hosts that favour a microbial fermentation with lowered methane emissions changes the energy source to the animal, and in turn both rumen physiology and body composition. Current methods for obtaining microbial DNA and subsequent sequencing of an animal's microbiome, however, are too expensive to implement in commercial selection programs. A methodology that offers fast, low-cost, high throughput profiling of rumen microbiomes using Genotyping-by-sequencing (GBS) has been developed using an unbiased reference free approach to group microbiota. To date, this has been applied to over 4,000 sheep samples and validated in cattle. Results show that microbial profiles are heritable and correlated with methane emissions and feed intake. This research is part of a flagship program funded by the global research alliance to disseminate global access to technologies that lower greenhouse gas emissions in ruminant livestock.

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## 215

## Identifying plants that reduce methane production using an in vitro system - helping the challenge to become C neutral

**Prof Philip E Vercoe[1],** Ms Amriana Hifizah[1,2,3], Dr Joy Vadhanabuti[1,2], Prof Graeme B Martin[1,2], Dr Zoey Durmic[1,2]

*[1]School of Agriculture and Environment, The University of Western Australia, Crawley, Australia, [2]UWA Institute of Agriculture, The University of Western Australia, Crawley, Australia, [3]Department of Animal Science, Faculty of Science and Technology, UIN, Alauddin, Indonesia*

The Australian red meat industry has set a goal to be carbon neutral by 2030. Reaching this goal will be a challenge and will involve targeting ways to increase carbon in the landscape, improve efficiency of production and reduce methane emissions from ruminants. There are a number of different options the industry can pursue to try and achieve its goal, including changing grazing management practices and land-use to changing the animal, what it eats and the microbial ecology in their rumen. No single one of these options will enable the red meat industry to become carbon neutral by 2030, it will take a combination of all of them to help meet the challenge. We have been using an in vitro batch fermentation system and a Rusitec system as a quick, relatively inexpensive, way to screen plants that already exist in our grazing systems, as well as novel plants, plant extracts and organic waste products from the horticultural industry, for their potential to improve the efficiency of fermentation and reduce methane production in the rumen. We have also used these systems to provide an initial clue about the mechanism of action at the level of the ruminal microorganisms. We have identified variation in these traits within species that currently exist in our grazing system as well as novel plants, extracts and horticultural waste products that could help develop systems that reduce the environmental footprint of ruminants in tropical production systems in Australia and in other parts of the world.

## 216

### A novel method to predict high-value traits, including methane emissions and feed efficiency, from rumen microbiome profiles

**Dr Elizabeth Ross**[1]

[1]*Queensland Alliance for Agriculture and Food Innovation; University of Queensland, St Lucia, Australia*

The microbiome is the complex population of microbial species that reside on and within the body. These microbes exist symbiotically with their hosts and are thought to have a significant effect on the host phenotype. In the human body the number of cells that make up the microbiome is 100X larger than the number of human cells. In ruminants the relationship is even more extreme, with more than 300X more bacterial cells than host cells. This is largely due to the presence of the rumen, which is a large chamber of the stomach that has evolved to facilitate microbial fermentation of basic forages. The rumen hosts microbiota including bacteria, archaea and fungi. Evidence that variation in the composition of these species has a direct impact of the animal's phenotype is growing. Information from the microbiome, in the form of sequenced microbiome profiles, can be used to predict an animal's phenotype for rumen centric traits such as enteric methane emissions. Additionally, there is evidence that by combining microbiome profiles with current genomic prediction methods we are able to achieve increased prediction accuracy. This is possibly because examining the rumen microbiome is in effect capturing some of the otherwise unexplained environmental variation present in the population.

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## 217

### Moving from clouds to the microbiome – an animal health perspective

**Dr Lida Omaleki**[1,2]**, Dr Patrick Blackall**[1]**,** Dr Conny Turni[1], Dr Scott Beatson[2], Dr Brian Forde[2]

[1]*Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, St Lucia, Australia,* [2]*School of Chemistry and Molecular Biosciences and Australian Centre for Ecogenomics, St Lucia, Australia*

In this presentation, we will overview how our research group has been seeking to move from a traditional culture based approach to animal health research to the final goal of microbiome-based approaches to animal health. We are using one major bacterial pathogen of animals, the iconic *Pasteurella multocida*, responsible for significant economic losses in all domestic livestock as well as being source of zoonotic infections. Our progression is a staged process in which we are firstly moving to whole genome sequencing of pure cultures. In this intermediate stage, we have been using whole genome sequencing and bioinformatic analysis to help understand the epidemiology of disease outbreaks caused by *P. multocida* in meat and laying chickens, captive seals and squirrel gliders. We are also using this bridging stage to provide far deeper and more relevant insights into the key immunogens present in outbreaks strains allowing us to provide rapid and specific advice on the best vaccines for use to control outbreaks of pasteurellosis. This bridging stage has clearly shown that infections associated with this organism involve a "cloud" of isolates and not a single strain. Our work demonstrates high levels of population diversity within individuals, between individuals and over time, which underlines the need for a microbiome type approach. A microbiome type approach would allow a recognition of the diversity in key immunogens present in an outbreak and also the presence of antimicrobial resistance genes.

## 218

## The genetics of rumen phage populations

**Dr Rosalind Gilbert**[1,2], Ms Diane Ouwerkerk[1,2]

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The microbial populations of the rumen are widely recognised as being essential for ruminant nutrition and health, utilising and breaking down fibrous plant material which would otherwise be indigestible. The dense and highly diverse viral populations which co-exist with these microbial populations are less understood, despite their potential impacts on microbial lysis and gene transfer. In recent years, studies using metagenomics, metatranscriptomics and proteomics have provided new insights into the types of viruses present in the rumen and the proteins they produce. These studies however are limited in their capacity to fully identify and classify the viral sequence information obtained, due to the absence of rumen-specific virus genomes in current sequence databases. The majority of commensal viruses found in the rumen are those infecting bacteria (phages), therefore we genome sequenced phage isolates from our phage culture collection infecting the common rumen microbial genera *Bacteroides, Ruminococcus* and *Streptococcus*. We also created a pan-genome using 39 whole genome sequences of predominantly livestock-derived *Streptococcus* isolates (representing *S. bovis, S. equinus, S. henryi,* and *S. gallolyticus*), to identify and characterise integrated viral genomes (prophage sequences). Collectively this approach has provided novel rumen phage sequences to increase the accuracy of rumen metagenomics analyses. It has also provided new insights into how viruses or virus-encoded proteins can potentially be used to modulate specific microbial populations within the rumen microbiome.

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## 219

## Innate variability in animal performance and rumen microbiota across seasonal changes in a northern Australian grazing system

**Dr Stuart Denman**[1], Dr Gonzalo Martinez Fernandez[1], Dr Ed Charmley[2], Dr Greg Bishop-Hurley[1], Dr Paul Greenwood[3], Dr Chris McSweeney[1]

*[1]Commonwealth Scientific and Industrial Research Organisation (CSIRO), Brisbane, Australia, [2]Commonwealth Scientific and Industrial Research Organisation (CSIRO), Townsville, Australia, [3]NSW Department of Primary Industries, Armidale, Australia*

In the grazing animal, efficiency is a function of how effective the animal can harvest the feed resource, the optimum rumen fermentation conditions and the genetic potential of the animal for intake and growth. All of these aspects are interdependent and influenced by many variables. Thus, improving cattle feed efficiency is not trivial. The northern Australian grazing system is highlighted by a dry winter season with poor quality fed followed by a wet summer season with relatively higher quality forage material. A grazing herd of 90 composite *Bos indicus* X *Bos taurus* animals were monitored for 18 months across multiple dry and wet seasons. Average daily weight gains (ADWG) were collected in real time using walk over weighers (WoW) to monitor live weight change throughout the trial. Animal rankings based on ADWG were not consistent across seasons. Rumen fermentation and microbiota parameters were significantly affected by seasons and quality of feed, with observed increases in the volatile fatty acid (VFA) average chain length (ACL), Acetate:Propionate, Butyrate, branched chain VFAs and ammonia between the dry and wet seasons. Total VFA measurements were observed to be lower in better performing animals and during the wet season. Bacterial species assigned to Bacteroidetes and Butyrivibrio were relatively more abundant in the wet season but lower in the better performing animals, while Firmicutes were lower in the wet season and higher in lower ranked animals. Fibrobacter and Ruminococcus species were relatively less abundant in the wet season when the animals were on better quality forage.

## 220

# Diversity breeding program on common bean (Phaseolus vulgaris L.) targeting rapid cooking and iron and zinc biofortification

**Dr Clare Mukankusi**[1], Professor Wallace Cowling[2], Professor Siddique Kadambot[2], Mr JeanClaude Rubyogo[1]

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Common bean *(Phaseolus vulgaris L.)* is a major component of agricultural systems and diets of the urban and rural populations of East and Central Africa, providing Fe and Zn essential to the health and well-being of African women and children, and protein essential for the entire household. However, bean consumption is limited by constraints such as long cooking time (CT). Cooking demands large amounts of water, fuel and time. It has negative effects on the environment, livelihoods, security and health. Genetic variability in cooking time is documented. Recent development of new breeding methods based on pedigree and genomic selection together with optimal contribution selection (OCS) offers an opportunity to accelerate breeding for rapid CT and higher Fe and Zn grain content. Genotypic and phenotypic data of an African diversity pool, representing key bean market classes, were used to generate genomic estimated breeding values (GEBVs) for grain yield, CT, Fe and Zn. GEBV's were weighted to maximise the desired outcome in an economic index. From 161 candidate bean genotypes with GEBVs, 67 were chosen for 80 matings within six major grain market classes. An additional 22 breeder nominated matings were included. The predicted outcomes in the first cycle showed a major improvement in population mean for index (+286.77 US$/ha), 6.2% increase in GY and 7.3% reduction in CT, with an achieved increase in population co-ancestry of 0.0753. A 30% reduction in the mean population CT and improved Fe (15%) and Zn (10%), is expected after 5 cycles of annual recurrent selection.

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## 221

# Meta-analysis of genome wide association studies for pre-breeding in agricultural crops

Dr Noel Cogan[1,3], Dr Mulusew Fikere[1,3], Ms Denise Barbluescu[2], Dr Sally Norton[2], Dr Surya Kant[2], Dr Michelle Malmberg[1,3], Dr Josquin Tibbits[1], Dr German Spangenberg[1,3], Dr Matthew Hayden[1,3], **Dr Hans Daetwyler**[1,3]

[1]*Agriculture Victoria, Bundoora, Australia,* [2]*Agriculture Victoria, Horsham, Australia,* [3]*La Trobe University, Bundoora, Australia*

Genome-wide association studies (GWAS) associate genetic markers with phenotypes, and, thus, provide information on important genomic regions for key breeding traits. In contrast to linkage mapping studies, GWAS work better in diverse germplasm with lower linkage disequilibrium levels, because this allows for more precise mapping. The Australian Grains Genebank contains diverse collections for the major Australian crops, including wild relatives, landraces, and breeding cultivars. We have genotyped and phenotyped diverse populations to underpin genomic selection and gene dissection in wheat, canola, safflower, and pulses. These genotyping datasets are deeply characterised with whole-genome or exome sequencing, which, together with imputation, allows for a high-resolution genomic mapping. GWAS can also be collectively analysed in a meta-analysis to increase the power on analyses. One such meta-GWAS approach combines GWAS summary statistics (marker effects and standard errors), which makes it easy to implement. Meta-GWAS is particularly useful to combine different pre-breeding experiments, which could include data from across the globe or historical data. Furthermore, the meta-analysis can integrate different traits altogether to provide information on genomic regions affecting multiple traits, possibly due to pleiotropy. A meta-GWAS example will be presented for canola blackleg disease, where meta-analysis was found to be more powerful leading to an increased number of detected regions and higher validation rates across years.

## 222

## The diverse functions of prussic acid in Australia's native sorghums: Lessons for domestication

**Prof Ros Gleadow**

*Monash University, Australia*

Prussic acid poisoning of cattle may occur when animals are allowed to graze on *Sorghum bicolor* that is young, heavily fertilised or during periods when temperatures are high and water availability is low. This is due to the accumulation of the cyanogenic glucoside, dhurrin. All domesticated species of sorghum have the capacity to make high concentrations of dhurrin in the leaves. By contrast, the 15 wild relatives of sorghum that are native to Australia contain very low concentrations. This natural diversity provides a powerful system to investigate the selective pressures that may have led to the evolution of this widespread phenomenon. Whole genome sequencing of these crop wild relatives together with ecophysiological studies are shedding new light on links with geographic origin, domestication, drought tolerance and nitrogen management.

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## 223

## Potential use of Australian crop wild relatives in agriculture and food production

**Prof Robert Henry**[1]

[1]*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Brisbane, Australia*

Australia has extensive populations of crop wild relatives. Many of these have the advantage of evolving in isolation from the production of domesticated crops and not being contaminated by gene flow from crop varieties. The Australian relatives of rice *(Oryza)*, sorghum *(Sorghum)*, soybean *(Glycine)*, mungbean *(Vigna)* and pigeon pea *(Cajanus)* are widespread and of major importance. Wild relatives of coffee, grape, citrus, macadamia and banana are also important resources for crop improvement. Genome sequencing is assisting the accelerated evaluation of the diversity and utility of these populations. The relationships between Australian wild plants and domesticated species are being better defined and novel alleles of value in crop breeding identified. This should result in greater utilization of Australian genetic resources in crop improvement. Strategies for improved in situ and ex situ conservation of these plant resources are required.

## 224

## Evolving gene banks – a continuously-improving genetic resource for crop breeders

**Prof Wallace Cowling**[1]

[1]*The University of Western Australia, Perth, Australia*

One of the greatest concerns for the future of crop breeding is the lack of genetic diversity for future genetic progress in elite crop breeding programs. This limits the efficiency of genomic selection and potentially imposes a premature plateau on future genetic performance. In contrast, there is large genetic diversity in crop wild relatives and landraces in genebanks, largely unknown and not readily available to breeders. In this paper, I propose a system of breeding with wild relatives and landraces in evolving gene banks. In this system, new genetic diversity will be introduced into a pool that may be linked by pedigree and genomic information into elite crop breeding programs. Evolving gene banks will have large effective population size, and will undergo long-term genetic improvement for an economic index based on multiple economic traits with the aid of optimal contributions selection. Evolving gene banks will be a public resource that is available for exploitation by commercial crop breeders.

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## 225

## Challenges of collecting and preserving crop wild relatives

**Dr Sally Norton**[1]

[1]*Australian Grains Genebank, Agriculture Victoria, Horsham, Australia*

Plant breeders need as much diversity as they can get to develop the more productive, resilient and nutritious varieties that are needed to feed the growing world population under pressures such as reduced arable land and the expected effects of climate change. Through history much of this genetic diversity has been provided by landrace and heirloom varieties, however, a much wider diversity of traits exists within crop wild relatives (CWR), the cousins of cultivated crops. The successful use of CWR is dependent on their availability for research from genebanks, and the subsequent information on the traits they can provide to plant breeders. There are significant challenges in both collecting CWR from the wild and in conserving them outside of their natural environments in *ex-situ* genebanks. In Australia, CWR are predominantly spread across the tropical regions of northern Australia in environments that are challenging in terms of their associated flora and fauna, seasonal conditions and accessibility. Once CWRs are conserved into genebanks, the challenge is to maximise their longevity when at times little is known about their seed storage behaviours or how to successfully grow them to produce viable seed. The Australian Grains Genebank has collections of many of Australia's CWR related to grain crops, and through trial, error and some luck have developed successful protocols for both making new collections from the wild, and in conserving them for future use as sources of valuable traits for plant breeding.

## 226

## Black soldier flies for waste recycling and protein: Livestock for livestock

**Dr Peter James**[1]

*[1]Queensland Alliance for Agriculture and Food Innovation (QAAFI), The University of Queensland, Dutton Park, Australia*

World population is predicted to reach 9.5 billion and global consumption of animal protein is expected to increase by 60-70% by 2050. Competition for high quality protein, such as fishmeal, is increasing costs for livestock and aquaculture feed and cost pressures will increase markedly in the future. In addition increasing intensification of plant and animal agriculture to meet these demands is generating ever-larger issues with waste disposal. Insects are nature's recyclers and there is growing recognition of the potential that insects offer as alternative protein and energy sources for livestock and human food. A number of insect species are being investigating for this use and prominent among them is the black soldier fly (BSF), *Hermetia illucens.* This species can efficiently utilise a wide range of organic wastes, provides high quality protein suitable for incorporation in livestock and aquaculture diets and has attributes that make it well suited for mass production. However, commercial insect production in Australia is in its infancy and a substantial research effort will be required to assist the development of a profitable and sustainable insect farming industry. Farmed insects can be functionally considered as livestock and the development of profitable and sustainable insect production systems will require attention to similar areas to those of importance on traditional livestock enterprises. This presentation will take a livestock production perspective on insect farming and briefly consider research needs in areas including reproduction, nutrition, genetics, management/production systems, products and markets, food safety and societal factors.

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## 227

## Insect farming is here, but are we ready for it?

**Ms Olympia Yarger**[1], Dr Rob Barwell[2]

*[1]Goterra, Canberra, Australia, [2]Animal Health Australia, Canberra, Australia*

Insect farming is emerging as a significantly fast moving industry globally, and Australian insect farms are commencing commercialisation. Insect protein for both human consumption and livestock feed are expected to see 100% growth over the next two years. And the Insect Protein Association of Australia has seen a 500% growth of companies and retailers entering the space over the last 2 years. With both markets predicted to be valued at +1 Billion globally by 2020. Rapid growth and development of this industry is creating biosecurity and quality assurance challenges that warrant attention. As this industry continues to grow, the regulations and best practices that underpin any new industry are also emerging. Insect farms attempting to scale production without cohesive industry or governmental guidance relative to best practice or quality assurance are experiencing challenges meeting government and other stakeholders' questions

The IPAA has begun work with other international associations to develop a global best practice of farming insects for human food and livestock feed. Furthermore the IPAA is creating comprehensive Best Practice, Production Guidelines and Biosecurity management plans for Australian based insect farms. These plans and guidance are informed through work with relevant state and federal bodies, Animal Health Australia and several international research bodies.

There are inherent challenges in identifying potential issues in such a new industry. To help mitigate this, the Association has taken meaningful steps to deliver on biosecurity and quality assurance questions. Of note, the Association has submitted samples of Black Soldier Fly (BSF) to an international DNA sequencing project. This data and subsequent sequenced DNA, will provide opportunities to detect incursions and discourage illegal imports of BSF.

How the IPAA delivers on its mission of creating biosecurity best practice for the Australian insect protein industry will be pivotal to its ability to meet the ever growing demand for insect proteins in Australia. Our work is relevant to the continued protection of Australia's biosecurity and the future proofing of an industry's integrity.

## 228

## Insect nutrition, feeding and artificial diets

**Dr Elsje Pieterse**

*Department of Animal Sciences, Faculty Agrisciences, Stellenbosch University, Stellenbosch, South Africa*

Insect mass rearing has, for a very long time, been within the domain of entomologists. As such the physiology and biology of the mass reared species have been sorted out brilliantly. One area which has always been lacking is the area of nutrition. Since the mass rearing of insects have been largely based on the production of insects for integrated pest management, and the value of the individual insect far exceeded the cost of production, the efficiency of feed utilisation has not been as important as it is in the field of animal sciences, where animals are produced for food production. In recent years there has been a shift in the purpose of insect mass rearing and feed conversion ratios or conversion rates have become increasingly important. In order to feed animals closer to their requirements it is necessary to determine the nutrient requirements of the animals. Three methods for doing such is described. Further cognisance should be taken of stimulants and deterrents, anti-nutrients, toxins and physical characteristics of the diet. Methods, successes and challenges with diet development of the false coddling moth (*Thaumatotibia leucotreta*), sugarcane stalk borers (*Eldana saccharina & Chilo sacchariphagus*), meal worms (*Tenebrio molitor)*, black soldier fly (*Hermetia illucens*) and cocoa pod borer (*Conopomorpha cramerella*) is discussed. Further the use of certain species as models for the mass rearing of other species is also discussed (i.e. the silk worm (*Bombyx mori*) as model for the mass rearing of the mopani worm (*Gonimbrasia belina*)).

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## 229

## Nutritional value of black soldier fly grown on abattoir waste

**Dr Luis F.P. Silva**[1], Dr Geoff W. Brown[2], Dr Peter J. James[1]

[1]*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), St Lucia, Australia,* [2]*Department of Agriculture and Fisheries, Dutton Park, Australia*

Meat processing plants generate a range of solid and liquid wastes, including manure, paunch solids, and biological solids from wastewater treatment. There is growing interest in alternative technologies for treating abattoir waste, including using insects to transform waste into high-value products. Black Soldier Fly (BSF) larvae may be a competitive source of digestible amino acids and, depending on the protein digestibility, can be used as a replacement for fish meal, soybean meal or cottonseed meal in livestock and aquaculture rations. The objective of this study was to evaluate the effect of using different substrates and substrate mixes from abattoir waste streams on the nutritional quality of BSF harvested at two growth stages (larvae and prepupae). Protein digestibility was evaluated using an adapted pepsin digestion. Averaged across all substrates, there was no difference between growth stages in total protein content (43.7%). However, protein digestibility was higher for larvae (86.5%) than for prepupae (65.1%). The substrate used greatly influenced the nutritional composition of BSF. Prepupae protein content varied from 42 to 48% and protein digestibility varied from 42 to 80%, according to the substrate. Variation in larvae across substrates was greater than prepupae for protein content (34% to 53%) but much lower for digestibility (80% to 91%). Both substrate and growth stage altered the mineral composition of BSF prepupae and larvae. Iron levels varied from 79 (paunch) to 453 mg/kg DM (substrate containing blood), illustrating the plasticity of BSF. In conclusion, BSF can be used to transform abattoir waste into high-value products.

## 230

## Impact of insect larvae on meat quality

**Prof Louwrens Hoffman**[1]

[1]*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Brisbane, Australia*

The use of the black soldier fly (BSF: *Hermetia illucens*) as a means of upstreaming waste has enjoyed increasing research the past few years. One of the uses of the resultant larvae is as animal feed, with particular success achieved when fed to mono-gastric animals. Most of the research has been on the use of BSF as feed in poultry and fish species. In poultry, larvae were produced on abattoir waste, kitchen waste or faecal matter (human and animal manure). The insects were grown until harvest as larvae, pre-pupae or pupae. The post-harvest processing included freezing, drying and/or milling. Where the poultry were fed Iso-nitrogenous/ Iso-energetic diets containing various proportions of BSF, no differences in production performance or carcass yields (breast-, thigh-yields) were found. As pertaining to meat quality, no differences for initial pH or ultimate pH of the meat were noted. Differences for breast colour measurements were found; larvae fed chicken breast meat was generally lighter and redder whilst results on the breasts' water binding capacity was inconclusive. For sensory attributes, no differences were observed except for juiciness and sustained juiciness. Sometimes a metallic flavour was noted, particularly on larvae fed on abattoir wastes. Manipulating the larvae's diet as a strategy to change the chemical composition of the poultry has focused on attempts to change the fatty acid profiles and yielded mixed results; irrespective of the fatty acid profile, the fat of BSF larvae contains large amounts of lauric acid; known to have profound antiviral and antibacterial activity.

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## 231

## Enzymatic fractionation of protein, fat and chitin from Hermetia illucens (L.) (Diptera: Stratiomyidae)

**Mr Michael Woods**[1], Prof Louw Hoffman[1,2], Dr Elsje Pieterse[1], Dr Neill Goosen[1]

[1]*Stellenbosch University, Stellenbosch, South Africa,* [2]*University of Queensland, Brisbane, Australia*

Insects have the ability to convert biowaste into valuable functional compounds, such as proteins, fat and chitin. Currently, unlike with conventional commodities, there are few fractionation methods to isolate these compounds for diversification of use. Enzymatic hydrolysis is a possible method to fractionate *Hermetia illucens* larvae, into protein, fat and chitin. This method is a particularly attractive due to the milder process conditions required compared to chemical methods, the relative ease to control the reaction and minimal formation of unpalatable and toxic by-products. A central composite design was used to help identify the optimum hydrolysis conditions for fractionation. At these conditions the fat recovery was ~ 81 %; substantially more than previous attempts and the fatty acid profile stayed unchanged from the original larvae material. The protein solubility was ~ 57 %, with a degree of hydrolysis of ~ 22 %, and was on par with previous studies. The amino acid profile of the soluble proteins differed from the original larvae material with a slight decrease in the ratio of essential to total amino acids. The insoluble proteins were accounted for with the chitin. A washing-and-sieving step, as means to recover the insoluble proteins from the chitin is envisaged. Also, the spray drying of the protein hydrolysate produced and its functional properties allows for future investigation. This technology allows for higher margins to be made, both environmentally as well as financially, compared to the use of the 'intact' biomass.

## 232

## The confluence of drivers of change on the emergence, re-emergence and geographic redistribution of pathogens and pests

**Dr James P Stack**

*Kansas State University, USA*

Abstract not available at time of publication

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## 233

## Yellow Canopy Syndrome: A physiological disorder not a disease

**Dr Frikkie Botha**[1]

[1]*Sugar Research Australia, Indooroopilly, Australia*

In 2012 unprecedented yellowing of sugarcane occurred in the Australia. The yellowing started within the mid-canopy and was described as Yellow Canopy Syndrome (YCS). The development of YCS symptoms is a physiological disorder due to a source sink imbalance resulting in sucrose accumulation in the leaf. There is a significant correlation between sink size and the severity of YCS expression. The failure to export sucrose is not linked to inadequate phloem loading. At the early stages of sucrose build-up primarily photosystem II in the mesophyll chloroplasts is affected with most of the genes of the components of PSII downregulated. This is indicative of a reduction of electron flow through the ETC and increased ROS production due a reduction in CO2 fixation in the cytosol of the mesophyll cells and accumulation of phosphorylated intermediates. Damage is minimized by a redirection of triose phosphate to Ð-glucan, the phenylpropanoid pathway and ascorbate synthesis. Accumulation of the Ð-soluble glucan is most noticeable in the midrib and leaf sheath. In the absence of a strong sink demand the midrib and leaf sheath becomes an important sink ensuring some electron flow through the photosystems. However, once the 'new sink' is filled sucrose build-up suppress chloroplast metabolism in all compartments. This results in uncoupling of the photoreaction centres from electron transport, stomatal closure, elevated leaf temperatures, accelerated senescence and rapid cell death. There are many know abiotic and biotic factors that will cause a prolonged reduction in sink strength in sugarcane and hence it is highly unlikely that YCS has a single cause. The data suggest that induction of YCS is most likely at the time in the season with peak irradiance.

## 234

# Current understanding of grain legume disorders in eastern Australia and association to phytoplasma infection

Dr Graeme Wright[3], **Dr Murray Sharman[1],** Mr Hugh Brier[2], Dr Peter Vukovic[1], Dr Fiona Filardo[1], Mr Steve Krosch[2]

*[1]Department of Agriculture and Fisheries, Queensland Government, Brisbane, Australia, [2]Department of Agriculture and Fisheries, Queensland Government, Kingaroy, Australia, [3]Peanut Company of Australia, Kingaroy, Australia*

In recent years there have been outbreaks of phytoplasma in a number of grain legume crops throughout the northern grains production region of New South Wales and Queensland, particularly in mung bean, peanut, soybean and pigeon pea. Phytoplasma are specialised bacteria that infect the phloem cells of plants, and are spread from plant to plant by insect vectors, such as leaf hoppers.

In late 2016 and early 2017, mung bean crops were affected in all major production areas. Many crops had greater than 40% disease incidence on the Darling Downs. Devastating disease outbreaks in several soybean crops from the same region were also associated with phytoplasma infection. Almost 100% of plants were affected in some paddocks with 200 ha of crop producing virtually no yield.

Strange fruit symptoms such as shrivelled, discoloured seeds in peanuts (typical of "peanut kernel shrivel - PKS" disorder) and puffy pod in mung beans appear to be associated with phytoplasma infection.

To our knowledge, these have been the most significant, widespread outbreaks of phytoplasma in broad acre crops to occur in this region of Australia. It is unclear what the underlying reasons are for this sudden increase in disease incidence in recent years and the decrease in the current season.

This paper will cover our recent investigations into the diversity and host range of phytoplasma from recent disease outbreaks in eastern Australia and association between phytoplasma and grain legume disorders.

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## 235

# Understanding of dieback in grass-pastures across Queensland

**Mr Stuart Buck[1]**

*[1]Department of Agriculture and Fisheries, Queensland Government, Rockhampton, Australia*

Pasture dieback is a condition currently causing death of a range of sown and native pastures across more than 200,000ha of Queensland's productive grazing lands. Observations have occurred from the Atherton Tablelands in north Queensland, throughout eastern Queensland to the south-east corner of the state. Pastures affected by this condition are rendered unproductive, leading to significant financial stress for affected graziers.

The current dieback event was first observed around 2012 where buffel grass *(Cenchrus ciliaris)* and creeping bluegrass *(Bothriochloa insculpta)* were initially impacted across large areas of central Queensland and Burnett districts respectively. Now, almost every sown grass species found in Queensland has been affected. Prior to this current outbreak, pasture dieback was reported between 1993-4 mainly in buffel grass across central Queensland. Despite research studies at that time, the causal agent(s) were unable to be identified. Recent studies are still inconclusive but there are indications mealy bugs may have a role.

Dieback in pastures is a complex condition. Similar symptoms in grass-pastures across Queensland have been reported previously however confirming similarities has been problematic. Further, establishing consistent symptoms has also been difficult due to inconsistencies derived from the interaction of immediate and past seasonal conditions together with landscape and grazing management. Investigations into potential causes and management solutions have been conducted, or are underway, with mixed results. Continuing research is required to confirm the causal agent(s) and determine effective management options to restore productivity.

## 236

## Smart surveillance to support plant biosecurity

**Dr Brendan Rodoni,** Mark Blacket, Rachel Mann, Linda Zheng, Piotr Trebicki, Fiona Constable

*Agriculture Victoria, Victoria, Australia*

Many pest and disease surveillance programs that have been initiated and established in recent times have failed beyond the initial research investment due to the high labour costs in sorting and identifying the biological specimens collected. An additional and chronic bottleneck for an informative and effective surveillance program is the investment in training of diagnostic staff required to accurately identify the organisms that are collected on a week to week basis. New technology is transforming diagnostic capability and capacity for the detection of pests and diseases and when properly designed can improve the speed, sensitivity and specificity of early detection. These advanced methodologies enable in-field detection and triage of pests and pathogens, enable rapid responses to outbreaks and facilitate the delivery of meta-scale surveillance programs. Working at scale, minimises labour inputs and can support large programs of emergency response or surveillance programs required for eradication and containment programs, or for evidence of absence data to support market access protocols. Technologies such as Loop-mediated isothermal amplification (LAMP) for in-field detection to support surveillance and triage activities as well as metabarcoding and metagenomic approaches to support surveillance programs will be discussed.

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## 237

## From colony collapse to complex syndromes: Pollinator health and disease transmission management in agricultural landscapes

**Dr Vincent Doublet[1,2],** Toby Doyle[2], Prof. Mark Brown[3], Prof. Lena Wilfert[1,2]

*[1]University of Ulm, Institute of Evolutionary Ecology and Conservation Genomics, Ulm, Germany, [2]University of Exeter, College of Life and Environmental Sciences, Penryn, United Kingdom, [3]Royal Holloway University of London, School of Biological Sciences, London, United Kingdom*

Insect pollinators, including wild bees, have suffered from recent declines in their worldwide populations; bumble bee community diversity has decreased and geographical ranges of solitary bees have shrunken. Honey bees *(Apis mellifera)*, the most important commercially managed pollinator, have suffered from high colony mortality, including colony collapse disorder (CCD), over-winter or seasonal colony losses. Many factors are suspected to have a detrimental impact on pollinator health, including direct anthropogenic pressures (fragmentation of habitats, loss of foraging resources and the use of pesticides) as well as the spread of parasites and pathogens. Horizontal transmission of infectious diseases is determined by the hosts' contact networks, but environmental variables that define the probability of contacts between individuals have been largely neglected in models studying epidemiology of wildlife diseases. I will present our recent work where we used insect pollinators to study the role of contact networks in a real-life multi-host pathogen community. We constructed high-resolution plant-insect visitor networks from ten farms in Southern England and sampled the most abundant pollinators to characterize their virome by deep transcriptome sequencing. We found that flower density and diversity strongly define pollinator density and foraging behaviour, and influence the structure of contact networks among pollinators. We combined environmental data and sequencing to reveal the impact of plant-pollinator interactions on virus dynamics in insects. Overall, we aim to identify ecological factors that significantly enhance the transmission of plant and pollinator diseases, to improve conservation programs with the ultimate aim of securing pollination as an ecosystem service.

## 238

## Yield forecasting using remote sensing in vegetables

**Dr Luz Angelica Suarez Cadavid**[1]

[1]*University of New England, Armidale, Australia*

Yield forecasting and yield mapping of root crops allows growers to better understand and then manage yield variability as well as form more accurate decisions around harvesting logistics and the forward selling of product. Currently there are few commercial yield monitors available for carrot growers and as such, remote sensing technologies may be a useable surrogate. As well as yield forecasting, satellite based remote sensing can be used to measure crop performance at key developmental crop stages, providing valuable information of crop health and potential incidences of weeds, pest, disease, nutrition and irrigation constraints. However, the application of this technology in vegetables and particularly root crops such as carrots is limited. This presentation will evaluate the potential of satellite multispectral sensors for measuring the spatial and temporal variably of carrot health as well as for forecasting yield. Yield forecasting algorithms were developed over several seasons in some of the principal vegetable growing regions in Australia with overall accuracies of up to 95% achieved at the field level. Better understanding of the relationship between the reflectance response and the carrot canopy is now available. Yield forecast and yield variability maps quantifying productivity (t/ha) were provided to growers, enabling them to have a greater understanding of yield variability and the degree of waste carrots produced across their farms.

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## 239

## Using precision information technologies to understand crop variability

**Miss Celia van Sprang**[1]

[1]*Department of Agriculture and Fisheries, Queensland Government, Gatton, Australia*

Adoption of precision agriculture (PA) technologies in the Australian vegetable industry remains limited. A national collaborative project led by the Department of Agriculture and Fisheries has established a series of case study sites across the country implementing a range of PA technologies (soil mapping, crop sensing and variable rate (VR) technologies) with a focus on field management outcomes.

Case study sites had previously exhibited anecdotal or visible variability in crop performance in terms of either growth, yield and/or maturity. Remotely sensed satellite imagery was employed to assess and quantify spatial variability on farm and the imagery classified with NDVI. Subsequent yield assessments from one case study identified a 30% reduction in low vigour areas across 30% of the field. In other cases, EM38 and Veris® soil mapping technologies, combined with in field ground truthing, have distinguished variability due to soil texture and constraints such as low soil pH, salinity and sodicity. VR lime application has improved low and variable soil pH from a range of pH 5.5-6.6 to pH 6.5-6.8.

Determining and understanding the underlying factors contributing to in-field variability is critical to informing management interventions that will minimise the subsequent impact on crop performance. A selection of these case studies will be discussed, including the technologies implemented, management outcomes and cost comparisons, highlighting the applicability of PA to the vegetable industry. The growers involved in the case study sites have already identified and planned their next steps on their journey to adopting PA, a key outcome of this project.

## 240

# Application of precision agriculture techniques and variable rate technology in horticultural production in north Queensland.

**Mr Chris Monsour**[1]

[1]*Prospect Agriculture Pty Ltd, Bowen, Australia*

Horticulture is one of the fastest growing agricultural industries in Australia with the greatest opportunity for horticultural expansion in Northern and tropical Australia. North Queensland is particularly attractive for horticultural diversification and expansion with the availability of water and land, the diversity in landscapes and climate, and opportunities for transport infrastructure. Intensive horticultural production in North Queensland presents significant challenges in environmental stewardship and resource efficiency. On the edge of the Great Barrier Reef, North Queensland growers are adopting new technologies to improve soil and crop health outcomes while reducing agricultural impacts on sensitive habitats. Precision agriculture (PA) is still a relatively new practice in horticulture but two North Queensland growers have proven adoption benefits of PA and Variable rate technology (VRT). Soil mapping using electromagnetic sensors and strategic soil cores allow growers to identify yield limiting areas of farmland. VRT tools apply soil ameliorants exactly where they are needed in the field and in the first year, this practice reduced production costs by up to $239/hectare. Over three years the effect of sodicity on vegetable crop yields was reduced by 20%. As technology becomes more affordable, growers seek to use it to maximise efficiency and profitability of their land and has led to the need for local, micro-climatic data. Automatic weather stations capable of alerting growers to real-time changes in weather conditions were installed at strategic locations within the Bowen horticultural production area to refine farm management practices, such as irrigation, fertigation and chemical application within optimal timeframes.

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## 241

# Adoption of precision information technologies: The grower's journey

Abstract not yet provided

## 242

# Drones for more vegetables - pathways to a commercial reality

**Mr Nathaniel Parker**[1], Mrs Julie OHalloran[2], Ms Celia vanSprang[2]

*[1]AirBorn Insight, Glenvale, Australia, [2]Queensland Department of Agriculture and Fisheries, Gatton, Australia*

Despite advances in drone platforms, flight automation and the sensors/cameras drones carry, the on-ground reality is that there are few examples of using drones for advanced decision making in vegetables at the commercial scale.

The Department of Agriculture and Fisheries and AirBorn Insight have been working for over three years in assessing the capacity of drone tech to advance decision making in vegetables. We have been using the latest sensors and drone platforms and analytical tools to assess the capability of this technology to add significant value to vegetable farming.

There is an exciting potential for drones in this industry, not only to support agronomic decision making, but also harvest scheduling, market forecasting and client/community engagement. Despite these potential benefits, it seems that the barriers to adopting drone technology still outweigh the benefits. This is evidenced by the irregular use of drones on farms, poor understanding of the data needed, and how to integrate this information with farm practises.

Key value adds for the industry we have been working toward include:

1. Developing 'vegetation health maps' to inform scouting and integrating this with farm management practices so this data is used day to day.
2. Crop counting and crop size distribution maps for crop plantings, which will better inform harvest timing and location, product application and market forecasting.

This presentation will discuss what works, current barriers and our learnings as we move toward drone technology for advanced decision making in vegetables.

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## 243

# Challenges and opportunities for PA adoption in vegetables

**Dr Julie O'Halloran**[1]

*[1]Department of Agriculture and Fisheries, Queensland Government, Gatton, Australia*

The Department of Agriculture and Fisheries is currently leading a national project directed at increasing the adoption of precision agriculture (PA) technologies in vegetable systems. The reality of PA adoption is that it time intensive with obstacles in accessing and interpreting data, technology and software incompatibilities and access to services and support. While PA adoption in vegetables is still limited, the national scope of this work highlighted differences between Australian states, with Queensland and Tasmania significantly more developed in awareness, understanding and implementation of PA technologies and more connected to a PA service provider network. With high literacy in PA very little support was needed for co-operators to advance their PA practices. In other regions, strategies focused on facilitating linkages between growers and PA service providers including increasing exposure of service providers previously associated with pastures, grains and viticulture to the vegetable sector. While this fostered linkages, it also highlighted the lack of regional PA service providers and inexperience in applying these technologies to vegetable systems. Obstacles associated with PA have undoubtedly hindered PA adoption, however, perseverance at the individual grower level is achieving successful implementation of these technologies and elevating these growers to industry leaders. Facilitation and development of a PA 'community of practice' for the vegetable industry is an outcome of this work. This community of practice will facilitate continued peer-to-peer learning and support for leading PA adopters and future adopters. It also provides researchers with opportunities to propose and test precision technologies and farming system approaches.

## 244

## The outlook for global scarcity of phosphorus reserves for agriculture

**Assoc Prof Brent Jacobs**[1]

[1]*University of Technology Sydney (UTS), Ultimo, Australia*

There is global recognition that society is vulnerable to continued use of scarce mineral P resources in food production. In addition, marine and freshwater ecosystems are being pushed to the brink of collapse through P leakage from agriculture and wastewater to the environment. Despite this, global phosphorus inputs to cropland are projected to nearly double by 2050 from a 2010 baseline of 14.5TgP/yr. Much of this increase will be driven by ongoing population growth and changes in land use through the expansion of crop and livestock agriculture. Based on recent trends, these changes are likely to be significant in tropical regions of the world (Latin America, Sub-Saharan Africa and East Asia). At national and sub-national scales, efforts to address P vulnerability vary. In some countries/regions multi-actor platforms (MAP) are established to engage a broad range of stakeholders in circularising the phosphorus economy (e.g. USA, Europe, Ireland). In the UK, the RePhoKUs project is exploring food system vulnerability to potential P disruption at farm, catchment and national scales. While the need for a new generation of multi-disciplinary researchers to seek solutions to P vulnerability is currently recognised that span the science-policy nexus, in many instances (e.g. Australia) policy responses lag the concerns of the research community.

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## 245

## Phosphorus in northern Australian soils supporting pastures or grain cropping

**Prof Michael Bell**[1], Mr Gavin Peck[2], Dr David Lawrence[2], Associate Professor Chris Guppy[3]

[1]The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Gatton, Australia, [2]Department of Agriculture and Fisheries, Toowoomba, Australia, 3University of New England, Armidale, Australia

Surface stratification of soil phosphorus (P) reserves, highly variable rainfall and a reliance on stored soil moisture accumulated during a short wet season or extended fallows result in intermittent access to available P by crop and pasture plants. Plant P supply issues are accentuated on soils with a history of rainfed cropping where extended periods with negative P budgets have depleted P reserves and minimum or zero tillage has increased surface P stratification. As these degraded soils become uneconomic for cropping they are typically returned to pasture, but pasture quantity and quality are typically constrained by nitrogen (N) and the ability to establish a persistent legume component to address the N limitation is hindered by low P.

In cropped soils, low P supply is addressed through banding ammonium phosphate fertilizers in both topsoils and subsoils. Banded P applications show clear economic as well as biological responses and an extended period of residual benefit in most soils. Strong root proliferation responses around bands (an enriched 'patch' of available P) are critical. Fertiliser recovery is affected by the frequency of those patches (band spacing), the intensity of the concentration gradient established (P rate), and the duration during a growing season when those bands are wet. Strategies to overcome low P availability in sown or native pastures are less developed. Direct supplementation of livestock provide economic responses in lower production environments but trial data and economic analysis suggest benefits from applying P fertilizer to legumes in tropical grass (C4) pastures.

## 246

## Phosphorus in the nutrition of poultry and pigs in intensive production systems

**Dr David Cadogan**

*Feedworks, Lancefield, Victoria, Australia*

Intensive pig and poultry diets require a significant amount of supplemental phosphorus (P), for skeletal growth, egg production, energy metabolism, lipid production and lactation. On average, only 25% of total phosphorus is available to monogastric, with the majority either locked in plant phytate (28.5% Phosphorus) or other bound forms. Most nutritionists either formulate diets on available P or digestible P. Available P usually expressed as a relative availability or relative biological value (RBV). It is the proportion of phosphorus retained in the animal's body compared to a highly available reference source which is assumed to have a biological value of 100. However this is not accurate, because this assumes that one of the highest availability of phosphorus being human grade monosodium phosphate (25% P) has 100% digestibility. In fact the P in high grade monosodium phosphate is only 90% digestible. Alternatively, digestible Phosphorus is defined as the actual proportion of the ingested phosphorus that has been absorbed, and the most accurate and reliable measured is using total tract or faecal P digestibility. The general conversion factor used to estimate Available P is the accepted digestibility coefficient of Dicalcium Phosphate, which is between 0.75 and 0.78. More digestible forms of inorganic P like monocalcium phosphate, rather than dicalcium or Tricalcium phosphate, are now being used in monogastric diets to a being significantly more digestible, improving diet density and growth performance as excessive undigested P and calcium can reduce diet digestibility. Another big factor in monogastric P nutrition is the use of Phytase. Phytase is the most widely used exogenous enzyme in poultry and pig diets globally. While phytate was primarily considered as an indigestible form of phosphorus and reducing other mineral availability, more recent evidence shows phytate has a negative effective on protein, and to a lesser extent, and energy utilisation in pigs and poultry. The use of commercial phytase not only reduces phosphorus and nitrogen excretion into the environment, but also saves up to $20 per metric tonne due to less minerals and protein required in the diet.

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## 247

## New-generation phytases for improved utilisation of diet phosphorus

**Prof Robert Speight[1],** Dr Laura Navone[1], Dr Jo-Anne Blinco[1], Dr Risa Luangthongkam[1], Dr Carlos Luna-Flores[1,2], Mr Juhani von Hellens[2]

*[1]Queensland University of Technology, Brisbane, Australia, [2]Bioproton Pty Ltd, Brisbane, Australia*

Phytase enzymes are ubiquitously used in poultry and swine diets to allow the liberation of phosphate from phytate, the major form of phosphate storage in the grains that are fed to livestock. Poultry and swine do not naturally produce phytase and so diets must be supplemented with this enzyme to allow access to the phosphate and reduce the amount of inorganic phosphate that is included in the feed. Phytate is also considered an anti-nutritional factor that binds essential minerals and protein and causes increases in gut viscosity, thereby limiting digestion. Given these benefits, phytase products have been on the market since the early 1990s but the market is still predicted to grow at a compound annual growth rate of over 6% from 2018, reaching a market size of over $1 billion by 2025 (Acumen Research and Consulting).

Despite the large market size and availability of a range of commercial products, there is still a demand for more active and stable phytases that can be economically manufactured using high yielding microbial host strains in high productivity fermentation systems. Following development of an improved stability phytase enzyme, a rapid and efficient platform was established for yeast production strain engineering, fermentation process development, and livestock testing. A number of strain engineering strategies were assessed for increasing production levels of the new phytase enzyme in Pichia pastoris *(Komagataella phaffii)*. Fermentation process development towards further increases in production levels has delivered an overall process for future commercial production.

## 248

## Phosphorus nutrition in ruminants grazing tropical rangelands

**Dr Rob Dixon**[1], A/Prof Stephen Anderson[2], Dr Lisa Kidd[3], A/Prof Mary Fletcher[1]

*[1]The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), St Lucia, Brisbane, Australia, [2]The University of Queensland, Faculty of Medicine, St Lucia, Brisbane, Australia, [3]The University of Queensland, School of Veterinary Science, Gatton, Australia*

Nutritional deficiency of phosphorus (P) is a major constraint to productivity of cattle grazing many tropical rangelands with low P soils, particularly in northern Australia, South America and Africa. Cattle growth and reproductive rates may be severely reduced. Such P deficiency is usually addressed by providing supplements containing calcium phosphates. In the seasonally dry tropics such supplements are most effective when fed during the summer rainy season when the pasture quality as energy and protein are highest. Young cattle often continue to grow slowly when P deficient, but with reduced bone mineralization. Cows with normally high bone mineral reserves (from previously P-adequate diets) can mobilize bone P during late pregnancy and lactation when diet P is insufficient. This mobilization may contribute up to ca. one-third of the P requirements and allow P-deficient cows to maintain milk production and calf growth, but is associated with reduced pasture intake and severe loss of cow liveweight. Cows can replenish bone minerals when P intake exceeds immediate requirements for growth and milk. Since on large commercial farms in rangelands it is often difficult to effectively implement P supplementation of cattle during the rainy season the mobilization and replenishment of body mineral reserves are important for managing P nutrition through the annual cycle. Biochemical markers in blood are valuable for diagnosis of P deficiency in grazing cattle. In conclusion, understanding of the nutritional physiology of cattle provides opportunities to improve management of P nutrition of cattle grazing P deficient rangelands and alleviating production losses.

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## 249

## Using digital soil mapping to estimate available soil phosphorus across Australian rangelands

**Mr Peter Zund**[1]

*[1]Queensland Government, Department of Environment and Science, Brisbane, Australia*

Australian soils generally exhibit a low Phosphorus (P) status. This could be due to inherently low P content of soils formed on old landscapes, or alternatively high P fixation in soils limiting availability. P is vital for pasture growth and consequently animal nutrition in rangelands. Hence, better knowledge of the P status of rangeland soils is critical for improved production, with available-P maps providing an improved regional perspective.

Current available-P maps for Australia are small scale and mostly map Total P, which does not quantify plant-available P in soils (usually tested by Colwell P method). Maps of plant available P have been produced for Central and Eastern North Queensland, and at a small scale for Australia.

The Department of Environment and Science (DES) is mapping plant available P across Australia in collaboration with the QDAF, MLA, TERN and CSIRO. The project is taking advantage of the greater availability of P data and the power of digital soil mapping technology to produce a finer resolution plant available P map than previously possible. Combining machine learning algorithms, a set of environmental covariates, the actual P data at thousands of sites across Australia and the Queensland Government high performance computer will see a reliable prediction of plant available P across Australia produced.

In addition to the P map, a P fixation/buffering trigger map will be produced based on pasture critical Colwell P thresholds and the Phosphorus Buffering Index. Early versions of the maps will be presented for discussion.

## 250

## Provenance - the Australian flavour story for meat

**Dr Heather Smyth**[1]

[1]*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Coopers Plains, Australia*

Australian beef comes from cattle reared in some of the harshest, most extreme, yet most beautiful regions Australia has to offer. Just as with wine, and other agricultural food products, the region from which the cattle is grown imparts unique characteristics into the meat resulting in distinctive flavour profiles. For animals that are grazers, this flavour profile can change enormously with the seasons according to availability of different plant species. Understanding and articulating the unique quality characteristics of Australian beef, as well as other meat products, is essential when companies want to market their products as superior in quality, build a brand identity with consumers based on provenance, and achieve a premium in the market. This presentation will explore the opportunity for regional flavour and provenance branding for the beef and meat industry in Australia, and present new ideas to achieve a market premium by focussing on a point of distinction.

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## 251

## Provenance of meat in Europe

**Dr Sara Erasmus**[1], Prof Saskia van Ruth[1]

[1]*Wageningen University, Wageningen, Netherlands*

Although the term 'provenance' is simply defined as "the place of origin of something", it becomes more complex for provenance foods. In fact, the provenance of meat is related to the environmental conditions of the defined origin in which the product is produced, in combination with the characteristic production and processing techniques employed. The end product has distinct intrinsic quality attributes (aroma, flavour, etc.) owning to these unique conditions, making the product authentic and valorising its name. Hence, provenance is reminiscent of the term 'terroir', used to describe the characteristic taste and flavour imparted to a wine by the environment in which it is produced. In the European Union, these products are protected through a system of geographical indications (GIs), where a GI is a distinctive sign used to identify a product whose quality, reputation or other characteristics are linked to its origin. A GI typically includes the name of the place of origin, and this name can be used by all organisations from the area which manufacture a given product in a prescribed way, like Prosciutto di Parma (ham). Products are protected through this scheme to prevent imitation and misuse (i.e. food fraud). However, analytical testing (product authentication) together with good traceability systems are also important to prevent fraud. On the one hand, it is required to confirm and protect product provenance (authenticity), while on the other it is important to validate claims associated with these products as they demonstrate how extrinsic factors can influence intrinsic meat quality.

## 252

## Provenance in sheep: The Karoo lamb story

**Prof Louwrens Hoffman**[1], Dr Sara Erasmus[2]

*[1]The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Brisbane, Australia, [2]Wageningen University & Research, AFSG – Food Quality and Design, Wageningen, Netherlands*

Noted for its unique herbaceous flavour which is imbued from a diet of indigenous fragrant plants, Karoo lamb is marketed as one of South Africa's finest meat products and enjoys Protected Geographical Indication (PGI) status in South Africa and the European Union. Its distinct quality is imparted through natural grazing of the sheep on the Karoo veld that has a significant influence on the sensory and chemical profile of the meat. Descriptive sensory analysis, fatty acid analysis, solid-phase microextraction, isotope ratio mass spectrometry, portable near-infrared reflectance spectroscopy and proton transfer reaction-mass spectrometry proved to be very successful analytical tools for the authentication of regionally unique lamb meat, distinguishing Karoo from Non-Karoo lamb. Characteristic volatiles, specifically terpenes, present in both the Karoo bushes and the Karoo lamb meat and fat were detected. The dominant terpenes were tentatively identified as Đ-pinene, Đ-pinene, limonene and trans-caryophyllene, and they were particularly prominent in the fat tissue. Within the Karoo, regional differences were apparent as Hantam Karoo lamb had the highest ratings for herbaceous aroma and flavour and contained the greatest concentration of terpenes. Herbaceous aroma and flavour attributes associated with a diet rich in fragrant Karoo plants were verified with stable isotope ratio analysis. The results confirm that Karoo bushes are responsible for the distinct aroma and flavour of Karoo lamb, thereby providing vital evidence for its certification and to justify the protection of its indicator status.

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## 253

## The effect of diet on meat provenance

**Dr Jeannine Marais**[1], Prof Louwrens Hoffman[2], Ms Nina Muller[1]

*[1]University of Stellenbosch, Stellenbosch, South Africa, [2]The Queensland Alliance for Agriculture and Food Innovation (QAAFI), Brisbane, Australia*

The effect of diet on the provenance of meat depends primarily on the production system selected for animal husbandry, i.e. intensive (i.e. 'farmed' or 'feedlot'), extensive (i.e. 'wild' or 'free range') and semi-extensive (i.e. wild/free range with supplement feeding) animal rearing. Consequently, differences in diet can influence the nutritional composition and sensory quality of meat (e.g. meat colour, aroma, flavour and texture). In South Africa, game species are primarily extensively reared in fenced off areas that vary in size, types of naturally occurring vegetation and animal species diversity. The type and quality of the vegetation in an area depends on the biome, in addition to climatic conditions (such as rainfall and temperature). Wild game species are selective or generalists in their feeding habits, in addition to being classified as pure browsers, pure grazers or mixed feeders. Springbok *(Antidorcas marsupialis)* and blesbok *(Damaliscus pygargus phillipsi)* are game species frequently utilised for meat production. Springbok are mixed feeders (graze and browse) and their diet (proportion of grazing to browsing) changes with the type of vegetation available in the habitat and the rainfall season. Consequently the nutritional composition and sensory quality of springbok meat can change with variation in their dietary regime. Conversely, blesbok are pure grazers, selecting only specific grass species, which results in only slight variation in their diet. Hence the meat derived from blesbok is more consistent in nutritional composition and sensory quality.

## 254

## What provenance means to red meat consumers

**Ms Lisa Sharp**[1]

[1]*Meat And Livestock Australia, Bowen Hills, Australia*

This presentation will draw on Meat and Livestock Australia's global customer and consumer research and share key insights relevant to provenance, including:

1) Provenance has physical (tangible) and intangible attributes
   - Provenance includes associations with product, people and place; where place – origin - has a material impact on perceptions. Perceptions of place can be influenced by many factors, sometimes not directly linked to the production of a particular good
   - Australian red meat is exported to over 100 countries. What does provenance mean to global customers and consumers? And how is this different by market, by channel, by segment, by product type, by demographic?
   - Provenance is sometimes considered a proxy for quality. Quality is typically amongst the top 3 purchase drivers across developed and developing markets for animal protein, including red meat. Eating quality is one aspect of quality, however there are other quality parameters that are important to consumers.
   - In a competitive global protein landscape, brands – underpinned by a compelling value proposition- will have an increasingly important role to play in the communication of features, attributes and benefits that underpin quality. Brand development and subsequent investments in brand promotion can further influence associations with product, place and people – provenance.

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## 255

## The role of Provenance of beef in a niche market: The OBE Beef story

**Andrew Blinco**

*OBE Organic Beef, Australia*

## 256

## Queensland's investment in managing drought, climate variability and adapting to climate change

**Mr Vern Rudwick**

*Department of Agriculture and Fisheries, Queensland Government, Australia*

The Queensland Government established the Queensland Drought Mitigation Centre (QDMC) in 2016 to fund and deliver a range of RD&E projects within the Drought and Climate Adaptation Program (DCAP) between 2016 and 2022. The objectives of DCAP focus on improving the capacity of producers to manage drought and climate variability and adapt to a changing climate. Projects directly target the northern Australian grazing industry, working with producers to:

- Extend the range of modelled pasture growth products, including pasture growth alerts, for management decision-making;
- Conduct social research to develop opportunities for customising extension programs and products to maximise producer adoption;
- Improve the skill of climate forecasts of extreme climate events (droughts, floods and temperature), northern rainfall season onset, monsoon bursts and passage of the MJO for northern Australia and support industry understanding and use of those forecasts in decision-making;
- Deliver economic knowledge and skills to improve drought management outcomes at the enterprise level across key grazing regions in Queensland; and
- Develop collaborative extension networks across the grazing industry to drive adoption of best grazing management practice.

The $21 million dollar DCAP program (leveraging a further $45M investment from partners) is underpinned by strong program governance, led by a multi-stakeholder Steering Committee, an independent Technical Reference Panel, independent monitoring and evaluation and innovative communications processes.

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## 257

## Turning on farm data into valuable insights. How the opportunity is being addressed today, and where it is heading

**Mr Michael Wang**[1], Mr Jamie Azzopardi[1]

[1]*IBM The Weather Company, Brisbane, Australia*

Observed weather data is an important core input into weather and climate models, and can therefore impact the accuracy of forecasts. Traditionally, weather data is captured primarily through public infrastructure with a national focus, and complimented by private networks and/or crowd sourcing collectives who use the data for their own specific purposes.

The effectiveness of this approach has been challenged due to the size and diversity of our county, but the advent of Internet of Things (IoT) at scale, improvements in data analytics, and use of Artificial Intelligence (AI) is creating new opportunities for increasing coverage, resolution, and accuracy across the country.

With this increase in data sources comes challenges with capture and collection, and ultimately real time processing of all the information for meaningful insights. This unrealised potential presents a significant opportunity for primary producers. This presentation will provide an overview of how this challenge is being addressed, explore public and private sector partnership opportunities, and cast a view forward.

## 258

## Prediction of northern Australian rainfall onset using the ACCESS-seasonal model

**Dr Tim Cowan**[1], Dr Matthew Wheeler[2], Prof Roger Stone[1]

[1]*University of Southern Queensland, Toowoomba, Australia,* [2]*Bureau of Meteorology, Melbourne, Australia*

The development of the Australian Community Climate Earth-System Simulator-Seasonal version 1 (ACCESS-S1) prediction system signifies a major step in addressing predictive limitations in multi-week to seasonal forecasting. It is anticipated that ACCESS-S1 will provide greater skill in its prediction of the wet season onset and intensity, both which are crucial to the viability of cattle grazing across northern Australia. We evaluate the hindcast skill of the ACCESS-S1 for the northern rainfall onset, defined as the date when 50 mm of precipitation has accumulated at a given location from the 1st of September, heralding the start of the seasonal dry-to-wet transition over northern Australia. We show that the raw ACCESS-S1 hindcasts, regridded to a 5 km observed grid, capture the broad-scale features of the median onset, including an early October onset over the western Top End and southeast Queensland, however the hindcasts fail to capture the later December onsets over central Australia. The greatest improvement in onset skill comes from first calibrating the hindcasts using observations, which outperform the raw model and bias corrected hindcasts over central Australia and the far west in the Pilbara-Gascoyne basin. Based on its simulation of realistic northern rainfall onset dates and variability alone, ACCESS-S1's prediction performance can be considered an improvement over the older predictive system. As the real-time onset forecasts have were issued using ACCESS-S1 in July 2019, it is expected that the calibrated predictions will help improve the resilience of cattle producers and graziers to drought across northern Australia.

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## 259

## Mechanisms of multiyear wet/dry conditions over northern Australia

**Dr Sur Sharmila**[1,2], Dr Harry H. Hendon[2]

[1]*University of Southern Queensland, Toowoomba, Australia,* [2]*Bureau of Meteorology, Melbourne, Australia*

Northern Australia wet season (November-April) rainfall exhibits strong variability on multiyear timescales, often triggering adverse socio-economic consequences. There is growing commercial and government interest in accessing multiyear climate forecasts, underscoring the necessity to better understand the underlying physical drivers of multiyear rainfall variations. As a part of the Northern Australia Climate Program (NACP), we investigate the causes of multiyear wet/dry conditions over Northern Australia based on observations and reanalyses for the period 1900-2017. Multiyear variability is found to vary independently across the north-west (NW) versus the north-east (NE) parts of Australia. The variability in the NE appears to be primarily controlled by the remote influence of low frequency variations of the El Niño-Southern Oscillation (ENSO). In contrast, multi-year variations in the NW appear to be largely driven locally and stem from a combination of the wind-evaporation-rainfall feedback and the soil moisture-rainfall feedback. Antecedent soil-moisture and associated evapotranspiration over northern Australia appear to act as sources of memory for sustaining multiyear wet and dry conditions over the NW. Our results imply that predictability of NW multiyear rainfall variability will depend on the initial soil moisture state and properly modelled land surface feedbacks, while predictability in the NE will be limited by the predictability of the low frequency variations of ENSO.

## 260

## The value of the Australian Drought Monitor to the cattle industry

**Dr Christa Pudmenzky**[1]

[1]*Centre for Applied Climate Sciences, University of Southern Queensland, Toowoomba, Australia*

Drought is the most severe climatic and costly natural disaster inflicting serious impacts on the socio-economy of Australia. An Australia-wide drought monitor is being developed to provide detailed and timely data regarding drought conditions that will aid producers and policy makers alike. The Drought Monitor development is an integral part of the Northern Australia Climate Program (NACP), a major partnership between Meat & Livestock Australia, the Queensland Government and the University of Southern Queensland.

The Australian Drought Monitor is based on the U.S. Drought Monitor (USDM) concept, which was developed by Mark Svoboda at the National Drought Mitigation Center at the University of Nebraska-Lincoln in the late 1990s. The Composite Drought Indicator (CDI), a scaled down version of the USDM, is widely applied in Europe, Asia, India, Jordan, Tunisia, Lebanon, Morocco, United Arab Emirates, New Zealand and others. The CDI is based on the combination of four indices/ indicators: Standard Precipitation Index 3-month (SPI-3 month), soil moisture anomalies, evapotranspiration anomalies and Normalised Difference Vegetation Index anomalies. 'Anomaly' parameters are used to represent the 'current' conditions related to historical baseline conditions for a given location and time period to establish the 'severity' of the drought conditions. The Drought Monitor relies on field observations from extension officers and other experts to provide feedback for validation and "Ground Truth".

The Australian Drought Monitor is a web-based map that will provide users with access to spatial information on the current status of drought to assist cattle producers and graziers with analysis, decision making, planning and reporting.

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## 261

## Climate mates: Bridging the gap between scientists and producers

**Dr Chelsea Jarvis**[1]

[1]*University of Southern Queensland, Toowoomba, Australia*

The Northern Australia Climate Program has been tasked with improving climate information and developing new climate products for red meat producers in northern Australia. A challenge has been how to effectively communicate project outputs to producers. Traditional extension methods generally rely on experts from outside of the target region(s), who fly in and fly out, having minimal connection to the producers. NACP has overcome this by employing 'Climate Mates' in extension work.

Eight 'Climate Mates', regionally-located part-time extension officers, were hired based on connections to their community, local knowledge of the grazing industry, and communications skills. Training was provided for the Climate Mates by experts in various climate and extension fields. The Climate Mates perform extension activities, such as speaking at workshops and 'Kitchen Table Talks' to communicate NACP findings and climate tools with the purpose of improving climate knowledge and incorporating that knowledge into a risk management plan.

Regional reception of the Climate Mates has been overwhelmingly positive, likely due to the existing relationships with other producers and their regional knowledge. Communication of NACP research and products to producers via the Climate Mates has been efficient and regionally applicable. Furthermore, feedback from producers can be communicated to the scientists via the Climate Mates. This enables scientists to tailor forecasts to suit local grazing industry requirements.

The 'Climate Mate' model is easily applicable to other regions and industries. Lessons learned from experiences with the NACP should be considered when implementing the Climate Mate model elsewhere.

## 262

## Genotype and management adaptation of wheat to heat and drought in current and future climates

**Dr Karine Chenu**[1], Dr Behnam Ababaei[1], Dr James Watson[1], Dr Scott Chapman[2]

[1]*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Toowoomba, Australia,* [2]*CSIRO, St Lucia, Australia*

Heat and drought stress limit wheat production in major production regions worldwide. With climate change, increase in $CO_2$ concentration, temperature, evaporative demand and rainfall variability are projected to impact different crop processes and their interactions. Here, we used a modelling approach to characterise the type of abiotic stresses that wheat crops are currently and will experience in projected climate scenarios across the Australian wheatbelt. Genotype and management adaptations were assessed in terms of crop maturity type and sowing date to best tune crop development with environmental variability. Results highlighted a shift towards earlier optimum sowing windows. Heat and its interaction with drought appeared as the dominant sources of yield loss across the Australian wheatbelt in the future climate scenarios. Different physiological adaptation will be discussed to promote increasing yield in these changing environments.

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## 263

## Modelling heat and drought adaptation in crops

**Dr Erik van Oosterom**[1], Mr Greg McLean[2], Mr Kurt Deifel[1], Dr Vijaya Singh[1], Prof David Jordan[3], Prof Graeme Hammer[1]

[1]*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Brisbane, Australia,* [2]*Agri-Science Queensland, Department of Agriculture and Fisheries, Toowoomba, Australia,* [3]*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Warwick, Australia*

Drought and heat stress are increasingly important abiotic limitations to productivity of sorghum. Here, we use long-term simulations to quantify the importance of transpiration rates to drought adaptation and the importance of threshold temperatures and tolerance above the threshold for adaptation of seed set to heat stress. Simulations were parameterised using results of detailed physiological studies. The importance of transpiration rates to drought adaption was studied by comparing productivity of maize and 3dwarf sorghum. These crops have similar transpiration efficiency but contrasting transpiration rates per unit green leaf area (TGLA), which was captured through differences in RUE. Results showed that the greater TGLA of maize reduced productivity under drought stress, but increased productivity in well-watered conditions, indicating a trade-off between yield potential and drought adaptation. The increased water use of maize associated with higher yield potential could negatively affect carry-over of soil water in a cropping systems context. Simulations for sorghum productivity under heat stress, using long-term weather records for six locations across the Australian sorghum belt, showed that the most common incidence of heat stress around anthesis was the occurrence of individual days with maximum temperatures of 36-38˚C. Because these temperatures were near the threshold that limits seed set, increased temperature thresholds generally minimised yield reductions. However, predicted temperature increases in coming decades justify additional selection for increased tolerance above the threshold. As manipulating sowing dates did not reduce risks of heat stress around anthesis, genetic improvement provides the best prospect to mitigate adverse effects on grain yield.

## 264

## How do crops balance water supply and demand when water is limiting?

**Prof Andrew Borrell**[1], Dr Barbara George-Jaeggli[1,2], Dr Erik van Oosterom[1], Prof Graeme Hammer[1], Dr Emma Mace[1,2], Prof Ian Godwin[1], Dr Guoquan Liu[1], Mr Albert Wong[1], Mr Temesgen Matiwos[3], Prof Kassahun Bantte[3], Dr Jack Christopher[1], Dr Lee Hickey[1], Dr Cecile Richard[1], Dr Hannah Robinson[4], Prof David Jordan[1]

*[1]The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Australia, [2]Department of Agriculture and Fisheries Queensland, Australia, [3]College of Agriculture and Veterinary Medicine, Jimma University, Jimma, Ethiopia, [4]InterGrain Pty Ltd, Bibra Lake, Australia*

Plants are sessile organisms requiring mechanisms that enable them to balance water supply and demand in dry environments. Demand (D) is largely driven by canopy size (transpirational leaf area), although differences in transpiration per unit leaf area also occur. Supply (S) is primarily driven by water capture via the root system. Drought stress can be defined as the situation where supply of water cannot meet demand of the crop, such that water availability is the limiting factor for biomass accumulation. Under such conditions, plants will need to reduce D in order to meet the limited S, access more water to increase S, or increase the efficiency with which water is utilised. We used sorghum, a model C4 crop species, to demonstrate how the stay-green trait can modulate canopy development and root architecture to enhance adaptation. We show how stay-green positively impacts the balance between S and D under post-flowering drought, including insights at the molecular level. We provide examples of how canopy and root traits impact the S/D balance in other cereals under water limitation. For example, on the supply side, the extent of genetic variation for root angle (RA) has been evaluated in sorghum, wheat and barley, and genomic regions associated with RA have been mapped. Furthermore, the relationship between RA and grain yield has been explored in barley and sorghum field trials. The capacity to manipulate components of S and D to optimise the S/D balance should assist crop improvement programs to develop enhanced ideotypes for dry environments.

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## 265

## The role of hydraulics in crop water use under drought

**Dr Vincent Vadez**[1,2], Dr Jana Kholova[2], Dr Kaliamoorty Sivasakhti[2], Dr Murugesan Tharanya[2]

*[1]IRD, Montpellier, France, [2]ICRISAT, Patancheru, India*

Roots have long been proposed as a major research avenue to improve crop adaptation to water limitations. The simple assumption is that deeper and more profuse root systems could tap extra water from the soil profile and alleviate drought effects. In the past few years, research showed that, rather than more water available to the plant, higher yield under terminal stress came from a higher water availability during the crops' grain filling period. This was a consequence of a water saving strategy of the plant taking place earlier during the cropping cycle, at vegetative stage. One of the traits involved in these water savings is the capacity to restrict transpiration under high vapor pressure deficit. The presentation will summarize on the discovery of that trait, the genetic variation across species, its direct linkage with a higher transpiration efficiency. It will then show the link between this trait and hydraulic features of the root system, where aquaporins play a key role in root water transport. A different role of roots in drought adaptation is proposed, in setting a hydraulic environment that allow plants to use water in a way that maximizes water use at critical stages.

## 266

## Phenotyping the hidden half: Measuring roots from long hairs to deep cores

**Dr Anton Wasson[1],** Dr Xiaoqing Li[1], Dr Emmanuel Delhaize[1], Dr Peter Ryan[1]

*[1]CSIRO, Black Mountain, Australia*

Three approaches to measuring root traits in wheat at different scales.

Firstly, a seedling assay that equates adherent soil with root hair length. 6 markers for root hair length have been identified and a further 5 markers for root hair growth on acid and aluminium toxic soil. The technique has been used to develop populations now being evaluated in the field. For example, RILs with these markers confer a 0.1 t/ha yield advantage on acid soils in Merredin, WA.

Secondly, the RhizoVisionCrown, an open-source phenotyping system developed by the York lab in Oklahoma. I will discuss how we have used it to investigate root crown traits in field trials assessing phosphorus use efficiency in wheat.

Finally, assessing root distribution into the subsoil using soil coring and core break root counting. Variation in rooting depth of 66 to 140 cm was shown in a multigenic mapping population of spring wheat. However, the challenge is to identify the genetic variation in root distribution across depths, given the strong influence of sample-to-sample variation in soil properties. Statistical approaches will be discussed; for example, a Bayesian hierarchical non-linear mixed model that fit genotypic intensity functions across root counts at all depths, giving an overall heritability estimate of 0.62 (with a confidence interval of 0.52 to 0.71).

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## 267

## Root responses of durum wheat ideotypes defined by contrasting root angles to localised phosphorus availability and dynamic soil profile moisture

**Dr Frederik van der Bom[1],** Dr Alwyn Williams[2], Dr Vijaya Singh[1], Prof Michael Bell[2]

*[1]The University of Queensland, St Lucia, Australia, [2]The University of Queensland, Gatton, Australia*

Historically, the productivity of grain systems in the northern region has been governed by the efficient capture, storage and extraction of water from the soil profile. Additionally, genotypes of winter and summer cereals are currently being screened for root morphological traits such as narrow seminal root angles, with the goal of enhancing access to deep soil water. Although these developments can deliver improved crop water-use efficiency, immobile nutrients such as phosphorus (P) have become increasingly concentrated in surface soil layers, or in shallow nutrient-rich bands. How crop root systems respond to the spatial separation of moisture and nutrient will determine productivity in any given set of seasonal conditions. Additionally, crops often display plastic root responses as a way to cope with the heterogeneous distribution of nutrients in soil. The heterogeneous nature of a localised P source such as a P band may thus influence root phenotype, regardless of seminal root angle.

A combination of experiments with rhizoboxes and an automated lysimeter system is used to investigate the responses of two durum wheat ideotypes (narrow and broad seminal root angle) to different localized availability of P (incl. stratified and banded) under contrasting patterns of soil moisture availability. It is envisaged that there will be trade-offs between P uptake, water use, and root system morphology. The experiments will be run in the winter of 2019, and the first results are anticipated to be presented at TropAg 2019.

## 268

## Advances in macadamia genomics

**Dr Agnelo Furtado**

*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Australia*

The Macadamia Genus is comprised of four species that are native to Australia; *Macadamia integrifolia, Macadamia tetraphylla, Macadamia ternifolia and Macadamia Jansenii.* The commercial macadamia industry is based on cultivars, which are diploid, highly heterozygous and derived from M*. integrifolia, M. tetraphylla* and hybrids of these species. *Macadamia ternifolia* and *Macadamia Jansenii* are smaller trees with small nuts having high levels of cyanogenic glycosides. Traditional breeding strategies and a long juvenile period impedes rapid genetic improvement of this important horticultural tree crop. The short stature of the ternifolia and the jansenii trees is an attractive trait for industry. Macadamia breeding benefit from the application of genomic tools in selection allowing an acceleration of genetic improvement and assisting the transfer of useful traits from the wild relatives. Genomic resources, including reference genome sequences, transcriptome sequences and sequenced genotypes are limited and currently mainly relate to *M. integrifolia* with efforts to generate similar resources for *M. jansenii* currently underway. The status of genomic resources and the need for additional analysis of all four macadamia species will be reviewed.

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## 269

## Breaking and flowering: The budding story of macadamia

**Dr Francois Barbier**[1], Ye Gong[1], Carola Parfitt[2], Dr Craig Hardner[1], Dr John Wilkie[3], Prof. Christine Beveridge[1]

[1]*The University of Queensland, Saint Lucia, Australia,* [2]*Department of Agriculture and Fisheries, Bundaberg, Australia,* [3]*Department of Agriculture and Fisheries, Wollongbar, Australia*

Macadamia is the only Australian native crop tree. Unlike some model crop trees like apple or peach trees, the understanding of the physiological mechanisms regulating bud break and flowering in macadamia has never been investigated. We have recently attempted to fill this gap by improving the genetic resources available for macadamia. We identified several components involved in flowering and bud break, including the FLOWERING LOCUS T (FT). FT is a mobile protein, synthesized in the leaves which triggers flowering in terminal and axillary buds. In macadamia, we found two *FT*-related genes, *FTa* and *FTb* namely. *FTa* and *FTb* are differentially regulated; *FTa* being more abundant in axillary buds than leaves, which is unexpected based on the studies performed in model plants. Analysis of the promoter sequences of *FTa* and *FTb*, revealed that the *FTa* regulation may be closer to *FT* regulation in the model plant *Arabidopsis thaliana.* Gene expression in buds revealed that the expression of *TERMINAL FLOWER1 (TFL1)*, a gene previously reported to inhibit flowering, was induced prior to bud break and flowering. The patterns of marker gene expression in buds highlighted that the bud dormancy decreased before May, after which flowering induction occurs. Altogether these results shed light on the regulation of bud break and flowering in macadamia and demonstrate that some regulatory mechanisms may be different from other models.

## 270

## The avocado genome - An update

**Dr Alice Hayward**[1], Stephen Fletcher[1], Prof Neena Mitter[1], Prof Victor Albert[2], Prof Luis Herrera-Estrella[3]

*[1]QAAFI, The University of Queensland, St Lucia, Australia, [2] Department of Biological Sciences, University at Buffalo, Buffalo, USA, [3]a Unidad de Genomica Avanzada/Langebio, México*

Avocado (*Persea americana* Mill) is a tropical fruit species belonging to the plant family Lauraceae, in the anciently-diverged magnoliid clade of angiosperms. It is the only commercial fruit species in this family and was one of the first fruit tree crops to be domesticated, as early as 4,500 B. C. Today, avocado has gained huge commercial momentum as high value, highly nutritious food.

Cultivated avocado varieties predominantly belong to three landraces that reflect three proposed independent domestication events: the Mexican, Guatemalan, and West Indian races. The most important cultivated variety, comprising 80% of the world's consumption, is Hass. This talk presents recent insights from a large collaborative project sequencing the nuclear genomes of Hass and the Mexican rootstock variety drymifolia. This has informed ancient evolutionary relationships and genome doublings, and allowed us to explore the evolution of genes commonly associated with pathogen interactions. Resequencing of Guatemalan and West Indian varieties, including the Australian rootstock Velvick, revealed for the first time that the Hass genome comprises 39% Guatemalan regions introgressed into a Mexican race background. It also revealed that avocado has experienced two lineage-specific polyploidy events during its evolutionary history. This avocado genome represents an important resource moving forward in the field of avocado genomics, breeding and improvement.

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## 271

## CRISPR kiwifruit – new opportunities for cultivation, breeding and research

**Dr Erika Varkonyi-Gasic**[1]

*[1]Plant and Food Research, Auckland, New Zealand*

Annualization of woody perennials has the potential to revolutionize the breeding and production of fruit crops and rapidly improve horticultural species. Kiwifruit *(Actinidia chinensis)* is a recently domesticated, temperate fruit crop, with a short history of breeding and tremendous potential for improvement. Previously, we identified kiwifruit PEBP (phosphatidylethanolamine-binding protein) genes with specific roles in regulation of kiwifruit vegetative and reproductive phenologies. *FLOWERING LOCUS T*-like *AcFT* was activated during winter chilling accumulation and promoted flowering, while *CENTRORADIALIS*-like *AcCEN* and *AcCEN4* marked active vegetative growth and repressed flowering. We used CRISPR/Cas9 to target kiwifruit *AcCEN4* and AcCEN. Mutation of these genes transformed this climbing woody perennial, which develops axillary inflorescences after many years of juvenility, into a compact plant with rapid terminal flower and fruit development. CRISPR/Cas9-mediated mutagenesis of *CENTRORADIALIS*-like genes is therefore a valuable means to engineer *Actinidia* amenable for accelerated breeding, indoor farming and cultivation as an annual crop. We are now using rapid flowering kiwifruit lines to study sex determination and fruit development in kiwifruit.

## 272

## Mango genomics: Drafting Kensington Pride

**Dr David Innes**[1], Dr Ian Bally[1], Mr Matthew Webb[1], Dr Natalie Dillon[1]

[1]*Department of Agriculture and Fisheries, Brisbane, Australia*

Mango is an important tropical fruit tree crop with an estimated 52 million tonnes of fruit produced in 2018 (FAO). The Queensland Department of Agriculture and Fisheries (DAF) has a long and successful history of delivering new mango varieties into the Australian market. DAF developed varieties R2E2 and Calypso™ comprised 43% of mango production in 2017-18. As with most tree crops, the major impediments to developing superior, locally adapted varieties include longer generation times and the relatively small number of progeny that can be generated and assessed in any given generation. Advanced DNA and statistical methodologies offer the advantage of either screening progeny for improved selection or predicting performance of crosses based on a detailed understanding of parental characteristics and assessment through training populations. Underpinning much of this is having detailed phenotypes of suitable populations and the necessary tools to exploit these, primarily, a genome. He were give a brief history of Queensland's mango breeding and biotechnology programme and how drafting the Kensington Pride genome is helping accelerate development of superior varieties for the Queensland industry.

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## 273

## Genetics of almond

**Dr Shashi Goonetilleke**[1], Dr Michelle Wirthensohn[1]

[1]*School of Agriculture, Food and Wine, Waite Research Institute, The University of Adelaide, Glenosmand, Australia*

Almond (*Prunus dulcis* Mill. D. A. Webb) is an important nut crop species and belongs to the family Rosaceae. It is an outcrossing species with a gametophytic self-incompatibility system. The self-incompatibility system in almond is genetically controlled by a complex S locus with many alleles. Almond has a small diploid genome of approximately 280 Mbp with sixteen chromosomes. One important objective of almond breeding is to increase yield and this can be achieved by exploring the self-incompatibility and by developing and implementing the molecular tools that could support genetic mapping and precision of the breeding process. Here, we report exploring genetic diversity in the self-incompatible locus of almond to develop high-throughput markers to differentiate nine S alleles *(S1, S3, S5, S7, S8, S9, S23, S25* and *Sf*) in almond and detection of novel quantitative trait loci (QTL) for shell hardness trait in almond using a linkage map from a cross between almond cultivars Nonpareil and Lauranne by applying genotyping-by-sequencing. For Nonpareil, QTL were detected on linkage group 5 (LG5) and For Lauranne, QTL were detected on LG2, LG5 and LG8. These S allele markers provide powerful tool to detect S alleles in almond and could serve as models for development of high-throughput markers for other crops with self-incompatibility system. The markers developed to detect polymorphism in almond populations and linkage maps constructed could be useful for cultivar verifications, genetic diversity assessment and marker assisted selection.

## 274

## Challenges of breaking into industry from an early career perspective

**Miss Rebecca Clapperton**[1]

[1]*Salisbury Plains Grazing, Bowen, Australia*

You know that crazy, tenacious squirrel from the movie Ice Age? The one that is always relentlessly trying to find its acorn, or trying to figure out how to keep the acorn. Full of enthusiasm, drive and passion, it relentlessly keeps trying, challenge after challenge. Long after most others would have thrown in the towel and walked away. In some ways, I can relate myself to that squirrel, and the agricultural industry, to the acorn.

When you are starting your career, and there are countless options out there, it can be both daunting and challenging trying to figure out how to find your acorn, let alone where to look. Then, just because you find it, it doesn't mean that you will be able to break into it right away, or be able to use it how you may have planned. I can't tell you what to do, nor do I have any magic solutions. However, I can share my journey and experiences, as well as what I've done with that acorn.

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## 275

## Opportunity and investment in the next generation of livestock scientists

**Dr Shannon Landmark**[1]

[1]*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Australia*

There are a number of opportunities that are open to young livestock scientists, extension staff and producers in the early stages of their career. These range in structure from scholarship opportunities with Nuffield Farming Australia to mentoring programs such as the Zanda McDonald Award and the Graeme Acton Beef Connections Program. These bursaries and awards aim to invest in the next generation of leaders allowing them a significant learning, mentorship and networking opportunity. These awards foster stewardship and develop alumni who go on to mentor further generations and recognise the importance of maintaining these opportunities.

Funding for these awards and scholarships largely come from significant industry bodies including pastoral companies, financial institutions and livestock agencies. Promotion of these awards has been achieved through media, social media, networks including the Future Farmers Network and events such as Beef Week. The continued support and investment in these opportunities is integral for growth and depth of knowledge in the industry; as mentorship and networking is one of the most valuable tools for creating and fostering young leaders.

## 276

## Career mobility to grow human capital in the tropical animal industries

**Dr Peter Johnston**

*Department of Agriculture and Fisheries, Brisbane, Queensland, Australia*

Growing human capital in the tropical animal industries will benefit from career mobility. Career mobility is more than just people move between organisations. It takes a semi-structured approach to long-term career development, requiring flexibility from both the organisations engaging our people and our emerging livestock specialists. The public and private sector have clear roles to play. This talk highlights the benefits of career mobility drawing on two case studies from Queensland, Australia.

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## 277

## International perspective of future career opportunities in animal science

**Dr Anna Okello**

*Australian Centre for International Agricultural Research (ACIAR), Australia*

The central importance of agriculture to both food security and economic development in Low and Middle Income Countries (LMICs) is undisputed, and by many accounts, growing. Smallholder farmers are the lifeblood of agricultural production in many of these economies, producing a large number of diverse products on small areas of land, in what are predominantly mixed crop-livestock systems. There are numerous instances in such international contexts to engage in animal science research and development in a broad range of technical subjects relating to livestock productivity, trade, food safety, natural resource management and socioeconomic and sociocultural considerations. In addition, there is a growing recognition of the importance of other disciplines perhaps not traditionally associated with animal science, but becoming more important in a globalised world, such as trade negotiations and regulation, political science and behavioural economics. Demand for animal-source foods is expected to rise by 70% by 2050 to feed an estimated global population of 9.3 billion people by this time; the need for animal science specialists who can put the discipline in the context of the growing challenges facing the sector at the global scale is urgent and growing.

## 278

## Mentoring and succession planning - talking from experience

**Prof Alan Bell**[1]

[1]*Cornell University, Ithaca, United States*

This presentation will draw on the speaker's experience of over 50 years as a student, early and mid-career researcher and teacher, and scientific administrator. The critical importance of good mentoring at different career stages and the characteristics of effective mentors will be discussed. Specific examples of best practice will be provided, including steps that can be taken by organisations to ensure that employees are appropriately mentored. The relations between mentoring, career development and succession planning will be briefly considered, with observations on individual behaviours and organisational practices that contribute to successful turnover of leadership and institutional renewal.

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## 279

## Building beef industry capacity in Northern Australia

**Mr Andrew Gatenby**[1]

[1]*Indigo Agriculture, Newstead, Australia*

Many years of under-resourcing and reduced capacity in whole of farm RDE&A expertise has led to a decline in evidence based research activity and coupled with minimal extension resources has negatively impacting the productivity and profitability of the northern beef industry.

PeopleBusinessConsulting and Indigo Agriculture were engaged by MLA to assess the need and viability of establishing a Northern Beef Hub located at James Cook University. The Hub would focus on capacity building to deliver a mentoring, professional and consultancy service to the northern beef industry.

Extensive consultation with the pastoral industry, government agencies, CSIRO, retired beef industry academics (potential mentors) identified gaps and confirmed that industry and MLA concerns are widely held and need to be addressed. It was established that there is a strong case for the establishment of a Northern Australia Beef Hub, with close association to a northern university where the necessary skills and expertise can be developed, applied and supported.

The Northern Beef Hub's Vision aligns with Meat Industry Strategic Plan 2020 pillar *Building Industry Capability*, supporting a sustainable and profitable beef industry for northern Australia through evidence-based advice and research meeting the on-going, practical needs of industry.

## 280

# Advanced technologies to increase profitability of the Australian tea tree industry

**Assoc Prof Tobias Kretzschmar**[1], Dr. Jos Mieog[1], Dr. Mervin Shepherd[1]

[1]*Southern Cross University, East Lismore, Australia*

Tea tree oil (TTO) is an iconic Australian natural product, marketed and sold throughout the world for use in a range of healthcare, cosmetic, pharmaceutical and veterinary products. TTO is rich in terpenoid compounds, providing its antimicrobial activities and distinct smell, which are produced in the leaves and stored in specialised oil glands. The entire above ground shoot biomass is harvested and steam distilled to produce a purified essential oil.

Initially led by NSW DPI and CSIRO, tea tree variety improvement formally commenced as recent as 1993, when the industry was transitioning from harvesting natural stands to harvesting purpose-grown plantations. Since 2017 SCU is leading national tea tree breeding efforts, which include the development of pre-breeding resources and supply chain technology to support the Australian Tea Tree Industry (ATTIA).

On the breeding side, SCU has developed and implemented a two tiered breeding strategy consisting of a rolling front elite by elite controlled crossing program and a conventional open pollinated population breeding pipeline. These activities are supported by an advanced breeding management system for data capture, storage and analysis. In parallel SCU is working on a commercially viable clonal propagation system and is providing seed production, storage and management services.

On the pre-breeding side, SCU is progressing toward a de-novo assembled draft genome, using Pac-Bio and Illumina sequencing technology, which will serve as a basis for trait development, gene discovery and marker applications. Furthermore, high-throughput phenotyping approaches are being established to capture TTO quality and yield at reduced time and cost.

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## 281

# Australian native plant foods and their contribution to diet diversity

**Assoc Prof Yasmina Sultanbawa**[1]

[1]*University of Queensland, Coopers Plains, Australia*

The triple burden of malnutrition is identified with overnutrition, undernutrition and hidden hunger. Although global food production in terms of calories has kept pace with population growth, low-quality diets that lead to micronutrient deficiencies and chronic diseases have become a global problem. Over 2 billion people globally suffer from micronutrient deficiencies as a result of insufficient intake of vitamins and trace elements in the diet. Currently, about 60% of dietary calories come from staple foods such as rice, maize, wheat, potato and soybean. There is a clear relationship between the reliance on a few staple crops or low dietary diversity and malnutrition. Dietary diversity is increased when consumption of cereals is accompanied by a high intake of fruits, vegetables and pulses. The occurrence of antioxidants and important dietary phytochemicals in these underutilised fruits and vegetables further enhances their value as dietary interventions to promote health and wellbeing.

Australian native plant foods are rich sources of micro nutrients. Some better known examples are, the Kakadu plum *(Terminalia ferdinandiana)* which is a good source of vitamin C, green plum *(Buchanania obovata)* which is rich in folates and the wattle seeds *(Acacia spp)* which are high in protein, dietary fibre and trace elements. Therefore, there is a need to develop strategies to include these food crops in nutrition intervention programmes and promote them as healthy food choices to be incorporated into the diets of Australians. The introduction of Australian native plant foods among nutritionally vulnerable communities where undernutrition, hidden hunger and chronic diseases have been reported will help alleviate these health problems.

## 282

## Genetic improvement and application of genomic tools for Bambara groundnut improvement in West Africa

**Dr Stephen Amoah**[1], Dr Joseph Nketiah Berchie[1], Dr James Yaw Asibuo[1], Dr Sylvester N.T.T. Addy[1], Mr Kennedy Agyemang[1], Mr Paul Marno[1], Dr Hans Adu-Dapaah[1]

[1]*CSIR-Crops Research Institute, Fumesua, Kumasi, Ghana*

Bambara groundnut *(Vigna subterranea)* is an indigenous African grain legume grown for human consumption. It is well adapted to harsher environments and constitutes an important part of the local diet, culture and economy. However, Bambara groundnut's geotropic pod development makes breeding through artificial hybridization difficult and is still cultivated from landraces rather than varieties developed for specific target environments or traits. Other challenges include the long generation cycle. Here, we describe progress of Bambara groundnut genetic improvement and the application of genomic tools to enhance genetic gain. Using a high-density oligonucleotide arrays we identified thousands of conserved ortholog set (COS) markers through DNA hybridization to the Affymetrix ATH1 GeneChip® for *Arabidopsis thaliana.* In order to shorten the generation cycle, mutation breeding techniques including gamma irradiation and *in vitro* techniques were used. Generation cycle were shortened from 160 days to 80 days in some genotypes. Progress made with the use of genome-wide association studies (GWAS) for marker discovery in Bambara groundnut is also discussed.

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## 283

## Knowledge representation and data management adding value to global niche crops

**Prof Graham King**[1], Miss Liliana Andres-Hernandez[1], Miss Razlin Asman-Halimi[1], Dr Ramil Mauleon[1]

[1]*Southern Cross Plant Science, Southern Cross University, Lismore, Australia*

Genetic resources of major and numerous minor crops have potential to address many aspects of global food and nutritional security. However, few information resources reflect cultivar-level variation to guide and align decisions for crop production and dietary nutrition. This is exacerbated by the lack of standardisation and cohesion in management and dissemination of nutritional data. We have assessed tools and resources for comparison of crop species and cultivars that would maximise genomic and phenotypic inferences, and identified considerable limitations within the existing Crop Ontology. We propose systematic controlled vocabularies to underpin development of a Crop Dietary Nutrition Ontology, with explicit compositional, functional and methods classes. The value for guiding crop improvement is demonstrated, with a comparative use-case for legume crops. Examples will be given of how such developments are being integrated into wider efforts to ensure crop genomic data meet Findable Accessible Inter-operable and Re-suable (FAIR) standards.

## 284

## A systematic approach to defining nutritional quality of underutilised crops

**Ms Razlin Azman Halimi**[1], Bronwyn J Barkla[1], Liliana Andrés-Hernandéz[1], Sean Mayes[2,3], Graham J King[1,2,3]

*[1]Southern Cross Plant Science, Southern Cross University, Lismore, Australia, [2]School of Biosciences, University of Nottingham, Loughborough, United Kingdom, [3]Crop Improvement and Production, Crops for the Future, Selangor Darul Ehsan, Malaysia*

Underutilised crops have potential to play an increasing role in the diet of many who may lack adequate nutrition. At present, there appears to be no comprehensive or systematic effort to collate and analyse nutritional composition data, although this is likely to make a significant contribution to global food and nutritional security. For example, determining intra- and inter- species variation for nutritional components would enable direct comparison with commodity crops. Using bambara groundnut (*Vigna subterranea;* BG) as a use-case, we present a systematic work-flow that facilitates comparison of nutritional composition and function for underutilised crops. This includes i) critical literature review of available data sources for the target and comparator crops, to determine the extent of variation reported for a range of nutritional components; ii) development of a Crop Dietary Nutritional Data Framework (CDN-DF) to assist in data curation; iii) de novo analysis of seed nutritional components for a subset of BG accessions selected to represent the global genepool. The CDN-DF includes controlled vocabularies organised in a hierarchical structure that represent a simplified subset of relationships for nutritional composition and dietary function This facilitates comparison of datasets between species and can help identify data gaps. This framework is currently guiding establishment of a formal nutritional ontology that more fully represents the complex relationships between nutritional components. Based on our analysis, it appears that seed protein, lipid and fibre concentrations cover a similar range in BG, chickpea and mungbean. Variation in BG protein concentration indicates scope for developing high protein cultivars.

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## 285

## Orange capsicums and chillies as a potential source of dietary zeaxanthin, an important macular carotenoid for eye health

**Ms Rimjhim Agarwal**[1,2], Dr Tim O'Hare[1,2], Dr Hung Hong Trieu[1], Dr. Robyn Cave[2], Dr Stephen Harper[3]

*[1]Centre for Nutrition and Food Sciences, QAAFI, Australia, [2]School of Agriculture and Food Sciences, The University of Queensland, St. Lucia, Australia, [3]Department of Agriculture and Fisheries, Gatton, Australia*

Zeaxanthin is a dietary carotenoid accumulated in the macula in order to reduce photoreceptor oxidation by blue light. Damage caused to photoreceptor cells in the human eye leads to macular degeneration, which is the leading cause of blindness in developed countries. Zeaxanthin, an orange pigment, is rarer in western diets as compared to the yellow pigment, lutein, the other important macular carotenoid. Orange capsicums (*Capsicum annuum*) have been reported to be an excellent source of zeaxanthin, but there are limited reports about its occurrence both within, and in other closely related species (*C. baccatum, C. chinense*). In the current investigation, yellow, orange and red coloured accessions of *C. annuum, C. chinense* and *C. baccatum* were analysed for their carotenoid profiles to identify high zeaxanthin accessions. A carotenoid extraction protocol and ultra-high-performance liquid chromatography-photometric diode array-mass spectrometry (UHPLC-PDA-MS) analysis was optimised to identify and quantify carotenoids in the capsicum accessions both before and after saponification. Interestingly, out of 22 varieties tested, only the 'Orange Belle' orange capsicum demonstrated a high accumulation of zeaxanthin. Other accessions exhibiting orange colour accumulated different orange carotenoid pigments to zeaxanthin, such as violaxanthin, beta-carotene, and beta-cryptoxanthin. Yellow coloured accessions accumulated a high concentration of lutein or alpha-carotene, while red cultivars were highest in capsanthin and capsorubin. The present findings suggests a need for further studies to identify high zeaxanthin germplasm which can be cross-bred with orange capsicums for future biofortification, in order to help increase the daily dietary intake of zeaxanthin in western diets.

## 286

## The RD&E response to Queensland's Panama disease TR4 incursion

**Mr Stewart Lindsay**[1]

[1]*Department of Agriculture and Fisheries, Queensland Government, South Johnstone, Australia*

Panama disease TR4, also known as Fusarium wilt of bananas (TR4), is caused by the fungus *Fusarium oxysporum f.sp. cubense* and poses a serious threat to banana production in Australia, and increasingly around the world. So far, Queensland has implemented one of the most successful containment efforts for this disease globally, an outcome significantly contributed to by a coordinated and complementary approach to Government and industry activities. Research, development and extension (RD&E) activities have supported the Biosecurity Queensland (BQ) and banana industry response to the incursion through a range of priority activities, identified from questions and feedback at key industry meetings for growers and other stakeholders, and through consultations with BQ and the industry representative organisation, the Australian Banana Growers Council (ABGC). From these activities, three different themes with differing timelines were identified, providing a structure for the RD&E activities to respond to the information required. The RD&E activities accessed much existing information and research work from Australia and overseas, but also recognised that significant knowledge gaps would be revealed that would require timely research efforts. The activities addressed a range of priority issues including improving knowledge of the disease amongst growers and stakeholders, on-farm biosecurity practice planning and implementation, disease epidemiology, inoculum management and screening for genetic resistance.

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## 287

## Alternative diagnostic tools for White Spot Disease

**Dr Beth Fowler**[1], Dr Rebecca Ambrose[1]

[1]*Queensland Department of Agriculture and Fisheries, Brisbane, Australia*

The Queensland prawn production industry is worth ↑$87 million annually and the 2016 White Spot Disease (WSD) outbreak caused ↑$25 million in losses and complete destruction of all livestock on eight farms in the Logan River region. Whilst the outbreak was restricted to SE Qld, its source, and hence the risk for re-infection, remains unknown, resulting in a need for ongoing surveillance. Early detection of WSD infection on farms is a high priority which can be facilitated via development of improved diagnostic tools. Current diagnosis requires specialised laboratory testing so there is a need for a simple, rapid, robust in-field diagnostic test to complement this.

We have developed an alternative diagnostic tool for WSD that is suitable for use both in the laboratory and at pond-side. Assay performance was evaluated with pure DNA and crude tissue samples with minimal preparation, giving results similar to traditional DNA testing performed in the laboratory. Our assay is sensitive, specific & accurate; gives results comparable to qPCR (current gold standard); has lower reagent costs; fast workflow of ↓90 minutes and is field-deployable.

Point of care detection for WSD is an important tool for the future, and our assay is an ideal candidate to fill this space as it will complement the current diagnostic tools already available, to help manage high sample loads and facilitate faster disease diagnosis. This will assist in limiting the spread of the virus through early detection and reducing the risk of disease outbreak, thus protecting Queensland's valuable prawn aquaculture industry.

## 288

## Start clean, stay clean

**Mr Mark Whattham**[1]

[1]*Department of Agriculture, Australian Government, Australia*

Starting clean and staying clean is one of the simplest ways to maximise and sustain a productive farming operation. Australia's geographical isolation and strict quarantine regulations has meant we have relatively fewer pests that affect primary industries compared to overseas. Healthy plants are easier to grow, require fewer chemicals and produce higher crop yield and quality. To remain internationally competitive and economically viable, the Australian agriculture sector needs to consider the positive impact that starting with healthy planting material and seed provides. Accurate and rapid diagnosis for viruses and other graft transmissible diseases that can spread through infected propagation material, plays a critical role in providing healthy plants for growers and supporting profitable production. Quarantine services provided by the Australian government and use of certified pathogen tested planting material greatly reduces the chance of introducing pests onto your property, that once established, can be difficult and costly to control. This presentation will provide a brief overview of programs available to *'start clean'* and then concludes by summarising actions you, the farmer, can do to help 'stay clean.'

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## 289

## Future systems for traceability in the red meat supply chain

**Ms Jo Quigley**[1]

[1]*Integrity Systems Company, Meat & Livestock Australia, North Sydney, Australia*

Australia's red meat integrity system is a key underpinning of the $18.4 billion red meat industry. Comprising three key pillars: the Livestock Production Assurance (LPA) program, National Vendor Declarations (NVDs) and the National Livestock Identification System (NLIS), each program plays a part in protecting the disease-free status of Australian red meat and underpins the marketing of the red meat product as clean, safe and natural.

With a heavy reliance on global export markets, it is essential that the Australian red meat industry maintains a competitive edge by meeting customer needs, both now and into the future. Through data, new technologies and novel approaches to integrity and traceability, the *Red Meat Integrity System 2025 Strategy* is the roadmap for the transformation of the red meat integrity system from 2025 and beyond.

Emerging technologies are creating opportunities for the Australian red meat industry to simplify, yet strengthen its offering in an increasingly competitive market through solutions that will contribute to enhanced traceability and biosecurity. Whether it be advanced facial recognition to uniquely identify livestock, satellites supported by imaging technology that enable livestock to be tracked in real time, or sensors that underpin market eligibility and provenance claims, there is tremendous opportunity arising from digital technology, data systems and analytics.

Through the *Red Meat Integrity System 2025 Strategy,* the red meat industry is aiming to deliver a seamless and valued integrity system, helping to create cost and operational efficiencies, while ensuring that customers continue to have absolute trust in Australian red meat.

## 290

# New technologies for weed eradication - invasive plants have no place to hide when DNA is involved

**Dr Laura Simmons**[1], Joe Vitelli[1], Steve Csurhes[1]

[1]*Biosecurity Queensland, Department of Agriculture and Fisheries, Dutton Park, Australia*

Building on the advances in molecular technology, two genetic based tools are being developed by Biosecurity Queensland to improve conventional invasive plant detection, monitoring and control. *Sporobolus* is a genus of almost 200 grass species from tropical and subtropical parts of the world. In Australia, 19 *Sporobolus* species are endemic and 8 species are introduced. Of these, 10 (5 natives and 5 introduced) are closely allied species and overlapping morphological traits makes accurate identification very difficult. Five of the introduced weedy *Sporobolus* grasses including Giant Rat's Tail Grass (GRT), threaten to cost the grazing industry of eastern Australia $60 million per annum, having the potential to infest 60% of Queensland and 30% of Australia. The success of four GRT biological control programs in Australia, hinge on the accurate identification of the host plant. The GRT project relies on a molecular approach to delimit and accurately identify these *Sporobolus* species, allowing for a more accurate and targeted control strategy to be used in the paddock.

The second molecular project focuses on the dioecious Mexican bean tree *(Cecropia spp.)*, a restricted pioneer tree that has invaded rainforests in tropical and subtropical Queensland. Molecular markers are being used to genotype an eradicated population to identify if there are any undetected parent trees within surveyed areas that may be residing in inaccessible rainforest patches, thereby preventing extirpation to occur. Dust monitoring devices to capture pollen are being trialled as an eDNA surveillance method for detecting unknown Mexican bean tree populations in remote rainforest locations.

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## 291

# Collaborative planning and shared decision making in biosecurity emergency management

**S. Perry** and R.J. Laws

Department of Agriculture and Fisheries, Dutton Park, Queensland, Australia

Robust planning and decision making processes are essential to manage biosecurity risks, particularly in emergency response situations that are highly complex, often contentious and can change rapidly. Effective risk management involves analysing large amounts of diverse scientific, technical and practical information; and dealing with competing priorities and conflicting interests amongst stakeholders. Furthermore, Australia's biosecurity system relies on shared responsibility, where governments, industry and the community work together to manage biosecurity risks. For shared responsibility to be successful, improved planning and decision making processes are required to ensure that decision making processes enable input from stakeholders. Stakeholder input into risk assessment and the development of risk management options results in more rigorous 'risk-informed' decision making.

We have developed a collaborative planning and shared decision making framework for risk-informed decision making in biosecurity. It is an integrated system that incorporates principles for involving stakeholders in risk analysis (including risk assessment, management and communication), good decision making and risk governance. We will present the application of the framework during the incursion of the tropical race 4 (TR4) strain of Panama disease in north Queensland, Australia where growers and other industry stakeholders were involved in the development and implementation of the risk mitigation during the emergency response.

The collaborative planning and shared decision making framework enables end-users to better manage biosecurity risks, with a logical and analytical planning and decision making process that integrates scientific, technical and practical knowledge and accounts for the political, social and economic values of stakeholders.

## 300

## Climate change impacts, adaptation and mitigation for tropical agriculture

**Prof Mark Howden**[1]

[1]*Australian National University, Canberra, Australia*

As climate change gains pace globally, many of the first and most severe impacts are falling on tropical regions. In particular these impacts are occurring in tropical agriculture and food systems with assessments of falling crop yields, decreases in the productivity of livestock and fisheries and increased climatic disruptions. This is likely to have already increased stresses in relation to food security and natural resource management, both on land and in the adjacent oceans. Unfortunately, increasingly negative changes appear to be likely, with projections of widespread and substantial negative future impacts of climate change on tropical agriculture. There are many potential adaptations to climate change, covering options ranging from incremental to transformational change each with different risk vs return profiles. Limits to adaptation and barriers to action are increasingly being seen as critical issues that will need a focus over the next decade. Similarly, integration of practices that reduce greenhouse gas emissions, enable effective adaptation to a variable and changing climate and enhance sustainable and stable agricultural production will likely become more important as climate change progresses. Furthermore, there will be a need to re-frame the science we do and the way we generate and deliver it. For example, science that is 1) demand-driven rather than supply driven, 2) that aligns with the values, needs or capability of users, 3) that is not presented as suitable for operational use when it is not. We can also better connect knowledge and action via co-learning that links closely the users and producers of climate information so as to address the correct time and spatial scales and climate variables and embed this information into the social and institutional processes through which decisions are made.

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## 301

## Next era livestock production

**Derrick Thompson**

*Hitachi Australia Pty Ltd, Australia*

Data. Data. Data. Data is everywhere but producers are often overwhelmed by the sheer volume of raw data. What is needed is easily usable and valuable decision-making information. The ever-increasing range of digital tools to assist producers in the decision-making process with improved data based decision-making knowledge requires the use of numerous platforms that are not integrated, nor able to communicate with each other nor able to interpret and analyse information at a high level. This makes the use of such tools complicated, tedious and can at times be somewhat misleading, with the result of discouraging widespread adoption of data sourced technology. By integrating these tools, so that they are accessible through one Control Centre, such data driven digital transformation greatly improves the efficiency of using the available tools, results in increased adoption of data usage - all leading to increases in productivity and profitability, on farm and across the supply chain. Data is the next "Era in Livestock Production". Hitachi's presentation will look at a few case studies that demonstrate the value of intelligent use of data in daily farm operations.

## 302

### Cropping systems modelling: Past, present and future

**Dr Peter Thorburn**[1], Dr Brian Keating[1]

[1]*CSIRO, St Lucia, Australia*

Cropping systems are characterised by complexity and variability, and modelling has evolved as a means of describing and interpreting multifaceted performance of these systems. It is also increasingly a means of predicting likely performance for better managing cropping systems. In this paper we will briefly describe the development path over the past five decades that has resulted in our current well developed cropping systems modelling capability. We will also discuss new initiatives in sensing, data acquisition and processing (ML/AI) and how these might influence the future of models. These development will result in our models to having even greater impact on the performance of cropping systems in the future.

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## 303

### Integrating crop modelling, physiology, genetics and breeding to aid crop improvement for changing environments

**Dr Karine Chenu**[1], Mr Andrew Fletcher[1], Dr Behnam Ababaei[1], Dr Jack Christopher[1], Dr Alison Kelly[1], Dr Lee Hickey[1], Dr Erik Van Oosterom[1], Prof Graeme Hammer[1]

[1]*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Australia*

Following advances in genetics, genomics, and phenotyping, trait selection in breeding is limited by our ability to understand interactions within the plant and with the environment, and to identify traits of most relevance to the target population of environments. We propose an integrated approach that combines insights from crop modelling, physiology, genetics, and breeding to characterize traits valuable for yield gain in the target population of environments, develop relevant high-throughput phenotyping platforms, and identify genetic controls and their value in production environments. This presentation will use transpiration efficiency (biomass produced per unit of water used) as an example of a complex trait of interest to illustrate how the approach can guide modelling, phenotyping, and selection in a breeding programme. We anticipate that this approach, by integrating insights from diverse disciplines, can increase the resource use efficiency of breeding programmes for improving yield gains in target populations of environments in current and future climates.

## 304

## Drivers of phosphorus efficiency in tropical and subtropical cropping systems

**Ms Bianca Das**[1,2], Dr Neil Huth[2], Dr Merv Probert[2], Dr Birthe Paul[3], Dr Job Kihara[3], Mr Peter Bolo[3], Prof Daniel Rodriguez[4], Honorary Professor Mario Herrero[2,4], Prof Susanne Schmidt[1]

*[1]The School of Agriculture and Food Sciences, The University of Queensland, Brisbane, Australia, [2]Commonwealth Scientific Industrial Research Organisation (CSIRO), Brisbane, Australia, [3]International Centre for Tropical Agriculture (CIAT), Nairobi, Kenya, [4]Queensland Alliance for Agriculture and Food Innovation (QAAFI), The University of Queensland, Brisbane, Australia*

Phosphorus (P) is an essential nutrient but is commonly limiting for food production in tropical and subtropical maize cropping. The efficiency of P fertiliser uptake is often low (5-30%) for various site-specific reasons and so identifying the drivers of P efficiency for different systems is important. We conducted a sensitivity analysis on the parameters of a well-established cropping systems model (APSIM) for a wide range of soil, crop and management factors to understand their influence on yield. The analysis was conducted for two contrasting maize cropping systems: (a) a high-input, large-scale commercial system in subtropical Queensland, Australia and (b) a low-input, small-holder system in tropical, western Kenya. In Queensland, yield was most sensitive to available P and mineral N supply, and the sensitivity of both increased with in-crop rainfall. Available P was also the most important parameter in Western Kenya, but N supply had much weaker influence due to higher levels of organic matter. Parameters controlling P sorption were more important than other soil parameters at both sites irrespective of seasonal conditions. In conclusion, these results suggest that efforts to improve efficiency of P use by plants need to account for interactions between water and N supply in environments where these are limiting. They also highlight a potential constraint to modelling of these systems as some of the most influential parameters are difficult to measure directly.

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## 305

## Improving crop adaptation to through improved phenology prediction: a case study with chickpea

**Dr Yash Chauhan**[1], Dr Merrill Ryan[2]

*[1]Department of Agriculture and Fisheries, Queensland Government, Kingaroy, Australia, [2]Department of Agriculture and Fisheries, Hermitage Research Facility, Hermitage, Australia*

Flowering time is a key phenological stage which in chickpea has been considered to be mainly driven by photoperiod and temperature. However, in spite of being able to be measured very accurately, these two factors are not able to fully account for seasonable and locational variation in flowering time. Analysis of published information and flowering data, collected in various projects on chickpea has led to the discovery of soil moisture being an additional critical driver of flowering and pod set in chickpea. High soil moisture status delays flowering in chickpea. An equation that captures the effect of soil moisture on flowering time has been developed. This equation enables prediction of flowering time in a very diverse range of environments and seasons with a high accuracy, further suggesting a putative role of soil moisture in modulating flowering. Similar improvements in prediction of flowering time have been noted in lentil and wheat also suggesting that soil moisture, similar to temperature and photoperiod, may have a universal role in modulating flowering of winter crops. The delaying effect of high soil moisture, while on one hand could assist in avoiding frosts, could lead to greater soil moisture and heat stress later in the season if the delay is considerable. This new research will enable more effective optimisation of flowering time of winter crops in different environments and provide breeders and physiologists the opportunity to unravel the genetic and physiological basis of phenological responses to soil moisture and exploit this response to improve crop adaptation to climatically variable environments.

## 306

# Learning through modelling to help on farm decisions in North Queensland

**Dr Keith Pembleton**[1], Mr Graham Harris[2], Mr Peter McDonnell[3], Dr Lance Pendergast[4], Dr Ando Radanielson[1]

*[1]University of Southern Queensland, Toowoomba, Australia, [2]Department of Agriculture and Fisheries, Toowoomba, Australia, [3]SunRice, Brandon, Australia, [4]Department of Agriculture and Fisheries, Townsville, Australia*

Agricultural systems models are complex mathematical representations of how farming systems responded to both environment and management. While they are commonly used by scientists to test hypothesis around the complex interactions that occur between plants, soils, livestock, management and climate they also have a role in guiding decision making by farmers and their advisors. This role becomes particularly important in situations and locations where there are limited experience to learn from. North Queensland has significant agricultural potential through both a diversification of the coastal sugarcane based farming system and the conversion of inland grazing lands to broad acre irrigated cropping. However, there is limited experiences of crops that could be used to capture such opportunities. Through this presentation, we will examine three cases where the Agricultural Production Systems Simulator (APSIM) was used to help overcome a shortfall in learned experience to make cropping decisions. The first case we will examine is the conversion of grazing land to irrigated broad acre cropping in North West Queensland. The second scenario to be examined will be the provision of pre-field experiment modelling-led hypothesis testing new crop varieties at a new irrigated cropping development site. In the final case we examine a replanting analysis after flooding destroyed rice crops grown in the coastal sugarcane farming system. From these examinations, we draw conclusions around the value of modelling to help decision makers operating in areas with limited agricultural experiences to learn from.

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## 307

# From fields to farms: Informing the trade-offs across the multiple functions of agriculture

**Prof Daniel Rodriguez**

*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Australia*

Adapting the nature and extent of agriculture to fit expected increases in food and energy demand, amid changes in climate and the environment, clearly requires the development and application of new scientific approaches and innovative solutions. High productivity is the result of the best combination of management variables that influence crop production in a given field, and the way limited resources e.g. labour, land, finances, are allocated across enterprises and fields at the whole-farm level. Focusing on the yield of individual crops is necessary but insufficient for several reasons. First, larger improvements in productivity are likely from interventions at scales beyond the crop or the field, i.e. the farming system, the farm, and their operating environment. Second, changes in the yield of individual crops might not reflect the fact that farmers manage the farm and resources to satisfy a number of usually competing objectives: livelihoods, returns, lifestyle, environmental outputs, rather than just increasing crop yields. This is important as changes in one enterprise at any point in time will limit options spatially across the farm e.g. due to land, labour or machinery constraints; and temporally across seasons e.g. due to follow-on implications on soil water and nutrients availability, or the need for breaks for pests or diseases between successive crops. Thus, when the analysis is removed from the farm business context, the disconnect between the more technical issues, e.g. choosing a cultivar or a particular rate of fertilisation, and the final decision made on the farm, can conspire against understanding why an individual piece of technology is not adopted, or why apparently a "sub-optimal" decision is finally made. Recognising that farmers grow crops in cropping systems, that they usually manage limited resources and that those resources need to be allocated to satisfy their multiple objectives across a number of alternative enterprises is the first step in understanding where the opportunities for improvement may lie. Farms are complex systems (Fig. 1), that is why the analysis requires involving all actors in participatory research approaches working with farmers at the level that they think and make decisions i.e. the farm business.

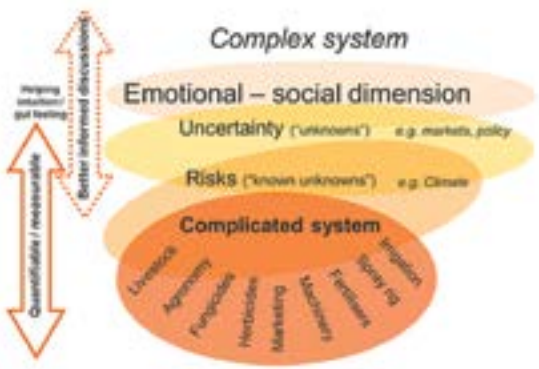


**Figure 1.** Conceptualization of the complexities in the management of a farm business and its disaggregation into quantifiable or measurable components, and the social-human dimension accessible via discussion, reflexion, and learning.

## 308

## Nanoplatforms for large and small molecule delivery to plant cells

**Prof David Cahill**[1,2], Professor Alok Adholeya[2], Dr Xinhua Lu[3], Dr Dequan Sun[3], Dr Jim Rookes[1], Dr Pavani Nadiminti[1], Professor Lingxue Kong[4]

[1]*Deakin University, School of Life and Environmental Sciences, Geelong Waurn Ponds Campus, Australia,* [2]*TERI Deakin Nanobiotechnology Centre, Gurgaon, India,* [3]*South Sub-Tropical Crops Research Institute, Chinese Academy of Tropical Agricultural Sciences, Zhanjiang City , China,* [4]*Deakin University, Institute for Frontier Materials, Geelong Waurn Ponds Campus, Australia*

We have been using a variety of nanoplatforms to deliver a range of molecules including DNA, herbicides and phytohormones to plant cells. The versatility of the nano approach and the diversity of cargoes that can be accommodated means that nanoparticles now offer viable alternatives for the delivery of biomolecules and agrochemicals in horticulture. We are currently exploring platforms such as nanobiochar, mesoporous silica nanoparticles (MSNs), self-assembling lipids, graphene oxide and nanoclays as delivery vehicles. The versatility of MSNs, for example, is demonstrated by their use as both a DNA and salicylic acid (SA) delivery vehicle. In proof of concept studies positively charged MSNs were employed as vectors to load a smGFP gene into protoplasts of *Arabidopsis thaliana* without any cytotoxic effects. The functionalised MSNs protected the bound pDNA against degradation by cellular nucleases and led to high gene expression levels and thus showed MSNs to be promising carriers for safe and effective gene delivery. We have also used MSNs to control the delivery of SA to pineapple roots to reduce disease caused by *Phytophthora cinnamomi*. The use of molecular gatekeepers to encapsulate SA within the mesopores allowed stress-induced glutathione-stimulated slow release and resistance induction. Similarly, abscisic acid has been delivered by MSNs to reduce water loss in *A. thaliana* under simulated drought conditions. We have also used biodegradable lipid-based nanoparticles and Al-Mg nanosheets to deliver the herbicide 2, 4, D to model and weed species. Nanoplatforms thus provide new, efficient and safe ways to introduce molecules into plants.

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## 309

## Nanomaterials enable delivery of genetic material without transgene integration in mature plants

**Asst Prof Markita del Carpio Landry**[1]

[1]*University of California-Berkeley, USA*

Genetic engineering of plants is at the core of sustainability efforts, natural product synthesis, and agricultural crop engineering. The plant cell wall is a barrier that limits the ease and throughput with which exogenous biomolecules can be delivered to plants. Current delivery methods either suffer from host range limitations, low transformation efficiencies, tissue regenerability, tissue damage, or unavoidable DNA integration into the host genome. Here, we demonstrate efficient diffusion-based biomolecule delivery into tissues and organs of intact plants of several species with a suite of pristine and chemically-functionalized high aspect ratio nanomaterials. Efficient DNA delivery and strong protein expression without transgene integration is accomplished in mature *Nicotiana benthamiana, Eruca sativa* (arugula), *Triticum aestivum* (wheat) and *Gossypium hirsutum* (cotton) leaves and arugula protoplasts [1]. DNA origami nanostructures further enable siRNA delivery to plants at programmable nanostructure loci [2]. Our work provides a tool for species-independent, targeted, and passive delivery of genetic material, without transgene integration, into plant cells for diverse plant biotechnology applications.

1. Demirer, G.S., Zhang, H., Matos, J., Goh, N., Cunningham, F.J., Sung, Y., Chang, R., Aditham, A.J., , Chio, L., Cho, M.J., Staskawicz, B., Landry, M.P. High Aspect Ratio Nanomaterials Enable Delivery of Functional Genetic Material Without DNA Integration in Mature Plants. Nature Nanotechnology (2019). DOI: 10.1038/s41565-019-0382-5NNANO-18081684
2. Zhang, H.*, Demirer, G.S.*, Zhang, H., Ye, T., Goh, N.S., Aditham, A.J., Cunningham, F.J., Fan, C., Landry, M.P. Low-dimensional DNA Nanostructures Coordinate Gene Silencing in Mature Plants. PNAS (2019). DOI: 10.1073/pnas.1818290116

## 310

## Novel nanoparticle platforms for chloroplast-targeted transgene delivery and expression across varied plant systems

**Asst Prof Seonyeong Kwak**

*Seoul National University, South Korea*

Plant genetic engineering is an essential tool used in current efforts in crop improvement, pharmaceutical biosynthesis, sustainable agriculture, and fundamental plant biology. However, conventional genetic engineering techniques target the nuclear genome, prompting concerns about outcrossing of transgenes. Chloroplast transformation offers advantages over conventional nuclear transformation technologies since the plastid genome is maternally inherited in most higher plants, motivating the need for organelle-specific and selective nanocarriers. Here, we rationally designed chitosan-complexed single-walled carbon nanotubes, utilizing the lipid exchange envelope penetration (LEEP) mechanism to maximize the trafficking efficiency of the plasmid DNA-SWNT complexes into the chloroplasts. The single-walled carbon nanotubes selectively deliver plasmid DNA to chloroplasts of different plant species without external biolistic or chemical aid. We demonstrate chloroplast-targeted transgene delivery by visualization of transient expression of a marker gene in mature *Eruca sativa, Nasturtium officinale, Nicotiana tabacum,* and *Spinacia oleracea* plants and in isolated *Arabidopsis thaliana* mesophyll protoplasts. The presented approach is simple, easy to perform, cost-effective and does not required specialized equipment. This nanoparticle-mediated chloroplast transgene delivery tool provides practical advantages over current delivery techniques as a potential transformation method for mature non-model plants to benefit plant bioengineering and biological studies.

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## 311

## Encapsidation of heterologous nucleic acids in virus-like particles: The potential for plant protection

**Dr Frank Sainsbury**[1]

[1]*Griffith University, Nathan, Australia*

Virus capsids have found many uses in biotechnology. From the well-known use as effective vaccines to enzyme-filled nanoreactors in biocatalysis, their favourable properties include exceptional structural fidelity, biocompatibility and benign manufacturing conditions. Recently, the concept of viral symbiosis has changed the way we think about plant viruses and elucidating the relationship between so called persistent viruses and their hosts may provide a new set of tools in plant biotechnology. A number of recombinant capsids, or virus-like particles, have been used to encapsidate heterologous nucleic acid for applications including gene delivery and virus mimics as diagnostic reagents. In addition, engineered infectious viruses have found success in diverse biotechnological uses such as gene therapy and the use of bacteriophages as biocontrol agents against bacterial plant pathogens. This work has inspired us to direct encpasidation of nucleic acids in virus-like particles as non-infectious biocontrol agents. We are exploring the directed encapsidation of nucleic acids within different VLPs and the long term stability of recombinant capsids from plant and animal viruses indicate that they are well suited to environmental applications. Recently, we determined the first structure of a persistent plant virus via the plant-based expression of Pepper cryptic virus 1 coat protein. We are exploring the use of this unusual structure as a carrier of heterologous nucleic acids in the control of insect pests.

## 312

## Clay nanoparticles facilitate delivery of antiviral RNA for crop protection

**Prof Zhiping (Gordon) Xu**[1]

[1]*The University of Queensland, Australian Institute for Bioengineering and Nanotechnology (AIBN), Brisbane, Australia*

Recently, nanotechnology, biotechnology and agriculture are gradually integrated into innovative crop protection product. My talk will present a good example that combines these expertise to develop clay nanoparticle-based gene pesticide for plant virus protection. I will first introduce a clay nanomaterial, and then present the details for its use as a vehicle for topical delivery of RNA pesticide to plants. Topical application of naked dsRNA onto plants can protect the plants from virus invasion for only 5 days. Once loaded on clay nanoparticles, the dsRNA does not wash off, shows sustained release and stays on sprayed leaves for 30 days. Significantly, a single spray of dsRNA-clay nanoparticles afford virus protection for 20-30 days for both sprayed and newly formed leaves. I will also show the possible pathways for delivered dsRNA to function.

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## 313

## A perspective on risks associated with RNAi-based biopesticides

**Dr Stephen Fletcher**

*Centre for Horticultural Science, QAAFI, The University of Queensland, St Lucia, Australia*

Sustainable agriculture relies on practices and technologies that combine effectiveness with a minimal environmental footprint. RNA interference (RNAi), a eukaryotic process in which transcript expression is reduced in a sequence-specific manner, can be co-opted for the control of plant pests and pathogens in a topical application system. Double stranded RNA, the key trigger molecule of RNAi, has been shown to provide protection without the need for integration of dsRNA-expressing constructs as transgenes. Consequently, development of RNA-based biopesticides is gaining momentum as a narrow-spectrum alternative to chemical-based control measures, with pests and pathogens targeted with accuracy and specificity. Limitations for a commercially viable product to overcome include stable delivery of the topically applied dsRNA and extension of the time period of protection. In addition to the research focus on delivery of dsRNA, development of regulatory frameworks, risk identification and establishing avoidance and mitigation strategies is key to widespread deployment of topical RNAi technologies. Once in place, these measures will provide the crop protection industry with the certainty necessary to expend resources on the development of innovative dsRNA based products. Readily evident risks to human health appear minimal, with multiple barriers to uptake and a long history of consumption of dsRNA from plant material. Unintended impacts to the environment are expected to be most apparent in species closely related to the target. Holistic design practices, which incorporate bioinformatics-based dsRNA selection along with experimental testing, represent important techniques for elimination of adverse impacts.

## 314

## Pregnancy nutrition affects calf survival in the tropics

**Dr Geoffry Fordyce**[1]

[1]*QAAFI, Charters Towers, Australia*

The net cost of calf loss between confirmed pregnancy and weaning in a north Australian beef business is ↑$400. In an epidemiological study of ↑46,000 pregnancies in commercial beef herds, median wastage was 9.5%, ranging from 0% to ↑30%, consistent with the situation in many tropical countries. Detailed study of ↑9,500 pregnancies in multiple research herds with similar loss showed 30% and 50% of losses occur within a day and week of calving, respectively. Stress and under-nutrition of the pregnant cow, eg, low dietary energy, protein or phosphorus, low body condition, poor handling and exposure to environmental extremes, have substantially-more impact on calf wastage than any of the risk factors traditionally blamed, ie, infectious disease, inherited, congenital or acquired defects of the calf and or cow, and natural causes such as predation or accidents. Nutrition- and stress-related risk factors with large impact on calf wastage may influence milk delivery, especially to neonates that require colostrum and as much as 5 L/d from birth. Neonatal calf diarrhoea is not usually a feature. Low milk delivery can be due to either insufficient milk production or to reduced calf capacity to suckle. Calf loss is also associated with mortality of poorly-nourished cows. Causal webs explaining calf loss in non-intensive tropical beef systems demonstrate the high degree of complexity, intervention points with greatest potential impact and that any potential interventions to reduce calf wastage have both negative and positive impacts. Systematic solutions should target critical control points and are situation-specific.

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## 315

## Maximising reproduction under extensive grazing conditions, regardless of rainfall

**Dr Kylie Schooley**[1]

[1]*The University of Queensland, Mundubberra, Australia*

Maximising reproduction in beef cows under normal grazing conditions takes planning, discipline and a firm belief in science. The things that hinder producers in this arena are the extreme variations in weather conditions, subjective beliefs, tradition and paradigms. What producers need to use to maximise Kg produced per hectare year in year out is objective measurement, benchmarking and solid adherence to science. The confounding factors that make this difficult are the vast array of variables which impact on cattle production. At Rocky Springs we endeavor to simplify these variables into a few objective measures, clearly defined trigger points and a very solid year around calendar of main events on farm.

This translates into ground cover assessments at key seasonal points, condition score assessments of cows during lactation, pregnancy testing with foetal aging, weight recording and condition assessments at weaning. Nutritional manipulation where needed. We always protect the feed base first, then breeder cow condition with a specific target of a condition score of 3.5 at calving to ensure strong mothering behavior and good quality colostrum. This is done with manipulation of stocking rate, early reductions in stock numbers if rainfall is poor and strict adherence to management calendar, regardless of rainfall. We always have trigger dates and live by them, if things get tough, responding early is most important for the bottom line

## 316

## Nutritional programming of beef heifers

**Dr Tryon Wickersham**[1], Mr. Colton Oney[1], Dr. Jason Sawyer[1]

[1]*Texas A&M University, College Station, United States*

Sustainability of beef cattle production is, in part, dependent on a supply of females selected and adapted to meet the production environment of a given operation. Ideally, replacement females would have no maintenance requirements, wean infinity calves, and each calf would perfectly match beef value chain expectations. However, bovine physiology has limitations (e.g., generally one calf per year and maintenance requirements are significant) and beef cattle operations have access to divergent quantities and qualities of nutrients with greater variability in those regions subject to drought. Therefore, developing heifers to meet performance expectations as efficiently as possible, under the constraints of an individual operation becomes an essential component of sustainable beef production. Heifer development generally is discussed as the period from weaning to breeding, with successful breeding defined as the endpoint, a critical outcome. However, nutrition at each stage of a heifer's life from conception to her subsequent rebreeding for a second calf plays a role in her long-term productivity and operational success. For example, the role of maternal nutrition is receiving increasing attention for its effects across the entire lifespan of the offspring. Therefore, describing the effects of nutritional programming at each stage of life and the plasticity of nutritional requirements will improve our ability to produce females capable of meeting production goals.

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## 317

## Prepartum supplementation to improve transfer of passive immunity and growth

**Dr Luis F.P. Silva**[1], Mr Jarud Muller[2], Dr John Cavalieri[3], Dr Geoffry Fordyce[1]

[1]*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), St Lucia, Australia,* [2]*Department of Agriculture and Fisheries, Charters Towers, Australia, 3James Cook University, Townsville, Australia*

Late pregnant cows often experience nutritional stress in northern Australia, which reduces colostrum secretion, health, and likelihood of survival of neonatal calves. The effect of prepartum supplementation on the transfer of passive immunity and growth of calves was investigated. The decline in prepartum progesterone was the hypothesised mechanism regulating the transfer of passive immunity. Ninety pregnant Droughtmaster heifers and 45 Brahman cows were used. Animals were stratified by body weight and expected calving date, and separated into two blocks of heifers and one block of cows. Animals were randomly allocated into nutritional treatments, where all were fed low quality Rhodes-grass hay: 1)Control hay only; 2)Protein (PRO), supplemented with 1kg/d of protein supplement; and 3)Yeast fermentation products (YFP), protein supplement plus 14g *Saccharomyces cerevisiae* fermentation product (NaturSafe™). Data for final analyses was available from 92 calves on transfer of passive immunity and from 59 cow/calf pairs on prepartum progesterone decline. Treatment means were compared via orthogonal contrasts for the effect of supplementation PRO and YFP. Protein supplementation for an average of 14d hastened the decline in the concentration of serum progesterone before parturition ($P\downarrow 0.01$) and tended ($P=0.09$) to increase growth rate of calves during the first 10d (1.0 vs. 0.9 kg/d). However, there was no effect of PRO on neonatal calves plasma immunoglobulin-G1 (IgG1) concentration ($P=0.43$). Adding YFP further hastened the progesterone decline before parturition ($P\downarrow 0.05$) and tended to increase plasma IgG1 ($P=0.08$). Short term nutritional supplementation prepartum may improve transfer of passive immunity and neonatal calf growth.

## 318

## Risk factors for dystocia in cattle

**Assoc Professor Scott Norman**[1,2]

[1]*Kallangur Veterinary Surgery, Kallangur, Australia,* [2]*Charles Sturt University, Wagga Wagga, Australia*

The understanding and classification of the general causes of dystocia in cattle has changed little in the past 40 years. In decreasing order of occurrence, the three most important general causes of dystocia in beef cattle are considered to be:

1. Fetopelvic disproportion.
2. Posterior presentation of the fetus
3. Ineffective labour

These three causes of dystocia are reported to account for 30-70%, 20-45% and 10-20% of dystocias in beef heifers respectively.

Although it is convenient and traditional to classify the causes of dystocia in this way, these broad classifications don't provide a clear basis for specific control measures to be implemented. For example, fetopelvic disproportion simply suggests an incompatibility between the size of the fetus and the size of the maternal pelvis. The reason for the incompatibility could be one, or a combination, of many factors. This presentation explores specific causes and risk factors for dystocia as a basis for developing effective control measures.

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## 319

## Strategic supplementation enhances rumen microbiome efficiency in pregnant tropical beef cows

**Dr Christopher McSweeney**[1], Dr Gonzalo Martinez-Fernandez[1], Dr Stuart Denman[1]

[1]*Commonwealth Scientific and Industrial Research Organisation (CSIRO), St Lucia Brisbane, Australia*

Lick-blocks that are used in northern Australian beef enterprises contain varying levels of macro-nutrients (crude protein, sulfur and phosphorus) to correct deficiencies in the forage. It is thought that organic forms of nitrogen and sulfur are used more efficiently for growth and function of the rumen than the inorganic nutrients. A trial was undertaken in pregnant heifers grazing a poor-quality dry season diet in the Northern Territory. The animals received three lick supplements containing varying forms of organic and inorganic N. No significant differences on animal performance and rumen fermentation parameters were observed between supplements. Animals were initially deficient for rumen ammonia-N (15.8 mg/L) and BUN (4.7 mg/100 mL) concentration. All nitrogen supplements led to a significant improvement in ammonia N (24.7 – 31.8 mg/L) but levels remained deficient until the wet season and availability of higher quality pasture. Even though the rumen ammonia levels were sub-optimal, the supplemented animals gained approximately 650 g liveweight daily compared with a weight loss of 330 g daily in un-supplemented animals. The increased availability of N in either an organic or inorganic form had a similar influence on the rumen microbiome and rumen fermentation products with increases in ammonia, branched fatty acids, butyrate and the acetic: propionic ratio. All three N supplements showed the same significant increase in species of *Ruminococcus, Bacteroidetes* and *Cyanobacteria (Melainabacteria)* involved in cellulose and hemicellulose digestion. It appears inorganic N is as effective as organic N in improving rumen efficiency when there is a gross deficiency of N for microbial growth.

## 320

## Genetics and metabolomics of aroma in rice

**Prof Melissa Fitzgerald,** Dara Daygon, Mary Garson

*The University of Queensland, Brisbane, Australia*

Aromatic rice commands the highest prices in both domestic and international markets because consumers prize both the mouth-watering aroma and delicate flavour of the rice. The major aromatic compound in fragrant rice is 2- acetyl 1-pyrroline (2AP). Using a panel of 380 diverse varieties of rice, metabolomics profiling of volatile compounds from the grain, and genome wide association with 33000 single nucleotide polymorphisms (SNPs), we were able to identify the most likely pathway for the synthesis of 2AP, as well as other candidate genes that regulate the amount of 2AP. Another 20 metabolites associated either positively or negatively with high quality jasmine fragrance. Several of these are considered unpleasant. This paper will discuss the positive and negatives of aroma, the pathways leading to them, and the candidate genes that control their synthesis, and the amount synthesised. We also deliver information and germplasm for the development of new populations targeted to provide appropriate phenotype data to identify QTLs and gene funciton for those important metabolites identified in this work.

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## 321

## SNPs linked to key traits in hybrids between African and Asian rice

**Hayba Badro[1],** Marie-Noelle Ndjiondjop[2], Agnelo Furtado[1] and Robert Henry[1]

[1]*Queensland Alliance for Agriculture and Food Innovation, University of Queensland, Brisbane, Australia*
[2]*Africa Rice Center (AfricaRice), Cotonou, Benin*

Association analysis was performed to determine trait-associated variants (TAVs) influencing three quantitative agronomic traits, heading date (Hd), tiller number at maturity (T) and 1000-grain weight (TGW) in a population developed by crossbreeding between WAB56-104 (O. sativa) and CG14 (O. glaberrima). DNA derived from extreme phenotypes (high and low-value) for each trait was bulked, sequenced and then mapped against the reference genome of O. sativa cv Nipponbare for two types of analysis, general association analysis and candidate genes analysis. In the general association analysis, a total of 5152 non-synonymous SNPs in 3564 genes distinguished the low and high bulks of Hd, T and TGW traits; however, only 611 non-synonymous SNPs in 447 genes were involved in KEGG pathways. Among these non-synonymous SNPs, only six SNPs in the sequences of LOC107275952, LOC4334529, LOC4326177, LOC107275432, LOC4335790 and LOC107275425 genes were associated with H, T and TGW traits. These genes participated in the following KEGG pathways: abscisic-acid biosynthesis, carotenoid biosynthesis, starch and sucrose metabolism, and cytokinin biosynthesis. Analysis of candidate genes using 9, 10, and 5 genes associated with Hd, T, and TGW traits showed 2, 2, and 3 non-synonymous variations in the sequence of Hd3a and Ehd2 from the group of Hd genes (no KEGG pathway); D10 and D53 from the group of T genes (strigolactones biosynthetic pathway), and Gn1a and GIF1 from the group of TGW genes (cytokinin biosynthetic pathway, and starch and sucrose metabolism pathway), respectively. The results of this study provides significant TAVs for subsequent applications in rice breeding programmes.

## 322

## Introgression of large grain size from Australian wild rice and its agronomical importance

**Ishikawa, R.**[1], Takahiro Mishimaki[1], Daiki Toyomoto[2], Koki Katano[3], Katsuyuki Ichitani[2,3], R. Henry[4]

[1]*Faculty of Agriculture and Life Science, Hirosaki University, Hirosaki, Japan,* [2]*United Graduate School of Agricultural Sciences, Kagoshima University, Kagoshima, Japan,* [3]*Faculty of Agriculture, Kagoshima University, Kagoshima, Japan,* [4]*QAFFI, The University of Queensland, St Lucia, Australia*

There are a few wild species belonging to genus Oryza in Australia. Taxon A and Taxon B have been characterized genetically and ecologically. We have backcrossed the Taxon B carrying larger seed size with Japonica type cultivated rice, Taichung 65 (T65). BC4F1 seeds selected the seed size of BC4F2 showed that Taxon B type subgroup carries 21.5% larger seeds size than T65. The heterozygous group showed incomplete dominance in seed size. Introgressed segments suggested that the causal gene could be a single and located on chromosome 3. By using BC4F2, we characterized agronomical traits to show how the large seed size gene affects to yield. The larger seed size did not show any correlation to number of panicles and panicle length. However, it affected negative effect on number of spikelets. It is explained as Trade-off relation. The negative effect will be resolved to introduce genetic factor related to number of tillers or spikelets per panicle, or they may be tried improved ways of cultivation. The seed size is attractive to improve new varieties as "Australian native rice" to be adopted with a variety of cooking style which prefer large grain size or a variety of application of the size. Japanese Sake is another way because it generally requires larger grain size to expect white core. We are generating pure lines carrying only the gene involving to the seed size with other negative traits for cultivation.

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## 323

## Iron responsive genes in rice: the multiple roles of WRKY factors

Vivian E. Viana, Carlos Busanello, Camila Pegoraro and **Antonio Costa de Oliveira**[1]

[1]*Plant Genomics and Breeding Center, Federal University of Pelotas, Brazil*

The rice crop is one of the most important worldwide. Its cultivation is under constant constraint by climate changes and increasing biotic and abiotic stresses. Brazil is the largest rice producer outside Asia and the rice crop in the country is constantly suffering from different stresses. The five major abiotic stresses affecting rice are cold, flooding, drought, iron toxicity and salinity. Our lab has been working in developing stress resilient lines to these different stresses. The understanding of plant response mechanisms is key to the development of stress resilient crops. WRKY transcription factors (TFs) are responsible for the regulation of genes responsive to many plant growth and developmental cues, and are involved in biotic and abiotic stress responses. Recently, functional genomics studies in model plants have enabled the identification of function and mechanism of action of several WRKY TFs in plants. Our group has been studying the structural and functional similarities and differences among WRKY TFs in order to identify candidate genes for genome editing and breeding for abiotic stress tolerance.

## 324

## Rice biofortification – progress and challenges in improving the nutritional value of rice

**Dr Russell Reinke[1],** Mallikarjuna Swamy[1], Md. Abdul Kader[2], Reynante Ordonio[3], Untung Susanto[4], Emily Arocena[3]

*[1]International Rice Research Institute (IRRI), DAPO Box 7777, Metro Manila, Philippines, [2]Plant Breeding Division, Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh, [3]Philippines Rice Research Institute (PhilRice), Maligaya, Science City of Muñoz, Philippines, [4]Indonesian Center for Rice Research (ICRR), Sukamandi, Indonesia*

Rice is the principal source of calories for more than half of the world's population, and while an excellent source of energy is a relatively poor source of micronutrients. Developing rice varieties with increased levels of bioavailable micronutrients is a sustainable and complementary approach to tackle micronutrient malnutrition, and may be achieved through transgenic or conventional breeding approaches. Using the former approach Golden Rice has been genetically engineered to produce Đ-carotene in the grain to address the persistent and pervasive problem of vitamin A deficiency, while high levels of iron and zinc have also been achieved via a transgenic approach. The primary focus of conventional breeding is increasing zinc content. This paper reports on the progress and challenges in developing and delivering rice with improved micronutrient content.

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## 325

## Meeting the consumer preference of high quality rice grown in a tropical environment

**Mr Russell Ford**

*SunRice, Australia*

Domesticated Rice has attempted to been grown through Northern Australia for 50 years. There have been isolated attempts in Western Australia, Northern Territory and Queensland. All of these attempts have failed, usually with the pressures of wildlife and also the lack of grain qualities to suit consumer requirements have been the major setbacks.

Rice types grown in countries of Tropical origin are typically adapted to the local consumer preference and improved varieties are strongly focused on agronomic improvements with grain quality addressed as a secondary focus.

In Australia, SunRice is the major marketer of Australian grown rice, with a strong focus on Sustainability and grains that meet consumer specifications and preferences. When SunRice look at developing varieties for Northern Australia, there needs to be a strong focus on what the consumer requires, but meet the needs of growers with a suitable agronomic performing variety package. This is sometimes a difficult blend.

Traditionally we know that indica spp. of Oryza sativa (domesticated rice) are best suited agronomically to tropical environments. Adapting japonica spp. to a tropical environment usually comes at the price of reduced yields and poor grain quality. There is now the need for a concerted effort to deliver the best agronomic and quality package of a tropically grown rice variety mix that meet specific consumer preferences.

## 326

## Why AgTech has disappointed us so far, why we need it, and how we can improve adoption rates.

**Mr Matthew Fealy**

*Blue Sky Produce, Australia*

Robots, automation and blockchain are promising to revolutionise farming forever, but why are farmers only reading about these technologies, rather than implementing them? The key objective of my presentation is to present a practical and realistic 'farmer first' overview of technology.

Technology is bringing change at a pace that is difficult to keep up with. Drawing on visits to America, Europe, Asia, the Middle East and the Netherlands where I shared a coffee, a beer and a burrito with some of the most innovative farmers in the world, my research provides a practical break down of technology that can make a difference to farming practices today, particularly horticulture and orchard production.

My presentation canvases numerous risks to agriculture, such as the increasing unpopularity of temporary worker schemes, rising production costs, urbanisation and food safety and regulatory demands on traceability. I then explore currently available technology designed to address these challenges.

AgTech has the potential to become a future pillar of rural economic development. As adoption of these technologies increase, so will the need for research and development, sales, service and support, resulting in the creation of new jobs for rural communities.

As the world continues to rapidly change and farm productivity growth has all but stagnated, farmers must look outside the box for new innovations, from new industries, for solutions. It will take brave innovators across all sectors of production, industry and government to lead change and assist in the adoption of these technologies for the advancement of Australian agriculture.

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## 327

## The Small Trees High Productivity Initiative: Principles and practice in high density orchard design

**Ms Helen Hofman**[1], Dr John Wilkie1, Dr Paula Ibell[2]

[1]*Department of Agriculture and Fisheries, Bundaberg, Australia,* [2]*Department of Agriculture and Fisheries, Mareeba, Australia*

The Small Trees High productivity Initiative aims to address low productivity in avocado, macadamia and mango through intensification. It includes field experiments, genetic and physiological analysis and functional-structural modelling, with a focus on controlling vigour through rootstocks and pruning, manipulating tree architecture, optimising canopy light relations and managing crop load. Trials that compared high density and conventional spacing and training systems were planted in 2014 in Queensland, Australia, for each of the three crops. These trials were also intended to improve our understanding of the key factors driving or limiting yield and quality. Early yield results look promising for the density/training systems we have planted for both mango and macadamia. For example, five years after planting, 'Keitt' mango planted at 1250 trees/ha in an espalier training system produced 53.4 tonnes/ha compared to 11.4 tonnes/ha for conventional plantings (208 trees/ha). For the macadamia variety 'A203', the high density planting (1000 trees/ha) yielded 5.01 tonnes nut-in-shell/ha; the low density planting (313 trees/ha) yielded 2.97. For 'Hass' avocado, however, the yield for central leader shaping and high density planting (1111 trees/ha) was 11.3 tonnes/ha compared to 19.5 tonnes/ha for the conventional shaping and spacing (222 trees/ha). We will discuss factors that may contribute to the relative success and failure of these high density planting systems, including tree structure, canopy volume, vegetative vigour, light interception and distribution, patterns of fruit set and retention, and root area.

## 328

## Intelligent systems for commercial application in perennial horticulture

**Dr Everard Edwards[1], Dr Peyman Moghadam[2]**

*[1]CSIRO Agriculture & Food, Glen Osmond, Australia, [2]CSIRO Data 61, Pullenvale, Australia*

Production in perennial horticulture relies on a high degree of crop management, but, due to that perenniality, management decisions need to balance short- and long-term impacts. Optimising these decisions requires information about the plants and it requires that information at multiple time-points.

The development of intelligent systems, based on new technologies and new data analytics that take advantage of always available high-performance edge computing, provide a unique opportunity to create a step-change in the management of perennial horticulture crops.

For example, combining LiDAR (3D laser imaging) with simultaneous localization and mapping (SLAM) enables the capture of 3D canopy structure on a per tree basis at the orchard scale. Vegetation indices like light penetration, light distribution or foliage density can be estimated directly, in real-time, without a labour-intensive process. Overlaying such an analysis with the output of other sensing modalities extends their application to provide real time, on-farm, decision support by monitoring the condition of every plant in 3D.

Even consumer RGB video cameras provide a resolution and frame-rate adequate for a wide range of applications when combined with computer-based image segmentation and machine learning techniques.

Such technologies offer the prospect of imaging and analysing a future orchard at any phenological time-point and having a block-level result for the parameter of interest, together with the spatial variability data that will assist in long-term management decisions.

In this presentation we will provide examples of these technologies, their current application and how they will be utilised in a future orchard system.

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## 329

## Increasing the diversity of crops that can be grown in urban and vertical farms.

**Dr Cathryn O'Sullivan[1],** Dr Graham Bonnett[1], Dr Lynne McIntyre[1], Dr Ian Dry[1], Dr Lekha Sreekantan[1]

*[1]CSIRO, St Lucia, Australia*

The FAO estimates that more than 800 million people engage in urban agriculture producing more than 15% of the world's food. Recently, there has been a resurgence of interest in urban agriculture in many wealthy, developed cities, with new technology and agro-architecture being employed to grow food in cities at commercial scale. This has been accompanied by an increase in media coverage. Big claims are being made, including that urban agriculture can help solve food security for growing urban populations, decrease greenhouse emissions, 'climate proof' farms, and provide chemical free food with no risk of pests and diseases. Many of these claims need to be rigorously tested to ensure that sound investments can be made in enterprises that are financially viable and capable of delivering on claims of social and environmental benefits.

Traditionally, agricultural researchers have provided biological, chemical, physical, economic and social research help broad-acre and horticulture farming increases productivity and decrease risk. Urban agriculture needs similar support as the industry grows and develops around the world.

There are opportunities to improve crop yields and quality by pairing advancements in environmental controls, phenomics and automation with breeding efforts to adapt traits for architecture, development and quality (taste and nutrition) allowing a more diverse set of crops to be grown in controlled-environment farms. CSIRO is looking to apply our establish capability and skills to support the urban and vertical farming industry to contribute to the nutrition of city dwellers as urban populations continue to rise.

## 330

# Robots and autonomous technology in orchards – the future is here, so what does it really look like?

**Mr Andrew Bate**[1]

[1]*SwarmFarm Robotics, Gindie, Australia*

What is the opportunity for autonomous agriculture in orchards? Sharing the learnings from SwarmFarm Robotics about creating real solutions for farmers, and ultimately creating new farming systems that will take agriculture to the next level of productivity and sustainability:

- Autonomous operation of existing field practices such as slashing between the rows.
- More intelligent and precise application of crop protection products. Spotting individual weeds and autonomous use of non-herbicide technology.
- Using robots to apply nutrients with precision, especially in high rainfall zones.
- Autonomous flower counting system for the apple industry, in order to develop individual tree histories and individual tree management practices.
- The benefits of taking an open approach to technology, seeing SwarmFarm robots as a platform for other Ag Technology to be bolted on and integrated via API, in order to collectively solve the real challenges facing the orchard industry.

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## 331

# Future of horticulture production systems from an RDC perspective

**Mr Byron de Kock**[1]

[1]*Hort Innovation, Lota, Australia*

Hort Innovation invests in transformational blue-sky R&D in Horticulture. Based on the current R&D investments, Byron de Kock, Hort Innovation's Head of R&D will provide a glimpse of what future Horticultural production systems may look like in 10, 20 and 30 years' time!

## 332

## Expedited crop improvement through deep learning and editing

**Dr Tengfang Huang**[1]

[1]*Elo Life Systems, Durham, United States*

Through thousands of years, we have greatly improved our food supply through domestication of crops. However, the pressing issues with changing climates and rapid evolvement of consumer demand requires the next round of crop innovation to take place in the next decade, instead of yet another thousands of years. The keys to solve these challenges are the ability to discover the genomic insights from our diverse germplasms and their evolutionary history, together with the power of precise genome optimization through genome editing. These breakthrough technologies are becoming available to many tropical crops, which provide opportunities to make them more nutritious and resilient to climate changes, in an unprecedented speed.

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## 333

## Presentation title not yet provided

Abstract not yet provided

## 334

## Presentation title not yet provided

Abstract not yet provided

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## 335

## Harnessing asexual seed formation to preserve hybrid vigour and complex yield traits

**Prof Anna Koltunow**

*The University of Queensland, Queensland Alliance for Agriculture and Food Innovation (QAAFI), Australia*

Efficiencies in plant breeding can fast-track the development of high yielding, resilient seeds to support food requirements of a growing world population. Seeds typically form via a sexual pathway resulting in diverse progeny through recombination during gamete formation and gamete fusion during fertilization. Breeders rely on sexual reproduction to generate diverse trait combinations, however, sexual reproduction makes it difficult to keep traits together during backcrossing required to stabilize a variety for evaluation. Hybrid crops can give significantly higher seed yields as a result of what is known as hybrid vigour (or heterosis). However, seeds from high yielding hybrids cannot simply be re-sown as heterosis is lost or inefficiently transmitted to the next generation because sexual reproduction breaks up heterosis and induces trait segregation in subsequent generations. Harnessing asexual reproduction (or apomixis) in plant breeding would enable rapid fixation of traits in F1 hybrids and the progeny of breeding crosses in a single generation as the progeny are derived from a cell that is not a product of meiosis or fertilization. The genotype is thus fixed and the seeds are clonal. In this talk, progress towards harnessing apomixis in a Bill and Melinda Gates Foundation funded project called Capturing Heterosis (CapHet) will be described. This multi-party project aims to develop the capability to synthesize apomixis in sorghum and cowpea and develop self-reproducing hybrid sorghum and cowpeas from which hybrid seeds can be economically saved and grown by smallholder farmers in sub-Saharan Africa without loss of yield or quality over multiple generations.

## 336

## Integrating gene editing techniques into modern cereal breeding

**Prof Ian Godwin,** Karen Massel, Guoquan Liu

*Centre for Crop Science, QAAFI, The University of Queensland*

New breeding technologies are revolutionizing plant and animal improvement programs worldwide. One of these transformative technologies is the application of gene editing, most commonly performed with CRISPR/Cas9. Gene editing allows for genes to be precisely knocked out, can create different proteins, can express genes at different level, tissues and developmental stages, all of which can confer novel trait combinations. Australian regulatory authorities have recently de-regulated the most simple class of edits (the Site Directed Nuclease-1 or SDN-1 edits). Plants and animals containing such edits can now be freely grown in the field with no restrictions, and hence can be used in normal plant and animal breeding programs. Similar rulings in the United States, Canada, Japan, Argentina and Brazil mean that gene edited crops are already entering the market. We are now using CRISPR/Cas9 to edit genes in sorghum and barley, including grain quality traits, disease resistance, and yield components and developmental traits. Using examples of recent work in sorghum, barley and rice, I will explore the ways in which gene edited plants can be integrated into inbred and hybrid plant breeding programs.

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## 337

## In-plant insect-proofing by trans-kingdom RNAi

**Dr Julia Bally**[1], Dr Elane Fishilevich[2], Dr Samanta Bolzan De Campos[1], Dr Marcelo German[2], Pr Kenneth Narva[2], Pr Peter Waterhouse[1]

[1]*Centre for Tropical Crops and Biocommodities, Queensland University of Technology, Brisbane, Australia,*
[2]*Corteva Agriscience, Agriculture Division of DowDuPont, Indianapolis, USA*

*Helicoverpa armigera*, the cotton bollworm, is a major insect pest for a wide range of agricultural crops. It causes huge yield losses through feeding damage and increasing the crop's vulnerability to bacterial and fungal infection. *H.armigera* has evolved substantial resistance to many different chemical insecticides, prompting the development of transgenic crop plants with alternative insect-resistance-conferring mechanisms. For example, transgenic crops producing Bacillus thuringiensis (Bt) toxins have been very successful. However, there is still a concern about insect populations emerging with resistance to these biopesticides. Novel strategies that give effective protection, without affecting the environment, need to be continuously developed and implemented. Such a strategy is Trans-kingdom RNAi, which is based on making plants express double-stranded (ds) or hairpin (hp) RNA for ingestion by herbivorous pests. The RNA triggers silencing of specific genes within the pest leading to its death or impaired growth. However, the efficacy of the approach appears to depend on the means of delivering the RNA. We will describe new approaches and delivery strategies, including chloroplast-based expression, which greatly enhance the potency of insect protection.

## 338

## Benefits and challenges for expanding protected cropping in the Australian tropics

**Dr Elio Jovicich**[1], Heidi Wittl[1]

[1]*Department of Agriculture and Fisheries, Queensland Government, Townsville, Australia*

Protected cropping of vegetables in Australia is largely located in temperate climate regions, however there are opportunities for growers in the Northern tropics to benefit from technologies that mitigate risks associated with climate variability and assist accessing domestic and export markets. Evidence from overseas and research by the Queensland Department of Agriculture and Fisheries (DAF) suggests that, for some high value commodities, protective cropping technologies are a cost-effective way for growers to mitigate the effects of extreme temperature, rainfall, changes in humidity, wind, solar radiation and pest and disease pressures which can negatively impact yield, quality and consistency of supply. Research for development of suitable protected cropping systems for growers in northern Australia has been focusing in awareness, proof of concepts, advice and information sharing. Discussions with industry stakeholders, on-farm demonstrations and trials, and industry study tours have been critical for the identification of cost-effective structure designs and agronomy practices. There are many aspects of these farming systems that still need to be advanced for warm climatic regions. To enable adoption, research will need to consider economic and environmental aspects within the context of resource diversity and availability and markets to be targeted. A new project aims to map potential pathways that will support adoption of protected cropping in the Australian tropics.

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## 339

## Innovative cost-effective protected cropping structure designs for the tropics

**Mr Bede Miller**

*Cravo Australia, Australia*

Take a look inside some of the most innovative projects where growers are creating production systems which are allowing them to achieve results in mild to hot climates which may not be possible outside, in a tunnel or a glass house. Growers are achieving higher yields, better quality, extending or shifting their harvest season while lowering their cost of production... simply by combining best of nature and protected environment.

## 340

## Our experiences testing protected cropping where nobody uses it

**Mr Josh Pirrone**[1], **Mr Ross Pirrone**[1], **Mr Chris Pirrone**[1]

[1]*Pirrone Brothers Produce, Ayr, Australia*

Pirrone Brothers Produce is a medium-size farming business growing a diversity of crops near Ayr, in the dry tropics region of North Queensland. Vegetables produced in this region are exclusively grown outdoors and, in terms of cropped area, they have a small share in an agriculture dominated by sugar cane. Still, the supply of vegetables from the dry tropics is critical to the southern urban areas of Australia during the winter months. Increasingly, domestic markets –as well as potential export markets in Asia- are becoming stricter with supply commitments that assure delivery of high quality produce. This demand criteria is challenged by climate variability. Even if adverse weather events can be predicted, there is little to nothing that farmers can do to mitigate crop losses in field-grown crops. In 2016 we built a high roof, passively ventilated greenhouse and commenced trialling a small but commercial area. Crop plots of capsicums, cucumbers, eggplants, specialty melons and tomatoes led to promising results to support a proof of concept. We commenced using low cost growing practices and, as we learned and gained experience, we moved into using more intensive technologies. We greatly benefited from participating in R&D projects that included on-farm research, and from scholarships, study tours, industry conferences and capacity building opportunities which have all assisted increasing our skills and confidence. We constantly review and identify what constraints exist in our farming system and look for cost effective solutions. The presentation describes our short journey testing protective cropping systems, highlighting critical aspects that are guiding us to adopt technologies which we think will become common in the Australia tropics in the near future, at least for a number of high value vegetable commodities.

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## 341

## How can protected cropping ensure an export supply of high quality melons from the tropics?

**Heidi Wittl** and Elio Jovicich

*Department of Horticulture and Fisheries, Queensland Government, Australia*

Queensland production of melons (*Cucumis melo L.*), typically rockmelon and honeydew fruits, is seasonal and practiced entirely outdoors. The horticulture industry has limited knowledge about using protected cropping as a technology to mitigate the effects of climate variability in melon crops. Some new specialty melon types now available in Australia require favourable environmental conditions and specific growing practices in order to obtain fruits with good visual and eating quality. Adoption of protected cropping could be a forthcoming technology to add diversity in fruit appearance, flavour and aroma, and guarantee consistent high quality of melons grown for export markets and niche domestic markets. The Queensland Department of Agriculture and Fisheries has been conducting agronomic research to develop guidelines that will assist growers produce specialty melons with protective cropping systems in the tropics. In a series of evaluations, crop performance and visual and eating quality were assessed. A range of desired fruit attributes were identified for rind colour and net patterns, flesh colour, texture and shelf life. There were examples of cultivars with remarkable sweet flesh (total soluble solids up to 16 °Bx) in large fruits. A group of promising cultivars had total marketable yields that ranged from 5.5 to 10 kg/m2 with fruit weights that ranged from 0.9 to 2.0 kg/fruit, and where total soluble solids ranged from 12 to 16 °Bx. A market-driven approach is providing information about the range of melon commodities that are desired in targeted markets. This approach is guiding the development of agronomic recommendations to assist with the delivery of consistent superior fruit quality in melon export programs.

## 342

## 6 marketing steps to ensure profit

**Mr Mike Evans**[1]

[1]*Fresh Partners Marketing, North Lakes, Australia*

Growing and packing a high-quality product is excellent BUT delivering that product to shoppers willing to pay a premium for it is where success is measured. Each of us is part of this extended supply chain with consumer satisfaction and willingness to part with their own money our chief focus. Watch as we prove that price is not the driver for being successful as we explore together the 6 steps which must be implemented to ensure success. The sale of High Value Melons farmed in Australia's Tropics and exported to Asian markets will give live examples and data of a developing program. Receive your free workbook to guide you through the steps to generate greater profit in selling your agricultural products.

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## 343

## Innovative control systems for protected cropping systems in the tropics

**Mr Odin Franssen**

*Powerplants Australia, Australia*

The cultivation of fruiting vegetables in a protected cropping environment requires the maintenance of a constant balance between current and future production. Between vegetative and generative control. There are significant differences among growers in terms of approach, production and quality. For this reason, maximum flexibility is required to enable growers to control the greenhouse climate, water and nutrient dosage in their own way. Integrated climate and Irrigation control systems offer every possible option for this.

Maintaining the balance in the crop is the greatest challenge facing growers of fruiting vegetables. They can exercise a high level of control using crop labour/cultural practice, climate, water and nutrient dosage, but the skill is to balance short-term goals with a longer-term outlook.

Fully integrated horticultural automation offered by Powerplants Australia and its controls technology partner - Priva, allows vegetable growers to have all the processes and settings at their fingertips. All the equipment in the greenhouse thus works together to achieve the optimum situation for the crop: air vents, heating, screens, assimilation lighting, CO2 dosage, ventilation, water dosage, nutrient dosage, misting, cooling. This total solution allows climate management, energy management and water management to be harmonized at all times, producing an optimum greenhouse climate with the minimum consumption of energy and the maximum reuse of water.

## 344

## Overcoming barriers to growth in horticulture

**Ms Marie Piccone**[1]

[1]*Manbulloo Ltd, Brisbane, Australia*

From a commercial perspective, the first point of discussion is to define "growth". In my experience, some key stakeholders in horticultural industries would describe growth as an increase in outputs, size and total volume produced. Others would picture growth as an increase in sales of inputs and/or produce measured seasonally or annually.

Growth is best measured by sustained, increasing, stable profit and better performance in efficiency and effectiveness. Most importantly, improvements in consumer loyalty, stronger levels of confidence in fresh produce and greater purchasing frequency are key to real growth. One of the major barriers to growth in horticulture is that there is too often a "mismatch" between what consumers wasn't versus what we produce as an industry.

Culture is a barrier unless the focus is truly understanding the consumer and then providing a satisfying consumer experience. Produce that is always a favourable, compelling eating experience is key to overcoming the "mismatch". Our business decisions eg selection of varieties, handling practices, are either a growth strategy or a negative barrier to growth.

Real collaboration with retailers and marketers is vital to grow. There is a need to attract and retain talented people in horticulture. Growth is crippled without great teams.

The need for business capital is often a barrier to growth. It's time to embrace the concept that access to capital other than traditional sources is an option.

More value for consumers, commitment to strategic relationships, professional teams, innovation, systems, and risk management are key to overcoming barriers to growth in horticulture.

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## 345

## The future of avocado

**Dr Antony Allen**

*The Avolution, Australia*

Abstract not yet provided

## 346

# Deploying new technologies to secure the banana industry

**Dr Rosie Godwin**[1]

[1]*Australian Banana Growers' Council, Brisbane Market, Australia*

Bananas are Australia's number-one selling supermarket product (in volume), with over five million of them eaten daily, all of which are grown in Australia. The 13,000 ha industry has a farm gate value of around $600m and contributes $1.3 billion to the national economy annually. Over the last 3-4 years the industry has been under considerable financial pressure from poor prices but this has been exacerbated by dealing with major responses to banana Freckle and Fusarium Wilt Tropical Race 4 (TR4). Banana Freckle has successfully been eradicated from Australia but the threat from TR4 is ongoing.

The Banana industry considers that R&D is critically important for successfully dealing with major disease threats and reducing their impact. The spread of TR4 has been slowed through a major control and containment program which has been underpinned by high quality research but this research needs to continue, to allow time to find long-term solutions that will safeguard the industry's ongoing viability.

The role science plays is multifaceted. The challenge for horticultural industries is to include both basic and applied research that is relevant to the needs of industry, fits within the constraints of legislation and the supply chain, meets the needs of consumers and will lead to outcomes that are implemented on farms by growers. Examples of how the banana industry is meeting these challenges will be discussed in this presentation.

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## 347

# Increasing macadamia production through thick and thin

**Mr Robbie Commens**[1]

[1]*2 Tonnes Enterprise, Clarence Valley, Australia*

The floodplain regions of the Northern Rivers in NSW, with their relatively flat topography, mild temperatures and high freshwater water tables have proven to be highly productive for macadamias. Multi year award winning orchards are located in the region. This success, and the high returns associated with macadamia production has triggered substantial investments into the development of new macadamia orchards, with an estimated 2,500 hectares developed in the next 3 to 5 years.

This region also presents multiple production challenges such as; acid sulphate soil and subsoils, low paddock heights (0.5m AHD to 1.8m AHD), high rainfall totals, high rain days annually, relatively poor and degraded soils, minimal drainage potential, high wind speeds, regular salt deposits *(due to the proximity to the pacific ocean without any reef protection*) and a history of a single major industry (sugar cane). Through thick and thin, Robbie and the 2te team have remained focused on achieving their desired outcome – a highly productive commercial macadamia orchard in the Northern Rivers of NSW. Robbie will be outlining some of the innovations he and his team have employed to; complete earthworks without disturbing the potential acid sulphate subsoils, drain blocks on a heavy clay soil that have an AHD as low as 0.5 m above sea level in a climate with an average annual rainfall of 1,900mm across 200 rain days annually.

## 348

## Innovation in plant protection in the citrus industry

**Dr Andrew Miles**[1]

[1]*2PH Farms, Emerald, Australia*

Citrus production is a significant component of the Australian horticulture portfolio. The value and volume of production of citrus in Australia is ~$7-800M and ~750,000 tons, respectively, but Australia is a minor contributor to the estimated global citrus production volume of ~50 million tons. Australia's relatively small industry must therefore compete on parameters of quality, rather than volume. However, producing a high-quality product is constantly challenged in Australia and abroad. Internationally, nationally and locally these challenges to production come in many different forms, requiring a diversity of innovations to mitigate them. Internationally, the 'huanglongbing' or 'HLB' disease, caused by the phloem-limited bacteria *Candidatus* Liberibater asiaticus and its Asian citrus psyllid vector *Diaphorina citri*, is threatening production and profitability in all locations the disease is found. Nationally, our industry is challenged by the need to keep threats such as HLB and citrus canker away from our shores, while at the same time maintain and grow export market access. While locally, we must respond to the issues that impact our bottom line today and into the near future. For 2.P.H. Farms, all these challenges are a reality to be face proactively, rather than reactively. Establishing an in-house R&D program is a key component of this proactive approach.

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## 349

## Cross sectoral biosecurity RD&E to protect the Australian horticulture industry

**Dr Jo Luck**[1], Dr Penny Measham[2]

[1]*Plant Biosecurity Research Initiative, Hort Innovation, Melbourne, Australia,* [2]*Hort Innovation, Brisbane, Australia*

There are many factors influencing plant biosecurity at a global scale, for example the increase in trade and people movement, the increase in intensification and expansion of agriculture and the increase in on-line retail and parcel movement.

In Australia, the horticulture industry has several features which may increase its biosecurity risk, such as the movement of commodities along a supply chain to market, the use of contract labour and sharing equipment between properties and the heterogeneity of crops grown on farms.

In recent times, several Australian horticulture industries have experienced the negative impacts of biosecurity incursions to production and trade. They have also experienced negative social consequences, with flow-on effects to employees and surrounding communities. The following recent examples will be presented; Tomato Potato Psyllid in Western Australia, Panama disease in Queensland and Citrus Canker in Northern territory and Western Australia.

On-farm biosecurity practices, in partnership with state and federal government regulation support strong and sustainable horticulture businesses, reducing the threat of pests and diseases. With a multitude of biosecurity threats facing the sector, such as Xylella, Brown Marmorated Stink Bug, Spotted Wing Drosophila and Spotted Lantern Fly, understanding the risks and quickly detecting and responding to these threats, if they arrive, is critical.

Access to innovation and technology to prevent new incursions, or the spread of existing pests and diseases, is also vital. In 2017, a novel partnership between Hort Innovation, six plant Research and Development Corporations, Plant Health Australia and Department of Agriculture was formed - the Plant Biosecurity Research Initiative (PBRI). The PBRI aims to avoid duplication of research efforts across industries and leverages investment to support larger cross-sectoral projects, to contribute to better biosecurity for Australian growers.

Examples of large biosecurity RD&E projects, coordinated by PBRI and supporting the Australian horticulture industry, will be presented.

## 350

# The role of science in understanding the multidimensional challenge of agrifood waste

**Prof Paul Bertsch**[1]

[1]*Office of the Queensland Chief Scientist, Queensland Government, Australia*

Tropical agriculture and the global food production system will be impacted by critical climate and sustainability challenges, ecological tipping points, and changing demographics. The United Nations has set ending hunger, achieving food security, improving nutrition, and promoting sustainable agriculture as the second of its 17 Sustainable Development Goals (SDGs) for the year 2030. A driver of change for agricultural industries is the push towards creating a sustainable food future. As stated by Al Gore during his recent visit to Brisbane, "The sustainability revolution has the magnitude of the industrial revolution and the speed of the IT revolution".

Revolutionary technologies have the potential to address many of these impacts, are emerging at break-neck speed, and adoption and uptake are likely to be rapid. Major disruptions are probable for all industry sectors, including traditional agricultural production systems. Enabling technologies such as advanced bio-manufacturing, digitization, automation, AI, nanosatellite communications, alternative energy sources are becoming embedded in food production industries.

Queensland is well placed to benefit from these technological advancements. 'Advanced agriculture' was identified by Data 61 as one of Queensland's eight emerging knowledge-intensive industries, by utilising deep food science expertise and enabling technologies to produce more sustainable, secure, and nutritious products.

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## 351

# Fighting food and packaging waste through the agricultural supply chain

**Mr Ben Baldwin**[1]

[1]*Department of Agriculture and Fisheries, Queensland Government, Brisbane, Australia*

The Agriculture and Food sectors are vital contributors to the Queensland economy with the current combined GVP valued at $17.59 billion at farm gate and first-stage processing.

A recent assessment conducted during the National Food Waste Baseline project, estimated that food waste generation within Queensland's Agriculture sector is 734,600T and 277,100T for Queensland's Food Manufacturing sector.

Queenland's Department of Agriculture and Fisheries (DAF), through Agri-Science Queensland view Agriculture and Food sectors as key for sustainable economic growth in the state. An opportunity currently exists for the State Government to play a leadership role in transforming the current food waste issues observed within these sectors into opportunities to drive the next stage of growth.

Over the next 10 years, DAF has committed close to $5million to the Fight Food Waste CRC, to capitalize on these opportunities, providing leadership and contributing to the national goal of halving Australia's food waste by 2030 as set out in the National Food Waste Strategy.

Working in collaboration with research organisations and industry partners DAF will be developing food waste solutions from horticultural waste to seafood shelf life to explore and develop high value food products and alternate packaging concepts that meet both industry need and consumer demand.

## 352

## Creating opportunities for resource recovery in the Queensland agriculture sector

**Mr Pravin Menon**[1]

[1]*Department Of Environment and Science, Brisbane, Australia*

On 1 July 2019 the Department of Environment and Science released Queensland's Waste Management and Resource Recovery Strategy. This is a highly ambitious strategy which provides the framework for Queensland to become a zero-waste society, where waste is avoided, reused and recycled to the greatest extent possible. It provides the framework to deliver coordinated, long-term, sustained growth for the recycling and resource recovery sector while reducing the amount of waste produced and ultimately disposed of by promoting more sustainable waste management practices for business, industry and households.

With the highest proportion of land area in Australia dedicated to agriculture, and over 30 000 businesses contributing more than $10 billion to the state's economy each year, the agricultural industry is a key part of Queensland's future waste plan.

The Waste Strategy sets the agenda for action over the coming decades, with work underway to establish Action Plans and Policies for organics and food waste; plastic pollution reduction; product stewardship; energy from waste; and infrastructure planning to underpin these priority areas. Opportunities for improvement include alternatives to trickle tape, recovery and recycling of agricultural plastics, appropriate treatment of biosolids, and the development of new markets for organic waste.

This exciting new direction will align with National Policy and Strategic Frameworks and will be built collaboratively with other jurisdictions, industry, government and the community. The agricultural sector can expect to benefit through cost savings associated with reduced waste, value adding of produce that is currently discarded and a reputation for improved environmental practices.

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## 353

## Transforming food waste into higher value products

**Dr Paul Luckman**[1]

[1]*Fight Food Waste Cooperative Research Centre, St Lucia, Australia*

The Fight Food Waste CRC Program aims to improve the competitiveness, productivity and sustainability of the Australian food industry. The TRANSFORM Program's goal within the Fight Food Waste CRC is to reduce food waste by transforming it into valued products. A core activity for this program is identifying valuable products from waste streams and developing processes and technology that can transform the waste materials into products. To compliment this technology development the TRANSFORM Program will also identify technology gaps and process limitations to waste transformation. Bringing together the learnings across projects, this program will also work to deliver a tool kit for selecting feedstock combinations for different processing priorities.

2018/19 has seen the collaboration of a wide range of participants working together to identify key projects and project objects that will assist the TRANSFORM Project portfolio to work towards achieving its goals and meet the needs of the industry involved. While a number of these projects are still being refined into 2019/20, a project unlocking value from waste and surplus horticulture produce has received high levels of interest. This project will look into the waste generated through a number of horticulture practices and links key participants to identify and enable research and development to achieve commercially valuable products from the identified waste. This project will review identified technologies to understand the benefits that could be achieved through their use.

## 354

## What is needed to make the Circular Economy for Organics a reality?

**Mr Johannes Biala**

*The University of Queensland, Centre for Recycling of Organic Waste and Nutrients, Australia*

'Sustainability' as a term, goal and buzz word has been largely replaced by the concept of the circular economy in the waste management and resource recovery sector. This is welcome news since sustainability never gained any real traction – everyone claimed to be sustainable but nobody wanted to pay to achieve it. The **circular economy** on the other hand is an **economic system** (supply chain) aimed at eliminating waste and the continual use of resources, which will only function if all involved parties receive equitable economic or other benefits.

The Circular Economy for Organics links generators, processors and users of organic residues and will be viable in the long-term only if it is driven by demand and economic advantage for all supply chain partners with additional costs being shard in an equitable and mutually acceptable way.

Organics recycling partnerships with agricultural industries offer long-term win-win solutions for both councils and the farming sector. This can be achieved if farmers are elevated in the organics recycling value chain, for example by contracting them to provide organics recycling services (co-composting / co-digestion) for local authorities, or by establishing long-term compost use partnership agreements with farmers that stipulate quality requirements and a fair price, while on the other hand guaranteeing the beneficial use of all generated compost.

Political will, expressed through progressive State policies and local authorities with a vision and farmer's entrepreneurial spirit will be key to realising these business opportunities for the agricultural sector.

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## 355

## AATLIS Precinct: Helping navigate pathways to sustainable solutions through digital technology adoption

**Mr Thomas Hall**[1]

[1]*FKG Group, Toowoomba, Australia*

AATLIS is the development of a multi-faceted, world-class, technology, innovation and fresh food precinct encompassing a land area of 760 hectares. AATLIS provides an environment to foster a collaborative and creative culture across co-located symbiotic businesses, transforming food production, manufacturing and value-adding industries and unlocking value for the Toowoomba region and Australia.

AATLIS Precinct will provide a platform to collaboratively solve challenges facing the agriculture and food sector in Australia and overseas. The precinct incorporates an integrated community comprising four sub-precincts and optimises a circular economy model to convert waste to value.

- AATLIS will improve the economics, integration and intensity of agri-food production to meet global demand for provenance assured quality food produce.
- Provide World leading connectivity via Pulse DC, Australia's first Tier III regional data centre
- Provision of a practical learning environment for developing the talent and capabilities needed for the jobs of the future in agriculture and food
- Low cost energy solutions through the development of on-site solar and gas energy generation.
- Designed to address 12 of the 17 UN Sustainable Development Goals.

AATLIS will achieve a true triple helix innovation model within the precinct bringing academia, industry and government together to create real world solutions and foster economic, business and social benefit.

356

## Advancing brewing science

**Birgitte Skadhauge**[1]

[1]*Carlsberg Research Laboratory, Copenhagen, Denmark*

Cereals were some of the first crops to be domesticated by humans. Today, cereals represent the biggest starch source in the world and are the primary raw material for food and feed. Modern breeding techniques produced high yielding varieties, but were based on a limited genetic background, which resulted in significant loss of genetic diversity. This could potentially result in major challenges due to recent climate changes and altered growing conditions. It is estimated that an increased global temperature will lead to dramatic loss in plant productivity in many parts of the world.

The barley breeding effort of the Carlsberg Research Laboratory combines decades of expertise to provide new varieties with unique quality and sustainability traits such as e.g. drought tolerance. Combining traditional breeding, genome data and a new method for screening genetics variants, we have radically shortened the development time of varieties with new traits. This has already resulted in the identification of several hundred genetic variants related to climate, sustainability, productivity and brewing quality. This accelerated approach can easily be applied for the development of other crops in both developing and matured markets around the globe, and help securing a sustainable supply of food and other agricultural products.