

TropAg2017



International Tropical Agriculture Conference

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20-22 November 2017 | Brisbane Convention & Exhibition Centre, Australia

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Book of oral
abstracts

Contents

100	Closing the tropical land frontier: The roles of globalization and intensification	11
101	Biodiversity and food and nutrition security: Drivers of food choices for dietary diversification for improved health and nutrition for vulnerable populations	12
102	Photons to food; Improving photosynthesis and yield potential in C3 and C4 crops	13
104	Field phenotyping for photosynthetic traits in sorghum	14
105	Modelling likely field impacts of modifying photosynthesis	15
106	Building climate resilience in agricultural crops by manipulating CO ₂ fixation	16
107	Horticulture- The vital industry	17
108	Impact of genomics and genetics on plant protection in bananas	18
109	Developing a professional vegetable supply chain in South East Asia	19
110	Impacts of plant breeding on the Australian mandarin industry	20
111	Reducing the impact of diseases on productivity and quality of avocado	21
112	Prospects for genetic improvement of macadamia	22
113	Sustainable livestock – Integrated approaches for multiple benefits	23
114	Key pathways for the livestock sector, sustainable intensification and mitigating vulnerability	24
115	Delivering livestock science solutions for development outcomes through two distinct approaches: philanthropy and shared value	25
116	New livestock genetics and genomics solutions and applications in the tropics	26
117	Animal and human health: A dangerous intersection or healthy future?	27
118	Optimizing the environmental footprint of livestock production	28
119	Improving food and nutrition security through dietary diversification: Promoting the rich Kenyan cuisine	29
120	Selection of suitable Kei-apple lines based on phytochemical content for functional product development	30
121	Value added nutritionally rich products from Australian wattle seeds (<i>Acacia species</i>)	31
122	Queensland grown Queen Garnet plum: Nutritious and healthy- A case study	32
123	<i>Buchanania obovata</i> : An Australian Indigenous food for diet diversification	33

124	Enhancing youth economic participation and entrepreneurship in agriculture	34
125	Using sustainable intensification principles to increase productivity of maize and wheat systems	35
126	Enhancing smallholder agricultural productivity, resilience and sustainability: Initial evidences from eastern and southern Africa	36
127	Overview of ACIAR programs focused on systems approaches for sustainable intensification	37
128	Legume intensification for food security and sustainability in Africa	38
129	Overview of systems approaches for sustainable intensification in China	39
130	UAV-based phenotyping of crop plants in field trials	40
131	Characterizing the sorghum pan genome	41
132	Exploring and exploiting natural variation in sorghum	42
133	Exploring the crop adaptation landscape in silico	43
134	Building new sorghum varieties in the 21st century	44
135	Tropical tomato breeding for Australian markets – Satisfying the diverse needs of producers, retailers and consumers	45
136	Demand-led approaches in the tomato industry in Ghana: Challenges and opportunities for breeding and crop improvement	46
137	Maximizing the impact of common bean (<i>Phaseolus vulgaris</i>) breeding for farmers and other value chain	47
138	Connecting public and private breeders and new vegetable varieties to developing markets in SE Asia and Sub-Sahara Africa	48
139	Custard apples – breeding for Australian domestic and export markets	49
140	Tropical horticulture – Exploring new approaches for sustainable funding of plant breeding in developing countries	50
141	Development of point-of-care and multiplex diagnostic methods for the detection of plant and poultry pathogens	51
142	Point-of-site diagnostic nanotechnologies for health and agricultural applications	52
143	From research to frontline laboratory	53
144	Diagnostic tools used to genotype and detect tick fever pathogens in cattle	54
145	A mass spectrometric targeted approach for the detection of exosomal protein biomarkers from bovine body fluids	55

146	Use of mobile technologies for research and engagement of smallholder cattle farmers in Vanuatu	56
147	Identifying and managing new hazards in the food supply	57
148	Food authenticity and traceability using stable isotopes	58
149	Mycotoxins in the food supply chain and promising interventions	59
150	Rapid detection methods for food adulteration and authentication	60
151	Oritain- Proving origin, protecting reputations	61
152	Molecular detection of Toxoplasma Gondii infection in small ruminants in Northwest Tunisia	62
153	Policy drivers of water resource development for agriculture in northern Australia	63
154	Maximising the cost-effectiveness of water supply in northern Australia	64
155	Expanding agriculture in Northern Australia: The need for improved transport logistics	65
156	Managing the impacts of agriculture to minimize offsite environmental impacts: A case study for nitrogen in the GBR lagoon	66
157	Opportunities and constraints for irrigated agriculture in the Northern Territory	67
158	Economic drivers of agricultural development in northern Australia	68
159	Transitions and transformations-drought, hotspots, and adaptation	69
160	Benefits of action and costs of inaction: Drought mitigation and preparedness	70
161	Modes of climate variability and drought forecasting	71
162	Building a National Drought Center: Science and policy approaches and experiences from the National Drought Mitigation Center's perspective	72
163	Improving drought monitoring and prediction science and services	73
164	Remote sensing applications for agricultural and horticultural crops: From the individual tree to whole of industry	74
165	Mapping horticulture tree crops in Australia	75
166	Intelligent sensing and information systems for tree crops	76
167	UAV imagery and its role in tactical agronomy trials	77
168	Estimating regional scale crop production: An integrated climate, biophysical and remote sensing approach	78

169	New frontiers in crop stress detection from satellite measurements of fluorescence, soil moisture, and canopy temperatures	79
170	The genetic architecture of tick resistance	80
171	Cutting and pasting: The future of genetic improvement for food animal genomes	81
172	The evolution of the Brahman genome- a crucial tropically adapted breed	82
173	Combining historical weather station records, climate change predictions and genomics to breed dairy cattle for future climates	83
174	Use of genomic technologies and composite cattle breeding within a large Northern Australian beef breeding enterprise	84
175	Mediterranean Diet in the Tropics?	85
176	Fatty Liver: It is not just about fat- Nutritional impact on non-alcoholic fatty liver disease (NAFLD)	86
177	Tropical fruits as functional foods for metabolic syndrome	87
178	Gut microbiome- Our life partner, for better or worse?	88
179	Berries for your renal health	89
180	The creation of employment, economic and social benefits to remote Australian communities through novel and added value products from native plants	90
181	Informing the design of climate resilient farming systems	91
182	Managing risks and tradeoffs in the intensification of agriculture: An ecologist perspective	92
183	What do we want and what are we likely to get?	93
184	Behavioral economics insight into drivers and constraints in the adoption of technologies	94
185	Designing less risky systems through investing in the adaptive capacity of farmers	95
200	Targeted plant breeding applications of CRISPR-Cas technology	96
201	The contributions of animal-source food to sustainable, safe, ethical and optimal human diets	97
202	Beyond digital revolution – Today’s research for tomorrow’s livestock tools	98
203	Using data to change tomorrow’s farm activities with power of prediction	99

204	How do we get our heads out of the sand when they are up in the clouds?	100
205	The digital agronomist – The changing face of farm advisory	101
206	Beyond the accepted methods – New targets for automated data gathering on farm	102
207	GPS cows: Bringing ag data and new technologies into high schools	103
208	Prediction based crop improvement by combining Whole Genome Prediction with Crop Growth Models	104
209	Why was genomic selection so rapidly adopted in the US beef and dairy industries?	105
210	Speed breeding with genomic selection to accelerate wheat variety development	106
211	Large scale genomic selection in tropically adapted cattle to improve fertility and meat quality	107
212	Genomic selection in horticulture	108
213	The future of genomic selection – Incorporating biological information in genomic predictions	109
214	Lessons from temperate crops for tropical crop biofortification	110
215	High folate strawberries – Finally something tasty?	111
216	Sweetcorn biofortification – Is a 1000% increase possible?	112
217	High pro-vitamin A bananas – A first for Africa	113
218	Potential health benefits of breeding high flavonoid apples	114
219	Not another typical corny trial: Genetic and agronomic zinc biofortification of sweetcorn	115
220	A global perspective on the responsible use of antimicrobials in veterinary medicine	116
221	Antimicrobial resistance surveillance in livestock in Australia	117
222	Antimicrobial use and stewardship in animal health in Australia	118
223	<i>Caeci Caecos Ducentes</i>	119
224	Molecular detection of tetracycline resistance genes in salmonella isolated from pork and poultry egg	120
225	Assessing the role of public institutions in facilitating an inclusive global value chain: A comparative analysis of the natural rubber industry in South and Southeast Asia	121

226	Smallholder participation in the palm oil value chain in Malaysia, Indonesia, and Thailand	122
227	Developing value-chain linkages to improve smallholder cassava production in Southeast Asia	123
228	The economics of small-holder cattle production and marketing in Eastern Indonesia	124
229	How does participating in an inclusive global value chain impact smallholder coffee producers in Indonesia?	125
230	Integrating small-scale vegetable farmers to better access high end market in Dili: The case of Josephina Farms with contract farming	126
232	The developing of genotyping and its future	127
233	Automated phenotyping and analytics	128
234	Statistical perspectives in the era of Big Data: Can dead fish read human minds?	129
235	Phenotypic prediction augmented through crop model-whole genome prediction: Application to ARGOS8	130
236	Biotechnologies and the future of plant improvement	131
237	Biofutures – Opportunities for agriculture in biobased fuels and bioproducts	132
238	Discovery, evaluation and manufacture of new livestock feed supplements	133
239	Biogas production from energy crops and agricultural residues	134
240	Converting agricultural wastes into valuable products	135
241	Cellulose nanofibres from spinifex arid grasses: “Unique properties and applications under development”	136
242	<i>Brassica carinata</i> : The sky is the limit	137
243	Expected market opportunities and demand profiles for tropical pulses to 2022	138
244	Sustainability and profit drivers for tropical pulses in sustainable cropping systems	139
245	Breeding strategies to unlock genetic potential of pulses	140
246	New genetic tools and solutions to make pulse crops more resilient to variable climates	141
247	Physiological, agronomic and modelling approaches to optimise productivity of tropical pulses	142
248	The past is history: A case study of Queensland’s successful chickpea industry	143

249	A research effort to improve subtropical and tropical tree crop productivity through intensification	144
250	Diurnal variation in the sensitivity of ‘Honey Gold’ mango fruit to developing under-skin browning	145
251	Pollination of macadamia	146
252	Breeding for adaptation during climate change: Hitting a moving target	147
253	Insights into the <i>Avocado-Phytophthora</i> interaction	148
254	A new approach in oil palm harvesting Improvement	149
255	The tropical aquaculture powerhouse – Global impacts and opportunities for Australia	150
256	Meeting the growing demand for aquaculture – Balancing biological requirement, sustainability and environment	151
257	Making aquaculture sustainable in the tropics – Growing algae to reduce nutrification and produce high-value products	152
258	Breeding for disease resistance in Australian shrimp: How do we get there?	153
259	The blacklip oyster – An alternative for tropical aquaculture in Australia?	154
260	In-vitro oocyte maturation by radial nerve extract and fertilization of the black sea cucumber <i>holothuria leucospilota</i>	155
261	Techniques and platforms for high-throughput phenotyping of canopies and plants	156
262	How would Google farm?	157
263	Autonomous adaptive precision irrigation for broad-acre agriculture	158
264	Seeking energy independence	159
265	Animal sensing will take the industry back 100 years	160
266	Field robotics in agriculture	161
267	Systems genetic studies of photosynthesis and water use efficiency in rice	162
268	Development of rice varieties for multiple abiotic – stress tolerance in the Mekong region and Australia	163
269	Mapping, mining and tracking tools to locate and harness climate resilience in rice	164
270	Climate-smart rice production for Australia and Asia	165

271	Generating useful genetic variation in crops by induced mutation	166
272	Iron tolerance in rice	167
273	Microbial manipulation of rumen efficiency	168
274	Estimating the efficiency of rumen microbial protein synthesis in cattle grazing tropical pastures, and implications for animal performance	169
275	The relationship of efficiency of microbial crude protein production with rumen microbial community structure in steers fed tropical pastures	170
276	Changing the interplay between gut and host to improve production efficiency of ruminants	171
277	What is the actual role of rumen for supplemented grazing cattle?	172
278	Live yeast supplementation improves rumen fibre degradation in cattle grazing tropical pastures throughout the year	173
279	Regulation and advancing GM technologies	174
280	Regulatory oversight of new breeding innovations in the US	175
281	Regulation of new breeding innovations – Implications for the grain trade	176
300	The Mediterranean Diet: A healthy and traditional dietary pattern embedded in a sustainable food system	177
301	The changing face of horticulture: Hello tomorrow!	178
302	Combining nanotechnology and molecular recognition for fertilizer applications	179
303	Regulatory science and agricultural innovation: Where do we stand?	180
304	A nanobiotechnology approach to protect plants from abiotic stress	181
305	Nano-enabled pesticides: An emerging technology in plant protection	182
306	Nanoparticles for animal healthcare	183
307	BioClay for crop protection against viruses	184
308	Constraints on photosynthetic efficiency in C4 crops, with special references to sugarcane	185
309	Licence to farm: Why nitrogen use efficiency matters and how we can achieve it in sugarcane	186
310	Control of sugar and fibre: Insights from the sugarcane transcriptome analyses	187
311	Application of high-throughput phenomics for sugarcane trait development and variety improvement	188

312	Sensitivity and plasticity of sugarcane leaf metabolism during stress	189
313	Using genomic sequencing to understand the sugarcane genome structure	190
314	The role of animal welfare in tropical beef production	191
315	Animal welfare issues in the grazing beef industry of northern Australia	192
316	Proteomics to detect biomarkers of pain and inflammation in cattle	193
317	Cage row arrangement affects the performance of laying hens in the hot humid tropics	194
318	Applications of endocrine physiology concepts to evaluate stress and welfare of production livestock	195
319	Feather-eating is related to stress level and sucrose preference in laying hens	196
320	Tropical rice: Challenges for quality	197
321	Starches in rice endosperm: Diversity and improvement	198
322	Opportunities and challenges of establishing a northern rice industry	199
323	Designing tropical rice for improved nutrition and palatability	200
324	Australian wild rice: Diverse and tasty	201
325	Where the rubber meets the road: Implementing molecular marker technologies in the Australian rice breeding program	202
326	The role of Australia's genebanks and crop wild relatives in all our futures	203
327	Drought proofing sorghum: Multiscale phenotyping and genotyping for nodal root angle	204
328	Interoperable infrastructure – A vision for DivSeek	205
329	Speed breeding to accelerate gene bank deposits into farmer fields	206
330	The genomics of rice genetic resources	207
331	Unlocking genomic diversity without assembly or alignment	208

100 Closing the tropical land frontier: The roles of globalization and intensification

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In 2015, the global community set a sustainable development goal of ending hunger by 2030 at the same time that it also set a goal of halting deforestation by 2020. Are these goals compatible and what will it take to do it? Until the 20th century most increases in agricultural production were provided by expanding land area. The first period of globalization in the 19th century saw the ploughing up of vast swathes of temperate grasslands in the Americas and Australia to supply industrializing Europe with wheat. Only modest clearing of tropical forests and savannas occurred mainly due to encroachment by small scale farmers driven by population growth and subsistence food needs. Even so, after WWII tropical forests were seen as low value assets with great potential to convert into productive farmland to feed the world.

The current period of globalization from around 1990 has witnessed unparalleled agricultural expansion in the lowland tropics driven mostly by global markets. This has occurred at the same time that the critical global values of tropical forests and savannas in conserving biodiversity and mitigating climate change have been recognized. I review the experience of the three most important commodities, beef and soybeans from Latin America, and oil palm from Southeast Asia. Although large areas of forests and savannas have already been converted to these commodities, much progress has been achieved in halting expansion in the past decade, especially in Brazil. Tropical agriculture has intensified, raising the productivity of existing farmland and saving natural areas from further conversion. However, intensification has only succeeded when accompanied by improvements in land and forest governance to provide incentives to intensify rather than expand area. Global oversight through major international treaties on biodiversity, climate change, and indigenous rights, and the FAO voluntary guidelines on land and natural resource tenure and private standards have also played a key role in protecting remaining natural areas.

In conclusion, I am cautiously optimistic that tropical land expansion can be halted without compromising global food security. Both governments and the private sector have made major commitments to reducing tropical deforestation. In addition, I project that the big market drivers of commodity expansion to provision emerging economies such as China will slow markedly in the coming years, further reducing pressure on tropical lands. The major challenges ahead are implement existing commitments on zero deforestation, slow conversion of remaining savannas, and more sustainably manage the emerging commodity expansion in Sub-Saharan Africa.

101 Biodiversity and food and nutrition security: Drivers of food choices for dietary diversification for improved health and nutrition for vulnerable populations

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Adequate quantity and quality of food are required for optimal health, growth and development of human life. Malnutrition, in all its forms, as a result of sub-optimal dietary practices, imposes unacceptably high costs on individuals, families and nations. This is considered a major impediment to achieving the 2030 Sustainable Development Goals. Despite significant global progress having been made over the last two decades, the number of hungry people remains unacceptably high. More than 239 million people in African continent are, at present, affected by hunger, malnutrition and poverty. This is notwithstanding the fact that Africa has abundant arable fertile land and human resources that could potentially be translated into increased production, incomes and food security. Importantly to note, over 60% of available unused farmland in the world is in Africa. In Kenya, over 10 million people in Kenya suffer from chronic food insecurity and poor nutrition. Notably, 2-4 million people require emergency food assistance at any given time. Nearly 30% of Kenya's children are undernourished with 26% being stunted. Further, micronutrient deficiencies are also widespread. Sustained high rate of stunting adversely affects human capital and economic progress. Literature reveals that 0.8% of GDP is lost due to vitamin and mineral deficiencies. There are increased cases of non-communicable diseases (NCDs) due to a rise in overweight and obesity. The major cause is the prevalent shift to increased consumption of highly refined foods with added sugars, salts & fats and shift to reduced physical activity and sedentary lifestyle. This has negatively impacted the society leading to; early and premature deaths, increased health care costs at national and household level, no savings for investment and poverty circle continues progressively. Major issues affecting food and nutrition security include: extreme poverty, population explosions and its impact on the GDP, inadequate food distribution, food spoilage and wastages- inadequate storage and processing technologies, supply disruptions, government policies that affects farmers negatively, environmental impacts- climate changes and unpredictable rainfall, low use of technology, price volatility-soaring food prices, political instability among others. The changes in food consumption at a global and regional level have caused considerable health consequences. The diverse nature of this transition may be the result of differences in socio-demographic factors and other consumer characteristics. Some of the factors significantly influencing dietary choices include; urbanization and food industry marketing; convenience-consumers are willing to pay more for convenience as their work habits and lifestyles change, advertisements, consumer attitudes and behavior- consumer health awareness continues to grow with the increasing availability of health information, income- increased consumption of processed foods, more animal foods and oils and fats and less of traditional foods across all income groups. To ensure optimal dietary intake, an integrated approach and collaborations among all relevant stakeholders, public/private sectors, and development partners to foster nutrition sensitive programs is utmost importance. Despite considerable documented knowledge on factors influencing food consumption, food insecurity, poverty and malnutrition remain prevalent; contrary to many countries reported rapid economic growth.

Keywords: Determinants of Dietary Choices, Nutrition and Health.

102 Photons to food; Improving photosynthesis and yield potential in C3 and C4 crops

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Agricultural production must increase by more than 70% over the next 30 years to meet global demand for food. Annual yield progress in breeding of our major cereal crops globally has dropped to below 1% per annum, making it unlikely that we will meet this target for crops, in the light of pressures from urbanisation and climate change. The plateau in yield improvement in cereals is now widely regarded to have resulted from the exhaustion of gains from improving genetic potential for harvest index and grain number. A new breeding frontier has emerged aimed at improving efficiency of photosynthesis and effective use of solar radiation for yield (Parry et al. 2011 JXB 62: 453–467; Furbank et al. 2015 Field Crops Research, 182: 19-29).

Globally, major initiatives have been established to improve photosynthesis in crops both by transgenic means and by harnessing advances in genomics and Phenomics to identify superior cereal germplasm and the allelic variation responsible. Targets range from enhancing the catalytic properties of Rubisco and screening germplasm for superior Rubisco performance, installing a CO₂ concentrating mechanism in C3 crops, improving access of CO₂ to enzymes of CO₂ fixation in the leaf and enhancing utilisation of the solar spectrum and responses to variations in canopy light levels. This presentation reviews recent progress in this field and discusses the challenges in translating this research to higher crop yields and food production.

104 Field phenotyping for photosynthetic traits in sorghum

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In many cereals, yield improvements are slowing down and the lower hanging fruit, such as maximising the amount of biomass invested in grain, have generally been picked. There has previously been little active selection for processes to do with primary plant productivity, or photosynthesis, in crop improvement programs, making this a worthwhile target for further yield increases.

Sorghum is an ideal model to identify traits and genomic regions associated with photosynthetic capacity. It is a diverse C4 crop that has been adapted to a wide range of environments. It is especially well adapted to hot and dry environments, which make it an important feed crop in the northern grain belt of Australia, and a staple food and feed crop in many sub-tropical areas around the world. It has a simple and well-characterised genome, which make it an ideal object for genetic studies. Furthermore, we have access to large diversity panels and mapping populations with high genotyping-by-sequencing marker density that enable genome-wide association studies.

Due to complex interactions and trade-offs between leaf-level photosynthetic traits and canopy architecture, the phenotyping of these populations requires an assessment of dynamic growth parameters of each genotype at the field-plot level. We describe how we use high-throughput remote and proximal-sensing platforms (UAV and tractor based) and an integrated image-analysis pipeline to identify differences in traits related to crop-level photosynthetic capacity such as radiation use efficiency. The use of the acquired phenotypic information in association mapping studies to identify candidate genes for photosynthetic capacity are also discussed.

105 Modelling likely field impacts of modifying photosynthesis

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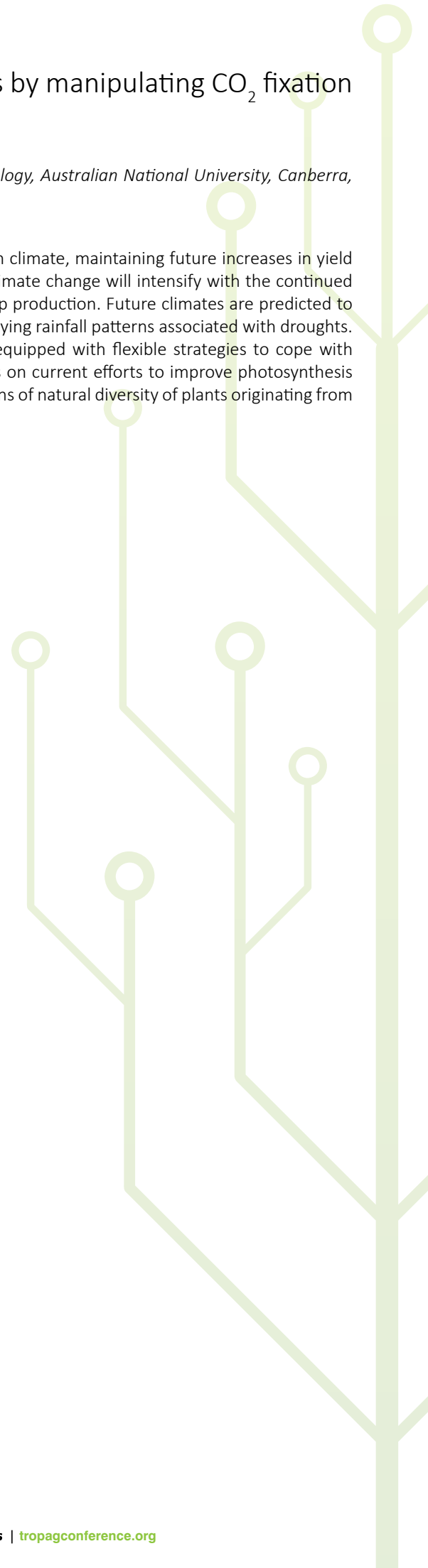
Enhancing plant photosynthetic efficiency has been identified as the next major avenue for improving plant resource use efficiencies and field crop performance, which is vital in meeting rising demand on crop production. Bioengineering targets to enhance photosynthesis at the leaf level have been identified, however, it is often difficult to foresee their likely impacts on field crops due to the scale gap between the two levels of biological organization plus influences of production environment. In this work, a description of a cross-scale modelling approach connecting biochemical/leaf level photosynthesis and crop level performance is presented. This approach utilizes existing advanced models at the different levels and emphasizes on two-way connections (interactions) between them, which involves photosynthesis models informing growth in crop models and crop models informing crop's attributes and capacity to capture resources (e.g. radiation and nitrogen) for driving photosynthesis. Analysis at the leaf and crop canopy levels of modelling showed sensible responses to key environmental factors and crop attributes; crop growth, development and yield simulations agreed adequately with observed field crop performance across a diverse range of genotypes and environments, indicating a robust predictive capability of the model. Furthermore, likely impacts of photosynthetic manipulation targets, associated with photosynthetic capacities and CO₂ diffusion, are simulated for sorghum crop in diverse production environments. This modelling work is aimed at extending prediction capabilities at the crop level and assisting identification of photosynthetic manipulation targets that could deliver the most crop-level improvements in production environments.

106 Building climate resilience in agricultural crops by manipulating CO₂ fixation

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With significant increases in the global population and the accelerating changes in climate, maintaining future increases in yield potential of food and fibre crops is coming under serious threat. The impact of climate change will intensify with the continued reductions in arable land and the availability of water that is often limiting for crop production. Future climates are predicted to increase the intensity and frequency of extreme events, such as heatwaves and varying rainfall patterns associated with droughts. To cope with future uncertain climates, agricultural crops will now need to be equipped with flexible strategies to cope with variable environments to mitigate declines in productive yields. My talk will focus on current efforts to improve photosynthesis under future climates through engineering changes to CO₂ fixation guided by screens of natural diversity of plants originating from different climates of origin and evolutionary lineages.



107 Horticulture- The vital industry

David Moore¹

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The Australian horticulture industry is an extremely diverse sector that makes a substantial contribution to the economy, accounting for 18% of the total value of Australian agriculture. The fruit, vegetables, nuts, flowers, turf and nursery products aggregate up to a gross value of horticultural production (GVP) of \$9.3 billion in 2015-16 to a projected \$10 billion in 2021-22, making it the third most valuable agricultural commodity. Based on land use value in 2015-16, horticulture contributed the greatest GVP per hectare for all of agriculture, employing 67,000 people as the second largest employer within agriculture.

The Australian horticulture industry enjoys a well-regarded international reputation as a sustainable producer of clean, safe, and premium quality food, attributed to a mature supply chain, from farm to fork. Total fresh horticulture exports reached \$2.32 billion in June 2016. Significant growth in exports of citrus, table grapes, almonds macadamias and carrots, along with the surge in avocado and berry plantings has seen the sector become a target for corporate investment.

In terms of horticulture's contribution to nutrition, health and well-being, medical and nutritional research has for decades made the association between the benefits from fruit, nut and vegetables consumption and the reduction in obesity, cardiovascular conditions, Type II diabetes, certain cancers and general wellbeing. While 50% of Australian adults met their daily intake guideline of 2 serves of fruit in 2014-15, only 7% consumed their recommended 5 serves of vegetables daily. Deloitte Access Economics recently highlighted that if vegetable consumption in Australia were 10% higher, commonwealth government health expenditure would be reduced by \$100 million, highlighting the importance of education, awareness and promotion programs for increasing consumption.

Research and innovation plays an important role in advancing the productivity and profitability of Australian horticulture. The sector makes annual investments of approximately \$120 million in this area through its unique research and development corporation model. An independent assessment of Australian horticulture sector strategic investment plans (2017-21) has highlighted that research, development and extension investments will generate a net industry impact of \$1.7 billion over 30 years, creating a benefit-cost ratio of 5:1. The sector has made many novel investments in research and innovation recently in horticultural robotics; development of nutrient dense functional foods, 3D printing of foods, alternate pollination technologies, sterile insect technology, leadership upskilling, and the future state of the art glasshouse and orchard architecture.

108 Impact of genomics and genetics on plant protection in bananas

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Banana is both a top staple and fruit crop in many domestic markets and one of prime tropical commodities. At the same time, banana is a typical orphan crop. Global inputs in research and development are minimal compared to other crops. Despite the immense genetic diversity, with its basis in South East Asia, it remains largely untapped. Indeed, breeding better bananas appears to be difficult, but the failure to develop and market replacements for the global Cavendish clones is also a matter of awareness, attention and simply input and critical mass. The number of banana improvement programs is negligible when compared with other crops. As a result, the sector at large suffers from immense disease threats that are embedded in complex multidisciplinary settings that can only be addressed through such avenues. Both black Sigatoka and Panama disease or Fusarium wilt are key problems that require basic biological grounding, yet the sector is used to short-term actions and solutions that historically have worked well. Hence, there is a threshold to develop and accept long-term strategies for sustainable and fair global production. Our work has largely focused on delivering basic facts dealing with genetic improvement of banana and understanding key factors for disease control. These revolve around genome analyses, genetic diversity and plasticity. The latest results will be presented, including a global analysis of reduced sensitivity in *Pseudocercospora fijiensis* to azole fungicides for black Sigatoka management and a diversity and dissemination analysis of *Fusarium oxysporum* f.sp. *cubense*, the cause of Panama disease.

109 Developing a professional vegetable supply chain in South East Asia

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Vegetables in South East Asia are traditionally produced on subsistence land holdings. Professionalisation of vegetable production is driven by increased urbanisation, the increase in rural labour costs and reduced labour availability as well as the entrance of professional retailers in the grocery market.

Increasingly, urban and educated South East Asian consumers are concerned about food safety with regard to chemical and biological contamination. Imported Australian and American products are trusted by consumers whereas local produce is not. Retailers are addressing this through local quality assurance programs with inherently more scrutiny on the use of pesticides thus reducing chemical treatment options for farmers. Vegetable producers are seeing an increase in cost for fertiliser, seed, pest control products and more insecurity on the demand side. Farmers who are able to deal with this increased complexity by cooperating in grower groups or by forming stronger connections in the supply chain with traders or supermarkets directly are winning increased business.

A prerequisite for strong relationships between growers and the supply chain is not only the ability to deliver “clean” produce but also to do so consistently. This is resulting in increased adoption of protected cropping systems and hydroponics.

Suppliers to these growers can strengthen relationships through providing products as well as technical support. Three case studies will focus on how seed supplier Rijk Zwaan has contributed to increased farmer income and cleaner vegetables for consumers.

110 Impacts of plant breeding on the Australian mandarin industry

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Australian mandarins are mostly grown in the summer-rainfall subtropics, about 100-300km inland from the coast. Orchard production costs are amongst the highest of any citrus exporting country which, when combined with a limited domestic market, makes a focus on high-quality fruit for export essential to commercial viability.

A small citrus breeding program has been operating for 25 years and has already helped supply growers with new and improved scion and rootstock cultivars. Our Murcott selections 'IrM1' and 'IrM2' have quickly become major new commercial varieties, offering lower seed numbers, improved colour and earlier maturity time. The breeding aim is new mandarin and orange hybrids that combine excellent eating quality with outstanding external appearance and high productivity. We are also developing rootstocks that further improve these critical quality and productivity traits. Genetic resistance to diseases is a key component of the program, employing efficient inoculation and screening methods for Brown Spot (*Alternaria*), Scab (*Elsinoe*), Citrus Tristeza Virus (CTV) and *Phytophthora*, and development of new techniques for Black Spot (*Phyllosticta*) and pre-emptive breeding for Huanglongbing (HLB). Close collaboration between Breeders and Plant Pathologists is a hallmark of the program.

Breeding programs are often criticised for taking too long. However, no other technology can deliver the quantum leap and genetic gain that new varieties provide. Mandarins are a fantastic 'product': they are tasty, healthy, convenient, visually attractive, and culturally significant. Targeted breeding programs will take this 'product' to a whole new level, and deliver benefits to growers, consumers, regional economies and the environment.

111 Reducing the impact of diseases on productivity and quality of avocado

Dr Elizabeth Dann¹

¹Centre for Plant Science, QAAFI, Brisbane, Australia

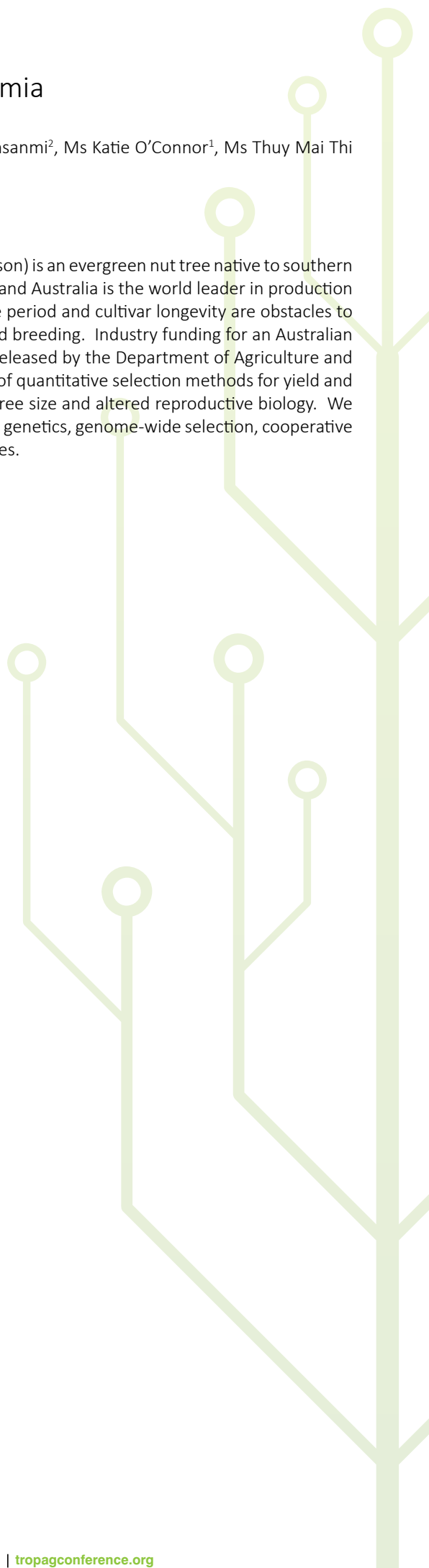
Phytophthora root rot (PRR) caused by *Phytophthora cinnamomi*, is undoubtedly the single most important constraint to avocado orchard productivity in Australia, conservatively estimated to cost the industry \$17 million per year. Postharvest fruit quality is compromised by anthracnose and stem end rot diseases, caused by fungal infections with *Colletotrichum* spp. and *Botryosphaeriaceae* during fruit development. Black root rot and brown root rot also impact establishment and tree health in some orchards. Adherence to current management strategies reduces the impact of these diseases, however, new strategies are being evaluated which may be easily implemented into disease management programs. For example, a new oomycete-specific chemical, applied to seedlings infected with *P. cinnamomi*, was effective at reducing root necrosis compared with untreated controls, and this new treatment is currently under investigation in the field. Orchard applications of commercial products with high soluble silicon content improved health of trees declining from PRR, and improved fruit quality by reducing disease. Commercial packing shed assessment of fruit from one trial showed a 20% increase in return to the grower after 6 soil drench applications with a soluble silicon product over a 2 year period. These examples and others will be discussed in relation to the immediate industry requirement for sustainable production of high quality export-ready fruit.

112 Prospects for genetic improvement of macadamia

Assoc Prof Bruce Topp¹, Dr Mobashwer Alam¹, Dr Craig Hardner², Dr Olufemi Akinsanmi², Ms Katie O'Connor¹, Ms Thuy Mai Thi Phuong¹, Mr Dougal Russell³

¹QAAFI, Nambour, Australia, ²QAAFI, Brisbane, Australia, ³DAF, Nambour, Australia

Macadamia (*Macadamia integrifolia* Maiden & Betche and *M. tetraphylla* L.A.S. Johnson) is an evergreen nut tree native to southern Queensland and northern New South Wales in Australia. Its kernel is highly valued and Australia is the world leader in production with about 6 million trees planted on 17,000 ha. Large tree size, extended juvenile period and cultivar longevity are obstacles to cultivar development but there is scope for significant genetic gain through directed breeding. Industry funding for an Australian breeding program commenced in 1996 and this has resulted in four new cultivars released by the Department of Agriculture and Forestry in 2017. A second generation of breeding is underway, continuing the use of quantitative selection methods for yield and exploring the opportunity to select for disease resistance, kernel quality, reduced tree size and altered reproductive biology. We are studying methods to improve breeding efficiency through the use of quantitative genetics, genome-wide selection, cooperative field trials with commercial producers and alternative breeding population structures.



113 Sustainable livestock – Integrated approaches for multiple benefits

Mr Henning Steinfeld¹

¹Fao, Rome, Italy

This paper summarizes the bio-physical foundations and processes of livestock systems at global level, covering energy and biomass, land, water, nutrients, environmental health and climate change, and contrasts them with human benefits derived from livestock systems, including food and human health, economic growth, employment and other social benefits, and cultural and aesthetic values.

Livestock systems are characterized by using the classical production factors of land, labour and capital, distinguishing between extensive, labour-intensive and capital-intensive livestock systems, using a combination of bio-physical and socio-economic criteria. Applying the concept of induced innovation, such a differentiation based on relative abundance of production factors allows us to outline development pathways of livestock systems.

Spatial and temporal linkages occur in the form of externalities, synergies and trade-offs which are analysed in an exemplary fashion, using an integrated approach that combines life-cycle analysis, value chain analysis and One Health assessments in a spatially explicit form. This leads to defining the key features of “sustainable intensification” in a way that is context specific as well as informing targeted policy making.

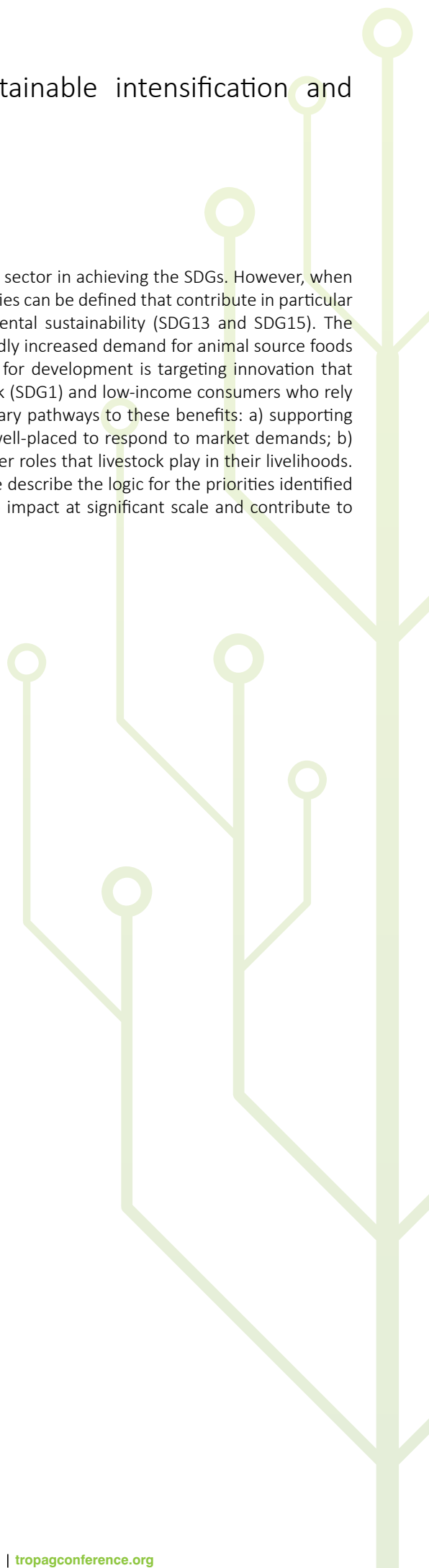
The paper shows that, given the multiple private and social benefits that can be derived from livestock, and integrated approach to livestock development is required that combines tools from various technical domains, reducing trade-offs and optimizing benefits.

114 Key pathways for the livestock sector, sustainable intensification and mitigating vulnerability

Dr Thomas Randolph¹

¹*Ilri, Nairobi, Kenya*

Science offers a wide range of opportunities to strengthen the role of the livestock sector in achieving the SDGs. However, when focusing on the SDGs of immediate relevance to LMICs, a more narrow set of priorities can be defined that contribute in particular to poverty reduction (SDG1) and food security (SDG2) while ensuring environmental sustainability (SDG13 and SDG15). The livestock sectors in LMICs are following diverse trajectories as they respond to rapidly increased demand for animal source foods driven by population and income growth. Within this context, livestock research for development is targeting innovation that will provide the widest benefits to low-income rural households that keep livestock (SDG1) and low-income consumers who rely on nutritionally valuable animal-source foods (SDG2). There are two complementary pathways to these benefits: a) supporting appropriate sustainable intensification and professionalization for those farmers well-placed to respond to market demands; b) strengthening resilience of poor communities by protecting and strengthening other roles that livestock play in their livelihoods. CGIAR livestock research addresses both. Using a Theory of Change framework, we describe the logic for the priorities identified by the CGIAR Research Program on Livestock and how this is expected to lead to impact at significant scale and contribute to achieving the SDGs.



115 Delivering livestock science solutions for development outcomes through two distinct approaches: philanthropy and shared value

Ms Jessica Ramsden¹

¹*Elanco Animal Health, West Ryde, Australia*

Livestock diseases remain a threat to achieving food and nutrition security (SDG2), are a source of economic losses for people who depend on livestock for their livelihood (SFG1) and increase pressure on human health (SDG3). Livestock diseases also exacerbate the environmental footprint of livestock production by increasing the amount of resources required to produce meat, milk, eggs (SDG2 and SDG12).

Since 2014, the Eli Lilly and Company Foundation has supported Heifer International's work on the East Africa Dairy Development Project (EADD) in Tanzania, Uganda and Kenya, including through the provision of direct support and technical expertise.

Elanco Animal Health (a division of Eli Lilly and Company) is also initiating a shared value model (SDG17) that involves the registration and sale of affordable high-quality veterinary products and the delivery of training initiatives for smallholder dairy and poultry farmers. This will assist with improved animal health practices as a means to relieve conditions of poverty and improve economic outcomes for farmers (social good) and to create value for the company (business good). AUEFSNON00032.

116 New livestock genetics and genomics solutions and applications in the tropics

Prof Appolinaire Djikeng^{1,2}, **Steve Kemp**³

¹Centre for Tropical Livestock Genetics and Health, Edinburgh, Midlothian, United Kingdom, ²The Roslin Institute /Royal (Dick) School of Veterinary Studies, Edinburgh, Easter Bush, United Kingdom, ³International Livestock Research Institute, Kenya

Livestock development is at the centre of most (and probably all) sustainable development goals through impact on people, the planet and the processes required to achieve global sustainability. Under SDG2 the following targets underscore the importance of livestock in global development: i) by 2030 double the agricultural productivity ii) by 2020 maintain genetic diversity of farmed and domesticated animals and their related wild species.

Unfortunately, livestock development in Africa and other tropical parts of the world still faces several important challenges including but not limited to: a) low productivity, b) regular losses due to abiotic and biotic stresses, c) unsuitable animals for resilience in various agro-ecologies, d) unavailability of genomics resources and tools for rapid identification and utilization of adaptable breeds, e) unexploited animal genetics resources. Irrespective of livestock species, there is evidence that key traits (disease resistance, variation in response to vaccination, adaptability to ecologies, ...) are clearly identifiable and can be harnessed to select for highly adaptable and productive animals. Current advances in genome sequencing and experimental manipulation, big data analysis and association of genetic profiles to traits can be leveraged to identify markers for breed identification and selection.

It is therefore feasible that profiles for tropically adapted livestock can be developed through our increasing ability to understand the genetic basis of key traits, to record phenotypes and to manipulate genes. A new initiative, the Centre for Tropical Livestock Genetics and Health (CTLGH) focused on using such approaches to improve tropical livestock resilience and productivity will be discussed.

117 Animal and human health: A dangerous intersection or healthy future?

Dr Delia Grace¹

¹ILRI, Nairobi, Kenya

In the second decade of the 21st century, our world has never been wealthier, healthier, or more worried. When it comes to worries, threats associated with animal disease are especially prominent. The avian influenza and Ebola pandemics showed the extent of death, disruption, and economic damage that can be caused by zoonotic pandemics. Better, cheaper, biotechnology potentiates the risk of bioterrorism and zoonoses feature prominently among diseases that can be weaponized. Concern over the role of the livestock and fish sector in generating antimicrobial resistance in human pathogens ratchets upwards. Animal source food is associated with over-nutrition and non-communicable disease.

At the same time, livestock systems contribute immensely to human health through a range of pathways from direct provision of safe and nutritious foods to enhancement of psychosocial wellbeing to generating income often used for food, education and healthcare. Benefits from livestock are especially important and varied in low and middle income countries (LMICs), where around one billion people depend on livestock for their livelihoods.

Using the framework of the Sustainable Development Goals (SDGs), we review the complex health risks and benefits associated with livestock keeping, and discuss how the livestock sector can contribute to attaining SDGs, focusing on LMICs. We discuss how the sectoral and static nature of SDGs creates challenges, that are especially pronounced at the interface between livestock and health, and we suggest science solutions for overcoming these, based on One Health principles and practice.

118 Optimizing the environmental footprint of livestock production

Dr Polly Ericksen¹

¹*Ilri, Nairobi, Kenya*

In addition to the nutritional and income benefits for which they are known, livestock can provide some important environmental “goods”, such as biodiversity and enhancement of soil nutrients, and they are a critical livelihood asset to help buffer against climatic and economic shocks. These dimensions are often overlooked in the attention given to the potentially negative consequences of livestock on the environment, especially in the context of rapidly growing demand for meat and milk. These environmental “bads” include GHG emissions, nutrient leaching, land use change and degradation. Research to optimize the environmental footprint of livestock production, such that the “goods” are enhanced and the “bads” minimized will contribute to SDG 13 (Take action to combat climate change and its impacts) and 15 (Protect, restore and promote sustainable use of terrestrial ecosystems) and is at the heart of achieving sustainable intensification and resilience. This new research portfolio covers three dimensions: 1) improved impact assessments of livestock production using site specific data for key systems across the tropics, 2) piloting solutions for optimizing environmental goods and reducing the “bads” across key landscapes, 3) embedding incentives for environmental management in governance arrangements and policies. This research speaks to both national priorities of many Low and Middle Income countries, as well as global agendas on climate change and sustainable food production.

119 Improving food and nutrition security through dietary diversification: Promoting the rich Kenyan cuisine

Assoc Prof Judith Kimiywe¹

¹*Kenyatta University, Nairobi, Kenya*

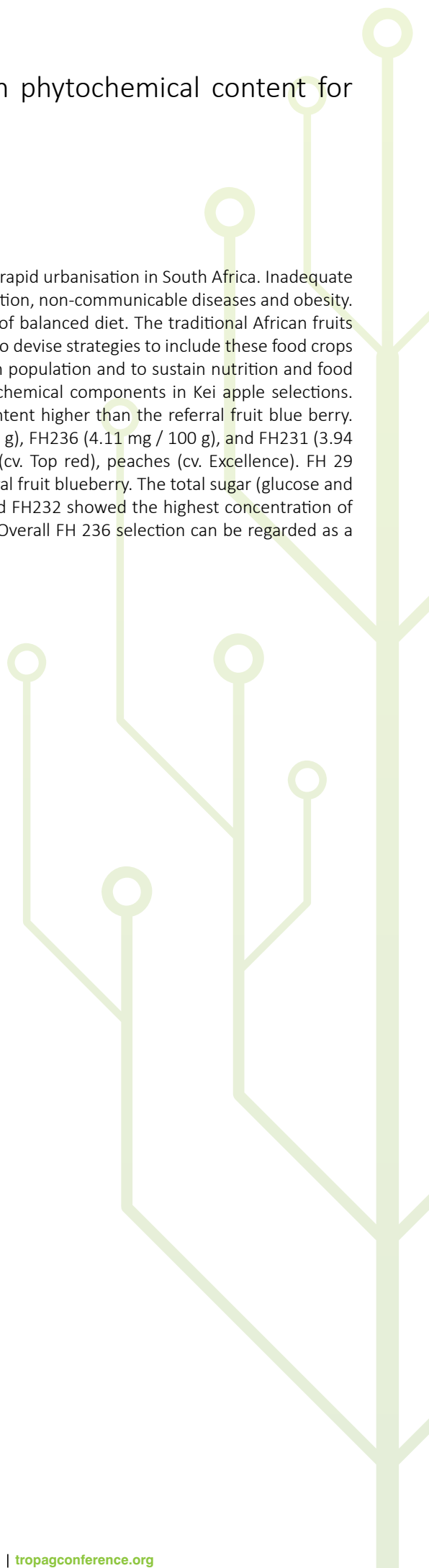
Traditional foods have a symbolic and religious value and are associated with cultural identity and social well-being. In Africa they are mainly used as food either in form of staples, snacks, appetizer, roughage, soups, drinks, and a sauce/relish or for medicinal purposes. In Kenya traditional foods are used to fill in gaps and in so doing contribute to the food security of the people. Epidemiological studies underlie the benefits of a varied diet particularly one including vegetables and fruits in increasing longevity of life and reducing rates of chronic degenerative diseases. Many households use traditional foods whenever other relishes are in short supply or when famine strikes thereby providing an alternative in times of need. Traditional food systems view food, medicine and health as interrelated. They have the potential to eliminate nutritional deficiencies among vulnerable groups such as children, expectant mothers and low income groups. There are misconceptions that traditional foods are less nutritious than exotic ones. Most of the urban dwellers especially the young don't appreciate them as credible sources of nutrients. Knowledge of the preparation of the foods is one of the main impediments to their utilization. Some of the traditional recipes are so crude that they cannot be applied in a modern kitchen. The presentation demonstrates nutritionally accepted methods of cooking that can fit into both modern and traditional kitchen. The goal is to promote Kenyan cuisine by enhancing the consumption and utilization of traditional foods especially in the urban areas hence the preservation of biodiversity.

120 Selection of suitable Kei-apple lines based on phytochemical content for functional product development

Prof Dharini Sivakumar¹, A/Prof Yasmina Sultanbawa, Ms Smargalene Mpai

¹Tshwane University of Technology, Pretoria 0001, South Africa

Inadequacy of a diversified diet is evident in the rural as well as urban areas due to rapid urbanisation in South Africa. Inadequate diets have been found to exert diverse effects on the population, including malnutrition, non-communicable diseases and obesity. Food security is associated with poverty that limits the access and the availability of balanced diet. The traditional African fruits and leafy vegetables are rich sources of micro nutrients; therefore, there is a need to devise strategies to include these food crops in nutrition intervention programmes to combat hidden hunger among the African population and to sustain nutrition and food security. Recently research has been initiated to study the nutritional and phytochemical components in Kei apple selections. Selection FH29 showed highest level (492.45 mg /100 g FW) of total phenolic content higher than the referral fruit blue berry. Selections FH14 (4.78 mg / 100 g), FH 232 (4.50 mg / 100 g), FH239 (4.17 mg / 100 g), FH236 (4.11 mg / 100 g), and FH231 (3.94 mg / 100 g) demonstrated higher levels of β -carotene than referral fruit apples (cv. Top red), peaches (cv. Excellence). FH 29 (49.75 μ mol TEAC per g FW) showed the highest antioxidant activity than the referral fruit blueberry. The total sugar (glucose and fructose) concentration were higher in selections FH240 (50 mg/g FW). FH239 and FH232 showed the highest concentration of asparagine (3122.18 mg/L) and gamma-aminobutyric (654.65 mg/L) respectively. Overall FH 236 selection can be regarded as a good source of essential amino acids.



121 Value added nutritionally rich products from Australian wattle seeds (*Acacia species*)

Assoc Prof Yasmina Sultanbawa¹, Dr Kinnari Shelat¹, Mr David Cross¹, Dr Sandra Olarte Mantilla¹, Dr Heather Smyth¹

¹Queensland Alliance for Agriculture and Food Innovation, University of Queensland, Brisbane, Australia

The seeds of *Acacia species* are known to have been an important seasonal component of traditional Australian Aboriginal diets. Due to their easy cultivation and high yields of seed that can be stored, the Australian acacias have the potential to be a major component of diets. The nutritional and chemical composition of four *Acacia species*: *A. coriacea*, *A. cowleana*, *A. retinodes* and *A. sophorae* were assessed. Based on sensory, nutritional and functional properties *A. coriacea* was selected as a functional ingredient to be added to a composite flour bread roll. The protein, total fat, dietary fibre of *A. coriacea* (%w/w) were 22.5, 9.8, 41.4 respectively, indicating a high protein and dietary fibre content. The monounsaturated fatty acids were highest at 51.3% in comparison to the saturated 31.1% and polyunsaturated 17.6%. Physico-chemical and sensory profiling methods were used to develop the bread technology. The resulting composite flour bread roll was assessed for both physical and sensory attributes to determine consumer acceptability. A consumer sensory trial with 101 panellists was conducted with results showing overall acceptability of a moderate inclusion of *A. coriacea* flour. The physical analysis showed that changes in hardness, cohesiveness, and springiness were all significant at $p < 0.05$ level and were consistent with the sensory analysis. The nutritional profile of the resulting bread was also enhanced with increased protein and dietary fibre, an enriched fatty acid profile, and notable amounts of iron and potassium. *A. coriacea* can be used successfully as a functional ingredient in composite flour bread.

122 Queensland grown Queen Garnet plum: Nutritious and healthy - A case study

Dr Michael Netzel¹

¹*Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Coopers Plains, Australia*

There is sustained increase in consumer interest in the potential health benefits of dietary derived plant polyphenols with a special focus on highly coloured compounds such as anthocyanins. A new variety of Japanese plum *Prunus salicina* Lindl., named Queen Garnet, was developed as a high anthocyanin plum in a Queensland Government breeding program. Queen Garnet plum (QGP) fruit can have an outstanding anthocyanin content of up to 280 mg/100 g fresh weight depending on maturity, environment and storage conditions. Apart from fresh fruit consumption, Queensland grown QGP is also processed into a range of retail-ready products based on juice and freeze-dried powder. The metabolism of QGP anthocyanins, potential anti-thrombotic and anti-hypertensive activities, and the effect on biomarker(s) for oxidative stress was studied in several human trials using QGP juice as the test-product. The key-results obtained in these trials will be presented at the Conference.

123 *Buchanania obovata*: An Australian Indigenous food for diet diversification

Mrs Selina Fyfe¹, Dr Michael Netzel², Dr Ujang Tinggi³, Miss Eva Biehl⁴, A/Prof Yasmina Sultanbawa²

¹School of Agriculture and Food Sciences, The University of Queensland, St Lucia, Australia, ²QAAFI, The University of Queensland, Coopers Plains, Australia, ³Queensland Health Forensic and Scientific Services, Brisbane, Australia, ⁴Technische Universität München, Freising, Germany

Buchanania obovata Engl., the Green Plum, is a small green fruit eaten by Australian Indigenous peoples of the Northern Territory and Western Australia that is previously unstudied and has potential as a source of food for diet diversification. Flesh and seed of the fruit are eaten and the plant is used as bush medicine. Proximate analysis revealed the flesh is high in protein (128 g kg⁻¹ DW) and both flesh and seed are high in dietary fibre (551 and 877 g kg⁻¹ DW respectively). Mineral/trace element and heavy metal profiles show the flesh is high in potassium (22,747 mg kg⁻¹ DW), and is a good source of magnesium (5705 mg kg⁻¹ DW), calcium (4260 mg kg⁻¹ DW) and phosphorous (2168 mg kg⁻¹ DW), whereas the seed is high in iron (81.5 mg kg⁻¹ DW). The flesh contains folate at 7174 µg kg⁻¹ DW and the seed at 1069 µg kg⁻¹ DW as Folic Acid Equivalent. The flesh and seed have good nutritional properties and can be used for diet diversification and nutrition in Indigenous and non-Indigenous populations in Australia.

124 Enhancing youth economic participation and entrepreneurship in agriculture

Mr Fahad Awadh¹

¹YYTZ Agro-Processing, Amaan, Tanzania, United Republic Of

Fahad is a young entrepreneur from Tanzania. He is the founder of YYTZ Agro-Processing, a cashew processing company. YYTZ Agro has been working with cashew farmer groups in the Mtwara region to help them add value to their own crop and earn more income.

YYTZ's flagship facility is located in Zanzibar. YYTZ recently won \$500,000 from AGRA's Africa Enterprise Challenge Fund competition. They are building a Cashew Farmer Processing Centre. The facility will have modern equipment and adequate storage facilities for farmers to use. Farmers are assured of a market; YYTZ are the sole off-takers. The semi-processed cashews are purchased from farmers at a higher price; they are sent to Zanzibar for finishing before export to European markets. YYTZ provides GAP, food safety training in addition to financial literacy and business skills training for their farmer groups. By integrating farmers in the cashew value chain, the farmers will be able to earn more from their crop. By empowering farmers YYTZ can help alleviate poverty in rural Tanzania.

As a young entrepreneur, Fahad will share his insights on the challenges he faced, constraints, the role of education and the need of role models for young people. He will provide actionable items that can be used to enhance youth economic participation and entrepreneurship in Agriculture.

Fahad has been listed by Forbes as one of the 30 Most Promising Entrepreneurs in Africa in 2017.

Learn more www.yytzagro.com

125 Using sustainable intensification principles to increase productivity of maize and wheat systems

Dr Hans-Joachim Braun¹, Dr Martin Kropff¹

¹*International Maize and Wheat Improvement Center, Mexico*

Since the 2008 food price crisis, agri-food systems have become even more central to global challenges – population growth, climate change and environmental protection. Now we are faced with agri-food systems that are fragile and constantly vulnerable to shock and with a situation in which we have to produce more with less, and even more efficiently.

Continued global challenges have made crop modelling and simulation of future agri-food systems increasingly important. However, the full potential of modelling will not be fulfilled unless well integrated into breeding programs. My dream has always been to integrate models from the genome level to crop level – and then to regional level (bringing in economic models).

Crop models are multi-functional and can be used as a) research tools (analyzing data, hypothesis generation and sustainable intensification, b) practical applications, e.g. climate change regional scenario studies, and c) capacity building. Regardless of their function, crop models must be proactive and ultimately lead to impact.

A scenario analysis conducted by the International Maize and Wheat Improvement Center (CIMMYT) in Bangladesh on the potential of moving from conventional to conservation agriculture is a prime example of this impact. Using models, and then on-farm and on-station trials to verify, CIMMYT together with the Commonwealth Scientific and Industrial Research Organization (CSIRO), optimized cropping systems.

Despite these achievements there hasn't been a major advancement in crop modelling in decades. Now we need to enter a new era, fully taking advantage of advances in data, and information and communication technologies (ICT).

126 Enhancing smallholder agricultural productivity, resilience and sustainability: Initial evidences from eastern and southern Africa

Dr Mulugetta Mekuria¹, Assoc Prof Daniel Rodriguez², Dr John Dixon³

¹CIMMYT Southern Africa Regional Office, Harare, Zimbabwe, ²QAAFI, Brisbane, Australia, ³ACIAR, Australia

The predominantly maize-based farming system of eastern and southern Africa is characterized by chronic low yield levels of the major staple crops compounded by chronic degradation of the natural resource base and soil fertility. Limited access to improved inputs and markets also contribute to lower productivity and poor incentives to invest and adopt technologies. Through broad, long-term partnerships, science, and support for Innovation Platforms, CIMMYT, QAAFI and NARS partners in Ethiopia Kenya Tanzania, Malawi and Mozambique are helping to foster the adoption of sustainable intensification practices.

The paper shares lessons and insights of a multi-disciplinary (agronomists/soil scientists, modelers; seed systems specialist, socio economist and gender specialist from CIMMYT, QAAFI and NARS) and multi-stakeholders research for impact project-SIMLESA. It is developing a range of conservation agriculture based of sustainable intensification options though on-station and on-farm trails.

Analysis of biophysical and socioeconomic data for the 2010-2016 demonstrate yield benefits of intercropping /rotations. Maize yields increased from 2.5 to 4 tons/ha and from 1.5 to 3 tons/ha legumes and 20-40% increases in financial benefits. Farmers in Tanzania and Malawi adopting zero tillage reported saved labour (30-50%), reducing production costs to use for other economic activities. SIMLESA-QAAFI studies suggested a reduction of down size yield risk by 45%. Adoption-Monitoring 2016 survey projected a 37% adoption rate. Perceived benefits are Long-term soil fertility improvements, erosion control and moisture conservation.

The challenge ahead is scaling out- plot to farm and community levels and develop sustainable and resilient climate farming system in the region.

1. Innovation platforms-/ networks- actors in the value chain involve, researcher, extension agents, NGO farmers, local community leaders, agro dealers, seed companies and policy makers

2. Sustainable Intensification of Maize-Legume Based Cropping Systems for Food Security in Eastern and Southern Africa (SIMLESA) is supported by a financial grant from ACIAR and managed by CIMMYT and its regional and national partners including QAAFI

127 Overview of ACIAR programs focused on systems approaches for sustainable intensification

Andrew Campbell¹

¹*Australian Centre for International Agricultural Research (ACIAR), Australia*

The world faces a major challenge of feeding some 9 billion or more people by 2050, as well as providing other agricultural products and ecosystem services. Many developing countries lack the technologies and/or the enabling institutional and policy environments to attain food security in a sustainable fashion. Therefore, global leaders have identified Sustainable intensification as one way to boost productivity while conserving or enhancing soil health and water resources, that is, to produce more with less resources. Sustainable intensification, while essential to assure food and nutrition security in future decades, needs to be supplemented by a strong focus on on-farm diversification. Sustainable intensification and diversification is embedded into the approach of many ACIAR projects, in order to deliver improved food and nutrition security, better health, strong natural resource management and to boost women's empowerment and opportunities for private sector engagement.

Food cannot be produced without energy and water, and these resources are under huge pressure for multiple uses by agriculture, cities and industry. Hence ACIAR is strengthening the focus on the Food-Energy-Water (FEW) Framework, which now informs the design and implementation of many ACIAR research projects.

With these approaches, ACIAR intends to combine intensification with sustainable natural resource management.

128 Legume intensification for food security and sustainability in Africa

Prof Sieglinde Snapp¹, Dr Regis Chikowo¹, Dr Vimbayi Chimonyo¹, Dr Wezi Mhango², Prof Mateete Bekunda³

¹Michigan State University, East Lansing, United States, ²Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi, ³IITA, Arusha, Tanzania

Legumes have a long history of cultivation in Africa and provide multiple benefits, but they suffer from under-investment. Intensification of food production in Africa cannot be achieved without greater adoption of improved pulses, nutrient management and agronomy. Modern high-yielding crop varieties are available, but there is urgent need promote those that also produce high quality biomass, to address multiple demands. Intensified legume systems are needed to support key agricultural system functions, with multipurpose pulses being uniquely placed to support improved fertilizer efficiency, nutritional diversity, fodder, fuel and ecosystem services such as soil organic matter and pollination. There is a trade-off between the harvest index of legume crops and other functions, which has too often been overlooked by researchers and decision makers who tend to focus on increasing grain yields solely. The Africa RISING project, provides an example of making a difference for smallholder farms in Africa by broadening the range of legume options and supporting innovation. The doubled-up legume rotation (DLR) technology was developed based on intercropping two grain legumes, exploiting the opportunity presented by complementary growth habits and plant architecture. This is exemplified by the groundnut-pigeonpea DLR with maize and integrated fertility. Africa RISING is now scaling DLR for soil rehabilitation and to provide multiple products on-farm, for a more secure future. Years of partnerships have led to these farmer-approved varieties, integrated nutrient use, and biologically-smart combinations such as 'doubled up legume innovations' being released by governments and taken up by communities in Malawi, and neighboring countries.

129 Overview of systems approaches for sustainable intensification in China

Prof Lingling Li¹, Prof Renzhi Zhang¹, Prof Junhong Xie¹, Prof Zhuzhu Luo¹, Prof Liqun Cai¹

¹*Gansu Agricultural University/Gansu Provincial Key Lab of Aridland Crop Science, Lanzhou, China*

China is an ancient country with thousands of years of intensive agriculture. However, China's has paid a heavy price for traditional intensive farming, such as soil erosion. The government responded severe soil erosion on the Loess Plateau with a policy called 'grain for green'. However, implementation has met with some resistance. Therefore, the development of sustainable intensification practices is needed.

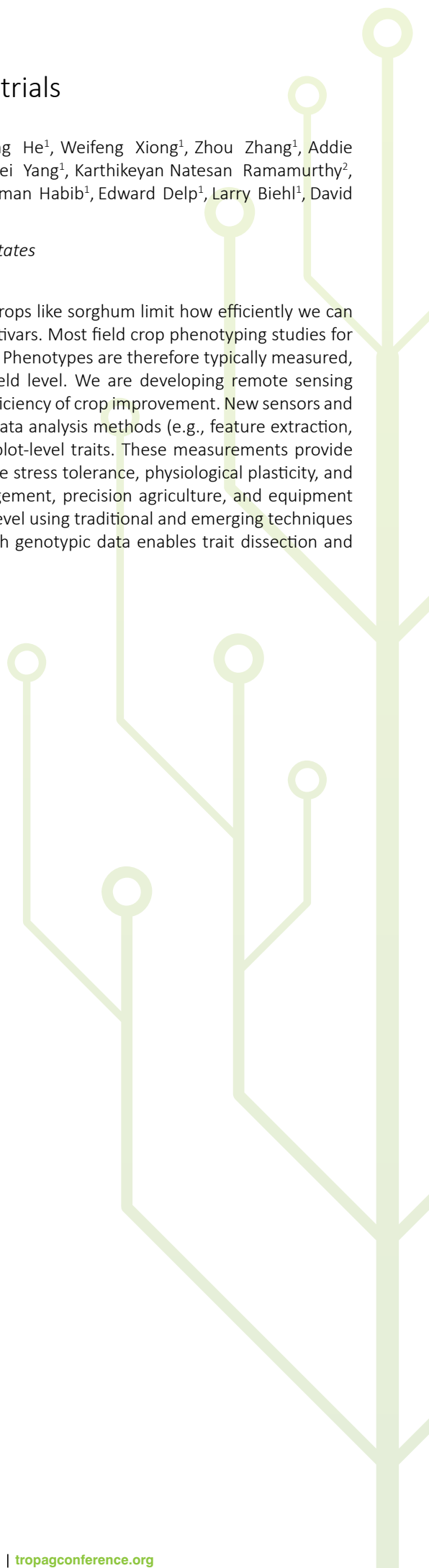
A case study was conducted to assess the influence of tillage practices on soil quality, crop yield and GHG emission in a spring wheat-pea rotation in rain fed semiarid Loess Plateau. The experiment was established in 2001, treatments include conventional tillage with straw removed (T), no till with straw removed (NT), no till with straw retention (NTS) and conventional tillage with straw incorporated (TS). NTS and TS treatments significantly increased soil organic C by 20.81% and 10.60%, respectively at a depth of 0–10 cm compared with T. NTS improved soil properties. NTS decreased cumulative N₂O emission (by 30.63% and 20.49%) and CO₂ emission (by 22.03% and 12.06%) compared with T and TS treatments, respectively. There was approximately 27.41% increase in CH₄ uptake in NTS soils compared with T field. Improved soil quality in NTS translated into higher biomass production and therefore higher grain yield. Overall, no-till with stubble retention demonstrated sustained increases in soil quality and crop productivity, and reduced greenhouse gas emissions in rain fed Loess Plateau. However, adoption rate of conservation agriculture has been low due to lots of reasons.

130 UAV-based phenotyping of crop plants in field trials

Dr Mitchell Tuinstra¹, Dr Chris Boomsma¹, Javier Ribera¹, Yuhao Chen¹, Fangning He¹, Weifeng Xiong¹, Zhou Zhang¹, Addie Thompson¹, Jieqiong Zhao¹, Patrick Sweet¹, Ali Masjedi¹, Behrokh Nazeri¹, Kai-Wei Yang¹, Karthikeyan Natesan Ramamurthy², Aurelie Lozano², Peder Olsen², Naoki Abe², Scott Chapman², Graeme Hammer², Ayman Habib¹, Edward Delp¹, Larry Biehl¹, David Ebert¹, Michael Leasure¹, Keith Cherkauer¹, Clifford Weil¹, Melba Crawford¹

¹Purdue University, West Lafayette, United States, ²IBM, Yorktown Heights, United States

Bottlenecks in our ability to collect accurate, high-resolution, phenotype data on crops like sorghum limit how efficiently we can combine plant characteristics with genomic information in developing superior cultivars. Most field crop phenotyping studies for above-ground traits occurs at the plant and canopy scale of biological organization. Phenotypes are therefore typically measured, analyzed, and/or expressed at the row, plot, strip, management zone, and/or field level. We are developing remote sensing platforms that can be used for high-throughput field phenotyping to enhance the efficiency of crop improvement. New sensors and sensor platforms, novel georeferencing techniques, and sophisticated image and data analysis methods (e.g., feature extraction, image segmentation) are being implemented to quantify variation in plant- and plot-level traits. These measurements provide insights into research plot and field quality, field equipment performance, genotype stress tolerance, physiological plasticity, and spatial variability. Such information contributes to field crop breeding and management, precision agriculture, and equipment manufacturing communities. Challenges from phenotyping at the individual plant level using traditional and emerging techniques will be discussed. Agronomic performance and remote sensing data matched with genotypic data enables trait dissection and optimization of sorghum for biomass and energy yield for transportation fuel.



131 Characterizing the sorghum pan genome

Scott J Lee¹, Adam Healey², Nadia Shakoor¹, Sujan Mamidi², Zhenbin Hu³, Jane Grimwood², Jeremy Schmutz², Geoff Morris³, **Dr Todd Mockler¹**

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Sorghum bicolor is an emerging cellulosic biofuel feedstock, a cereal crop, and serves as a model system for other bioenergy and food crops. Currently, sorghum is the focus of the ARPA-E TERRA program, which is currently developing and operating cutting-edge remote sensing platforms, complex data analytics tools, and conducting high-throughput plant phenotyping in both controlled greenhouses and field sites. Genomic re-sequencing of a diverse panel of 384 sorghum lines, known as the sorghum bioenergy association panel (BAP), was performed in order to accelerate trait discovery and breeding. The sorghum BAP encompasses all five major races, all 16 intermediate races, as well as vast geographic ranges and climates. Through the sorghum BAP, we are exploring the scope of natural variation in the sorghum pan-genome for copy number variation (CNV), structural variation (SV), and presence/absence variation (PAV). In total, de novo assembly of the sorghum pan-genome expands the sorghum gene space by >15% and will be leveraged to inform association studies using robust phenomic data collected in the ARPA-E TERRA program. Population substructure analysis reveals 5-6 unique subpopulations within sorghum containing potentially adaptive gene sets that may be useful for allele mining approaches. The combination of precision field and greenhouse phenotyping on this diverse collection will allow for accelerated identification of genetic elements controlling agronomically important phenotypes including yield, growth rate, biomass accumulation, water-use efficiency, and drought resistance. Using pan-genomic information will maximize the available genetic resources to map key traits and accelerate breeding approaches to enhance this important crop.

132 Exploring and exploiting natural variation in sorghum

Emma Mace^{1,2}, A Hathorn, Dr Yongfu Tao¹, Ms Colleen Hunt², A Cruickshank, S Tai, David Jordan¹

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Amongst the cereals, sorghum is one of the best adapted to drought and high temperatures. It is likely that sorghum will play an increasingly important role in meeting the challenges arising from feeding a growing population in the face of likely negative impacts of climate change combined with dwindling soil and water resources for agricultural production. To date sorghum plant breeding programs have made relatively limited use of the wealth of diversity available to them in germplasm collections to address the challenges of overcoming abiotic stresses and improving yield and instead have focused on the core adapted gene pool. Sorghum is in a unique position to explore and exploit the genetic diversity available in landraces and wild relatives through the recent development and application of a range of genetic resources for complex trait dissection including a large diversity panel, nested association mapping panels focused on both cultivated and wild species gene-pools and the development of a sorghum pan-genome to facilitate the identification of the full complement of genes within the primary sorghum gene pool. In this paper we will present our experience in using the range of unique genetic resources for quantitative trait mapping using optimised GWAS algorithms in order to better harness this untapped genetic diversity for the enhancement of elite sorghum germplasm.

133 Exploring the crop adaptation landscape in silico

Prof Graeme Hammer¹, Greg McLean², Al Doherty³, Dr Carlos Messina⁴, Dr Mark Cooper⁴, Dr Erik van Oosterom¹, Prof David Jordan⁵, Dr Bangyou Zheng⁶, Prof Scott Chapman^{1,6}

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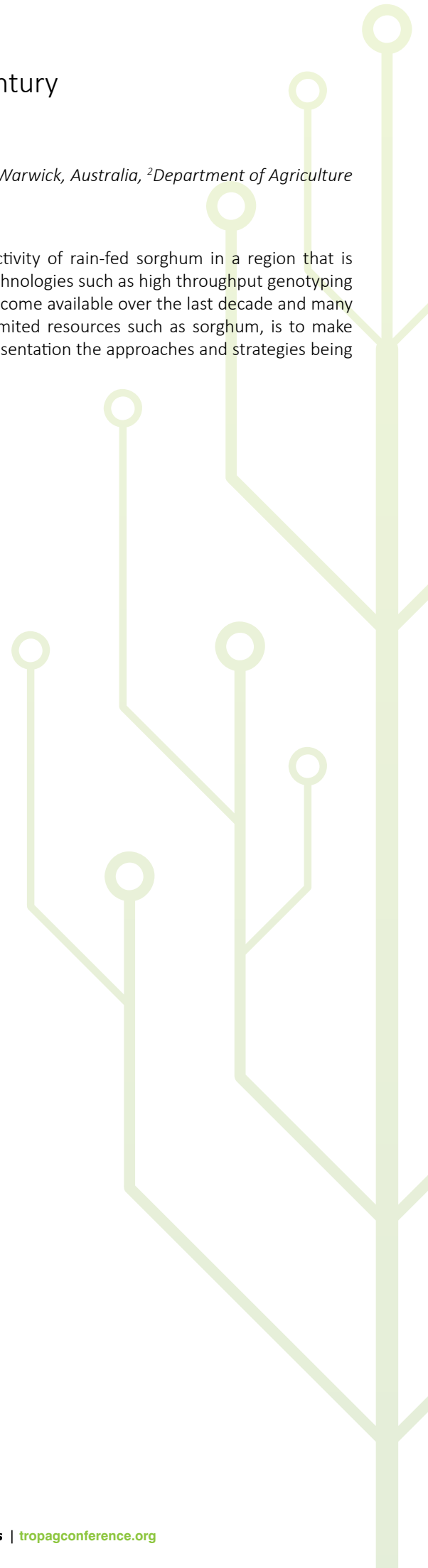
Climatic variability in dryland production environments (E) generates variable yield and crop production risks in many parts of the world. Optimal combinations of genotype (G) and management (M) depend strongly on E and thus vary among sites and seasons. Traditional crop improvement seeks broadly adapted genotypes to give best average performance under a standard management regime across the entire production region. This process does not search the full spectrum of potential GxMxE combinations forming the adaptation landscape. Here we examine the potential value of using in-silico analysis to inform crop design and improvement. A comprehensive crop modelling and simulation approach that considers interacting effects of G and M factors on yield likelihood and risk in the target population of E is invoked. Case studies for sorghum and maize production are used to highlight the concepts.

134 Building new sorghum varieties in the 21st century

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Sorghum breeders in Australia face a complex challenge to improve the productivity of rain-fed sorghum in a region that is characterised by highly variable rainfall patterns and soil types. A range of new technologies such as high throughput genotyping and phenotyping, simulation modelling, remote sensing and CRISPR–Cas9 have become available over the last decade and many new ones are on the way. The challenge for breeders in crops with relatively limited resources such as sorghum, is to make decisions about which technologies to deploy and how to deploy them. In this presentation the approaches and strategies being used in pre-breeding program run by UQ/DAF are described.



135 Tropical tomato breeding for Australian markets – Satisfying the diverse needs of producers, retailers and consumers

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A balanced tomato improvement program should address priorities for producers, retailers and consumers so that benefits for all members of the value chain are optimised. A requirement for improved fruit firmness and shelf life by major Australian supermarkets 20 years ago introduced new tomato cultivars with superior fruit quality to consumers. Retailers and consumers benefited immediately but producers suffered increases in production costs and crop disease because the new cultivars were seriously unadapted. A breeding program was subsequently undertaken to improve agronomic performance and disease resistance across Queensland. Increased fruit size, improved internal fruit structure and several Fusarium resistance genes were initially targeted. Additional disease resistances became necessary as the program developed and within 5 years 5 major genes were introduced to a large range of improved parent lines and F1 hybrids by DNA marker assisted selection. Consumer interest in functional foods has been increasing in the last decade. High-lycopene tomatoes expressing an intense red colour have a potential health benefit of lowering the incidence of prostate cancer. The red pigment 'lycopene', the phytonutrient linked with this benefit, can be increased in concentration up to threefold using a combination of two recessive genes, *ogc* (old gold crimson) and *hp1* (high pigment 1). The base-pair alterations underlying these genes are known, and we have applied SNP (Single Nuclear Polymorphism) technology to incorporate high lycopene into a superior phenotypic background. A combination of improved field performance and fruit quality will provide broad benefits in an environment of changing market priorities.

136 Demand-led approaches in the tomato industry in Ghana: Challenges and opportunities for breeding and crop improvement

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Tomato remains one of the most cultivated and consumed vegetables in Ghana. It is key to the health and nutrition of Ghanaians, being an important source of vitamins, minerals, antioxidants and fibre. Its cultivation is also more profitable than many other staple food crops grown across the country. Despite favorable growing conditions for its production, its importance for food and nutrition security and job creation, current production does not meet local demands. Thus, Ghana relies heavily on the import of both fresh and processed tomatoes. Many constraints such as pests and diseases, environmental stresses, use of inappropriate agricultural techniques and post-harvest losses hinder productivity and competitiveness. In addition, very little tomato breeding has been done due to lack of investment. Most of the widely marketed tomato varieties were bred outside the country and are not adapted to our local growing conditions.

Any attempt to salvage the tomato industry in Ghana must be holistic, involving contributions from all actors in the value chain including government policy makers and officials. We have engaged all the key players and catalyzed funding for four PhD postgraduate tomato breeding programs. Research is focussing on virus-resistance, heat-tolerance, shelf-life and tomato processing characteristics. Best practices in demand-led breeding are being used to ensure that modern varieties from these programs will match the needs and stimulate our tomato industry. Here, we report on some of the successes and challenges encountered, and highlight opportunities for developing improved varieties of tomato to increase productivity and incomes in Ghana.

137 Maximizing the impact of common bean (*Phaseolus vulgaris*) breeding for farmers and other value chain

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Bean is nutritious food for millions of people in sub-Saharan Africa. Per capita consumption is as high as 40 to 50kg/year in East Africa. It is the most traded grain legume by poor farming households; mostly by women who sell up to 50-60% of their harvests. Beans contribute to improved livelihoods.

Through the Pan African Bean Research Alliance (PABRA), CIAT and national bean researchers have partnered with the private sector and developed varieties that respond to the needs of farmers and other value chains actors. Public and private seed organizations and over 90 individual entrepreneurs have capitalized on business opportunities in East and Southern Africa and now provide seed and services for smallholder farmers and traders. Access to highly marketable varieties and trading opportunities has incentivized smallholder farmers to improve their crop management and yields are dramatically rising. For instance in Uganda, bean yield has been growing at an annual rate of 4.2% during the period 2011-2015. In Ethiopia between 2002 and 2016, bean yields increased from 0.53 to 1.75 tons/ha. Export volumes increased 15-fold, from US\$8 million to US\$ 120 million, employing 1.5 million small holders and thousands of support service providers; while the price of white pea beans increased from US\$200 to US\$600 per ton.

Looking forward, PABRA is focusing on market-led breeding to create varieties with consumer traits that are adapted to perform in ever changing agro-ecological conditions, and to encourage private sector engagement in the development of innovative technologies, scale-up and distribution of varieties to smallholders.

138 Connecting public and private breeders and new vegetable varieties to developing markets in SE Asia and Sub-Saharan Africa

Mr Clive Murray¹, Dr Ian Barker¹, Mr Camille Renou¹

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Improving and promoting widespread access to quality seed of new varieties are critical factors in modernizing small-holder agriculture in S.E Asia and Sub-Saharan Africa.

The majority of crop genetic improvement in these geographies is conducted by breeders within the CGIAR and National Agricultural Research Systems. Outreach of these public sector programs to bulk and deliver seeds to farmers in many cases is limited or inefficient, resulting in slow and poor uptake.

The Syngenta Foundation for Sustainable Agriculture (SFSA) has developed a scalable idea or offer called Seeds2B that addresses this challenge. Its aim is to encourage and de-risk the entry of private sector seed organisations into new and currently marginal seed markets. SFSA focuses in areas of market failure, where the private sector is not addressing the needs of the market or where public sector is failing to develop and introduce improved material. This market-driven approach identifies suitable varieties from public and private crop breeding programmes, establishes evidence for workable and profitable seed value chains and develops appropriate partnerships.

The Seeds2B “core” offer identifies smallholder farmers without reliable access to quality seed, conducts market value and segmentation analyses, develops “product profiles” that define the crop characteristics needed by each farmer segment and their customers, seeks varieties that meet these needs and connects private sector partners seeking business expansion.

The presentation will showcase two case studies, namely the development of the potato seed industry in Indonesia and secondly the development of the improved okra varieties in Senegal.



139 Custard apples – breeding for Australian domestic and export markets

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Australian Custard Apples, a deliciously sweet subtropical fruit, are a type of Atemoya. Atemoyas are hybrids between *Annona cherimoya* and *Annona squamosa*. The Australian industry is currently based on the cultivars African Pride, Pinks Mammoth and budsports from Pinks Mammoth. The majority of recent plantings are of a budsport named K J Pinks. K J Pinks have been demonstrated to be amenable to high density production both in trellised and hedgerow systems. In experimental plots, yields have been as high as 80 tonnes per ha per annum.

Large, top quality Australian Custard Apples are sought in premium Asian and Middle East markets. Preference in these export markets is for very large and very sweet fruit. The largest domestic markets are in Sydney and Melbourne where consumers, with Asian heritages in particular, seek the fruit. Australians of European heritage, in general, prefer less sweet, medium sized fruit.

A breeding program in QLD has produced a number of new Custard Apple types. A green skin selection, 453, appears to be favoured by Australians with European heritage. Other green skin selections offer large fruit size and reduced seed number. A red skinned type has also been developed and is currently being assessed in regional trials. This red skinned, white fleshed atemoya is expected to attract premium returns in Asian markets.

The future market potential of Australian Custard Apples is enormous. The domestic market is still far from saturated and markets in Asia and the Middle East still in the infancy stage of development.

140 Tropical horticulture – Exploring new approaches for sustainable funding of plant breeding in developing countries

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Fruits and vegetables are key sources of essential vitamins, micronutrients and fibre for a healthy diet. Horticulture crops also typically offer higher sources of income for smallholder farmers in developing countries, than staple cereal or root crops. But investment in plant breeding programmes to improve the quality, productivity and appeal for consumers is lacking by both national governments and international donors. In countries with developed domestic or export markets, creation of new varieties is mainly financed by private sector organisations, or using monies from farmer levies combined with some government contributions. History shows that as markets develop funding shifts from government programmes to greater engagement and direction from private sector beneficiaries and farmer contributions.

More innovation is needed to encourage investment in the future of horticulture crops and healthier diverse diets, accelerate the engagement of seed organisations and private enterprise, and catalyse new market opportunities for smallholder farmers in developing countries. Greater use and remuneration of genetically diverse germplasm is required to provide resilience to current and future biotic and abiotic risks. This paper highlights existing mechanisms to support plant breeding to address the ongoing challenges facing farmers and their value chains. It also explores current issues and new ideas on how to maintain and encourage greater and sustainable investment in market-driven crop breeding programmes. A special focus is given to these particular challenges and the investment and remuneration systems needed to create improved varieties that will reach smallholder farmers growing fruits and vegetables in Africa and South East Asia.



141 Development of point-of-care and multiplex diagnostic methods for the detection of plant and poultry pathogens

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Nucleic acid point-of-care bioassays that can be performed on-site are in high demand, however a number of challenges need to be overcome before the new technologies can be widely implemented. One of the main requisites is to create methodologies that do not require a laboratory environment, while being reliable. Other considerations such as the increased probability of contamination, multistep sample preparation and availability of trained personnel further complicate the problem. We have created a suite of simplified approaches and custom-made portable equipment that can be reliably used in rural and remote environments without the need to carry biological samples back to the laboratory for analysis. Our methods can perform diagnostic assays in less than an hour from sampling to retrieving the results and can be performed on-site.

142 Point-of-site diagnostic nanotechnologies for health and agricultural applications

Prof Matt Trau¹

¹The University of Queensland, Centre for Personalised Nanomedicine, Australian Institute for Bioengineering and Nanotechnology (AIBN), School of Chemistry and Molecular Biosciences, Brisbane, Australia

The concept of personalised diagnostics is to direct accurate clinical decisions based on an individual's unique disease molecular profile. Lab-on-a-chip (LOC) systems are examples of personalised diagnostics which seek to perform an entire sample-to-outcome detection of disease biomarkers on a single miniaturised platform with minimal user handling. Despite the great potential of LOC devices in providing rapid, portable, and inexpensive personalised diagnosis at the point-of-care (POC), the translation of this technology into widespread use has still been hampered by the need for sophisticated and complex engineering. As an alternative, our lab has recently developed a variety of miniaturised diagnostics platform free of precision fabrication¹⁻¹⁰. These are termed "lab-in-a-drop" (LID) systems in which an entire laboratory-based diagnostics workflow can be downscaled and largely integrated within a single fluid droplet for POC detection of nucleic acid, protein, exosome &/or cell-based biomarkers. In this paper, we will focus on miniaturised biosensing strategies suited for integrated LID diagnostic development. Although developed for human health applications in mind, the platform nature of the LID approach lends itself also to agricultural applications.

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143 From research to frontline laboratory

Ms Aileen Vanderfeen¹

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From the beginnings of laboratory science, research has been adapted so that the discoveries and techniques developed during research projects can be transformed into tools to advance and streamline the capabilities of diagnostic laboratories.

From Antonie van Leeuwenhoek who invented the Microscope which allowed the microbes to be seen, to Pasteur and Koch who are regarded as the first bacteriologists through to the present day researchers scientists have continued explore new and different ways of achieving knowledge and adapting that knowledge into practical methods and techniques

Over the last 50 years with the advent of computer systems and more recently gene sequencing equipment, the identification and reclassification of bacteria has proceeded rapidly. These tools were once the province of researchers as they were both slow and expensive however with the rapidly advancing technology the cost has diminished and the speed of the result being available has become faster. Frontline laboratories usually have a need for tests to be cost effective, timely and also accurate in nature so now this technology is becoming more common in the normal diagnostic laboratory.

In the very near future robotics and computer systems are going to be the way forward so my question is will we need to employ scientists in frontline laboratories in the future as machines can process samples and all the knowledge required to make a judgement on the results will be uploaded to computer systems.

144 Diagnostic tools used to genotype and detect tick fever pathogens in cattle

Mr Peter Rolls¹, Mr Phillip Carter¹, Dr Jacqui King¹

¹DAF Tick Fever Centre, Wacol, Australia

Bovine tick fever, caused by any of *Babesia bovis*, *Babesia bigemina* or *Anaplasma marginale*, is endemic in many countries in the tropical and subtropical regions of the world. In Australia, the vector cattle tick is *Rhipicephalus australis* (formerly *Boophilus microplus*). Bovine anaemia caused by the *Theileria orientalis* group has been of concern in recent years in Australia.

The Tick Fever Centre was established in Queensland in 1966, to produce living tick fever vaccines and undertake research in tick fever control. The vaccine is a live, whole organism, blood-based vaccine containing attenuated strains of *B. bovis* and *B. bigemina* as well as *Anaplasma centrale*, a related less virulent organism providing reasonable cross protection against *Anaplasma marginale*. Tick Fever Centre also undertakes most tick fever diagnostic work for submissions to Queensland's state veterinary laboratory. Light microscopy and serology are the most frequently used diagnostic tools.

An important characteristic of infection of cattle with tick fever organisms is the long-term, carrier status of the infected animal. The gold standard for detecting persistent infection was traditionally sub-inoculation of splenectomised calves with blood from the donor animal. Real-time polymerase chain reaction techniques now play some role in this. Electrophoresis techniques also allow differentiation of vaccine and field strains of *Babesia bovis*, and monitoring of the attenuation process. Strain identification is an important consideration in theileriosis in Australia. The place of such molecular techniques in routine diagnostic work will be discussed.

145 A mass spectrometric targeted approach for the detection of exosomal protein biomarkers from bovine body fluids

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Exosomes are membrane bound vesicles of endocytic origin. They encapsulate bioactive molecules and are released by multiple cell types into body fluids, which can then be sampled. All exosomes share certain common characteristics (e.g. the presence of exosomal protein markers). The exosomal protein content has been shown to vary in dairy cows of divergent fertility and metabolic states and thus may be useful as a diagnostic tool. In the current study, we extracted exosomes from milk and plasma from dairy cows and then characterized by nanoparticle tracking analyses (NTA), exosomal markers CD63, Flotillin-1 and TSG-101 (immunoblotting) and transmission electron microscopy (TEM) for exosomal morphology. We developed a targeted proteomic approach using the quadrupole-ion trap (Q-TRAP) mass spectrometer. TSG-101 peptide precursors, (1) LDQEVAVDKNIELLR with transitions (1000.579 Da, 885.552 Da and 643.414 Da) and (2) DEELSSALEK with transitions (747.425 Da, 661.268 Da and 574.235 Da) were detected in both the milk and plasma exosomes. This method can provide an alternative approach for screening and validating exosomal protein markers that are common to all exosomes present in the different body fluids. This proteomic approach is robust, able to identify specific peptide sequences and can identify lower concentrations of protein (1.6µg protein loaded onto column) overcoming amounts required for immunoblotting (10µg protein). Furthermore, this method also negates the dependence on antibody specificity required for immunoblotting. The ability to efficiently detect exosomes from different body fluids through targeted proteomic applications will aid our effort to develop novel diagnostics and prognostics for specific pathologies.

146 Use of mobile technologies for research and engagement of smallholder cattle farmers in Vanuatu

Dr Simon Quigley¹, Mr Keith Antfalo², **Mr Stephenson Boe**³, Mr Mangau Navian³, Mr Joseph Sul³, Ms Antoinette Nasse², Ms Jerine Natapu⁴, Ms Norah Rihai⁵, Mr Noel Kalo², Mr Jimmy Rantes², Mr Nambo Moses³, Mr Lonny Bong³, Dr Scott Waldron¹, Prof. Dennis Poppi¹, Dr Kendrick Cox⁶, Ms Amber Gregory⁷, Mr Stuart Higgins⁷, Dr Cherise Addinsall⁸

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Smallholder farmers have the potential to increase the productivity of the household and national cattle herd in Vanuatu. However, engagement with this group of farmers in the industry has declined in recent years. The Australian Centre for International Agricultural Research funded 'Bisnis Blong Buluk' project is conducting integrated livelihoods-business-production research and training with smallholder cattle farmers on Santo island, Vanuatu. The project is using mobile technologies to record and share data with farmers. Surveys used in the project are designed using CommCare software (Dimagi Inc.) and deployed on tablets to collect quantitative data on livelihoods (household, household member) and cattle production (individual, herd) with co-operating households. Household members provide verbal consent recorded on tablets to participate in project activities. Surveys capture gender-disaggregated data on living standards, access to information, roles of household members and role of cattle in livelihoods. GPS units record waypoints, map farm boundaries, calculate farm area's and measure distances between key household resources. Cattle are weighed on a mobile cattle crush (Leichts CIA) with liveweight and other data recorded on tablets. A summary of liveweight, liveweight change since previous measurement and an estimate of the value of individual animals is generated in CommCare using available market prices. The summary is printed on-site and provided to farmers the day measurements are conducted. This real-time information can assist farmers with management and marketing decisions regarding their cattle and farm planning. Quantitative and qualitative data will be linked to build case studies for different types of cattle farming households.

147 Identifying and managing new hazards in the food supply

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Food safety risks can emerge when new hazards are identified or if new information comes to light about an existing hazard e.g. increased exposure.

Identifying and monitoring emerging issues allows Food Standards Australia New Zealand (FSANZ) to better predict possible food safety risks, and when necessary and working with our regulatory (including international and jurisdictional) partners, develop appropriate measures to reduce the effect of those risks. This presentation will provide some general background on how we approach these issues, and some case examples of new hazards and detail risk management strategies to keep levels of contaminants in the food supply to As Low As Reasonably Achievable (ALARA).

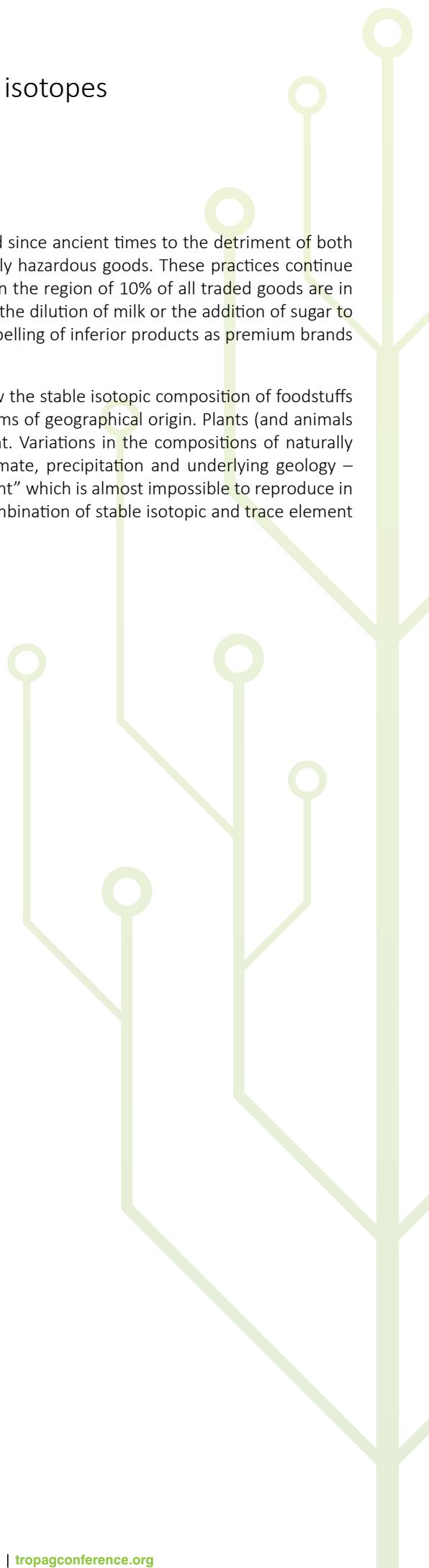
148 Food authenticity and traceability using stable isotopes

Dr James Carter¹

¹Queensland Health Forensic and Scientific Services, Cooper Plains, Australia

The counterfeiting, substitution and adulteration of foodstuffs have been practiced since ancient times to the detriment of both suppliers and consumers through poor brand-experience of inferior and potentially hazardous goods. These practices continue today, with increased sophistication, and official estimates state that somewhere in the region of 10% of all traded goods are in some way fraudulent. Some types of fraud can be relatively easy to detect such as the dilution of milk or the addition of sugar to fruit juices. Other forms of fraud can be more difficult to detect, such as the mislabelling of inferior products as premium brands or false claims of geographical origin.

This presentation will outline the nature and scope of food fraud and illustrate how the stable isotopic composition of foodstuffs can be used to distinguish genuine and counterfeit goods and to authenticate claims of geographical origin. Plants (and animals feeding on those plants) accumulate elements from their immediate environment. Variations in the compositions of naturally occurring stable isotopes (and trace elements) are driven by factors such as climate, precipitation and underlying geology – parameters which give rise to an invisible “isotopic signature” or “isotopic fingerprint” which is almost impossible to reproduce in a counterfeit product. The strength of the evidence that can be derived from a combination of stable isotopic and trace element composition provides a powerful tool in the fight against food fraud.



149 Mycotoxins in the food supply chain and promising interventions

Assoc Prof Mary Fletcher¹

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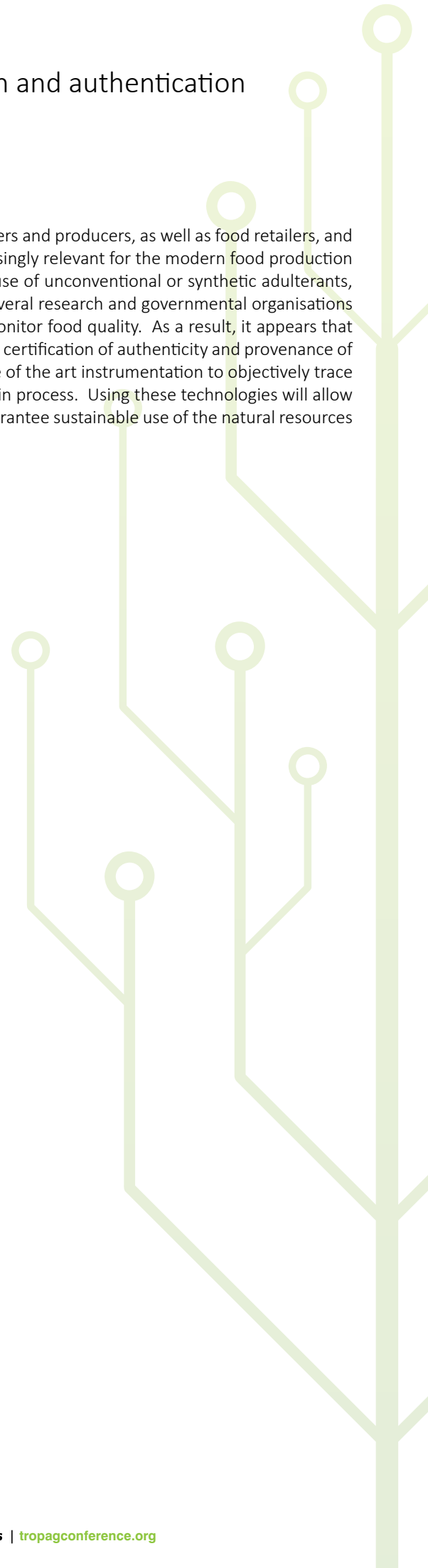
Mycotoxin contamination is a global problem that is estimated to affect 25% of all foods worldwide. Mycotoxins are toxic secondary metabolites produced by fungal species (primarily *Aspergillus*, *Penicillium*, *Fusarium*, and *Alternaria*) and pose a significant risk to the food chain. These toxins are considered the most hazardous of all food contaminants in terms of chronic toxicity, and legislative limits on their levels in food and feed continue to be developed worldwide. Methods for mycotoxin suppression and decontamination include preventative strategies both in the field and in storage, together with both biological and non-biological methods to facilitate degradation of such toxins in food and feed commodities, or reduction of their absorption and/or bioavailability when ingested. Many potential control methods are however not without their own safety concerns for the consumers. Photodynamic inactivation is a novel light-based approach which offers a promising alternative to conventional methods for the control of mycotoxigenic fungi. When coupled with natural photosensitisers such as curcumin this strategy has demonstrated efficacy in the inactivation of spores of *Aspergillus flavus*, fungal producers of the most potent mycotoxin aflatoxin.

150 Rapid detection methods for food adulteration and authentication

Assoc Prof Daniel Cozzolino¹

¹Central Queensland University, Rockhampton, Australia

Food authenticity, traceability and origin are important issues for both the consumers and producers, as well as food retailers, and agribusiness. Issues related with food fraud and adulteration are becoming increasingly relevant for the modern food production systems. In recent year, food quality has become more sophisticated due to the use of unconventional or synthetic adulterants, which has resulted in growing concern about potential associated health risks. Several research and governmental organisations have attempted to demonstrate the ability of different sensors to measure and monitor food quality. As a result, it appears that there is an imperative need to find objective methods and systems that support the certification of authenticity and provenance of foods. The aim of this presentation will be to discuss the possibilities of using state of the art instrumentation to objectively trace or assure the origin of agricultural products as well as monitor the whole food chain process. Using these technologies will allow producers and food manufacturers to better market their products as well as to guarantee sustainable use of the natural resources required for food production.



151 Oritain- Proving origin, protecting reputations

Mr Sandon Adams¹

¹*Oritain Australia Pty Ltd, Australia*

Oritain is a global leader in scientifically proving the origin of food products to protect and enhance brands. We offer traceability without packaging- by testing what naturally occurs inside products Oritain can determine where they were grown or manufactured to help businesses support their provenance claims and identify counterfeit goods.

Founded in 2008, Oritain partners with some of the world's leading producers, food service companies and retailers across the Meat, Dairy, Horticulture, Aquaculture, Eggs, Honey, Fibre / Textile, and Pharmaceutical sectors.

With offices in Australia, New Zealand and the United Kingdom, as businesses look beyond standard QA processes to mitigate well-known risks in their supply chains, our role is to protect the reputations of our customers from the growing global issue of food fraud in markets all around the world.

Prior to Oritain Sandon managed all sales and business development for an Australian horticulture agribusiness, and has worked in senior FMCG roles for the world's largest food & beverage company (Nestlé), responsible for managing some of Australasia's largest brands including Nescafé and Milo. As a member of a fourth generation farming family, Sandon has a background in agriculture having grown up with a mixed farming operation (cattle grazing and broadacre cropping) in the family.

152 Molecular detection of *Toxoplasma Gondii* infection in small ruminants in Northwest Tunisia

Miss Yosra AMDOUNI¹, Mr Mohamed Ridha Rjeibi¹, Mme Mariem Rouatbi¹, Mme Safa Amairia¹, Miss Sofia Awadi², Mr Mohamed Gharbi¹

¹National School of Veterinary Medicine of Sidi Thabet, Sidi Thabet, Ariana, Tunisia, ²Regional Slaughterhouse of Béja, 9000, Tunisia, Béja, Tunisia

Between March and October 2015, a total number of 270 meat samples (neck muscles) were collected from 150 ewes and 120 goats slaughtered in the regional slaughterhouse of Béja (North Tunisia). The samples were screened for *Toxoplasma gondii* infection. DNA was extracted using Wizard® Genomic DNA purification kit (Promega, Madison, USA) according to the manufacturer's instructions. Each sample was amplified by a PCR reaction detecting specific *T. gondii* DNA.

The overall molecular prevalence of *T. gondii* in sheep and goats were 33.3 (50/150) and 32.5 (39/120), respectively. The molecular prevalence of *T. gondii* in small ruminants was significantly higher in adults compared to young animals ($p < 0.001$). The infection distribution differed within localities and breed in both sheep ($p < 0.001$) and goats ($p < 0.001$). These results provide important information about human exposure to *T. gondii* through the consumption of raw or undercooked meat.

An extension programme should be implemented to decrease the risk of infection related to sheep and goats' meat manipulation and raw or undercooked meat consumption.

153 Policy drivers of water resource development for agriculture in northern Australia

Mr Richard McLoughlin¹

¹*Department of Agriculture and Water Resources, Canberra, Australia*

The Australian Government “Our North, Our Future: White Paper on Developing Northern Australia” is the key policy driver for water resource development, to expand our agricultural production base and improve productivity.

To stimulate and accelerate the construction of major water infrastructure in northern Australia, the Australian Government is making the most significant investment in water infrastructure in Australian history.

The \$500 million National Water Infrastructure Development Fund (the fund), announced in the White Paper on Developing Northern Australia, is taking a staged, strategic, financially prudent and evidence based approach to accelerate the economic development of Northern Australia. At least \$170 million of the capital component of the fund to co-fund water infrastructure construction is dedicated to northern Australia. The fund is complemented by the \$2 billion National Water Infrastructure Loan Facility.

The \$15 million CSIRO Northern Australian Water Resource Assessments, in conjunction with a \$25.4 million investment in a further 15 water infrastructure feasibility studies in Northern Australia, will help ensure that investments in water resource development is based on sound evidence and that the projects are economically viable and in the long-term national interest. These investments will allow governments and their project partners to make fully informed decisions about the best development opportunities and contribute to mitigating water infrastructure investment risks.

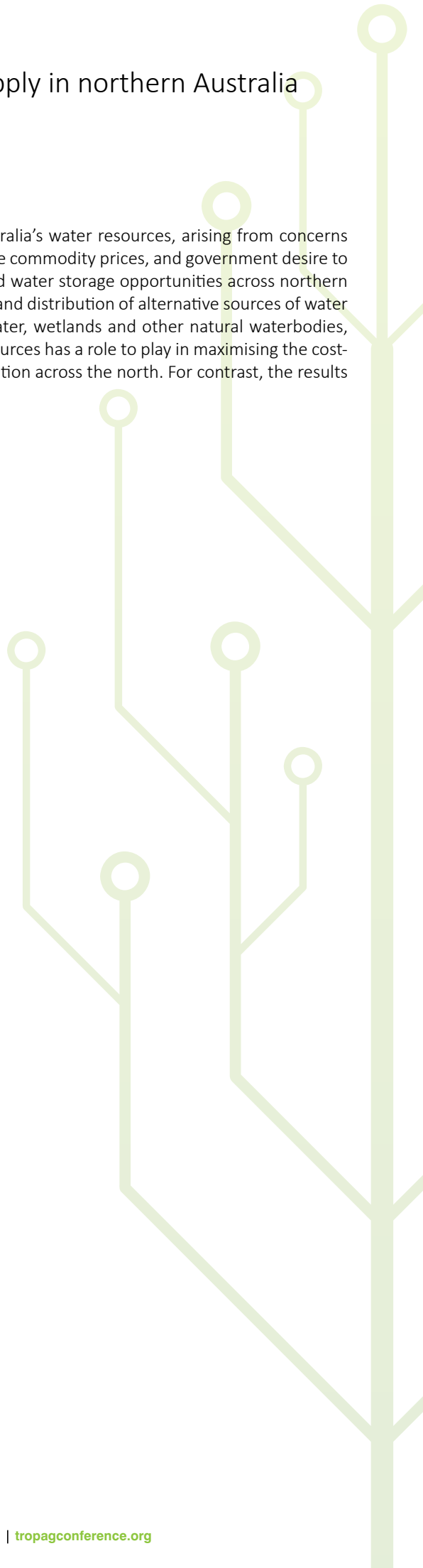
Australian Government investments in infrastructure will be specifically designed to enhance investment confidence and security for state and territory governments and their project partners by providing greater certainty around the rights, responsibilities and likely costs for water users consistent with the principles of the National Water Initiative (NWI).

154 Maximising the cost-effectiveness of water supply in northern Australia

Dr Cuan Petheram¹

¹CSIRO, Canberra, Australia

There is renewed attention towards exploring the potential uses of northern Australia's water resources, arising from concerns about threats to water availability in southern Australia, speculation regarding future commodity prices, and government desire to develop regional economies. This paper presents information on the hydrology and water storage opportunities across northern Australia, so as to broadly inform land and water management decisions. The scale and distribution of alternative sources of water are outlined, including large in-stream and off-stream dams, ring tanks, groundwater, wetlands and other natural waterbodies, and 'subsurface' dams. A key finding of the study is that each of these alternative sources has a role to play in maximising the cost-effectiveness of water supply in northern Australia, and there is no one 'water' solution across the north. For contrast, the results are compared to the situation in southern Australia and other parts of the world.



155 Expanding agriculture in Northern Australia: The need for improved transport logistics

Dr Andrew Higgins¹, Mr Stephen McFalan¹, Mr Adam McKeown¹, Ms Caroline Bruce¹, Dr Chris Chilcott¹, Dr Oswald Marinoni¹

¹*Csiro Land and Water, Brisbane, Australia*

New or expansion of agricultural industries in tropical Northern Australia requires efficient and reliable supply chains to domestic and international markets. A major challenge is long transport distances of over 1000km between production in the north and markets in the south, along a sparse rural road/rail network that is disrupted by seasonal flooding.

A range of possible future industry scenarios is being developed by industry, local, state and federal governments to reduce costs of existing supply chains and to plan for new production and markets. Infrastructure investment and regulatory changes can substantially reduce logistics costs across agricultural enterprises. To inform these investments, CSIRO developed the Transport Network Strategic Investment Tool (TraNSIT) which provides an independent and holistic view of transport cost savings to infrastructure investments and logistic improvements.

TraNSIT was applied to 98% of agricultural production across Australia through an initiative of the Australian Government - Agricultural Competitiveness White Paper. The comprehensive logistics tool has the largest data set ever assembled for Australian agricultural transport. An overview of the latest applications of TraNSIT specifically as they relate to northern Australia will be presented, along with planned future developments that identify options for reducing economic impact from rain events. An overview will also be given of how TraNSIT addresses inefficiencies in beef and horticulture supply chains in South East Asia- many of which originate in Northern Australia.

156 Managing the impacts of agriculture to minimize offsite environmental impacts: A case study for nitrogen in the GBR lagoon

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The water discharged into the Great Barrier Reef (GBR) lagoon carries land-derived suspended sediments, nutrients and pesticides. Total nitrogen (N) loads have more than doubled due to anthropogenic activity, with extensive grazing and intensive sugarcane industries the largest contributors. Runoff and soil erosion are the main sources of riverine particulate nitrogen (PN) while fertilizer application has contributed to the increase in dissolved inorganic nitrogen (DIN). Dissolved organic N (DON) loads have increased to a lesser extent and it is unclear if DON has changed with development. The transport and fate of the constituent N forms differs.

River discharge is the largest external source of “new” nitrogen to the GBR system, with sections of the inner GBR lagoon episodically eutrophic during and after flood events. The outer GBR can also be affected by elevated N loads, through increased coral vulnerability to temperature stress and greater pressure from coral competitors and predators.

A combination of changes to land use and nutrient management practices will be required to reduce N loads and improve water quality. Prioritization of actions will require greater certainty around underlying processes contributing to N loads and an improved understanding of the relative impact of different management interventions at different spatial scales. Uncertainties include the importance of minimizing discharge of DIN compared to total bioavailable N, the contribution of runoff compared to other N input pathways and the relative importance of hillslope and gully/streambank erosion and the relative contribution from different geomorphic gully units to the outflow of bioavailable N.

157 Opportunities and constraints for irrigated agriculture in the Northern Territory

Dr Mila Bristow¹, Dr Ian Biggs¹, Mr Callen Thompson¹

¹*Northern Territory Department of Primary Industry and Resources, Darwin, Australia*

Irrigated agriculture in the Northern Territory (NT) of Australia contributes \$350M to the NT economy, and current policy is aimed at expansion, diversification and intensification to meet growing market demand in the region. While there is excitement about the opportunities of land and water availability, this optimism is countered with sizable challenges. Water is both a strength and hindrance to the development of agriculture in the NT. The challenging seasonal supply of rainfall in the Top End demands that agriculture must either complete crop growth during the short wet season or store the rainfall to irrigate during the dry season. This storage is currently only in natural aquifers. Land is plentiful, but soils are often characterised as having low water holding capacity and poor natural fertility. A range of crops are suited to the climate, soils and water, but the cost required to irrigate in the current groundwater-fed agricultural systems limits the choice to high value crops or cropping systems. Producers cite water security and costs of supply as a key impediment to irrigated agriculture and it is recognised that prospective investors have little to know knowledge of policy, environment, agronomics or logistics in the NT. While it is known that future agriculture depends on sustainable use of water resources, water policy development is in its infancy and few alternatives exist to groundwater extraction. These are a few of the constraints requiring investment in order to realise the opportunities of irrigated agriculture in the NT.

158 Economic drivers of agricultural development in northern Australia

Mr Ian Baker¹

¹North Australian Agribusiness Management, Darwin, Australia

Developing opportunities for northern agriculture has been elusive. Failure haunts northern agricultural development.

Despite challenges, the Qld, NT & Ord horticultural industries demonstrate success is possible in the north. GVP for NT and Ord horticulture is \$300 million, from zero 35 years ago. Success is possible with a strong economic and market focus, and appropriate business models.

Broad acre cropping remains small, despite many resources directed to its development. Economic modeling is critical for R&D and resource assessments to plan viable development.

The north should produce more agriculture. CSIRO estimates 60 per cent of Australia's surface water runoff occurs in the north, potentially supporting 1.4 million hectares of irrigation. Resources are not the constraint, rather viable business models.

The development question should be how to, rather than can't do, through a good understanding of markets and economics first.

Low capital cost is critical for broad acre cropping. On farm dams and furrow irrigation can be a low cost development. Capex for this development is around \$7,000-10,000/ha, necessitating crops, or crop systems with a gross margin of over \$1,200/ha/yr. for a viability. Cotton, aromatic rice, mung beans, fodder crops can generate this revenue.

Pivot irrigation using ground water costs \$12,000-15,000/ha, necessitating crop systems with a gross margin over \$2,000/ha/yr. for viability. Only a 2 crop per year system can generate this revenue. The ground water resource is much smaller than surface water.

R&D and resource assessments must be driven by understanding profitable cropping development.

159 Transitions and transformations-drought, hotspots, and adaptation

Dr Roger Pulwarty¹

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All aspects of food production and security are affected by climate. Projected impacts vary across crops, regions, and adaptation scenarios. For major crops (wheat, rice, and maize), changes without adaptation will have negative impacts, although individual locations may benefit. A range of adaptation options exists. While analyses acknowledge nonstationarity, many still assume a fixed or “changed” future climate. Systems, and equilibrium assumptions, may change faster than models can be recalibrated, and projections, especially on thresholds, may be most unreliable, at critical times. Key factors are intra-seasonal to decadal variability effects on quantity, quality, and access, including crop migration, storage and utilization. There remain limited assessments of impacts and adaptation options for non-production elements. We will address factors driving climate extremes, sources of knowledge and uncertainty in characterizing hotspots that have developed over time in the U.S. and elsewhere, impacts on productivity, and links between early warning and adaptation priorities. We argue that immediate needs are to:

- Acknowledge the cross-scale nature of climate, of early warning information and of climate-resilient strategies affecting food production and security, including critical interdependencies derived from water and land resources.
- Produce empirical evidence on the effectiveness of technological interventions and social adaptations at all levels of the food system
- Craft an acceptable, fundable, collaborative framework among research, information services and management

Most critical is the development of sustained networks, such as through the US National Integrated Drought Information System, across institutions to ensure that lessons are being learned, as risks and opportunities emerge.

160 Benefits of action and costs of inaction: Drought mitigation and preparedness

Mr Frederik Pischke¹, Mr Robert Stefanski²

¹Global Water Partnership, Geneva, Switzerland, ²World Meteorological Organization, Switzerland

Significant progress has been made over the past decade in improving understanding of droughts and their impacts. However, significant gaps in research, policy and practice remain, particularly regarding the merits of risk management compared with traditional crisis management approaches.

Presently, many available estimates of drought costs are partial and difficult to compare. The problem is compounded by the lack of data on droughts and their impacts. Moreover, relatively little knowledge is available on the costs of indirect and longer-term drought impacts. There is thus a need for mutually compatible methodologies as a means of comprehensively assessing drought costs and impacts as well as the benefits of preparing for and mitigating drought.

The costs of action against droughts can be classified into three categories: preparedness costs, drought risk mitigation costs and drought relief costs. Benefits can be classified as reduced drought costs, savings in relief costs and economic and social co-benefits. A work stream of partners of the Integrated Drought Management Programme (IDMP) is aiming to chart a way forward to support a proactive approach to drought management. Building on a literature review released by the IDMP (WMO and GWP 2017) and two expert group meetings, this presentation reviews the main obstacles and opportunities facing the transition from crisis management to risk management and drivers of ex ante and ex post action against drought as well as the co-benefits of drought mitigation and preparedness.

Reference: World Meteorological Organization (WMO) and Global Water Partnership (GWP) (2017). Benefits of action and costs of inaction: Drought mitigation and preparedness- a literature review (N. Gerber and A. Mirzabaev). Integrated Drought Management Programme (IDMP) Working Paper 1. WMO: Geneva, Switzerland and GWP: Stockholm, Sweden.

161 Modes of climate variability and drought forecasting

Dr James Risbey¹

¹*Csiro Oceans & Atmosphere, Hobart, Australia*

Drought is a persistent climate event spanning seasons, multiple years, and longer. The predictable component of drought is related to slower processes in the tropical Pacific Ocean such as ENSO.

Teleconnection processes in the atmosphere carry the climate signal from the tropical Pacific to extratropical continental regions. We examine the pathways that need to be understood in transferring the climate signal from the tropics and their interaction with modes of variability underlying drought in midlatitudes.

162 Building a National Drought Center: Science and policy approaches and experiences from the National Drought Mitigation Center's perspective

Assoc Prof Mark Svoboda¹

¹*National Drought Mitigation Center, Lincoln, United States*

Unlike most hazards, the fact that droughts typically evolve slowly, last for months or years and can cover thousands of square miles across multiple geopolitical boundaries and economic sectors can make it a daunting task to monitor, mitigate and plan for. In the United States, many partners are working together via the National Integrated Drought Information System (NIDIS), the National Drought Mitigation Center (NDMC), tribes, state and federal agencies, regional and state climate offices, river basin authorities and various communities toward a more coordinated and comprehensive national drought early warning and information system centered around a drought risk management approach.

The NDMC works to reduce societal vulnerability to drought by helping decision makers at all levels to: implement drought early warning systems, understand and prevent drought impacts and increase long-term resilience to drought through proactive planning. The NDMC is a national center founded in 1995 at the University of Nebraska-Lincoln. The NDMC conducts basic and applied research along with the maintaining of a number of operational drought-related activities.

This presentation will describe in more detail the various drought resources, tools, services and collaborations already being provided by the NDMC and its partners along with a look at what is in store for the future in helping others toward developing drought early warning and risk management systems both in the U.S. and around the world.

163 Improving drought monitoring and prediction science and services

Mr Neil Plummer¹

¹*Bureau of Meteorology, Melbourne, Australia*

The Bureau of Meteorology has worked with governments and industry partners in predicting rainfall over Australia for more than two decades and monitoring droughts for longer.

Official rainfall observations extend well back into the nineteenth century and, thanks to observation standards and dedicated volunteers, we can track Australian rainfall variability and change for well over 100 years. Automated data analysis systems from the 1990s allowed for better drought monitoring and analysis, including for rainfall trends. The Bureau's data and information have also played a key role in informing decisions about assistance to support farm families, farm businesses and rural communities. Support from state governments are further improving automated analyses, including through a climate model reanalysis approach.

The Bureau analyses, models and predicts a range of ocean and atmosphere circulation indicators to get intelligence on the likely onset, duration and decay of droughts. Predictions currently focus on likely shifts in rainfall, temperature, streamflow, tropical cyclones, northern rainfall season onset and, through the Bushfire and Natural Hazards CRC, bushfire outlooks.

Support through several Rural Research and Development Corporations and led by the Managing Climate Variability program (MCV) has been essential to the development of 'seasonal' forecasting in Australia. The MCV is now leading a project on climate extremes that builds on a current project, supported through the Agricultural Competitiveness White Paper, to improve seasonal forecasting services. The extremes project includes forecasting dry periods as well as facilitating a direct link between research groups, regional and industry-specific reference groups and agribusiness supply chains.

164 Remote sensing applications for agricultural and horticultural crops: From the individual tree to whole of industry

Assoc Prof Andrew Robson¹, Dr Moshir Rahman¹, Ms Jasmine Muir¹, Mrs Luz Angelica Suarez¹, Mr Brian Dunn², Dr Mila Bristow³, Dr Ian Layden⁴, Dr Julie O'Halloran⁵

¹University of New England, Armidale, Australia, ²NSW Department of Primary Industries, Yanco, Australia, ³Department of Primary industries and Resources, Darwin, Australia, ⁴Department of Agriculture and Fisheries (Qld), Nambour, Australia, ⁵Department of Agriculture and Fisheries (Qld), Gatton, Australia

This paper reviews remote sensing applications currently being developed across a range of crops, including mango, avocado, rice, sugarcane and carrots. Technologies being evaluated include very high resolution multispectral (Worldview-3) satellite imagery, Landsat, Sentinel and SPOT satellite imagery, UAV and ground based sensing. For horticultural crops, an evaluation of 18 structural and pigment based vegetation indices (VIs) measured by Worldview-3 imagery identified a positive relationship to total fruit yield (kg/tree) (up to $R^2 = 0.89$ for an individual orchard) and individual fruit weight (up to $R^2 = 0.76$ for an individual orchard) over a 4 year period (avocado) and to fruit yield measured across two locations in one season (mango) (up to $R^2 = 0.82$ for an individual orchard). A similar process also identified strong coefficients of determination between carrot yield and canopy reflectance information at the individual block level (up to $R^2 = 0.89$). For sugarcane, yield forecasting and yield mapping from satellite imagery is far more evolved. Landsat derived 'time series' yield models have been developed for a number of Australian growing regions with the derivation and distribution of crop (~100,000) and regional yield and vigour maps being automated through python scripting. As well as yield determination, research in both sugar cane and rice has identified optimal spectral band ratios for measuring foliar Nitrogen content. With an improved understanding of the spatial and temporal variation of nitrogen concentration across individual crops, growers can implement improved Nitrogen application strategies at panicle initiation (rice) and before the out of hand stage (sugarcane).

165 Mapping horticulture tree crops in Australia

Mr Joel McKechnie¹, Mr Craig Shephard¹

¹Queensland Government Department of Science, Information Technology and Innovation, Brisbane, Australia

The Queensland Land Use Mapping Program (QLUMP) has mapped the location and extent of all commercial avocado, macadamia and mango orchards in Australia. These efforts are part of a national project, 'Multi-scale monitoring tools for managing Australian tree crops—industry meets innovation'. This project is managed by Horticulture Innovation Australia, coordinated by the University of New England and funded by the Australian Government Department of Agriculture and Water Resources—Rural Research and Development for Profit programme.

The broader project scope showcases the value of science and innovation within horticulture industries. This is a result of collaboration between government, universities, private organisations and industry including the Australian Macadamia Society, the Australian Mango Industry Association and Avocados Australia.

QLUMP developed the mapping program that combines industry and government data interpreted with imagery to map and classify the location and extent of tree crops at the desktop. We developed a citizen science 'Land Use Survey' app for this project, so users can make their own observations to better inform the mapping. QLUMP also built the 'Industry Engagement Web Map' to assist in the peer review. Industry experts could review the draft mapping to provide their feedback before final mapping products were compiled.

The mapping we produce is the fundamental spatial data required to support agricultural productivity, decision-making and innovation. The data enhances biosecurity and natural disaster response and recovery for the Australian avocado, macadamia and mango industries.

166 Intelligent sensing and information systems for tree crops

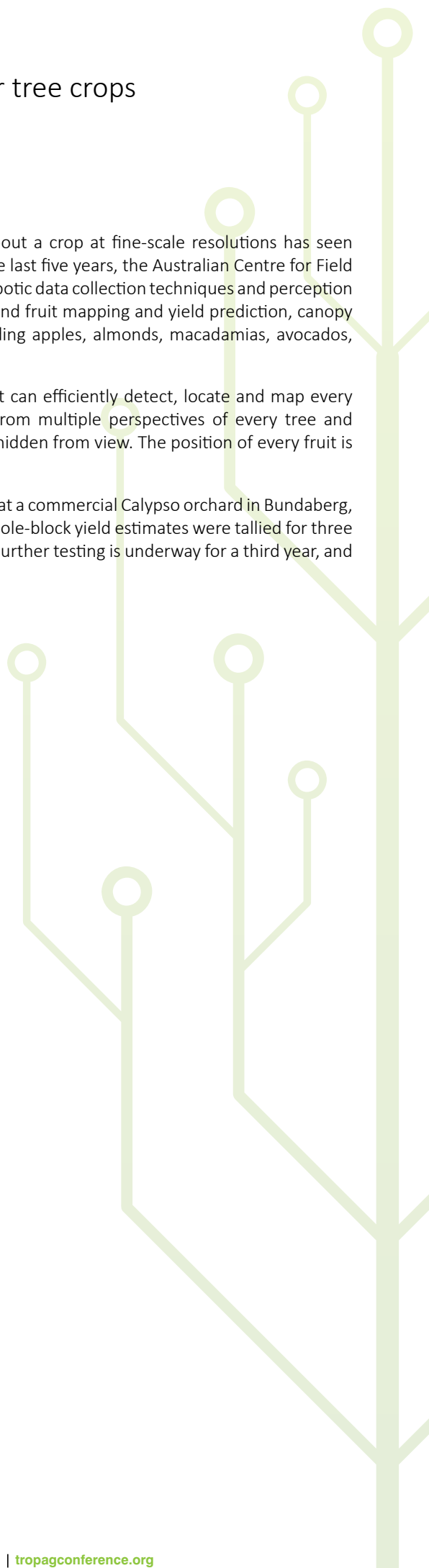
Dr James Underwood¹

¹*The University of Sydney, The University Of Sydney, Australia*

The use of robotic systems to automate the process of collecting information about a crop at fine-scale resolutions has seen increasing interest due to its potential applications in precision agriculture. Over the last five years, the Australian Centre for Field Robotics at The University of Sydney has engaged in a series of projects to develop robotic data collection techniques and perception systems for tree crops. These projects have examined applications such as flower and fruit mapping and yield prediction, canopy structure estimation and light interception modelling, for a range of crops, including apples, almonds, macadamias, avocados, lychees, bananas and mangoes.

In this talk we present our latest results, including a new multi-sensor system that can efficiently detect, locate and map every piece of fruit in a commercial mango orchard. Photos are automatically taken from multiple perspectives of every tree and processed with machine vision techniques to detect fruit that would otherwise be hidden from view. The position of every fruit is triangulated, providing a 3D fruit map for whole orchard blocks.

Mango counts were compared against post-harvest hand-counts for individual trees at a commercial Calypso orchard in Bundaberg, showing accurate results two years in a row ($r^2=0.90$, uncalibrated bias <1.5%). Whole-block yield estimates were tallied for three different orchard blocks and found to be within 6% to 12% of the pack-out reports. Further testing is underway for a third year, and for other mango varieties such as Kensington Pride.



167 UAV imagery and its role in tactical agronomy trials

Mr James McLean¹, Dr Joseph Eyre¹, Dr Andries Potgieter¹, A/Prof Daniel Rodriguez¹

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

Monitoring of large on-farm agronomic experimentation is usually constrained by time and labour for intensive data collection activities. Currently the determination of crop growth and development characteristics involves manual collection, logistics, processing and analyses of large quantities of vegetal material. This limits the sample areas within each plot and potentially introduces sources of error. Sampling time and labour also limits the number of factors in each trial site and number of sites that can be performed in any one season.

Two years of research station field trials were conducted where two maize hybrids (DuPont Pioneer P1467, Advanta Pacific Seeds PAC727IT) were grown using contrasting spatial arrangement i.e. single rows and rows split into twin row triangular sowing arrangements. Crop biomass, leaf area and yield components were empirically collected and ground cover was estimated by ceptometer.

Vegetation indices were derived from UAV multispectral imagery (MicaSense RedEdge) in the red and near infrared wavelengths of the light spectra to predict ground cover, biomass and establishment. Relationships were developed between sensed and empirical data.

We found ground cover derived from ceptometer and UAV imagery were highly correlated ($R^2 = 0.87$). The Simple Ratio vegetation index provided a strong relationship with empirical measurements for both biomass ($R^2 = 0.95$) and leaf area ($R^2 = 0.95$). Crop establishment predictions with object based image analysis were highly correlated although the observed population range was very narrow.

Here we discuss methods for routine implementation of UAV imagery in agronomy trials.

168 Estimating regional scale crop production: An integrated climate, biophysical and remote sensing approach

Dr Andries Potgieter¹, Jason Brider³, Prof Graeme Hammer¹

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The highly variable climate of Australia, combined with a strong influence of markets on grain price, and thus crop choice, impede accurate prediction of regional scale crop production. To date, regional crop-modelling approaches have delivered relatively good estimates throughout the season of the final crop yield for that season. However, accurate, timely and objective information on specific crop area, and thus total production, well before harvest for a shire or region has been mostly unavailable. This is further exacerbated by a projected increase in market and climate volatility within Australia and globally. Here we present a holistic approach to estimating regional scale crop production. The approach integrates climate forecasting with biophysical crop modelling for yield, and remote sensing technologies to quantify crop area across regions for the main crops of Australia.

169 New frontiers in crop stress detection from satellite measurements of fluorescence, soil moisture, and canopy temperatures

Prof Alfredo Huete¹, Ms Jianxiu Shen¹, Mr Nguyen Ngoc Tran¹, Dr Leonardo Hardtke¹, Prof Qiang Yu¹

¹University of Technology Sydney, Ultimo, Australia

Recent advances in synoptic satellite sensor data offer new opportunities to monitor crop productivity and assess stress-induced crop growth limitations in near real-time. Space-based monitoring of sun-induced chlorophyll fluorescence (SIF) provide a direct measure of the gross primary production (GPP) of cropland. This link with crop photosynthesis is instantaneous, in contrast to traditional remote sensing measures of canopy chlorophyll content (e.g. greenness vegetation indices, VIs) which may take several weeks before crop stress is known; hence spectral VIs may underestimate stress related effects on crop production and overestimate crop yields, relative to SIF- retrievals. Himawari-8 satellite data now provide diurnal measures of crop canopy temperatures at 10 minute increments, while the Soil Moisture Active Passive (SMAP) sensor potentially tracks soil moisture deficits. In this study, we combined SIF measures from the Global Ozone Monitoring Experiment-2 (GOME-2), soil moisture data from SMAP, and crop canopy temperatures from Himawari-8, with flux tower measures of gross primary production (GPP) over three winter wheat sites to demonstrate the inter-relationships of satellite productivity measures and water and heat stress related factors. We aim to assess SIF capabilities for early warning detection of stress and reductions in productivity. The new sensor datasets reveal important new directions and opportunities for crop monitoring amidst changing climate conditions.

170 The genetic architecture of tick resistance

Dr Mahlako Linah Makgahlela^{1,2}, Dr Ntanganedzeni Olivia Mapholi⁴, Prof Heather M Burrow³, Prof Azwihangwisi Maiwashe^{1,2}

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About 80% of the world's beef and dairy cattle are at risk of ticks and tick-borne diseases, with estimated economic losses of ~US\$20-30 billion/year. Losses arise from cattle mortalities and marked reductions in reproduction, meat and milk production. Chemical treatments to control ticks is not a long-term solution as chemicals lose efficacy through rapid evolution of resistance of the ticks to chemicals. Contamination of animal products and the environment by chemicals also causes concern. Resistance of beef and dairy cattle to ticks is moderately to highly heritable, even in British breeds, though *Bos indicus* and tropically adapted *Bos taurus* breeds have greater resistance to ticks than British and European breeds. Availability of chip-based genotyping platforms for assaying thousands genetic variants (SNP) associated with major genes (QTL) for complex traits enabled genome-wide studies, to detect statistical associations of each SNP independently to economic traits, including resistance to ticks. Published results generally identified many SNP, each explaining a small proportion of the genetic variance, with notable overlap among regions associated with tick resistance in cattle. These reports support the polygenic inheritance pattern. In modern breeding programmes, associations between thousands of SNP that jointly explain ample variance for a trait are used in the prediction of breeding values for genetic improvement (genomic selection). Accuracies for young animals without phenotypes are higher than traditional evaluations, with moderate accuracies reported for tick counts. Improved resistance to ticks will conceivably be achieved through genomic selection, which still requires phenotypes, and incorporating QTL based on whole-genome sequences.

171 Cutting and pasting: The future of genetic improvement for food animal genomes

Dr Tad Sonstegard¹

¹*Acceligen/Recombinetics, St. Paul, United States*

Genetic improvement programs for food animals raised in tropical production systems often lag behind those found in temperate production systems for a multitude of reasons ranging from poor infrastructure to endemic disease challenges. Although genome selection programs have now been initiated for popular breeds in Australia and Brazil, other technologies are needed to introduce economically important traits that accelerate genetic improvement for livestock systems in countries with emerging economies. Gene editing based on site-directed nucleases is recognized as one of those methods best suited to introduce high effect production alleles into naïve, indigenous populations. Herein, we review how site-directed nucleases are best deployed to produce precision bred alleles into animal genomes. We also discuss the breadth of traits being deployed, and differences between introducing alleles already found in nature versus mutagenesis to break coding regions or other rationale design approaches for genetic improvement of disease resistance. Finally, perspectives for regulatory approval and commercialization are summarized to highlight some of the obstacles, which may hinder the widespread adoption of gene editing technology as one of the primary tools of animal breeding.

172 The evolution of the Brahman genome- a crucial tropically adapted breed

Prof Steve Moore¹, Dr Ross Koufariotis¹, Prof Ben Hayes¹, Dr Brian Burns², Dr Russell Lyons³, Dr Matthew Kelly⁴

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Bos indicus cattle are adapted to harsh tropical environments. The Bos indicus breed widely used in beef production in Northern Australia are Brahman. The Australian Brahman breed was developed in the southern USA through cross-breeding 4 types of Zebu (Bos indicus) cattle breeds, Ongole, Guzerat, Gir and Krishna cattle. Australian cattle were “graded up” twice to increase numbers once in USA and then in Australia using Brahman bulls and Bos taurus cows with the resulting calves then back crossed to Brahman bulls. The grading up process has led to an introgression of 7-10% Bos taurus genome into modern Brahman cattle. Identifying variation in Brahman genomes associated with adaptation, fertility, meat quality and growth rates would facilitate genome selection and therefore accelerate genetic gain for these traits, in both Brahman cattle and composite cattle with Brahman ancestry. With this ultimate aim, 46 sequenced Brahman cattle that were key ancestors of the breed were whole genome sequenced. Regions of Bos Taurus introgression and regions favouring Bos indicus alleles were identified.

173 Combining historical weather station records, climate change predictions and genomics to breed dairy cattle for future climates

Dr Thuy Nguyen¹, Ms Josie Garner², Dr Jennie Pryce^{1,3}, Prof Ben Hayes^{1,4}

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Given the projected increase in temperature in many Australian dairying regions, there is a need to identify and breed heat tolerant dairy cattle. We have achieved this through the development of genomic breeding values for heat tolerance. We first merged climate data with milk production records between 2003 and 2016. We determined the rate of decline of milk, fat and protein yield (namely cow slope) for 424,540 Holstein and 84,702 Jersey cows when temperature and humidity exceed the comfort level. Slope of a sire is the daughter average. A reference population consisting of 11,853 cows and 2,236 sires for Holsteins and 4,268 cows and 506 sires for Jerseys (both having estimated slope and high density genotype), were used to derive a genomic prediction equation. Genomic estimated breeding value (GEBV) for heat tolerance (HT) can then be determined for other animals with genotypes. To validate these GEBV, we predicted HT GEBV for 390 Holstein heifers, then selected 24 extreme predicted heat tolerant and 24 extreme predicted heat susceptible heifers for a 4-day heat challenge. The predicted heat tolerant group showed significantly less decline in milk production, lower rectal and intra-vaginal temperatures than the predicted heat susceptible group. This indicates that the HT GEBV will enable selection for cattle with better tolerance to heat stress. We also developed an online future-scenarios selection tool to assist farmers in making selection decisions to balance HT and other priorities. In this tool, the combined information of HT GEBV and the projected future temperature and humidity can be visualised and used to make selection decisions.

174 Use of genomic technologies and composite cattle breeding within a large Northern Australian beef breeding enterprise

Mr Sam Harburg¹

¹*The North Australian Pastoral Company, Brisbane, Australia*

The North Australian Pastoral Company (NAPCO) is one of Australia's largest beef producers with a herd of 180,000 head of cattle across properties in the Northern Territory and Queensland. In the 1980's, NAPCO recognised that development of 'Composite' cattle breeds represented a means of integrating important traits from diverse breeds of cattle, and generating and retaining hybrid vigour. NAPCO has now produced and stabilised two Composite breeds that are deployed across its portfolio of properties.

NAPCO operates a closed herd, breeding all replacement bulls and heifers internally. Its bull breeding programs utilise genomically-enhanced EBVs to identify elite animals within each Composite. NAPCO has been SNP genotyping every calf (50K and 18K SNP chips) within its Nucleus herds since 2010, as well as most bull calves within its Multiplier herds. Genomic breeding values were derived from an internal reference population maintained from 2002 to 2010.

Genomics are playing an increasingly important role in NAPCO's genetics programs and will continue to increase in prominence. From migration onto single step genetic evaluations, implementation of genomic-based inbreeding estimation and mating optimisation, and genomic analysis of foundation breed composition trends, NAPCO continues to innovate in the integration of genomic information into its breeding program. Future priorities will focus on selective harvesting of phenotypic and genotypic data from its large commercial cattle herd to improve trait accuracies and develop new traits for selection within its Nucleus herd.

175 Mediterranean Diet in the Tropics?

Prof Lluís Serra-Majem^{1,2}

¹Preventive Medicine & Public Health, Director of the Research Institute of Biomedical and Health Sciences, University of Las Palmas de Gran Canaria, Canary Islands, Spain. ²President of the International Foundation of Mediterranean Diet.

Food globalization, and above all what is called fast food or Western Diet, concisely represents the erosion of the Mediterranean Diet's cultural values, not only because of what the globalized Western food model represents-based mainly on meat, refined flour, sugars, soft drinks, dairy and food transported from anywhere in the world with international free trade laws- but also because of how all these foods have an impact on the ways in which they are consumed: in the traditional recipes themselves, in landscapes, crops and even in the markets. Nowadays, for example, we have built a food model around the globalized market of tourism that resembles more the Western Fast Food model than the traditional Mediterranean Diet. We are missing out on an opportunity to disseminate our Mediterranean Diet as a cultural model and as an excellent food model for public health. The foodways of proximity, respecting traditions and seasons (which usually go together) also represents an opportunity for the economic sector, for tourism, for the environment, etc.

Probably, the most important and determinant food ingredient of the Mediterranean Diet is olive oil, and olive trees are only growing under selected circumstances. Several Mediterranean regions with similar geography, climate and plant biodiversity are defined around the planet: in California and the Northwest part of Mexico, Chile and Argentina, South Africa and Australia. From the Mediterranean region and those other more remote regions foods like olive oil (or wine) may be produced and distributed to other contiguous regions to complete these key ingredients of the Mediterranean Diet not produced at local level.

Globalization of the Mediterranean Diet may be undertaken under environment and cultural respectful initiatives.

176 Fatty Liver: It is not just about fat- Nutritional impact on non-alcoholic fatty liver disease (NAFLD)

Prof Karmin O^{1,2}, Miss Victoria Sid^{1,2}, Miss Yue Shang^{1,2}, Dr Yaw Loong Siow^{1,2}

¹University Of Manitoba, Winnipeg, Canada, ²CCARM, St. Boniface Hospital Albrechtsen Research Centre, Winnipeg, Canada

Non-alcoholic fatty liver disease (NAFLD) has become a worldwide epidemic, which is associated with obesity, diabetes mellitus and cardiovascular disease. NAFLD covers a broad spectrum of disorders that range from simple lipid accumulation in the liver (steatosis) to oxidative stress and inflammation (steatohepatitis). There is currently no approved treatment for this disease. Chronic consumption of high energy diets (i.e. diet rich in fat content) promotes the development of NAFLD. Dietary supplementation of vitamins or phenolic compounds has been suggested to be a beneficial strategy for NAFLD management. Folic acid is a water soluble B vitamin that has been demonstrated to have lipid-lowering and anti-oxidant effects. Tyrosol is one of the major phenolic compounds in olive oil and wine which are two unique dietary staples in diet. We investigated the impact of dietary intervention on hepatic metabolism and oxidative stress in a rodent model with NAFLD. Male C57BL/6 mice were fed a low-fat diet (10% kcal of fat) or a high fat diet (60% kcal of fat) for 5-12 weeks. Feeding mice with a high-fat diet stimulated rapid body weight gain and induced NAFLD phenotype with hepatic lipid accumulation, hyperglycaemia, increased oxidative stress and proinflammatory cytokine expression. Supplementation of folic acid and natural compounds (i.e. tyrosol) could alleviate high-fat diet induced hepatic lipotoxicity. The beneficial effects of dietary intervention were mediated through regulation of endogenous lipid biosynthesis, homocysteine-hydrogen sulphide metabolism as well as restoration of redox balance. Dietary interventions may have important clinical implications in NAFLD management.

177 Tropical fruits as functional foods for metabolic syndrome

Prof Lindsay Brown¹

¹*University Of Southern Queensland, Toowoomba, Australia*

Functional foods provide health benefits in chronic diseases such as obesity, hypertension, diabetes and inflammatory bowel disease, in addition to nutrition. The metabolic syndrome includes central obesity, insulin resistance, elevated blood pressure, impaired glucose tolerance, non-alcoholic fatty liver disease and dyslipidaemia; these signs are due to chronic low-grade inflammation combined with oxidative stress. We have shown that a diet high in fructose and saturated/trans fats induces these cardiovascular, liver and metabolic signs in rats. We have shown that components of foods can reverse all these symptoms in diet-induced obese, hypertensive and insulin-resistant rats. In particular, tocotrienols from palm oil, dietary fibre from tropical seaweeds anthocyanins from tropic Australian native fruits such as Davidson's plums, and polyphenols from Garcinia fruits such as achacha lowered blood pressure, prevented inflammatory cell infiltration into the heart, liver and fat pads, improved plasma lipid profiles and decreased plasma inflammatory biomarkers. All these interventions, especially tropical fruits and seaweeds, could be produced commercially, sustainably and cost-effectively in many tropical countries, with the aim of reducing the incidence of metabolic syndrome, and decreasing the risk of costly cardiovascular and metabolic disorders.

178 Gut microbiome- Our life partner, for better or worse?

Dr Connie W Woo¹, Mr. Jensen HC Yiu¹, Mr Wai Lun Fung¹

¹*Department of Pharmacology and Pharmacy, The University of Hong Kong, Hong Kong SAR, China*

Trillions of bacteria are living in our bodies and implementing mutualistic functions to us. The gastrointestinal tract alone houses more than 10^{14} bacteria. One of their known functions is to promote energy extraction from our diets, thereby allowing us to better utilize our food source, particularly in nutrient-scarce environments. This function plays an important role during pregnancy when extra nutrients are needed for the development of the foetus. [Before birth] Substantial changes in the bacterial pattern in the gut have been found in pregnant women from the 1st to 3rd trimesters. This kind of commensalism remains despite the agricultural advances in that have led to a stable nutritional supply, which implies some additional functions of the gut bacteria in pregnancy. Due to the advance of medicine, now we have choices in the modes of delivery. However, caesarean section-delivered babies have a higher risk to develop certain metabolic and autoimmune diseases in early childhood. [At birth] Such risk is related to the differences in bacteria colonization upon different modes of delivery. [After birth] During adulthood, our diet and external environment can substantially change the gut microbiota. Many animal models have proven the effectiveness of faecal transplantation to reverse several diseases, implying the therapeutic potential of altering gut microbiota. However, bed-translation remains limited due to the complicated bacterial ecology and cross-species interaction with host. Investigation from the very beginning of life will help us gain a full picture of how we interact with these commensal microorganisms, thus affecting our health.

179 Berries for your renal health

Dr Yaw (Chris) Siow^{1,2,3}, Cara Isaak^{1,2,3}, Suvira Prashar^{1,2}, Susara Madduma Hewage^{1,2,3}, Jo-Ann Stebbing^{1,2}, Dr Samir Debnath⁴, Prof Karmin O^{2,3,5}

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Kidney is one of the major organs for our body to remove metabolic waste products. It is becoming the focus of many scientific investigations due to the increasing incidence of metabolic syndrome. Injuries to the kidney can also arise due to complications from major surgeries (such as coronary artery bypass and kidney transplants) or in response to injury of distal organs. Additionally, primary kidney diseases may be due to some inflammation-induced conditions. Signaling pathways in the injured organ can induce inflammation, resulting in pathophysiological conditions that lead to organ dysfunction and potentially organ failure. Recent research data in cells, animal models and human trials have demonstrated the bioactivities of berry polyphenols. In addition to the antioxidant properties, these polyphenols have anti-inflammatory properties and were found to have protective effects against acute kidney injury and chronic kidney diseases. Berries grown both in the northern hemisphere (such as blueberries and lingonberries) and the tropics (such as acai, black mulberry and madroño) share a similar arsenal of bioactive compounds, albeit at varying amounts. Adding and consuming berries in your daily diet may have beneficial effects for your kidney and help alleviate incidences of kidney diseases.

180 The creation of employment, economic and social benefits to remote Australian communities through novel and added value products from native plants

Assoc Prof Yasmina Sultanbawa¹

¹*Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Brisbane, Australia*

Kakadu Plum (*Terminalia ferdinandiana*) is a tree endemic to northern Australia and the fruit has been consumed for its nutritional and therapeutic value by indigenous Australians for thousands of years. Presence of high levels of ellagic acid and ascorbic acid in the fruit makes it a rich source of antioxidants. These properties make Kakadu plum very attractive for use as an ingredient in mainstream food and other industries.

The aquaculture industry in Australia has been using Kakadu plum products to improve quality and extend shelf life of prawns for the past four years. A catering establishment has used its high antioxidant properties to extend the shelf life of frozen ready meals. The use of Kakadu plum as a natural food additive has had far reaching economic benefits to northern Australian indigenous communities.

This emerging business model for Kakadu plum indicates the effective engagement with indigenous communities and successful commercial application of an indigenous food in the food industry.

This paper will provide a synopsis of the unique chemical and bioactive properties of Kakadu plum, innovative cross-industry applications, the proposed business model and its potential to incorporate indigenous communities from across northern Australia as well as private industry inputs that are required to drive this industry. The value chains and business acumen that are created through the commercialisation of Kakadu plum will create the pathways for other native species within a framework where Indigenous ecological knowledge is valued and protected.

181 Informing the design of climate resilient farming systems

Assoc Prof Daniel Rodriguez¹

¹*Qaafi, Toowoomba, Australia*

We started modelling dryland agricultural systems in the early 1990s. Since then, value of the technology has been shown across multiple applications and disciplines, though particularly in (i) the synthesis and integration of knowledge about the functioning and dynamics of rainfed agricultural systems, where biotic processes interact with climatic, soil and biological drivers at a range of temporal and spatial scales; and (2) informing (and overcoming) the complexities in the management and improvement of dryland agricultural systems, both at the level of crop (GxM), cropping systems, farming systems, and farm business design. Here we provide a summary of our achievements in the use of modelling tools in dryland agricultural systems, and provide examples of the important opportunities for the development and application of integrative approaches in farming systems design to support the medium to long-term transformational changes required in our dryland agricultural systems. Particular emphasis is given to the role of modelling tools to quantify benefits and trade-offs in the management of crops and farm businesses in highly-variable climates; and the medium and longer term benefits from changes in strategies, farming systems designs and allocation of limited resource. We also propose that field crops research will increasingly require cross-links between disciplines integration and participatory approaches to allow for the sustainable intensification of agricultural production, and that the modelling agricultural systems will continue to be a crucial tool in making better informed decisions across a range relevant scales, the crop, the farm, the landscape and region.

182 Managing risks and tradeoffs in the intensification of agriculture: An ecologist perspective

Prof Kerrie Wilson¹, Dr Elizabeth Law¹

¹*The University of Queensland, St Lucia, Brisbane, Australia*

Land-use planning typically involves multiple objectives sought by multiple stakeholders. These are often specified as 'target constraints', or with one or two dimensions examined using trade-off curves. One such trade-off curve that has been of particular interest in environment and development discussions is that between biodiversity and production, and whether the contrasting strategies of land-sharing or land-sparing ought to be applied to jointly improve landscape-level production and biodiversity conservation. Using contrasting case studies from Borneo, we create three-dimensional trade-off curves that describe the Pareto frontier for biodiversity conservation, production (timber, oil-palm, and general agricultural suitability), and carbon. We demonstrate the impact of changing land-use composition and allocation, as well as land-use intensities, in these different landscape contexts. Thereby, we demonstrate the usefulness of Pareto frontier modeling in land-use and environmental planning, in particular to clarify the trade-offs of multiple objectives in terms of opportunity/potential benefit, in an extended land-sharing versus land-sparing framework.

183 What do we want and what are we likely to get?

Dr Peter Hayman¹, Dr Harry Hendon²

¹South Australian Research and Development Institute, Adelaide, Australia, ²Bureau of Meteorology, Melbourne, Australia

Information rich farming systems are foundational to agricultural intensification. Timely, and reliable information from climate science on the coming season can be used to reduce risks in poor seasons and take advantages of good seasons.

Farmers have always sought information on the coming season and climate forecasts have been available in many parts of the world since the mid-1990s. Following the successful prediction of the 1997/98 El Nino, a US National Research Council Report described seasonal climate forecasts as one of the premier advances of atmospheric sciences. The same report also noted that probabilistic seasonal forecasts were ill suited to decision making and decision making was ill suited to probabilistic forecasts. What has changed in the last 20 years?

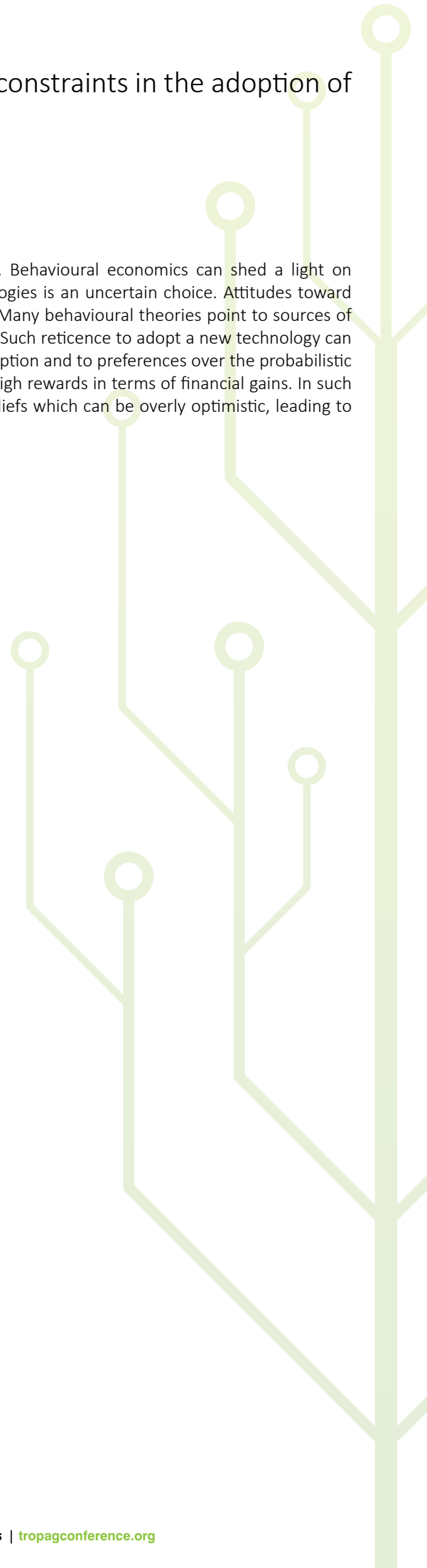
This presentation will provide a brief overview of the improvements and challenges in seasonal forecasting before addressing the challenges of incorporating this information into decision making. Some of the technical challenges are new as we shift from statistical analogues to ensembles generated by dynamic forecasts. Other challenges are ongoing and relate to communicating and using probabilistic information in planning and decision making.

184 Behavioral economics insight into drivers and constraints in the adoption of technologies

Prof Lionel Page¹

¹*Queensland University of Technology, Brisbane, Australia*

The adoption of new technologies is a key factor of growth and development. Behavioural economics can shed a light on some factors driving and constraining adoption. By nature adopting new technologies is an uncertain choice. Attitudes toward uncertainty and the propensity to take risk are key to understand this behaviour. Many behavioural theories point to sources of risk/uncertainty aversion which will limit the propensity to adopt new technology. Such reticence to adopt a new technology can be due both to people's preferences over the possible outcomes following the adoption and to preferences over the probabilistic risk taken. At the same time, successful adoption is associated with potential for high rewards in terms of financial gains. In such situations, economists have found that people may form systematically biased beliefs which can be overly optimistic, leading to an over-adoption.



185 Designing less risky systems through investing in the adaptive capacity of farmers

Dr Nadine Marshall¹

¹*Csiro Land and Water, Townsville, Australia*

Designing less risky agricultural systems in Australia must involve strategies that directly consider the current levels of adaptive capacity of Australian Farmers. Recent research with the northern beef industry suggests that only 16% of cattle producers have sufficient skills to deal with the climate challenges of the future. Efforts are needed to assist farmers to; (i) understand and manage climate risks and implementing new solutions, (ii) develop strategic skills that encourage learning, experimenting and refining, (iii) develop financial and psychological buffers, and (iv) take a pro-active approach to managing change scenarios. Only once farmers have committed to developing their own capacity to adapt to the increasingly changing world around them, will climate risks become manageable within the industry. Only then will new technologies be welcomed. The trade-offs between what is needed and what is possible in Agriculture become much more positive when one considers the options available to farmers with high adaptive capacity.

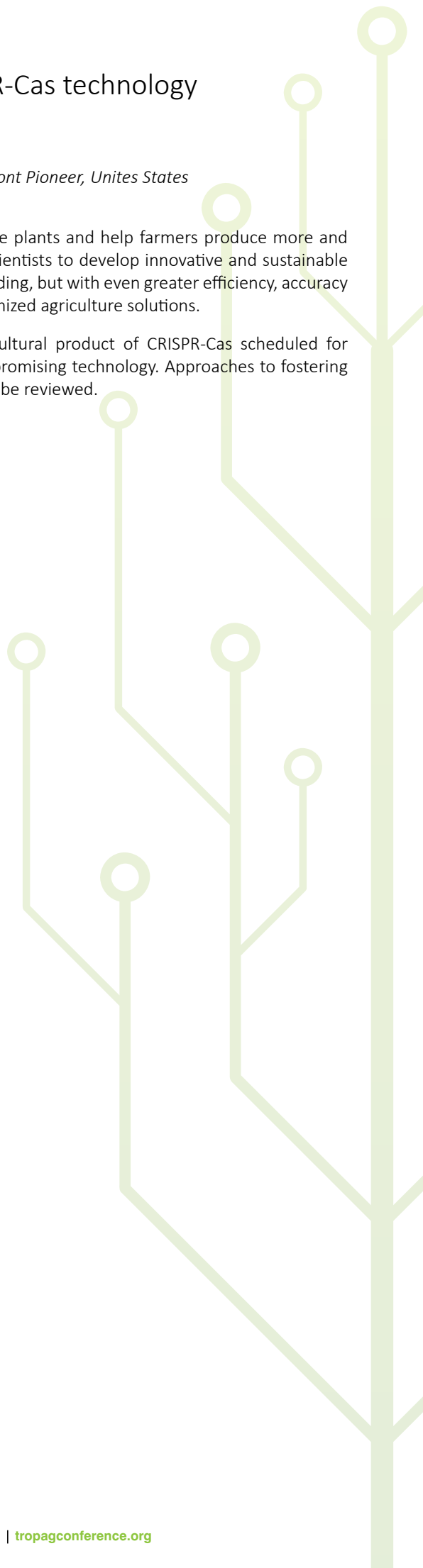
200 Targeted plant breeding applications of CRISPR-Cas technology

Kevin Diehl¹

¹Director, Regulatory Product Strategy, Scientific Affairs and Industry Relations, DuPont Pioneer, United States

CRISPR-Cas as an advanced plant breeding tool is a more efficient way to improve plants and help farmers produce more and better food, with fewer resources. The superior properties of CRISPR-Cas allow scientists to develop innovative and sustainable seed products for growers similar to those realized through conventional plant breeding, but with even greater efficiency, accuracy and quality. DuPont Pioneer is leading the application of this tool to develop customized agriculture solutions.

In this talk, Pioneer's next generation of waxy maize hybrids as the first agricultural product of CRISPR-Cas scheduled for commercialization will be discussed along with additional product targets of this promising technology. Approaches to fostering social license and implementing an open innovation model for CRISPR-Cas will also be reviewed.



201 The contributions of animal-source food to sustainable, safe, ethical and optimal human diets

Assoc Prof Robyn Alders¹

¹*School of Life and Environmental Sciences, Charles Perkins Centre, University of Sydney, Sydney, Australia*

Nourishing a growing human population in a warming world of increasingly scarce natural resources is one of the greatest challenges facing humanity. Yet, even under current conditions, over 10 per cent of people globally are undernourished and approximately 30 per cent are deficient in key micronutrients. These burdens tend to be higher in resource-poor households, and especially amongst the more vulnerable members of households. This is reflected in the fact that households in low- to middle-income countries account for almost all undernourished children. Anaemia is prevalent in approximately 50 per cent of pregnant women in these same countries.

Efficient and appropriate consumption of animal-source food (ASF) can provide protein with an optimal mix of amino acids and bioavailable micronutrients such as haem iron that can significantly enrich cereal-based diets. In mixed farming communities, households that raise animals may have access to ASF items throughout the year, whereas stored crops often dwindle in the weeks to months prior to harvest, resulting in a hunger period. Unfortunately, despite the availability of ASF, data suggests that actual consumption of ASF by households is extremely low in resource-poor settings.

This paper discusses key challenges and potential solutions to limited ASF intake in low- to middle-income countries in relation to i) improving animal health management to reduce the risk of unplanned reductions in herd and flock sizes; ii) effective, gender-sensitive communication with animal-owning households relating to animal health and human and animal nutrition; iii) identifying climate-smart animal production initiatives that are locally feasible; iv) investigating options for the sustainable inclusion of safe, ethical and optimal nutrition via the regular incorporation of ASF from domesticated and/or non-domesticated animals into human diets.

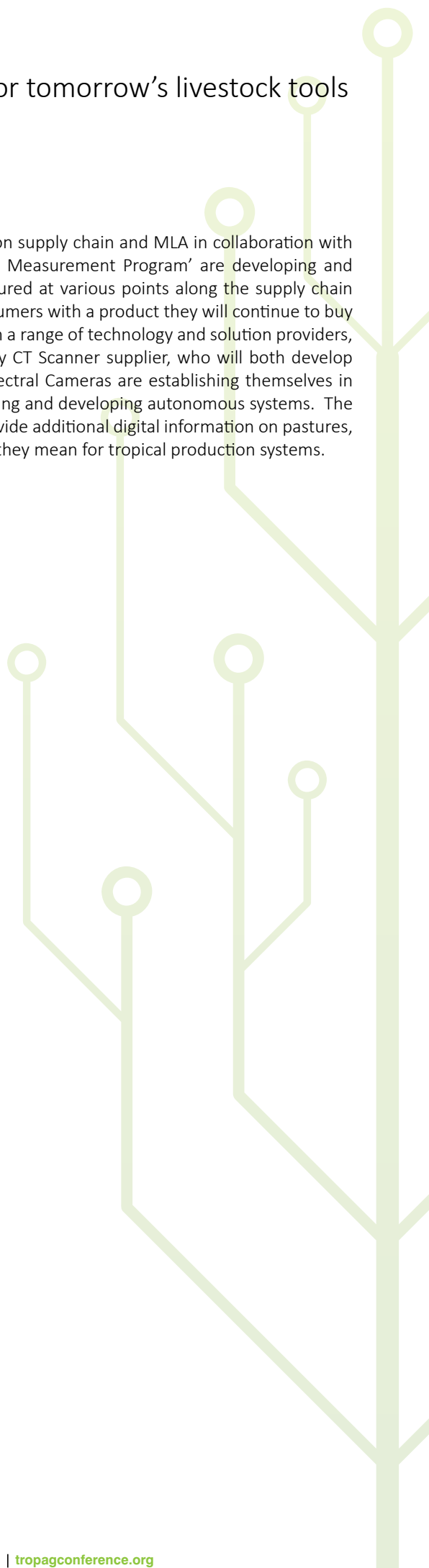
A Planetary Health approach (recognising that the health of human civilisation depends on the health of natural systems) was used in the framing of this paper. The production of sustainable, nutritious and safe ASF delivered with minimal waste has the potential to promote human, animal and environmental health. As governments worldwide grapple with unsustainable health budgets, nutrition-sensitive ASF value chains, bolstered by more effective policy frameworks, can help to prevent malnutrition and ensure that the ASF produced delivers maximum benefits. Resourceful and strategic production and utilisation of ASF has a crucial role to play in achieving the second Sustainable Development Goal relating to ending hunger, delivering food security and improved nutrition, while at the same time promoting sustainable agriculture.

202 Beyond digital revolution – Today’s research for tomorrow’s livestock tools

Doug McNicholl¹

¹*Meat & Livestock Australia, Brisbane, Australia*

Australian red meat producers are beginning to adopt various aspects of a precision supply chain and MLA in collaboration with industry is support and driving this change. Programs such as MLA’s ‘Objective Measurement Program’ are developing and adapting technologies that allow the objective measurement of information captured at various points along the supply chain with the aim of improving supply chain performance and ultimately supplying consumers with a product they will continue to buy and pay a premium for. The success of this this program has attracted interest from a range of technology and solution providers, including an Equine Computed Tomography (CT) supplier and an Aviation Security CT Scanner supplier, who will both develop solutions for CT scanning live animals. Another company who develops Hyperspectral Cameras are establishing themselves in Australia. A second MLA program known as ‘Unmanned’, is demonstrating, evaluating and developing autonomous systems. The program which covers both aerial, land, tethered and satellite solutions aims to provide additional digital information on pastures, weather and livestock. Doug will provide an overview of these programs and what they mean for tropical production systems.



203 Using data to change tomorrow's farm activities with power of prediction

Prof James Rowe¹, Prof Lewis Kahn¹, Mrs Lu Hogan¹, Mr Johan Boshoff², Mr Michael Thomson³

¹Sheep CRC, Armidale, Australia, ²University of New England, Armidale, Australia, ³CQUniversity Australia, Rockhampton, Australia

Many farm management decisions are based on intuitive judgement that draw on: inter-generational experience; keen observation; farm data; and various sources of trusted information and advice.

Activities are often planned around long term average seasonal conditions, but ever changing weather and market conditions raise the need for rescheduling or reassessment when the future brings new challenges or opportunities. In practice, most rescheduling occurs once conditions have changed rather than in anticipation of those changes.

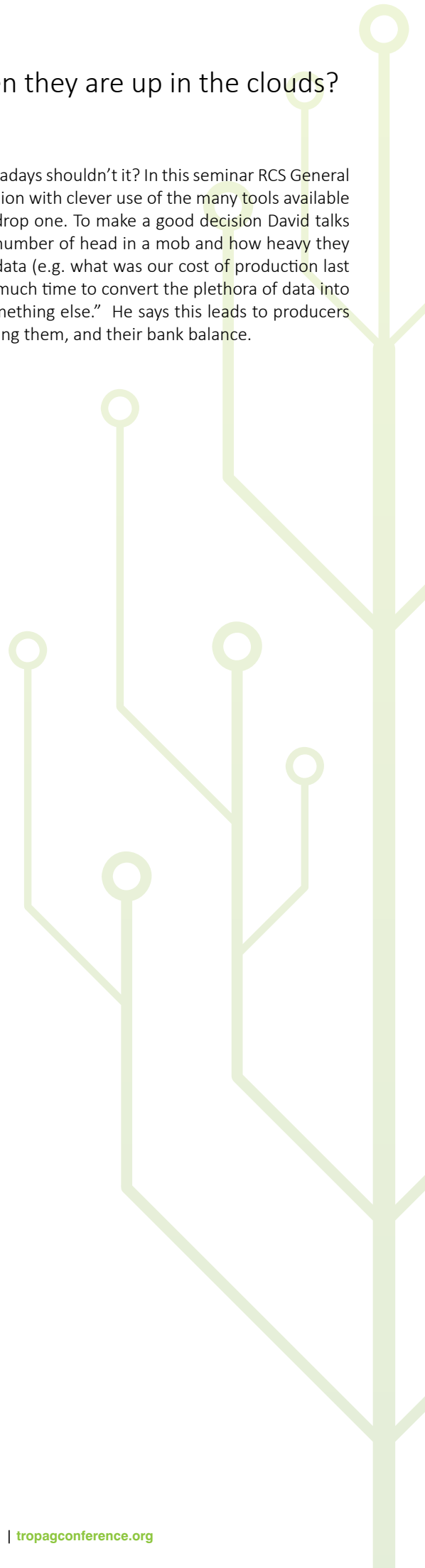
The transition from being reactive to proactive requires assistance to look into the future and interpret the complex interaction between soil, plants, livestock and the probabilities of rain, heat and cold. ASKBILL is a web-based program that does just that! At the level of an individual farm, ASKBILL provides daily updates of long term feed budgets, disease risks and production targets and sends an alert if any action or a change of plan is needed.

Predictive analytics in ASKBILL use all the data that the Bureau of Meteorology can provide combined with biophysical models for soil moisture, pastures, worms and flystrike to provide alerts with respect to opportunities and risks. ASKBILL is not prescriptive in telling what to do but provides timely prompts and valuable what-if scenario analysis to support intuitive decision making. Just ASKBILL for a calculated view of the future.

204 How do we get our heads out of the sand when they are up in the clouds?

Mr David McLean

With the rapid advances in technology, making good decisions should be easier nowadays shouldn't it? In this seminar RCS General Manager, David McLean will talk about what is needed to make a professional decision with clever use of the many tools available today. Producers are juggling a lot of balls on a daily basis and it is expensive to drop one. To make a good decision David talks about how producers need to learn how to combine the ground level detail (e.g. number of head in a mob and how heavy they are now compared to 3, 6, 12 months ago etc) up with the high level aggregated data (e.g. what was our cost of production last financial year). "We need meaningful information at our fingertips. If it takes too much time to convert the plethora of data into meaningful information, the producers are less likely to do it as they prioritise something else." He says this leads to producers relying on gut instinct and ignoring the useful information that could be really helping them, and their bank balance.



205 The digital agronomist – The changing face of farm advisory

Mr Tim Neale¹

¹*DataFarmer, Highfields, Australia*

Agronomy is almost as old a profession as growing crops themselves, but the pace of change in our digital world is shifting the way we advise. Everything from soil testing, crop checking, on farm trials, and yield recording has now hit the digital age.

Agronomists are using GPS to target and re-visit soil testing locations, giving us new insights into soil nutrition and amelioration (especially pH) trends.

Crop checking now can be highly targeted based on high resolution satellite, aerial, or drone imagery. NDVI (normalised difference vegetation index) is the most popular surrogate for crop health, and can quickly steer an agronomist to parts of the field that need attention. There are now several good mobile platforms available for agronomists to make recommendations and send these to the grower in real-time; whilst the chemical is dispatched from the warehouse simultaneously.

On-farm trials are getting easier, with the advent of variable rate technology and yield mapping. An advisor can now run a fertility trial without the grower lifting a finger. Making each farm and 'research station' is now a reality giving locally relevant, near real-time, information back to the grower.

When things go wrong, such as hail or spray drift, unbiased assessments using yield data can be conducted; taking some of the guesswork out of what can often be considerable claims.

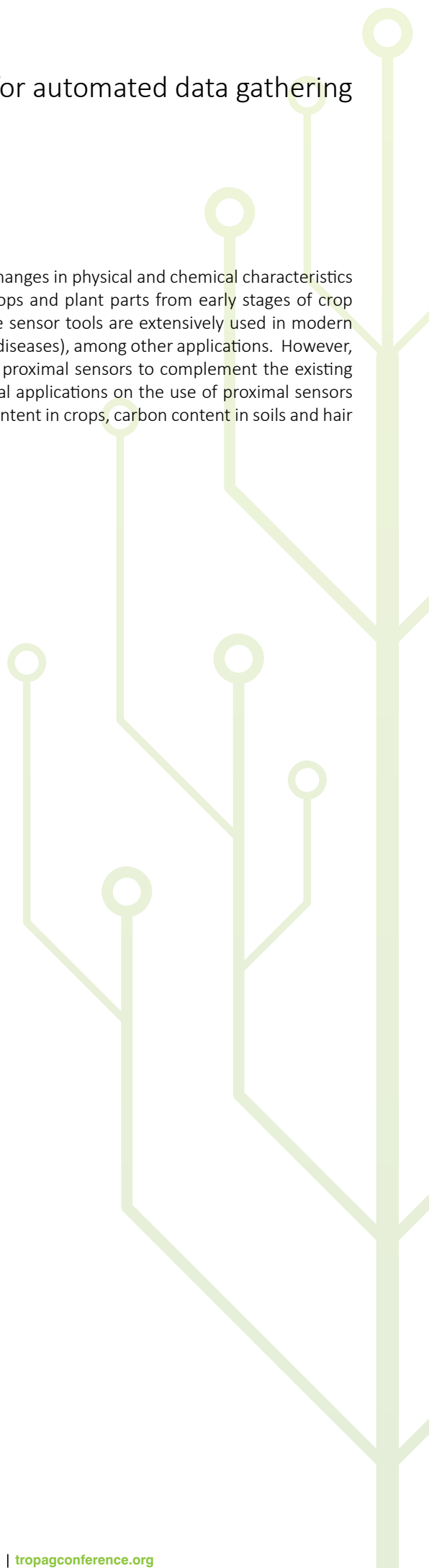
Possibly the most exciting part of the future with all this data, are deep insights we could gain with data analytics.

206 Beyond the accepted methods – New targets for automated data gathering on farm

Assoc Prof Daniel Cozzolino¹

¹Central Queensland University, Rockhampton, Australia

Farmers are demanding rapid, cost-effective and easy-to-use tools for monitoring changes in physical and chemical characteristics or properties in a diverse range of agricultural products and materials such as crops and plant parts from early stages of crop development until harvest, animal tissues, fluids and hair, soil, water, etc. Remote sensor tools are extensively used in modern agriculture to monitor different aspects of cereal production (e.g. fertilization, crop diseases), among other applications. However, the need to increase of our understanding and monitoring capabilities the use of proximal sensors to complement the existing tools is needed. This presentation will discuss, with examples, recent and potential applications on the use of proximal sensors based on near infrared (NIR) spectroscopy to monitor dry matter (DM) and water content in crops, carbon content in soils and hair analysis in beef cattle.



207 GPS cows: Bringing ag data and new technologies into high schools

Dr Amy Cosby¹, Associate Professor Mark Trotter¹

¹*Institute for Future Farming Systems, School of Medical and Applied Sciences, Central Queensland University, North Rockhampton, Australia*

The agricultural workforce of the future need to possess a different set of skills and knowledge to ensure the industry continues to innovate and adopt new technologies. The “GPS Cows” program aims to encourage and inspire students to pursue a career in the agricultural industry. It will provide the next generation with knowledge of the latest advances in livestock tracking and the skills to collect and analyse data which can be used to increase on-farm productivity, profitability and sustainability.

The project is based around the collaborative development of a learning resource by several key stakeholders including leading educators, researchers and industry professionals. Nine schools from Queensland and New South Wales and the Queensland Agriculture Training Colleges will contribute to the development of the learning module before delivering the resource to their students. Each school will deploy GPS tracking collars on their school farm to answer a research question they are interested in.

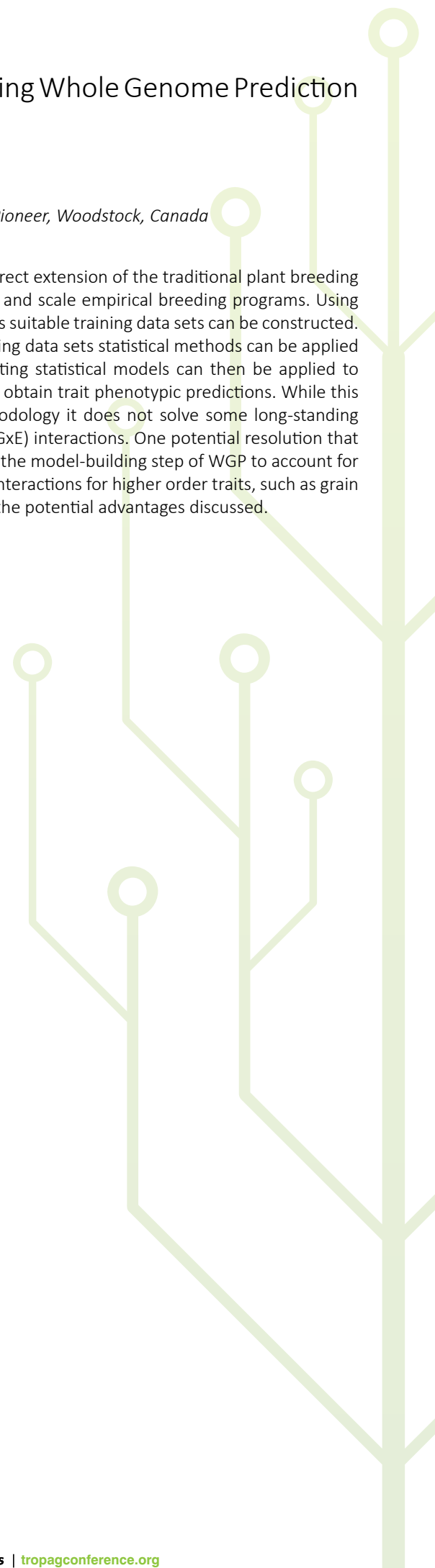
The “GPS Cows” resource will be evaluated to determine its effectiveness in engaging students in digital literacy and improving knowledge of the relevance of technology in agriculture. The action research protocol being followed ensures that feedback is gained from all participants to improve the learning module and improved understanding of the challenges for all participants. It is expected that the students and educators involved in the project will walk away with an increased appreciation and knowledge of the role of technology in agriculture and the social, economic and environmental benefits that can be obtained.

208 Prediction based crop improvement by combining Whole Genome Prediction with Crop Growth Models

Dr Mark Cooper¹, Dr Carlos Messina², Dr Frank Technow³

¹Zenrun42 Inc., Johnston, United States, ²DuPont Pioneer, Johnston, USA, ³DuPont Pioneer, Woodstock, Canada

Prediction based crop improvement is feasible today. One popular approach is a direct extension of the traditional plant breeding methods, using applications of Whole Genome Prediction (WGP) to complement and scale empirical breeding programs. Using the phenotypic data generated by the empirical testing stages of breeding programs suitable training data sets can be constructed. With access to sequence based fingerprints of the individuals included in the training data sets statistical methods can be applied to associate sequence polymorphisms with trait phenotypic variation. The resulting statistical models can then be applied to individuals that have been genotyped, with or without phenotypic information, to obtain trait phenotypic predictions. While this prediction-based methodology allows a scaling of the traditional breeding methodology it does not solve some long-standing problems, in particular complications associated with genotype-by-environment (GxE) interactions. One potential resolution that has been proposed involves the use of a suitable crop growth model (CGM) within the model-building step of WGP to account for the influences of environmental variation and trait variation giving rise to the GxE interactions for higher order traits, such as grain yield. The current status of this CGM-WGP methodology is reviewed and some of the potential advantages discussed.



209 Why was genomic selection so rapidly adopted in the US beef and dairy industries?

Dr Stewart Bauck¹

¹*Neogen Geneseek, Lincoln, United States*

Since the introduction of the Illumina Bovine SNP50 chip to the global community in January 2008, and the launch of genomic enhanced PTA in the U.S. dairy evaluation, there has been a steady adoption of the technology in the cattle industries in the United States. Behind this are a variety of factors that have created a “perfect storm” of circumstances revolutionizing animal breeding.

First among these is the availability of high density genotyping arrays that produce accurate, repeatable and high quality genotype data that is consistent from sample to sample. Coupled with this high fidelity in the design and functionality of the arrays is a concomitant decrease in the cost per sample – up to five fold reduction over the past 9 years. With high quality data has come rapid evolution in the bio-informatics and statistics for incorporation of genomic data in to genetic prediction, such that highly accurate predictions are available from animals that are one day or age (or less now, with embryo biopsy).

In addition to the technical features of the chips and genomic predictions are less obvious but equally important changes including new sample collectors that are easy to apply and deliver integrity in the sample (eg. Allflex TSU), rapid turnaround time on the samples and data (including Guaranteed Turn Around Time for GeneSeek Genomic Profilers) and the availability of adjacent technology such as gender selected semen that ensures 90+% females calves from inseminations, with little or no loss in fertility or pregnancy rates.

210 Speed breeding with genomic selection to accelerate wheat variety development

Miss Amy Watson¹, Dr Lee Hickey¹, Dr Jessica Rutkoski², Dr Jack Christopher³, Dr Jesse Poland⁴, Prof Ben Hayes¹

¹QAAFI, The University of Queensland, Brisbane, Australia, ²Cornell University, Ithaca, United States, ³QAAFI, The University of Queensland, Toowoomba, Australia, ⁴Kansas State University, Manhattan, United States

Genomic selection (GS) in wheat could accelerate yield gain principally through a reduction in breeding cycle duration. A method for rapid generation advance called 'speed breeding' (SB) enables up to six generations of spring wheat per year, and could be used to accelerate the development of inbred lines required for GS, thus enabling even further gains. To improve the accuracy of selection for improved yields, many heritable traits that are genetically correlated with yield could be measured under SB and used in multivariate models to improve genetic gain (over that of traditional univariate models only containing yield data of the training population). For ease of computation, these proxy traits may be consolidated into a small number of principal components (PC). To test these hypotheses, 130 double-haploid lines from a SeriM82 x Hartog spring wheat population, genotyped with 4,000 GBS polymorphic markers, was grown under glasshouse SB conditions and phenotyped for the following traits: days to anthesis, height, and spike and flag leaf length. The population was evaluated for yield in non-water stressed, anthesis water stress and post-anthesis water stress field environments. Using five-fold cross validation, yield prediction ability for each environment, using both univariate and multivariate models including SB proxy traits or their PCs, were compared. Results indicate multivariate GS prediction including SB proxy traits or their PCs can improve selection for field-based yield. These traits could be phenotyped during rapid line development under SB and used with training population yield data to advance genetic gain and wheat variety development.



211 Large scale genomic selection in tropically adapted cattle to improve fertility and meat quality

Dr Matthew Kelly¹, Dr Gerhard Moser¹

¹*Australian Agricultural Company, Brisbane, Australia*

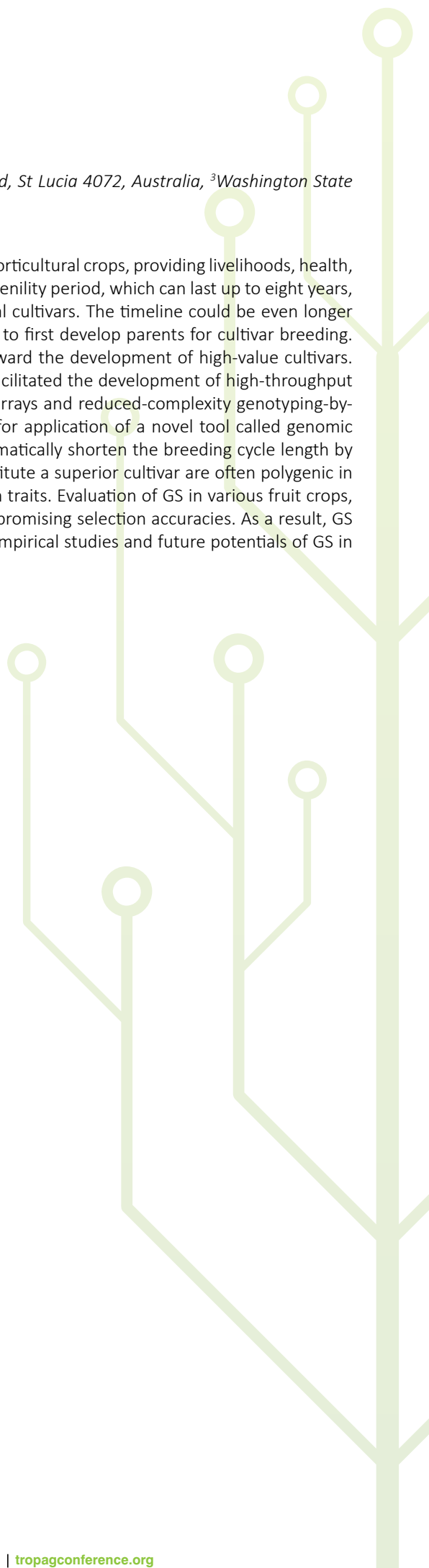
Australian Agricultural Company (AACo) is Australia's largest integrated cattle and beef producer. ACo operates a strategic balance of properties, feedlots and farms comprising around 7 million hectares of land in Queensland and the Northern Territory. Most of these properties are located within tropical environments as such our cattle must be able to thrive under harsh environments where they are exposed to many stressors including heat, humidity and parasites. ACo runs three seed-stock breeding operations tailored to produce bulls suited to their appropriate environment and supply chains. Our Brahman herd produces bulls for our harshest environments. ACo's four-breed composite females are mated to Wagyu bulls to produce crossbred calves for the commercial supply chain. The Wagyu seedstock herd also produces bulls for our long-fed purebred production system. Integrated supply chains allow ACo to capture the benefit from genetic improvement and clear market signals inform selection decisions. Collecting genomic information on commercial animals measured for growth and carcass traits will significantly increase the rate of genetic improvement in all three breeding programs. Female reproductive performance is a key profit driver for the northern beef industry. Rate of genetic gain could be dramatically increased by developing a resource population by collecting lifetime reproductive performance of females to develop genetic evaluation for young bulls.

212 Genomic selection in horticulture

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Perennial fruit crops such as citrus, banana, apple and grape are important among horticultural crops, providing livelihoods, health, and adding billions of dollars to the world economy. Most fruit crops have a long juvenility period, which can last up to eight years, so that traditional fruit breeding often takes up to 25 years to develop commercial cultivars. The timeline could be even longer if novel attributes (e.g., disease resistance) are introgressed from wild germplasm to first develop parents for cultivar breeding. Genomics-assisted breeding provide more direct and quicker solutions to fast-forward the development of high-value cultivars. Sequencing of genomes of some major fruit species during the last 10 years has facilitated the development of high-throughput cost-effective genotyping platforms such as single nucleotide polymorphic (SNP) arrays and reduced-complexity genotyping-by-sequencing (GBS). Access to these genomic resources is providing opportunities for application of a novel tool called genomic selection (GS). The most attractive feature of GS is that it has the potential to dramatically shorten the breeding cycle length by obviating the need to phenotype selection populations. Fruit characters that constitute a superior cultivar are often polygenic in their inheritance, and GS is best suited for selection of cultivar candidates for such traits. Evaluation of GS in various fruit crops, including apple, pear, peach, grapes, sweet cherry and strawberry, have provided promising selection accuracies. As a result, GS is now being used in some commercial fruit breeding programmes. Results from empirical studies and future potentials of GS in fruit crops will be discussed.



213 The future of genomic selection - Incorporating biological information in genomic predictions

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To date, genomic prediction of performance in animals and plants exploits relatively dense genome-wide DNA markers (SNP chips). Genomic prediction works by applying statistical methods that link the DNA markers genotypes to the expression of complex traits, such as growth or disease resistance, that may be influenced by many hundreds of causal mutations. These genomic prediction methods require no prior biological knowledge of genes or mutations that affect a trait, and indeed assume that all the DNA markers are equally likely to be associated with the trait. This naïve approach works well if the DNA markers lie close to, or are strongly linked to all the causal mutations that underpin the trait. However, this is not always the case and for example, genomic predictions do not work well when the target population is not closely related to the population used to train the genomic prediction (such as a different breed/strain). A potential solution is to impute all individuals with SNP chip genotypes to whole-genome sequence, and in theory this will include the causal mutations. However, in practice using the naïve genomic prediction models with whole-genome sequence has not improved the accuracy of genomic prediction. We have developed a genomic prediction method that incorporates biological information and exploits sequence data. We will present practical examples to demonstrate the application of this method to improve the accuracy of genomic prediction.

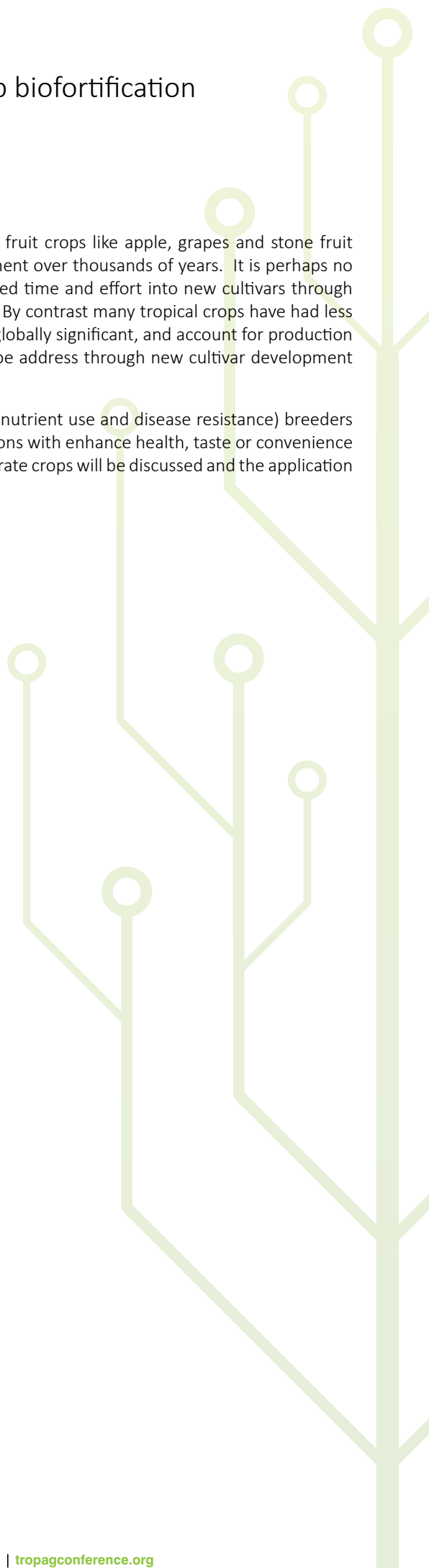
214 Lessons from temperate crops for tropical crop biofortification

Prof Roger Hellens¹

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Horticultural crops were some of the first plants to be domesticated. Temperate fruit crops like apple, grapes and stone fruit (Peaches, plums and apricots) have benefited from considerable genetic improvement over thousands of years. It is perhaps no surprise that these heavily populated and wealthy regions of the globe have invested time and effort into new cultivars through selection, breeding and at least two examples of deregulated genetic modification. By contrast many tropical crops have had less investment in new cultivar development. Crops such as banana and mango being globally significant, and account for production volumes great that the top temperate crops, they face many challenges that can be addressed through new cultivar development programmes.

In addition to selection of attributes for improved production (productivity, yield, nutrient use and disease resistance) breeders of whole food also need to focus on traits that are consumer to consumers. Selections that enhance health, taste or convenience have the most influence on consumption. The development of these traits in temperate crops will be discussed and the application to new cultivars of tropical and sub-tropical crops considered.



215 High folate strawberries – Finally something tasty?

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Strawberries are considered a tasty and healthy fruit by consumers and may potentially be an important dietary source of natural folates. The relative importance of strawberry as a source will depend on bioavailability and concentration and is likely influenced by cultivar and environment. Folates are a group of water-soluble vitamers and are coenzymes for methyl, formyl and other single functional carbon group transfers. Folate vitamers are involved in DNA, protein and neurotransmitter synthesis and cannot be biosynthesized in humans. Folate is also considered as a critical vitamin. Folate deficiency is associated with neural tube defects in newborns. An inadequate intake is also known to be involved in cardiovascular and Alzheimer's disease as well as in the development of certain forms of cancer. In an initial unreplicated screening study of a sample of Australian grown commercial and experimental genotypes of strawberry, and using state-of-the-art stable isotope dilution assays (SIDA), we found total folate contents of 82–161 µg/100 g fresh weight. These levels are well above the value in the NUTTAB database (39 µg/100 g fresh weight). At these high concentrations, a single serve of Australian grown strawberries may deliver a considerable amount of the FSANZ recommended daily intake (RDI) for folate. The results of a pilot bioavailability study with healthy human subjects consuming strawberries, 5-methyltetrahydrofolate (supplement) and a folate-free control will be also presented.

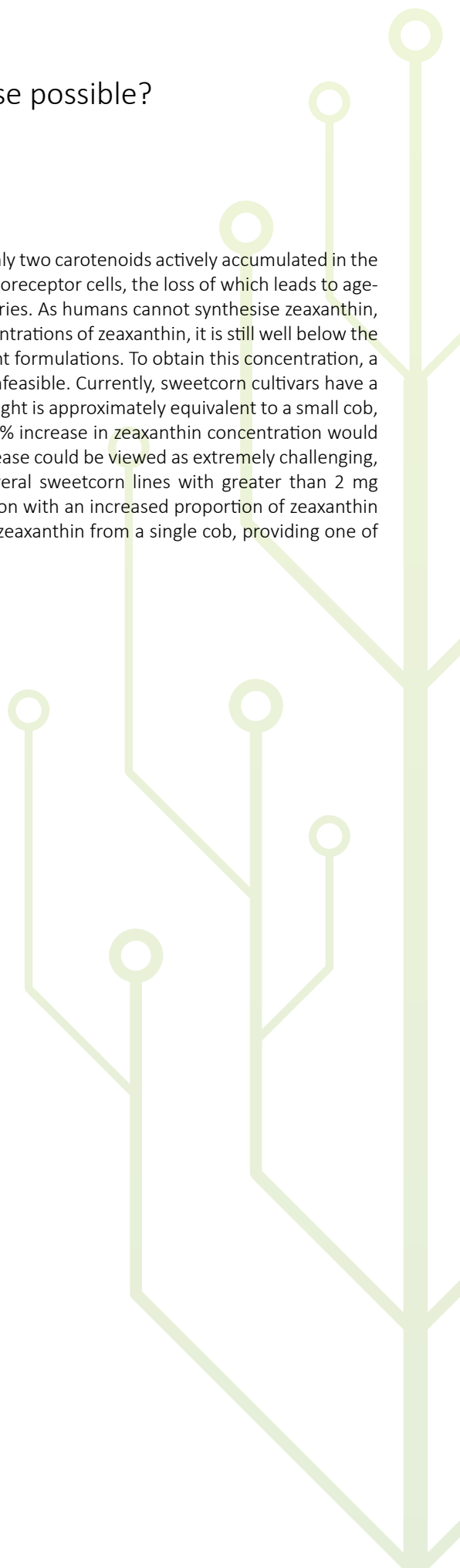
[This study was partly funded by Horticulture Innovation Australia Ltd., project: "Naturally Nutritious"/HN 15001]

216 Sweetcorn biofortification – Is a 1000% increase possible?

Dr Tim O'Hare¹

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Sweetcorn is a good dietary source of the carotenoid pigment 'zeaxanthin', one of only two carotenoids actively accumulated in the human macula. Zeaxanthin is thought to protect against blue-light oxidation of photoreceptor cells, the loss of which leads to age-related macular degeneration, the leading form of blindness in industrialised countries. As humans cannot synthesise zeaxanthin, it must be obtained from our diet. Although sweetcorn has one of the highest concentrations of zeaxanthin, it is still well below the consensus concentration of 2 mg/person/day used for clinical studies or supplement formulations. To obtain this concentration, a person would have to consume approximately 4-11 cobs per day, which is clearly infeasible. Currently, sweetcorn cultivars have a zeaxanthin concentration of approximately 0.2 mg per 100 g kernels. This kernel weight is approximately equivalent to a small cob, which could be consumed as part of a normal meal. This means, a tenfold or 1000% increase in zeaxanthin concentration would be necessary to provide a daily dosage of 2 mg from a single cob. Although this increase could be viewed as extremely challenging, it was recently achieved via conventional breeding with the development of several sweetcorn lines with greater than 2 mg zeaxanthin per 100 g. By combining a 2-3 fold increase in total carotenoid production with an increased proportion of zeaxanthin from 20% to 70% of total carotenoids present, it is now possible to ingest 2 mg of zeaxanthin from a single cob, providing one of the best sources of zeaxanthin in our diet.



217 High pro-vitamin A bananas – A first for Africa

Prof James Dale¹

¹Queensland University of Technology, Brisbane, Australia

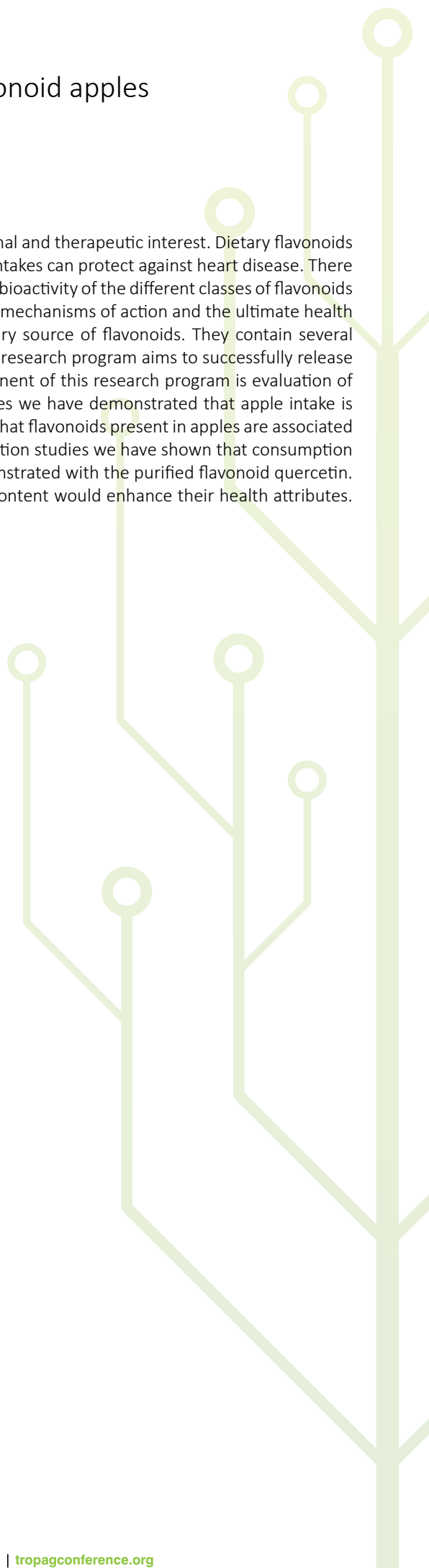
Micronutrient deficiencies, often known as the hidden hunger, are one of the most serious of the public health problems in the world. Vastly disproportionately affecting developing countries, strategies to overcome these deficiencies such as supplements and food fortification have been very effective but miss many of the poorest of the poor. Biofortification is a very attractive strategy where staple crops are developed with high levels of specific micronutrients. In Uganda and other surrounding countries, the levels of vitamin A deficiency (VAD) are high and increasing. Cooking bananas are the major staple food with consumption in Uganda more than 500g per person per day. As a contribution to alleviating VAD in Uganda initially, QUT joined with the National Agricultural Research Organisation of Uganda to develop East African Highland bananas with significantly elevated levels of pro-vitamin A (α & β -carotene). The strategy was to develop the technology in Australia through field trials using Cavendish bananas as the model and then transfer the technology to Uganda for deployment in East African Highland bananas. We have been able to generate both Cavendish and East African Highland bananas with more than three times the target level of pro-vitamin A by overexpressing a single banana gene, the phytoene synthase 2a gene derived from *Asupina*, a banana naturally very high in pro-vitamin A. These modified plants are now in a line selection trial in Uganda from which a small number of elite lines will be progressed through multi-location field trials to deregulation.

218 Potential health benefits of breeding high flavonoid apples

Prof Jonathan Hodgson¹

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Flavonoids are natural phytochemicals that are currently the focus of much nutritional and therapeutic interest. Dietary flavonoids can improve vascular function and there is mounting evidence that high flavonoid intakes can protect against heart disease. There are many hundreds of structurally distinct flavonoids present in the human diet. The bioactivity of the different classes of flavonoids and of flavonoids with different structural characteristics can vary widely. Thus, the mechanisms of action and the ultimate health impact of specific polyphenol-rich foods may vary. Apples are an important dietary source of flavonoids. They contain several flavonoids, but the skin of apples is particularly rich in the flavonoid quercetin. Our research program aims to successfully release new Australian-bred apple varieties with enhanced health attributes. A key component of this research program is evaluation of the vascular health benefits of apples and their flavonoids. In observational studies we have demonstrated that apple intake is associated with lower risk of mortality and lower risk of severe atherosclerosis, and that flavonoids present in apples are associated with lower risk of cardiovascular disease and all-cause mortality. In human intervention studies we have shown that consumption of apples can improve vascular function, but the same benefits could not be demonstrated with the purified flavonoid quercetin. These studies provide proof of concept that breeding apples with high flavonoid content would enhance their health attributes. This may be an important component of the market success of new apple varieties.



219 Not another typical corny trial: Genetic and agronomic zinc biofortification of sweetcorn

Mr Zhong Xiang Cheah^{1,2}, Dr Tim O'Hare², Dr Stephen Harper³, Dr Jitka Kochanek¹, Dr Peter M. Kopittke¹, Prof Michael Bell^{1,2}

¹*School of Agriculture and Food Sciences, The University Of Queensland, Gatton, Australia*, ²*Queensland Alliance for Agriculture and Food Innovation, Gatton, Australia*, ³*Department of Agriculture and Fisheries, Gatton, Australia*

Zinc deficiency is widespread in agricultural soils, resulting in ca. 30% of the world's population being considered zinc-deficient. This deficiency is ranked as the fifth leading cause of disease in the developing world, especially among children, pregnant women and the elderly. It has also been associated with age-related macular degeneration (AMD), the leading source of blindness in the developed world.

Biofortification has been shown to be the most cost-effective approach to addressing malnutrition, but zinc biofortification of maize over the last 15 years has not reached its full potential as the tough outer layer, where zinc is deposited, is often removed during processing into flour. A promising alternative is sweetcorn, since the entire kernel is consumed, including the zinc-rich outer layer. Being one of the widely consumed fresh vegetables worldwide, it is a candidate for zinc biofortification research, promising to deliver potential benefits in both developed and developing countries.

This study focuses on zinc biofortification of sweetcorn, a previously unreported research area. In this research, genetic variation for high zinc uptake and storage is being quantified in breeding populations, with suitable candidates identified as potential future parents for targeted crosses. Concurrently, research is also exploring agronomic and fertilizer application strategies that may deliver elevated zinc concentrations in commercial crops. Early results indicate that sweetcorn zinc concentrations could potentially be doubled or even tripled, enabling sweetcorn to contribute a large proportion of the recommended daily intake of this important micronutrient.

220 A global perspective on the responsible use of antimicrobials in veterinary medicine

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Antimicrobial use in veterinary medicine has become an important political issue, especially in relation to the contribution that antimicrobial resistance might play a significant role in human medicine and their struggles to contain their own antimicrobial problems in health care situations such as in hospitals and care homes, leading to calls at a political level for national action plans to be developed. The WHO and OIE have created critically important antibiotic list for human medicine and veterinary medicine, respectively. Regional CIA have been developed by the FDA in the US and EMA in the EU. With respect to veterinary medicine it can be agreed that antibiotics are an essential tool to maintain the health of animals and more importantly are needed to maintain production of safe food for human consumption.

Antibiotics are typically used in veterinary medicine either for a therapeutic indication of diseases i.e. for treatment, control and prevention or as a growth enhancer, also called AGP use. There has been much debate over the AGP use of antibiotics in veterinary medicine and the EU, taking the precautionary principle approach, banned AGP use as of 1st January 2006. In contrast, based on scientific risk assessments and learnings from the EU, the US FDA took a more pragmatic approach limiting AGP use only to non-medically important antibiotics.

This talk will give an overview of some of the significant global developments with regards to antimicrobial use in veterinary medicine especially recent developments around National Action Plans, AGP, colistin and zinc oxide.



221 Antimicrobial resistance surveillance in livestock in Australia

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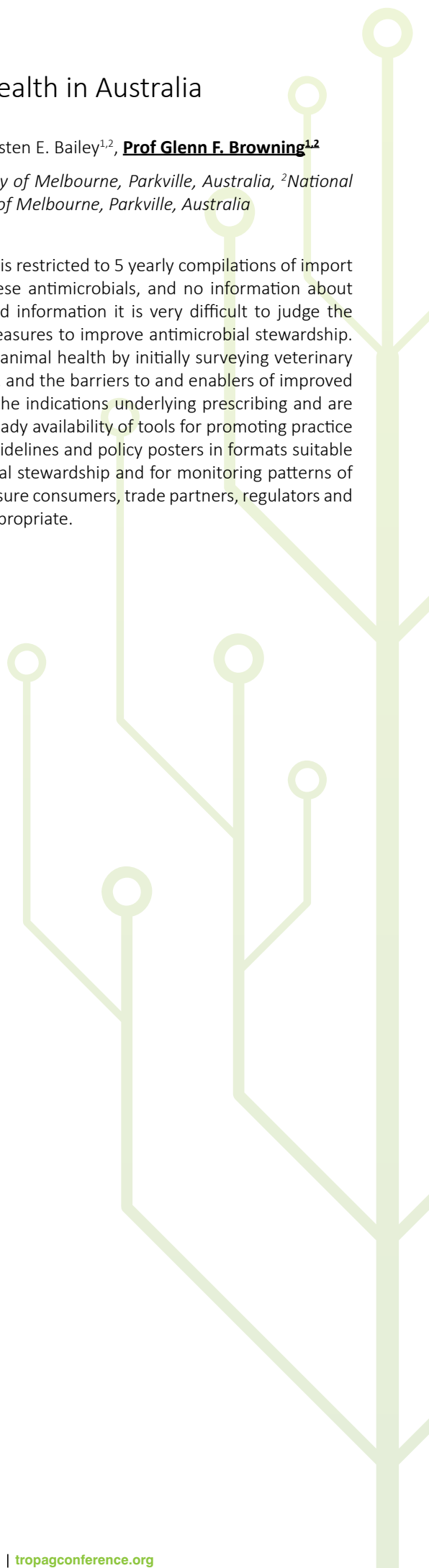
Australia is a large, isolated island with diverse climate and geography, a sparse human population (22.7 million, 2.9 people per km² with over 60% living in cities of greater than 1 million people), significant populations of food-producing animals (e.g. 74.7 million sheep; 28.5 million cattle) and a substantial meat export industry. In line with restrictions on fluoroquinolone use in humans, Australia is the only country that has legal measures in place to exclude the use of fluoroquinolones in food-animal species. Label constraints for third generation cephalosporin use in Australian food-animals are very strict by international comparison, and there are no registered products for Australian livestock that contain fourth generation cephalosporins or colistin. There also are large differences between Australia and other countries with respect to animal production (a stronger reliance on extensive production without housing), quarantine bans on the importation of fresh meat and live animals, and the fact that Australia is geographically isolated with no shared land borders. Whilst Australia also does not currently have a national, federally funded antimicrobial resistance surveillance programme focused on animals, a number of pilot surveys and feasibility studies have been conducted in recent years. These studies have consistently confirmed a low public health risk in the food-animal sector related to resistance against critically important drugs such as fluoroquinolones. However, the recent emergence of MDR *Salmonella enterica* serotype Typhimurium containing blaCTX-M-9 in dairy cattle in Victoria is a cause for concern and should refocus attention on the off-label use of ceftiofur in dairies.

222 Antimicrobial use and stewardship in animal health in Australia

Dr Laura Y. Hardefeldt^{1,2}, Dr Helen Billman-Jacobe^{1,2}, Prof James R. Gilkerson¹, Dr Kirsten E. Bailey^{1,2}, **Prof Glenn F. Browning^{1,2}**

¹Asia-Pacific Centre for Animal Health, Melbourne Veterinary School, The University of Melbourne, Parkville, Australia, ²National Centre for Antimicrobial Stewardship, Melbourne Veterinary School, The University of Melbourne, Parkville, Australia

Current understanding of patterns of antimicrobial use in animal health in Australia is restricted to 5 yearly compilations of import data. These data provide little information about the final patterns of use of these antimicrobials, and no information about the indications underlying their administration to animals. Without more detailed information it is very difficult to judge the appropriateness of antimicrobial use in animal health and impossible to target measures to improve antimicrobial stewardship. We have focussed on developing tools for improving antimicrobial stewardship in animal health by initially surveying veterinary practitioners about their approach to prophylactic administration of antimicrobials, and the barriers to and enablers of improved antimicrobial stewardship. We have developed a pilot tool for gathering data on the indications underlying prescribing and are currently trialling its use in the field. One of the barriers we have identified is the ready availability of tools for promoting practice antimicrobial use policies. To facilitate this we have generated antimicrobial use guidelines and policy posters in formats suitable for use in practice. Ongoing development of tools for promoting good antimicrobial stewardship and for monitoring patterns of antimicrobial use to assess the effects of stewardship measures will be needed to assure consumers, trade partners, regulators and the general public that the use of antimicrobial drugs in Australian agriculture is appropriate.



223 *Caeci Caecos Ducentes*

Dr Pat Blackall¹

¹QAAFI, UQ, Brisbane, Australia

The title of this presentation is a recognition of the prior publications of high profile microbiologists – one a clinical microbiologist (David Greenwood- *In vitro veritas?* 1980 *J Inf Dis* 144:380-385) and the other two veterinary microbiologists (John Woolcock and Mal Mutimer- *Caeci caecos ducentes?* 1983 *Vet Rec* 113:125-128). Both publications questioned the role and reliability of in vitro antimicrobial sensitivity testing – one from a human medicine view and the other from the veterinary view. David Greenwood presented an argument that routine antimicrobial sensitivity testing in the clinical laboratories was a waste of resources – arguing that focussed testing only when justified by the individual situation (serious and or problematic infections) should be the norm. John Woolcock and Mal Mutimer argued that the veterinary situation was different as serious illness and problematic infections are not a major feature of the veterinary scene. However, they argued that there were major limitations to the interpretation of antimicrobial sensitivity testing in the veterinary diagnostic setting. They argued that both the laboratory staff and the veterinarian using the results need to have a much greater awareness of these limits of in vitro testing. This talk will look at whether the intervening 30 years of research and standardization have altered the situation for veterinary diagnostic laboratories.

224 Molecular detection of tetracycline resistance genes in salmonella isolated from pork and poultry egg

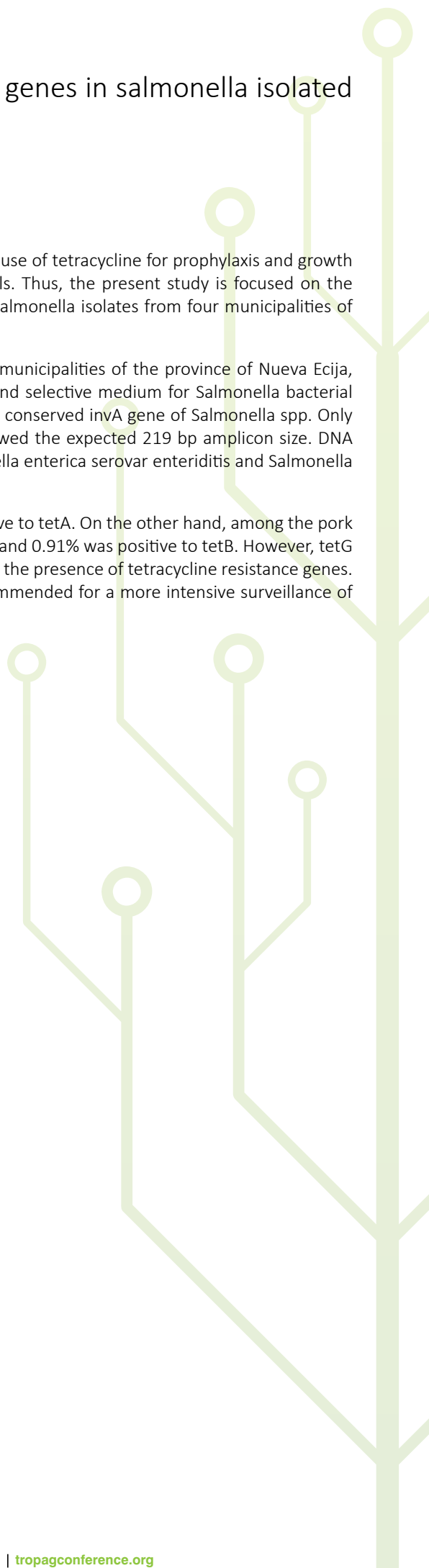
Paul Blanca Gaban¹

Philippine Carabao Centre, Phillipines

Tetracycline resistance in bacteria is a serious issue worldwide due to the frequent use of tetracycline for prophylaxis and growth promotion, aside from disease treatment and prevention among livestock animals. Thus, the present study is focused on the detection of tetracycline resistance determinants (tetA, tetB, tetG) on identified Salmonella isolates from four municipalities of Nueva Ecija, Philippines using a PCR-based protocol.

240 eggs and 180 fresh pork cuts were bought from different wet markets in 10 municipalities of the province of Nueva Ecija, Philippines. All the samples were cultured in non-selective enrichment medium and selective medium for Salmonella bacterial culture and isolation. Isolated colonies were subjected to colony PCR targeting the conserved invA gene of Salmonella spp. Only 13 isolates from the albumin samples and 18 isolates from the pork samples showed the expected 219 bp amplicon size. DNA sequence identified two Salmonella species with 99% identity, these were Salmonella enterica serovar enteritidis and Salmonella enterica serovar typhimurium.

41.67% of albumin isolates from Guimba were positive to tetB and 8.33% are positive to tetA. On the other hand, among the pork samples from Cabanatuan City, Talavera and San Jose City 5% were positive to tetA and 0.91% was positive to tetB. However, tetG was not detected among all the isolates. Thus, the protocol used was able to detect the presence of tetracycline resistance genes. However, a larger study area including all the municipalities in Nueva Ecija is recommended for a more intensive surveillance of tetracycline resistance in the province.



225 Assessing the role of public institutions in facilitating an inclusive global value chain: A comparative analysis of the natural rubber industry in South and Southeast Asia

Dr Ammar Abdul Aziz¹, **Muhammad Fadzli Ali**¹

¹University of Queensland, Gatton, Australia

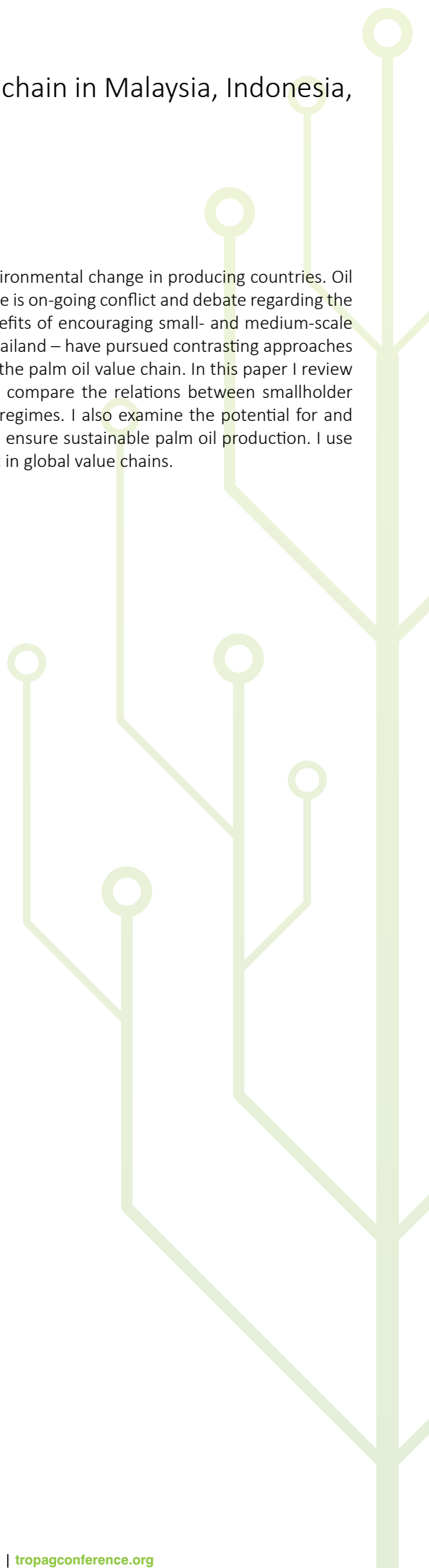
Engagement with an inclusive agricultural commodity chain has been shown to play a crucial role in improving smallholder livelihoods and promoting rural economic development. While the production of many agricultural commodities benefits from private agribusiness firms facilitating the inclusion of smallholders through contributions such as technology, capital, markets, labour, and knowledge, the natural rubber industry is primarily reliant on national policies and public institutions to support rubber smallholders. This is mainly due to the lack of incentive for the involvement of private agribusiness firms. Smallholders account for more than 90% of global natural rubber supply. Therefore, effective smallholder-oriented policies are essential for a sustainable rubber industry. In this paper we analyse the roles of research organisations, extension service providers, and support mechanisms for replanting in improving the integration of smallholders in the global value chain. We examine the natural rubber industry in Thailand, Indonesia, Malaysia, and India to compare the impact of these public institutions on the production efficiency of the smallholder sector and the improvement of rural livelihoods. The data and analysis are derived from ongoing research and secondary sources. The comparison of the four producing countries highlights the achievements and challenges of these organisations in ensuring a sustainable smallholder-based rubber industry. The analysis confirms the effective role of government policies in spearheading research and development and facilitating the effective transfer of technology. The productivity and profitability of the smallholder sector is heavily dependent on the support systems available through these public institutions.

226 Smallholder participation in the palm oil value chain in Malaysia, Indonesia, and Thailand

Prof Rob Cramb¹

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The long boom in tropical oil crops has generated major economic, social, and environmental change in producing countries. Oil palm production has been at the centre of this change in Southeast Asia, where there is on-going conflict and debate regarding the merits of large-scale corporate production systems versus the developmental benefits of encouraging small- and medium-scale holdings. The three major Southeast Asian producers – Indonesia, Malaysia, and Thailand – have pursued contrasting approaches to this issue, with significant impacts on the degree of smallholder participation in the palm oil value chain. In this paper I review the debate about the merits and modes of supporting smallholder oil palm and compare the relations between smallholder oil palm producers and other value-chain actors under the three different policy regimes. I also examine the potential for and constraints to smallholder participation in global certification schemes designed to ensure sustainable palm oil production. I use this study to suggest a general framework for the study of smallholder engagement in global value chains.



227 Developing value-chain linkages to improve smallholder cassava production in Southeast Asia

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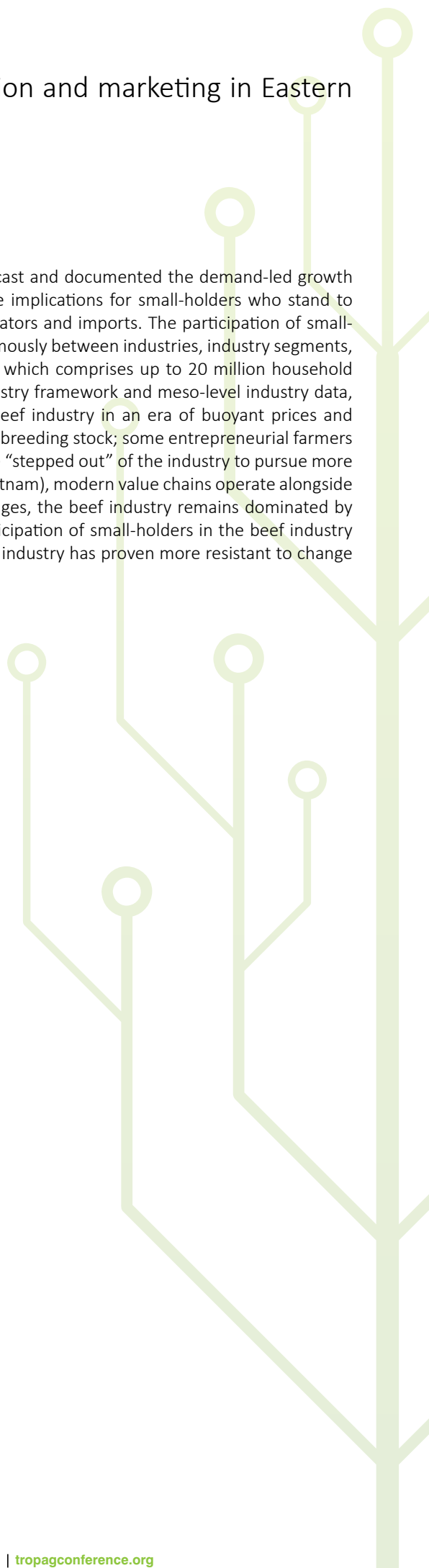
The recent boom in global markets for cassava has created livelihood opportunities for many smallholders in Southeast Asia. Research has generated an abundance of technologies that could enhance the productivity and sustainability of these cassava producers. While national government policies have not prioritised the dissemination of these technologies, we hypothesise that, in particular contexts, private-sector value-chain actors have incentives to invest in the promotion of suitable varieties, fertiliser regimes, pest control, and other production practices. In other contexts there is little incentive for private-sector involvement, and support from public-sector or non-government actors will be required. In this paper we provide an overview of smallholder cassava production in the region and the drivers behind the recent boom. We then present a framework to analyse the incentives for private value-chain actors to invest in the promotion of different technologies, taking into account (1) the characteristics of the technology, (2) the nature of the production system, and (3) the features of the value chain, including the ability of agribusiness actors to capture the benefits of any investment in technology dissemination. We test this framework through a preliminary analysis of three contrasting case studies: (1) a value chain centred on a large starch factory with a wide catchment area of smallholder suppliers in Daklak Province, Vietnam; (2) a cross-border value chain linking smallholders in Kratie Province, Cambodia, to starch factories in Vietnam; and (3) a local value chain for cassava as a food crop in Nusa Tenggara Timur Province, Indonesia.

228 The economics of small-holder cattle production and marketing in Eastern Indonesia

Dr Scott Waldron¹

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The “International Livestock Revolution” literature has over the last 30 years forecast and documented the demand-led growth of the livestock sector in the developing world. There is particular interest in the implications for small-holders who stand to benefit from new markets, but who can also be crowded out by commercial operators and imports. The participation of small-holders is determined by biological, cost, policy, and other factors, which vary enormously between industries, industry segments, and regions. This paper examines the beef industry of China and Southeast Asia, which comprises up to 20 million household cattle producers, traders, butchers, and beef retailers. Based on a segmented industry framework and meso-level industry data, the paper documents the multiple trajectories of small-holders in the regional beef industry in an era of buoyant prices and constrained supply. Small-holders throughout the region have responded by selling breeding stock; some entrepreneurial farmers have “stepped up” into the specialised fattening sector; while millions in China have “stepped out” of the industry to pursue more lucrative activities. In areas with large cattle imports and feedlots (Indonesia and Vietnam), modern value chains operate alongside or incorporate small actors including butchers and retailers. Even with these changes, the beef industry remains dominated by households operating in efficient, low-cost, generic beef chains. The ongoing participation of small-holders in the beef industry hardly provides a pathway to prosperity, but neither are they being squeezed. The industry has proven more resistant to change than other livestock sectors, where a revolution may be more apparent.



229 How does participating in an inclusive global value chain impact smallholder coffee producers in Indonesia?

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Indonesia is the world's third largest coffee-producing country and the fourth largest coffee exporter. More than 90 per cent of coffee producers in the country are smallholders and some of them engage in the global value chain through an inclusive business model developed by agribusiness firms (exporters and processors). We aim to assess the impact on smallholders who participate in this inclusive global value chain. We address two key research questions: What are the contributions of large agribusiness firms to smallholder coffee production? Have the contributions made a beneficial impact on participating smallholders? The study is based on semi-structured interviews with 70 coffee farmers in Lampung Province and in-depth interviews with other key actors in the value chain. The results show that in an inclusive coffee value chain, agribusiness firms played a significant role in improving the production and marketing of the crop. While independent farmers had more freedom to sell their products based on the market price, farmers who actively engaged with agribusiness firms through the facilities and services they provided gained increased economic benefits, such as a price premium, and non-economic benefits, such as production knowledge and skills, translating into good agricultural practices. Participation also promoted social bonds within farmer groups and between groups and company agents. Recommendations to further improve the outcomes of the inclusive business model are also discussed.

Keywords: livelihoods of small farmers, coffee value chain, globalization of markets

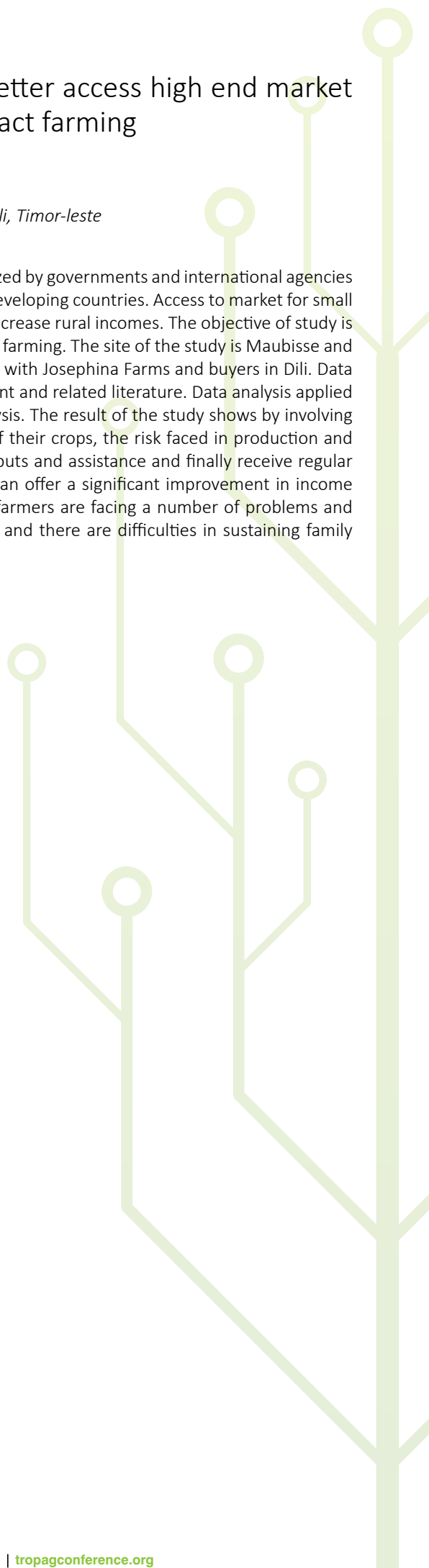
230 Integrating small-scale vegetable farmers to better access high end market in Dili: The case of Josephina Farms with contract farming

Dr Vicente Correia¹

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Increasing participation of small farmers into higher value markets has been recognized by governments and international agencies as an important factor for economic development and poverty reduction in many developing countries. Access to market for small farmers is important as this can enhance agriculture-based economic growth and increase rural incomes. The objective of study is to examine how vegetable farmers are link to the high end market through contract farming. The site of the study is Maubisse and Ermera and respondents are those farmers engage in the contracting arrangement with Josephina Farms and buyers in Dili. Data gathering methods include face-to-face interviews, RRA, desk top research of current and related literature. Data analysis applied was qualitative and quantitative analysis including case study and value chain analysis. The result of the study shows by involving in the contract farming farmers can increased their production and productivity of their crops, the risk faced in production and marketing is reduced, better access to high end market in Dili, better access to inputs and assistance and finally receive regular weekly cash payment. The study is also reveal from vegetable production alone can offer a significant improvement in income per farm household in the study area. This is really important as the majority of farmers are facing a number of problems and challenges including the farm site that is isolated, the size of farm which is small and there are difficulties in sustaining family income from other crops.

Key words: Marketing, contract farming, income, productivity



232 The developing of genotyping and its future

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Understanding and improving agricultural species depends upon the availability of genotyping techniques. Advances in molecular technologies have facilitated the continual development of faster and cheaper genotyping techniques. The progression of techniques from hybridization to PCR based to sequencing based methods can be tracked. The ultimate genotype is the whole genome sequence for the nuclear and organellar genomes. The complete methylome defining the exact methylation status of the genome is also now possible. As sequencing costs reduce and accuracy improves this becomes the preferred option, first for species with small genomes and then extending to larger genomes as the technology improves. Whole chloroplast genomes sequences are now a practical option for routine barcoding of plants. Because the chloroplast is present in the cell in very high copy number the sequence can be obtained at high quality from low pass sequencing of total DNA from the sample. Crops with small well characterized genomes such as rice are now candidates for re-sequencing as a method of nuclear genome genotyping. Sequencing to around 10X allows variant calling over the whole genome with little missing data and provides an increasingly attractive genotyping approach. For larger genomes enrichment (to remove repetitive elements) or targeting of the sequencing is required to reduce costs but it seems only a matter of time until this will no longer be necessary.

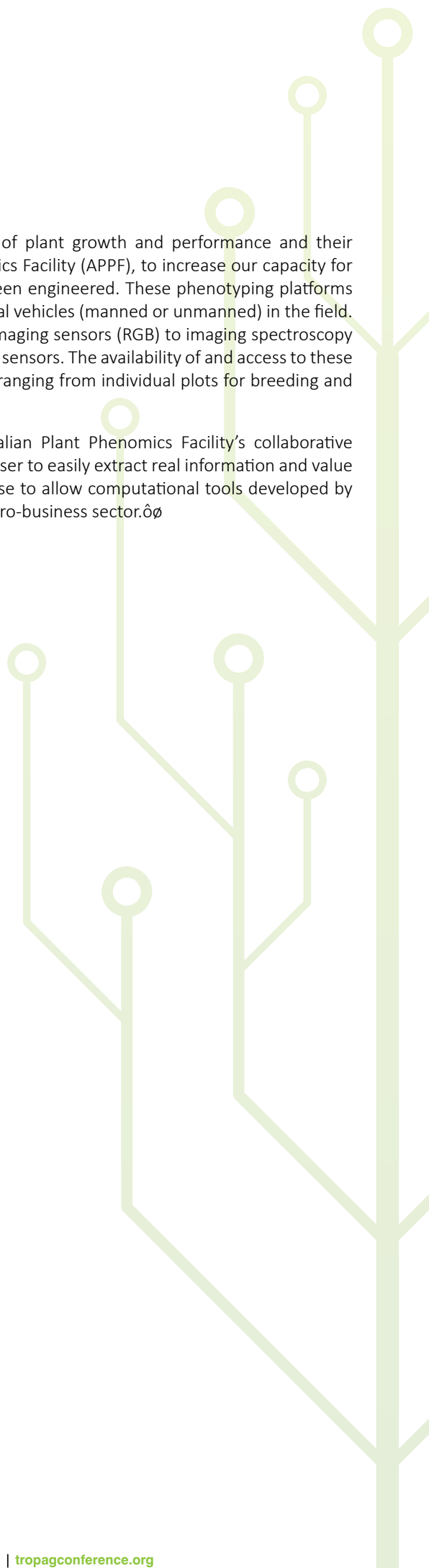
233 Automated phenotyping and analytics

Dr Michael Schaefer¹

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Plant Phenotyping is key to understanding the physiological and genetic bases of plant growth and performance and their application for crop improvement. In Australia within the Australian Plant Phenomics Facility (APPF), to increase our capacity for measuring plant traits, a range of high-throughput phenotyping platforms have been engineered. These phenotyping platforms range from automated systems in controlled environments to ground-based or aerial vehicles (manned or unmanned) in the field. These platforms offer a range of sensors that they integrate, ranging from visible imaging sensors (RGB) to imaging spectroscopy sensors or from thermal infrared (IR) sensors to Light Detection and Ranging (LiDAR) sensors. The availability of and access to these platforms for researchers and industry alike is transforming phenotyping at scales ranging from individual plots for breeding and physiological studies through to entire farms.

For analysis of the vast array of high-throughput phenotyping data, the Australian Plant Phenomics Facility's collaborative e-infrastructure platform phenoSMART⁰ is being utilised. This platform allows the user to easily extract real information and value from the data collected using phenotyping tools. The platform also serves as a base to allow computational tools developed by other research groups across Australia to become available to others and/or the Agro-business sector.∅



234 Statistical perspectives in the era of Big Data: Can dead fish read human minds?

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While mathematical thinking has evolved since ancient times, the theory of statistics applied in the scientific reasoning process has only become established over the past century. The science of biometrics had its beginnings in agricultural research at Rothamsted Research Station in the United Kingdom, through the work of RA Fisher (1920). The new discipline arose as field scientists and geneticists grappled with determining cause and effect relationships in the background of variation that is inherent in agricultural research. Over a century later we can now question and review the changing role of statistics in the era of big data.

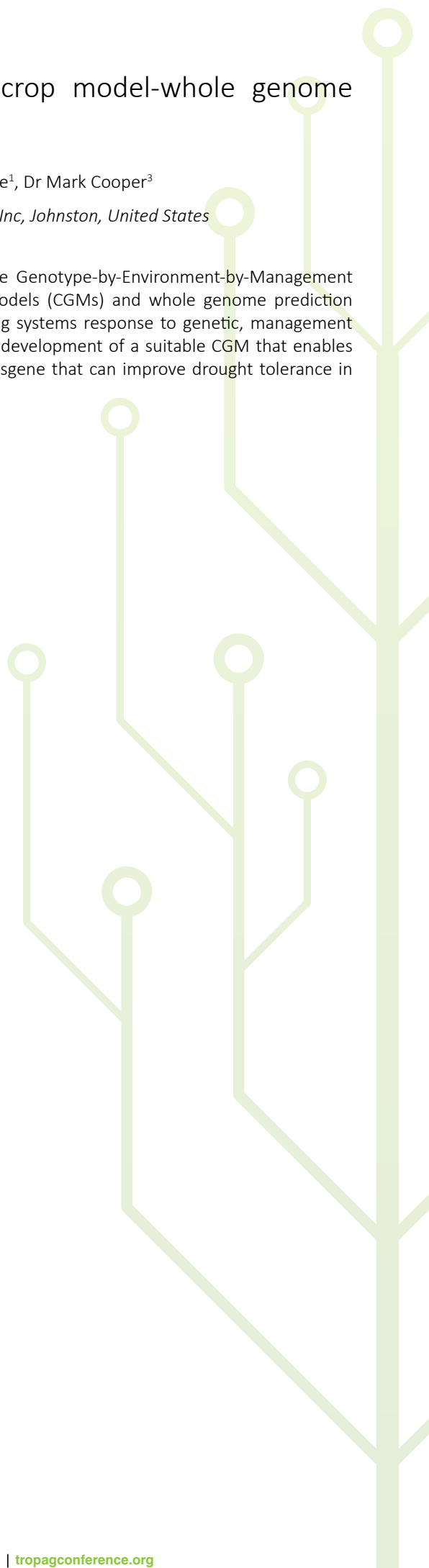
The principles of cause and effect will be explored by dissecting a study on neuro-imaging of atlantic salmon (Bennett et al., 2009). The experiment exposed (dead) atlantic salmon to different facial expressions in humans and measured changes in neuro-functioning in response to human emotion. The results are fascinating, and provide an ideal basis for exploring the role of statistics in the world of big data. The study demonstrates the danger of using black-box statistical approaches to multi-variate imaging data without an understanding of statistical theory and reasoning. More importantly, it reinforces the need for sound scientific process through forming a research hypothesis and devising an experimental design to ensure valid scientific findings, and hence robust conclusions from research.

235 Phenotypic prediction augmented through crop model-whole genome prediction: Application to ARGOS8

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Phenotypic prediction accuracy for yield is limited in agricultural systems where Genotype-by-Environment-by-Management (G×E×M) interactions are ubiquitous. Recent advances in fusing crop growth models (CGMs) and whole genome prediction (WGP) methods created opportunities to improve prediction accuracy of cropping systems response to genetic, management and environmental change. We demonstrate the methodology with focus on the development of a suitable CGM that enables establishing the proper link with quantitative genetic models, for ARGOS8, a transgene that can improve drought tolerance in maize.



236 Biotechnologies and the future of plant improvement

Prof Jimmy Botella¹

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Shortage of many 'important' human necessities such as cars, mobile phones or PlayStations are unlikely to start a revolution, but lack of food will surely do the trick. There are 7.5 billion people living in this planet and population keeps growing fast. Unfortunately the good old times when increasing agricultural production was just a case of sowing more wheat fields or raising more cattle are far gone as we are running out of land and water. We need to produce more whilst using less earth resources and while the green revolution led by Dr Norman Borlaug in the 1950's achieved an unprecedented increase in productivity we have now achieved a yield plateau in which even small improvements are difficult. Biotechnology can provide a new, and so far relatively unexploited, set of tools to accelerate agricultural improvement. Biotechnological methods allow to break the species barrier and transfer useful genes between different crops. Disease and insect resistance genes can now be incorporated into crops in which they don't naturally exist while drought tolerance traits can be transferred from dry environment plants to water thirsty crops. The advent of new technologies such as next generation sequencing and precise gene editing by CRISPR are spearheading a new biotech revolution providing more data that scientists can easily digest and allowing precise genome engineering in a way that was unthinkable just 5 years ago. New disciplines such as nanotechnology are complementing and potentiating the biotech possibilities with the creation of new materials and new applications.

237 Biofutures – Opportunities for agriculture in biobased fuels and bioproducts

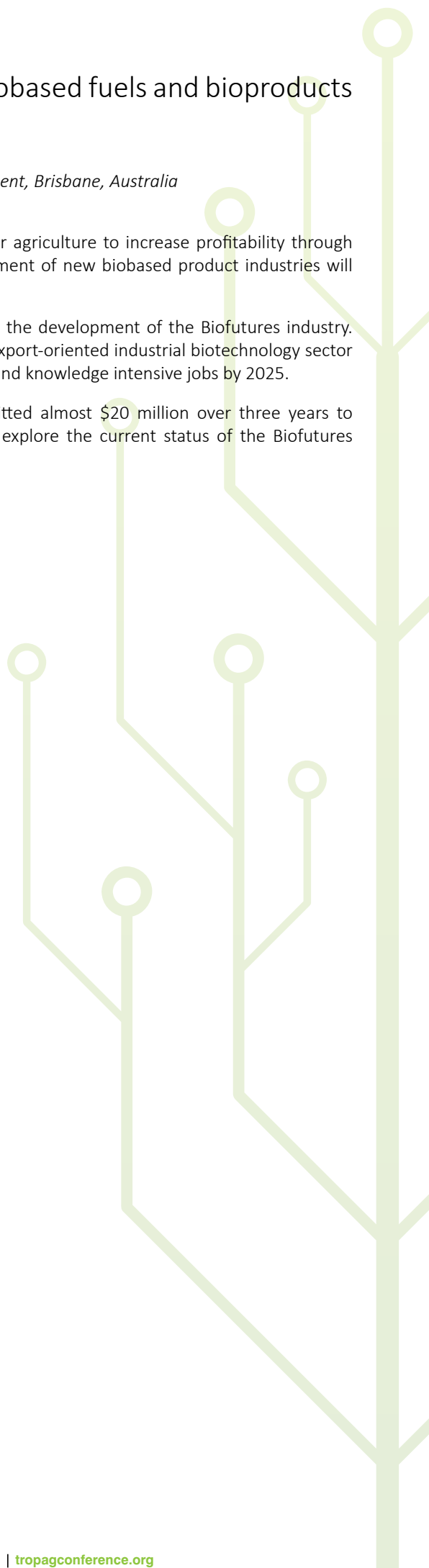
Prof Ian O'Hara^{1,2}

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The production of biobased fuels and products offers significant opportunities for agriculture to increase profitability through revenue diversification and adding value to wastes and coproducts. The development of new biobased product industries will create jobs in rural and regional Queensland.

In 2016, the Queensland Government developed a Roadmap and Action Plan for the development of the Biofutures industry. The Roadmap and Action Plan identifies the vision of a \$1 billion sustainable and export-oriented industrial biotechnology sector attracting international investment and creating thousands of regional, high value and knowledge intensive jobs by 2025.

Supporting this roadmap and action, plan, the Queensland Government committed almost \$20 million over three years to stimulating the industrial biotechnology and bioproducts sector. This paper will explore the current status of the Biofutures industry in Queensland and describe progress in the development of the sector.



238 Discovery, evaluation and manufacture of new livestock feed supplements

Assoc Prof Robert Speight¹

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Animal feed typically contains a variety of different types of supplements to help livestock digest the feed and remain healthy. These supplements include probiotics and digestive enzymes. Probiotics are live microbial cells that can enhance the health and performance of an animal and enzymes are added to help break down feed to release extra energy and nutrients. The discovery, evaluation and development of new probiotic and enzyme supplements will be discussed, particularly for inclusion in feeds based on low-cost fibrous ingredients such as sugarcane bagasse. The microbes that naturally exist and thrive in distinct environmental niches in sugarcane bagasse stockpiles may have adapted to this material. Each niche contains microbes with distinct characteristics and enzymes for surviving in each environment. These microbes are thus a potential resource for the discovery of feed supplements.

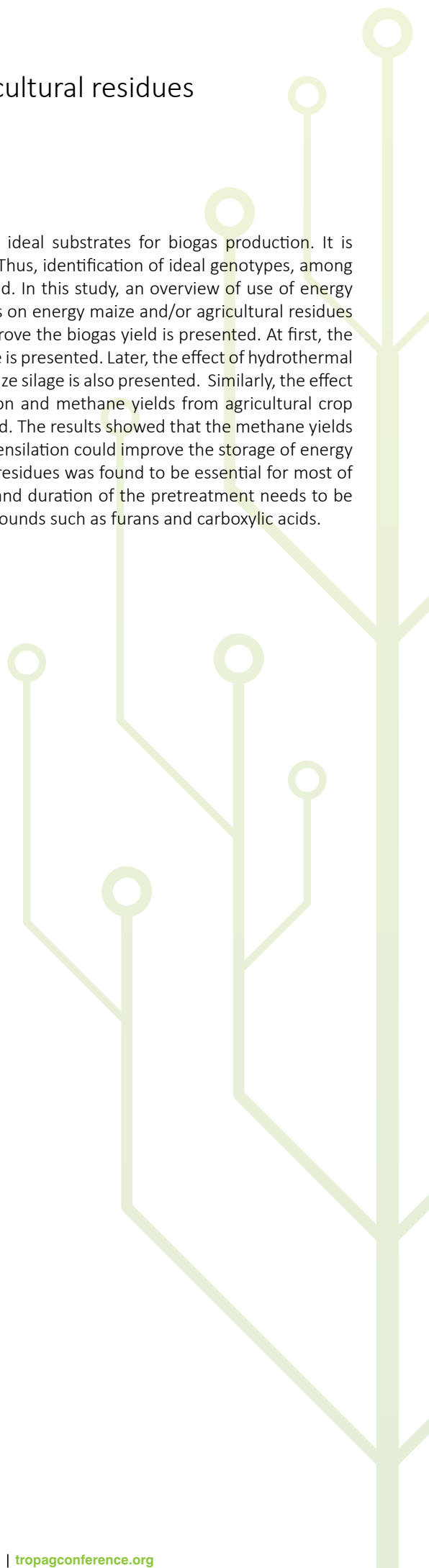
For supplements to be commercially successful they must be manufactured economically, be proven to deliver livestock benefits and be approved in target geographical areas and for specific livestock markets. A new collaborative project will also be presented that is aiming to increase the speed, efficiency and reliability of new supplement discovery commercialisation from the lab to the market. The project is closely integrating fermentation process development with livestock trials to enable rapid information feedback for improved supplement discovery, design and manufacture and to accelerate the path to commercial products.

239 Biogas production from energy crops and agricultural residues

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¹Griffith University, Nathan, Australia

Lignocellulosic biomass such as energy crops and agricultural crop residues are ideal substrates for biogas production. It is anticipated that the use of lignocellulosic biomass will increase in the near future. Thus, identification of ideal genotypes, among other things optimum storage and pretreatment technologies should be developed. In this study, an overview of use of energy maize as substrates for biogas production and the effect of different pretreatments on energy maize and/or agricultural residues such as energy maize, sugarcane bagasse, sunflower stalks and/or sorghum to improve the biogas yield is presented. At first, the effect of ensilation on the chemical composition and methane yields of energy maize is presented. Later, the effect of hydrothermal pretreatment on chemical composition and methane yields from the pretreated maize silage is also presented. Similarly, the effect of different chemical and/or hydrothermal pretreatments on chemical composition and methane yields from agricultural crop residues such as sunflower stalks, sugarcane bagasse and sorghum stalk is presented. The results showed that the methane yields from maize silages were comparable to that of fresh energy maize suggesting that ensilation could improve the storage of energy crops for year round feedstock supply. Similarly, pretreatment of agricultural crop residues was found to be essential for most of the lignocellulosic biomass to improve the methane yields. However, the dosage and duration of the pretreatment needs to be optimized in order to prevent inhibition due to the intermediate degradation compounds such as furans and carboxylic acids.



240 Converting agricultural wastes into valuable products

Dr Paul Jensen¹

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Agricultural industries are among the largest land users and water consumers within Australia; and generate large volumes of wastewater and solid waste rich in organic contaminants, nutrients and metals. Management of these wastes is a significant cost exceeding AUD\$200M per year in the animal industries alone. However, recent advances in process design and environmental biotechnology are creating significant opportunities to reduce water use, recover resources and develop new and sustainable value-add products.

Traditional waste-to-energy technologies, such as anaerobic digestion and biogas production are commercially advanced. While AD is an effective technology to offset fossil energy and reduce greenhouse emissions, many agricultural wastes have moderate to poor biodegradability and therefore anaerobic digestion processes utilize only some of the carbon available in the agricultural wastes. AD processes can also be a useful method to mobilise nutrients for downstream capture, however additional technologies are generally required to realise the value of these components.

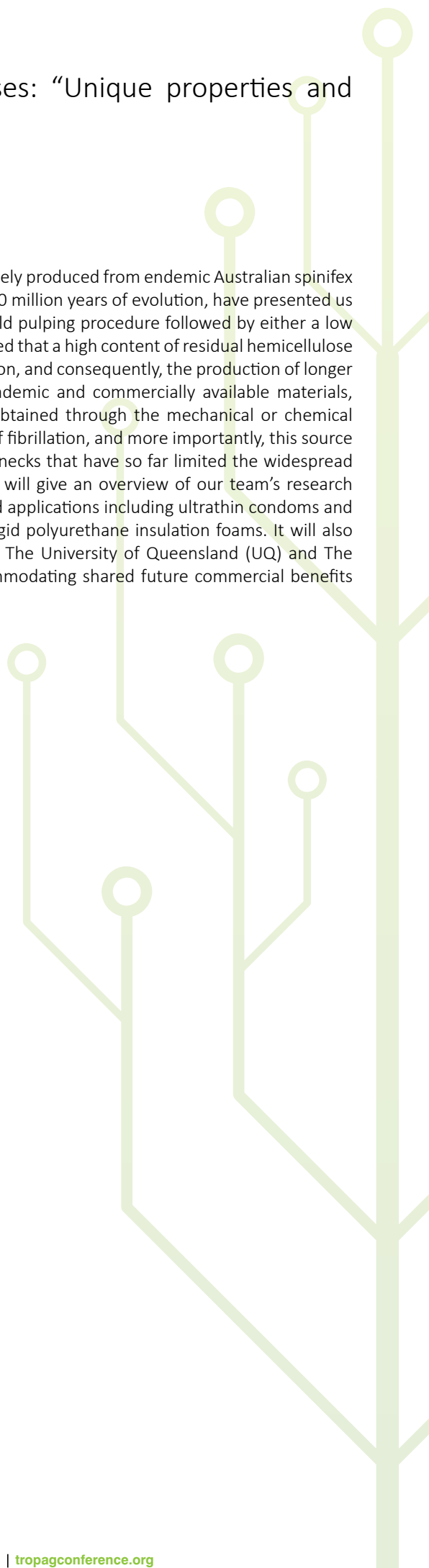
Rapid advances in biotechnology are creating a range of other 'waste-to-value' options with higher revenue potential that utilise a broader fraction of the waste (that includes carbon in the form of protein, fats, starch, lignocellulose, bioplastics, biocomposites, carbon dioxide and methane; and nutrients such as nitrogenous compounds, phosphate, vitamins, amino acids and trace elements such as metal ions). These new technologies, and the diverse products they produce create competition for the bio-chemical components of waste streams. However, not all wastes are equal. Careful technology selection and application of novel technology combinations is increasingly required to maximise commercial value from wastes.

241 Cellulose nanofibres from spinifex arid grasses: “Unique properties and applications under development”

Prof Darren Martin¹

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We recently discovered that a unique type of cellulose nanofibre can be cost-effectively produced from endemic Australian spinifex grasses from the *Triodia* genus. These fascinating extremophile grasses, with over 20 million years of evolution, have presented us with a most unique source for nanocellulose. Our fibrillation process involves a mild pulping procedure followed by either a low mechanical energy treatment or a mild sulfuric acid hydrolysis. We have demonstrated that a high content of residual hemicellulose and lignin in bleached and unbleached pulp results in superior cell wall deconstruction, and consequently, the production of longer and more flexible nanofibres. When benchmarked against the other leading academic and commercially available materials, spinifex nanofibres have the highest aspect ratio compared against nanofibres obtained through the mechanical or chemical treatments of the other sources of cellulose. This novelty means that our method of fibrillation, and more importantly, this source of cellulose have the potential to directly address the current technological bottlenecks that have so far limited the widespread translation of nanocellulose technology into more applications. This presentation will give an overview of our team's research and technology development activities including spinifex nanofibre production, and applications including ultrathin condoms and gloves, polymer composites, enhanced recycled paper and board products and rigid polyurethane insulation foams. It will also introduce a landmark umbrella agreement and commercial partnership between The University of Queensland (UQ) and The Indjalandji-Dhidhanu traditional owner group, which provides a framework accommodating shared future commercial benefits and Indigenous economic development from the generated IP.



242 *Brassica carinata*: The sky is the limit

Dr Anthony van Herwaarden¹, Dr Christopher Lambrides¹, Mr Hank Krakowski², Dr Daryl Males², Dr Rick Bennett², Dr Phillip Salisbury³, Mr Trent Potter⁴

¹The University of Queensland, St Lucia, Australia, ²Agrisoma Biosciences Inc., Gatineau, Canada, ³The University of Melbourne, Parkville, Australia, ⁴Yerunga Crop Research, Naracoorte, Australia

The current global jet fuel consumption is 300 billion litres annually and expected to grow to 500 billion litres annually by 2030. The aviation industry has committed to a carbon neutral future targeting a 50% reduction in CO₂ by 2050. While biofuels are currently mandated in 62 countries around the world, and demand for renewable diesel and jet fuels is the most rapidly growing segment of the renewable fuels industry, the 'biojet' component has approximately 100 billion litres of demand that is currently not being met.

Biojet fuels produced from Carinata (*Brassica carinata*) oil have already been used successfully in both commercial and engineering flights, including the world's first 100% biojet fueled flight. Today many flights are powered by biojet fuels. With 40% erucic acid content, Carinata offers manufacturers more efficient conversion into biojet fuel with reduced amounts of secondary products compared to other industrial oilseeds and bio-waste streams. Commercial Carinata operations are established on three other continents so this project focuses on genetic selection, adoption and scale-up within the Queensland agricultural environment.

Carinata is reputedly tolerant of heat and drought which means it can be grown on some of the most challenging farmland where winter-broadleaf crop options are limited. We will present results from our fieldwork selecting adapted lines with the correct phenology for Australian environments and efforts towards introduction and scale-up of a renewable and sustainable source of high quality oil for bio-fuels, feedstock for bio-plastics and the remaining high-protein meal used in formulation of animal rations.

243 Expected market opportunities and demand profiles for tropical pulses to 2022

Mr Peter Wilson¹

¹*Agt Foods Australia, Toowoomba, Australia*

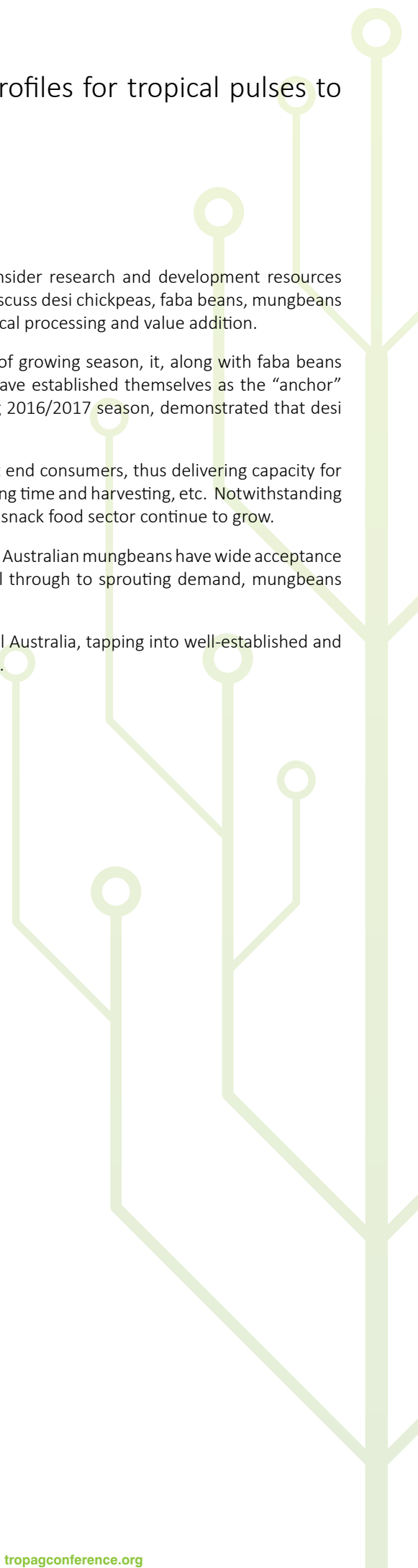
TropAG2017 affords the pulse industry in tropical Australia, an opportunity to consider research and development resources available, and consider the best means to deploy these funds and initiatives. We'll discuss desi chickpeas, faba beans, mungbeans and the future found in pigeon peas or Toor into the future; plus opportunities for local processing and value addition.

The big game in town, for the foreseeable future, will be desi chickpeas. In terms of growing season, it, along with faba beans benefit greatly from tropical moisture over the summer months. Desi chickpeas have established themselves as the "anchor" of the northern Australian pulse industry. Producing around 2 million tonnes during 2016/2017 season, demonstrated that desi chickpeas are delivering farm profitability and rotational sustainability.

Faba beans provide significant benefit to agronomic rotations; marketed to different end consumers, thus delivering capacity for farmers to manage market exposure and provide agronomic flexibility regarding seeding time and harvesting, etc. Notwithstanding current difficulties in Egypt, markets for split faba beans and whole beans within the snack food sector continue to grow.

Mungbeans deliver a genuine gross margin and rotational choice for northern farmers. Australian mungbeans have wide acceptance into both bulk and refined end market consumers. From manufacturing mung dhal through to sprouting demand, mungbeans seem destined to grow in influence into the future.

Pigeon Peas have opportunity to develop into a second option for farmers in tropical Australia, tapping into well-established and large markets in the Indian sub-continent and parts of Africa and Asia into the future.



244 Sustainability and profit drivers for tropical pulses in sustainable cropping systems

Prof Michael Bell¹

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Tropical pulses can make a significant contribution to the productivity of cropping systems in the tropics and subtropics, with their general under representation in both intensive and extensive crop rotations contributing to the emergence of a growing number of challenges to both sustainability and profitability. These include a growing reliance on increasingly expensive external sources of nutrients to balance removal in harvested produce, development of a suite of specific and non-specific soil-borne pathogens that limit grain crop productivity and the development of weed resistance to a number of important herbicide modes of action.

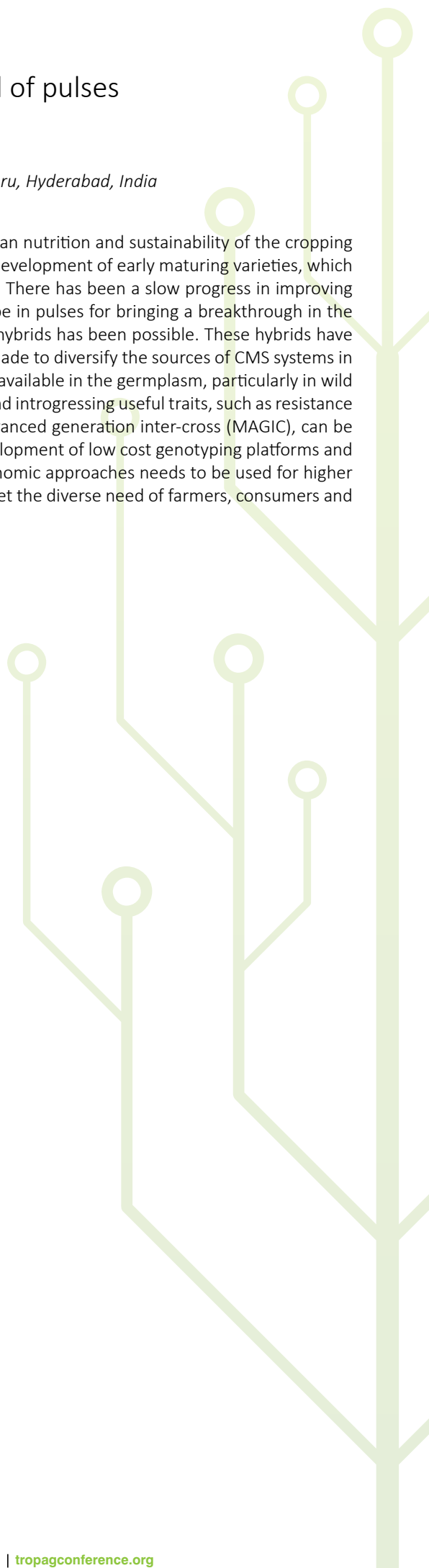
Pulses offer a more diverse and in some cases very effective solution to some of these issues. They allow focus on non-nitrogenous nutrient inputs during at least part of the crop rotation, can provide a non-host for major soil-borne cereal pathogens and provide an opportunity to rotate herbicide modes of action. However, the diversity and relatively small scale of the various tropical pulse industries has led to a lack of intensive research effort on many species. This has led to deployment of less well adapted genotypes or ones that are less effective in delivering systems benefits, contributing to perceptions that pulse crops can be 'risky' to grow and not very effective rotation options. An intensified research effort to understand the nuances of choice of different tropical pulse species and genotypes on addressing the various cropping systems challenges is needed, as well as improving the robustness of tropical pulse performance in response to contrasting soil and climatic challenges.

245 Breeding strategies to unlock genetic potential of pulses

Dr Pooran M Gaur¹

¹*International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad, India*

Pulses are globally grown in about 85 million ha and play an important role in human nutrition and sustainability of the cropping system productivity. One of the major achievements in pulses improvement is the development of early maturing varieties, which has helped in expanding cultivation of pulses to new niches and cropping systems. There has been a slow progress in improving productivity of pulses. Concerted efforts are needed on restructuring the plant type in pulses for bringing a breakthrough in the productivity. Pigeonpea is the only pulse crop where development of commercial hybrids has been possible. These hybrids have given 25 to 40% higher yield than the varieties at farmers' fields. Efforts are being made to diversify the sources of CMS systems in pigeonpea and develop hybrids in different maturity groups. The genetic variability available in the germplasm, particularly in wild species, of pulses should be exploited for broadening the genetic base of varieties and introgressing useful traits, such as resistance to insect-pests and diseases. Novel breeding approaches, such as multi-parent advanced generation inter-cross (MAGIC), can be used for enhancing genetic recombination. There has been a rapid progress in development of low cost genotyping platforms and genomic resources for pulses in the recent years. Integrated breeding involving genomic approaches needs to be used for higher precision and efficiency of breeding programs so that improved varieties, which meet the diverse need of farmers, consumers and the industries, can be developed rapidly.



246 New genetic tools and solutions to make pulse crops more resilient to variable climates

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¹Centre for Tropical Crops and Biocommodities, Queensland University of Technology (QUT), Brisbane, Australia

Chickpea is one of the world's most economical sources of protein for food and feed. It is also high in the essential amino acids lysine and methionine and thus nutritionally complementary to the cereals which are deficient in both these amino acids. Despite this importance, the gap between production and increased consumption of chickpea continues to widen, globally. With this increased global demand comes unprecedented opportunities for Queensland agriculture. While we have some natural advantages, increasing Queensland pulse production also has inherent challenges. Abiotic stresses, mainly drought and salinity, and pathogens such as *Botrytis grey* mould significantly hinder chickpea production. To ensure continued production in future environments we must develop strategies to improve stress tolerance of crops. In 2013, the Queensland Government made a strategic investment in the QUT-DAF Tropical Pulses for Queensland (TPFQ) research program aimed to develop and deliver effective technologies and solutions that address industry challenges limiting the production of tropical pulses in Queensland. A major goal of the TPFQ project was the development of an efficient chickpea transformation system for the generation of stress tolerant, pathogen resistant chickpea, as well as chickpea that accumulate high levels of bioavailable iron. Here we present outputs from the generation and assessment of transgenic chickpea developed in the TPFQ project. It is envisioned that outputs from this project will substantially assist the Queensland Government in delivering their vision to double agricultural production by 2040.

247 Physiological, agronomic and modelling approaches to optimise productivity of tropical pulses

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Although there is awareness about the importance of food legumes in human, animal and soil health, development and adoption of technologies for legume crops improvement is not proceeding at the same pace as for cereal crops. Since the 1960s, cereal and oilseed crop production increased by 800%, compared to only 54% in pulses over the same period.

Although the Australian mungbean and chickpea production has nearly tripled in the past 3 years the average yield however has remained at 1.15 t/ha and the yields in developing countries have even declined over the past decade due to subsoil constraints and by ongoing climate change. The increasing market demand coupled with scanty information on how to manage pulses has added urgency to the research effort, which historically has been done in a somewhat piecemeal way.

Most of the legumes have evolved under subsistence farming conditions with some unique intrinsic physiological traits such as adaptation to marginal soils, little response to inputs, indeterminacy and N-fixation capacity etc. While these traits satisfied the requirements of the era of subsistence farming, there is a need to develop better yielding genotypes and innovative agronomy to optimize resource use in a given environment. Resource capture models can be pro-actively used as a tool to simulate yield variation due to genotype, environment and management.

This paper explores physiological constraints limiting the yield of mungbean and chickpea in tropics and sub-tropics discusses avenues for future research.



248 The past is history: A case study of Queensland's successful chickpea industry

Dr Merrill Ryan¹, Mr William Martin¹, Mrs Penny Borger¹

¹DAF Qld, Warwick, Australia

2016, the International Year of Pulses, saw chickpea (*Cicer arietinum* L.) reaffirm its position as Queensland's most profitable grain crop worth a forecast \$793M. This was driven by record sowings, high grain prices and availability of resilient and profitable Australian-bred chickpea varieties.

Desi chickpea varieties were first released and sown in Australia, here in Qld in 1979. For nearly 40 years there has been continuous effort by DAF Qld in developing varieties with superior grain yield, plant height and export grain quality. The Qld crop accounts for 55% of the 1.3MT national crop, grown in Southern and Central Qld and now as far north as Georgetown in North Qld.

Thirty years of successful breeding in national collaborative projects, most recently led by NSW, has been underpinned by an integrated, across discipline effort in the areas of genetics, agronomy management packages, specific support in pathology, fungicide spray regimes, entomology thresholds and seed quality parameters.

Major disease threats have focussed much of our chickpea research. Phytophthora root rot (*P.medicaginis*) remains a key problem to solve and novel approaches of sourcing resistance genes from the wild relative genepool such as *Cicer echinospermum* have been utilised. In 1998, an *Ascochyta* blight (*Phoma rabiei*) epidemic decimated the Australian chickpea industry. *Ascochyta* resistance genes continue to be sourced from overseas germplasm to effectively combat this ongoing threat.

Research innovation has driven a remarkable success story for chickpea and given industry the tools to reliably produce the chickpeas our global customer's desire.

249 A research effort to improve subtropical and tropical tree crop productivity through intensification

Dr John Wilkie¹

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The intensification of temperate tree crop orchard systems over recent decades, in particular apple, have been accompanied by large increases in productivity. We are attempting to adapt relevant principles from this intensification and the associated understanding of the orchard system physiology that underlies productivity to subtropical and tropical tree crops, which are generally still grown in extensive systems. We are working with three tree crops: macadamia, avocado and mango.

We have identified four components of orchard systems in these subtropical and tropical tree crops that we believe require improved understanding and improved ability to manage in order to increase productivity: vegetative vigour, development of crop load, tree architecture and orchard light relations. In addition to studying these orchard systems components in isolation, we are also undertaking experimentation that allows us to examine the effects of the interactions between them on the productivity of the system.

The first of the integrating activities is Planting Systems Trials where we are investigating the effects of plant density and rootstock (avocado) or plant density, tree training system and scion cultivar (mango and macadamia) on productivity. The second of the integrating activities is Functional – Structural Plant Modelling, which is being used to simulate effects of orchard configurations on the orchard light environment and effects of management on competition between vegetative and reproductive growth. Finally, a molecular biology component of work is being undertaken and used as a tool to help understand the underlying physiology, in particular the timing and location of floral initiation.



250 Diurnal variation in the sensitivity of 'Honey Gold' mango fruit to developing under-skin browning

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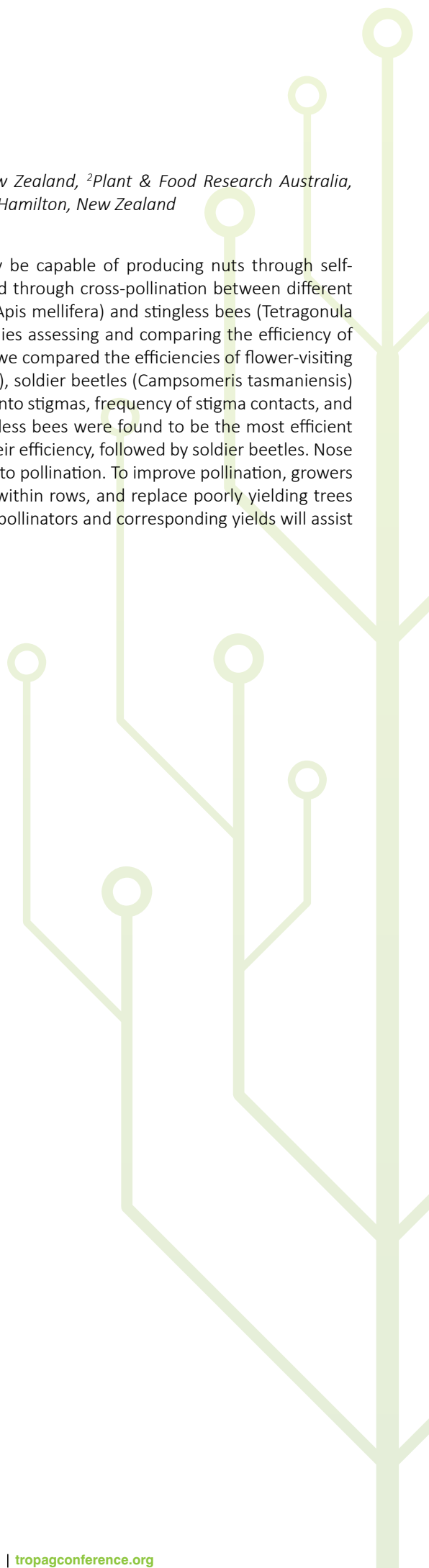
Under-skin browning (USB) is an unsightly physiological disorder that afflicts 'Honey Gold' mango fruit. USB symptoms express after harvest upon the interaction of physical abrasion and physiological chilling stresses. Less understood pre-harvest and / or harvest factors evidently also influence fruit susceptibility to USB. The effect of harvest time during the diurnal cycle on propensity to develop USB was examined. Fruit were harvested at 4- 6 hour intervals over a diurnal cycle. They were lightly abraded with sandpaper to simulate vibration damage during refrigerated road transport, then held at 12-14°C for 6 days. Spurt and ooze sap that exudes from fruit peduncles was collected at each harvest time. The samples were separated and analysed by GC-MS. Fruit harvested at 1000, 1400, and 1800 hours exhibited 3- 5-fold higher incidence of USB than those picked at 2200, 0200, and 0600 hours. Sap concentrations of the key aroma volatile compounds 2-carene, 3-carene, α -terpinene, p-cymene, limonene, and α -terpinolene were higher for fruit harvested at 1400 hours as compared to those picked at other times. In the afternoon harvest fruit, skin abrasions treated with spurt sap sampled at 1400 hours had 14.3-fold and 29.0-fold higher incidence and severity, respectively, of induced browning than did those treated with sap collected at 0600 hours. The results showed that fruit harvested in the afternoon were more susceptible to USB than those picked at night or in the early morning. The diurnal variation in sensitivity was evidently associated with temporal variation in sap phytotoxicity.

251 Pollination of macadamia

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Although cultivated macadamia (*Macadamia integrifolia* and *M. tetraphylla*) may be capable of producing nuts through self-pollination, studies strongly suggested that improved final nut set can be achieved through cross-pollination between different cultivars. To achieve cross-pollination, insect pollinators, particularly honey bees (*Apis mellifera*) and stingless bees (*Tetragonula carbonaria*) are considered important for vectoring pollen. However, detailed studies assessing and comparing the efficiency of different flower-visiting insects in macadamia remain very limited. To address this, we compared the efficiencies of flower-visiting insects – honey bees, stingless bees, net winged beetles (*Metriorrhyncus rhipidius*), soldier beetles (*Campsomeris tasmaniensis*) and nose flies (*Stomorhina discolor*) – by assessing their abilities to deposit pollen onto stigmas, frequency of stigma contacts, and movement patterns between racemes. Based on these combined measures, stingless bees were found to be the most efficient pollinators. Nectar-collecting honey bees and net winged beetles were similar in their efficiency, followed by soldier beetles. Nose flies were the least efficient of the insects assessed; however, they still contributed to pollination. To improve pollination, growers should promote insect cross-pollination by planting a mix of cultivars, preferably within rows, and replace poorly yielding trees within single-cultivar blocks with a different cultivar. Monitoring the abundance of pollinators and corresponding yields will assist growers in improving future pollinator management strategies.



252 Breeding for adaptation during climate change: Hitting a moving target

Dr Jose Chaparro¹

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Climate Change is reducing the number of chill (0-7.2 C) hours available for the normal growth and development of temperate tree crops. The cumulative chill hours for Alachua County, FL for the 2015-2016 and 2016-2017 peach production seasons were 59% and 50% of the long-term average of 457 hours, respectively. This lack of chilling is creating highly unpredictable cropping for existing peach cultivars in the southeastern US, reducing the peach crop by at least 75% for the 2017 season in central Georgia alone. During the past 65 years, the University of Florida Stonefruit breeding program has focused on breeding low chill and subtropical peach cultivars. The experience obtained in adapting a temperate crop to a subtropical climate can be used to predict the expected impacts of global warming on peach production. We have initiated an effort focused on developing peach selections adapted to high frequency no chill conditions experienced in the southern most range of peach production in Florida. Difficulties encountered during the development of subtropical peaches will be discussed, a few are: delayed bud break, low yield, poor shape and small fruit size.

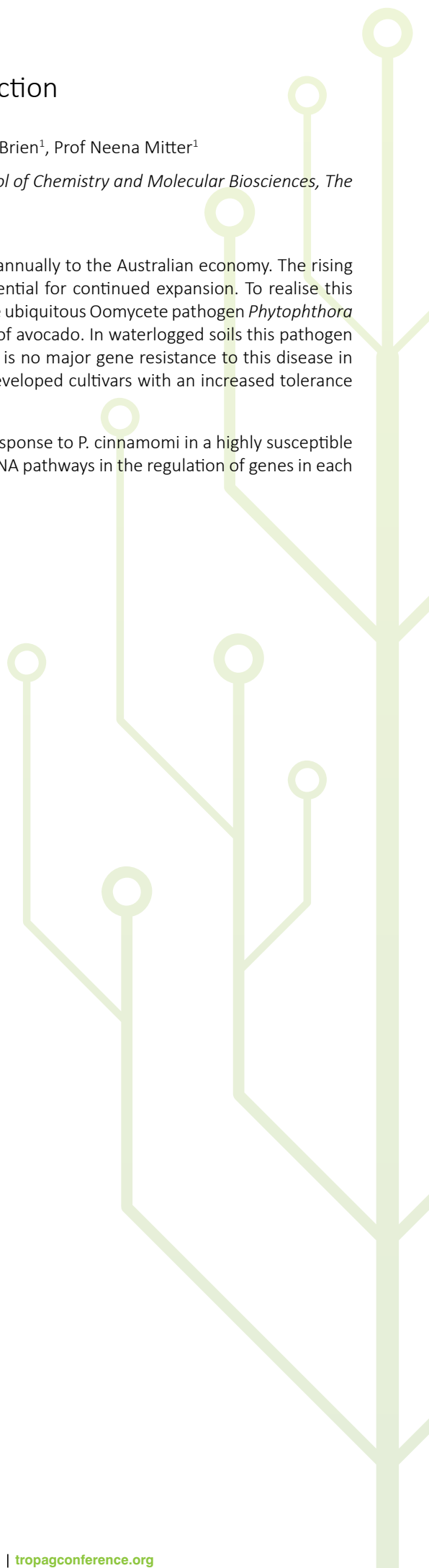
253 Insights into the Avocado-*Phytophthora* interaction

Dr Alice Hayward¹, Mr Stephen Fletcher^{1,2}, Madeleine Gleeson¹, Mr Christopher O'Brien¹, Prof Neena Mitter¹

¹Queensland Alliance for Agriculture and Food Innovation, St Lucia, Australia, ²School of Chemistry and Molecular Biosciences, The University of Queensland, St Lucia, Australia

Avocado (*Persea americana* Mill.) is a subtropical horticultural crop worth \$920M annually to the Australian economy. The rising popularity of avocado has seen the industry grow 65% since 2003, with vast potential for continued expansion. To realise this potential requires research towards sustainable control of major disease threats. The ubiquitous Oomycete pathogen *Phytophthora cinnamomi*, casual agent of root-rot, is the most economically devastating disease of avocado. In waterlogged soils this pathogen can rapidly decimate an orchard, with young plants particularly susceptible. There is no major gene resistance to this disease in commercial avocado rootstocks, however a number of breeding programs have developed cultivars with an increased tolerance to the disease.

This project is using transcriptome and smallRNA data to compare the molecular response to *P. cinnamomi* in a highly susceptible cultivar (cv Reed) versus a tolerant cultivar (cv Velvick). The potential role of small RNA pathways in the regulation of genes in each pathosystem will be discussed.



254 A new approach in oil palm harvesting Improvement

Miss Wan Rusydiah W Rusik¹, Mr Mohd Zulfahmi Mohd Yusoff², Mr Mohaimi Mohamed¹, Mr Ahmad Zamri Md Yusof², Dr David Ross Appleton¹, Dr Harikrishna Kulaveerasingam³

¹Biotechnology & Breeding Department, R&D Centre, Sime Darby Plantation Sdn Bhd, Banting, Malaysia, ²Advanced Mechanisation & Robotics, R&D Centre, Sime Darby Plantation Sdn Bhd, Banting, Malaysia, ³R&D Centre, Sime Darby Plantation Sdn Bhd, Banting, Malaysia

In recent years, labour shortage has been one of the major challenges to oil palm industry. Being a labour intensive industry, it requires high labour per area ratio to operate efficiently. The major tasks in field operations are the harvesting, collection and evacuation of the oil palm fresh fruit bunches (FFB). Harvesting of the oil palm FFB requires skilled labours especially for tall palms. Research and operational efforts to introduce mechanisation in field operations has been established, however, the operational implementation is low due to below average acceptance by the industry. In trying to be part of the efforts in mechanisation, we have embarked on a project to breed long stalk oil palm FFB of more than 20cm to make harvesting easier and at the same time to develop and design new harvesting tools to complement this long stalk trait to make harvesting effortless, more productive and efficient. Three designs of harvesting tools are proposed in this paper which is expected to increase the productivity in harvesting FFB as well as reducing fatigue and energy expenditure of the harvesters.

255 The tropical aquaculture powerhouse – Global impacts and opportunities for Australia

Dr Nigel Preston¹

¹*University of Queensland, Brisbane, Australia*

Three-quarters of countries where fish contributes more than one-third of animal protein in the diet are low-income, food-deficit, tropical countries where fish is often the cheapest and most accessible animal-source food. To meet future demand, particularly in these developing countries, fish production will need to double by 2030. Over the past two decades the growth of tropical aquaculture has been phenomenal with clearly demonstrated impacts on reducing poverty and improving food security. Meanwhile, the production of animal protein from terrestrial agriculture in tropical countries is facing critical constraints including intense competition for land and increasingly variable supplies of freshwater. In contrast, farming of marine and estuarine fish, crustaceans and molluscs is free from these constraints. There are vast tracts of tropical coastlines, including desert coastlines, that are unsuitable for agriculture but highly suitable for saltwater aquaculture. This is a huge competitive advantage for marine and estuarine aquaculture. However, efforts to sustain or accelerate the growth of tropical aquaculture must address the key challenges of; breed improvements, managing disease, developing more sustainable feeds, improving environmental management and socially equitable distribution of the benefits of aquaculture. This presentation illustrates some species-specific examples of these challenges how they are currently being addressed and the potential benefits of emerging technologies. It also highlights the opportunities for Australia, including the potential for a step-change in sustainable domestic tropical aquaculture production, the global impacts of some of Australia's current tropical aquaculture research and some key areas for additional, high-impact, research in this domain.



256 Meeting the growing demand for aquaculture - Balancing biological requirement, sustainability and environment

Dr Richard Smullen¹

¹*Ridley Agrifoods, Australia*

The demand for fish protein is increasing and in the market place, this is competing with other protein sources such as beef, pork and poultry. Aquaculture globally is growing to meet this demand and compared to other livestock, fish are known to be the more efficient converters of feed. Yet as an industry, there is growing internal and external demand for greater sustainability and better use of overall resources. As feed is the major farm input both financially and environmentally, this is typically the first port of call for the industry when looking to meet a growing demand for environmental responsibility. As such, the focus on sustainable sourcing of raw materials, while maintaining cost relevance and still meeting environmental output targets on the farm has been growing constantly. This talk gives an overview of the demands on the sector and how the industry has to balance new raw material development, the changing environment and financial considerations while still meeting the biological requirement of the target species.

257 Making aquaculture sustainable in the tropics – Growing algae to reduce nutrification and produce high-value products

Mr Arnold Magnott¹

¹*MBD Energy Ltd, East Melbourne, Australia*

Nutrient rich wastewater from the agriculture or aquaculture industry can lead to eutrophication of sensitive ecosystems. The expansion of the QLD aquaculture industry is heavily regulated due to its proximity to the GBR Marine Park. All new development need to abide to a zero net environmental impact, which has restricted all growth of the aquaculture industry in Queensland over the last 16 years.

MBD has spent several years piloting scaled land-based and on-farm cultivation of macro algae (seaweed) to remediate waste water from actual aquaculture sites. The successfully developed low-cost bioremediation technology guarantees clean discharge water which enables the industry to increase their operation capacity while conforming to strict legislation. This working solution has attracted aquaculture companies from Australia and overseas.

MBD is currently integrating its algae bioremediation technology into two of the largest prawn production companies in Australia and Vietnam. The new development in Australia (2018) will comprise of 259ha with approximately 25ha of algae to remediate the nitrogen and recycle the waste water. The scale in Vietnam will be 10 fold.

For each kg of nitrogen removed MBD will produce 25kg of valuable seaweed. Algae products from these commercial developments are targeting high value products for fertiliser, feed, food and human health supplement markets.



258 Breeding for disease resistance in Australian shrimp: How do we get there?

Miss Tansyn Noble^{1,2}, Dr Greg Coman², Dr Nick Wade², Prof Dean Jerry^{1,2}

¹James Cook University, Townsville, Australia, ²CSIRO, Brisbane, Australia

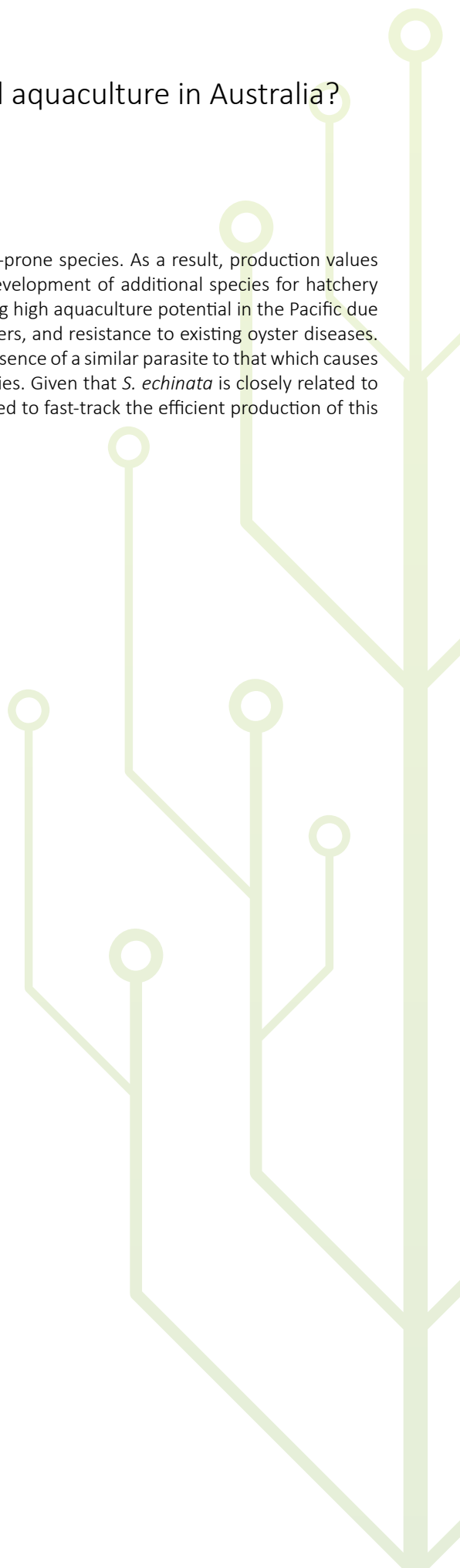
Shrimp farming is a highly valuable aquaculture industry globally. In Australia, the shrimp farming industry is worth over \$86 million with plans for massive expansion, particularly in northern Australia. Disease is the single biggest threat to shrimp production globally. Management of disease in overseas production has been through the use of domesticated and specific pathogen free (SPF) stocks, which has allowed farming of shrimp to continue, although disease remains a big problem. Selective breeding is thought to be a more effective long term disease management strategy. So far, breeding disease resistant shrimp has been accomplished for very few diseases using laboratory challenge tests, sib-selection and conventional breeding methodologies. Highly pathogenic diseases such as that caused by white spot syndrome virus (WSSV) still cause tremendous production losses globally, including recently in Australia. Improved accuracy of selection and increased selection intensity is needed if disease resistant shrimp are to be fully realised. Genomic selection offers the potential to significantly advance shrimp selective breeding particularly for complex traits like disease resistance. In Australia, a breeding program is currently underway developing and applying new and improved methods for selection for disease resistance in shrimp. This presentation will provide an overview of how disease has been managed in the past and how disease resistant shrimp will become a reality in Australia.

259 The blacklip oyster – An alternative for tropical aquaculture in Australia?

Dr Carmel McDougall¹

¹Griffith University, Nathan, Australia

The Australian edible oyster aquaculture industry is wholly reliant on two disease-prone species. As a result, production values have been in decline since 2010. One potential solution for the industry is the development of additional species for hatchery production. The 'blacklip oyster' (*Saccostrea echinata*) has been identified as having high aquaculture potential in the Pacific due to its tolerance of environmental fluctuations, fast growth, acceptance by consumers, and resistance to existing oyster diseases. However poor larval survival in culture is a current barrier to production, and the presence of a similar parasite to that which causes QX indicates that disease mitigation strategies may also be important for this species. Given that *S. echinata* is closely related to the Sydney rock oyster, I outline how comparative molecular techniques can be used to fast-track the efficient production of this species.



260 In-vitro oocyte maturation by radial nerve extract and fertilization of the black sea cucumber *holothuria leucospilota*

Mr Chieu Hoang Dinh^{1,2}, A/Prof. Scott F Cummins¹, Prof. Abigail Elizur¹, Ms Saowaros Suwansa-ard¹, Mr Tomer Abramov¹, Ms Mitu Shahida Akter¹

¹University Of the Sunshine Coast, Sippy Down, Australia, ²Research Institute for Marine Fisheries, Ngo Quyen, Vietnam

The overexploitation of wild sea cucumbers has led to an increasing need to develop its aquaculture. Artificial induction of oocyte maturation followed by in-vitro fertilization represents an innovative approach that could help increase supply. The inducers of oocyte maturation are naturally synthesised within neural tissue, which in sea cucumbers includes a circumoral nerve ring and radial nerves. In this study, we prepared radial nerve extract (RNE) that was incubated with ovary tissue to induce in-vitro oocyte maturation of the black sea cucumber *Holothuria leucospilota* (Brandt, 1835). Maturation was determined by germinal vesicle breakdown (GVBD) at 3 h post-treatment. GVBD was most efficient with 0.7 mg RNE (98.9%), compared to 1.4 mg RNE (77.6%) and filtered artificial seawater (1%). RNE-matured oocytes were fertilized (99%) and larvae developed to late Auricularia stage (25 days post-hatch). These results provide a scientific foundation for the identification of the bioactive RNE factor that may be used for large-scale artificial breeding in black sea cucumber hatcheries.

261 Techniques and platforms for high-throughput phenotyping of canopies and plants

Dr Xavier Sirault¹

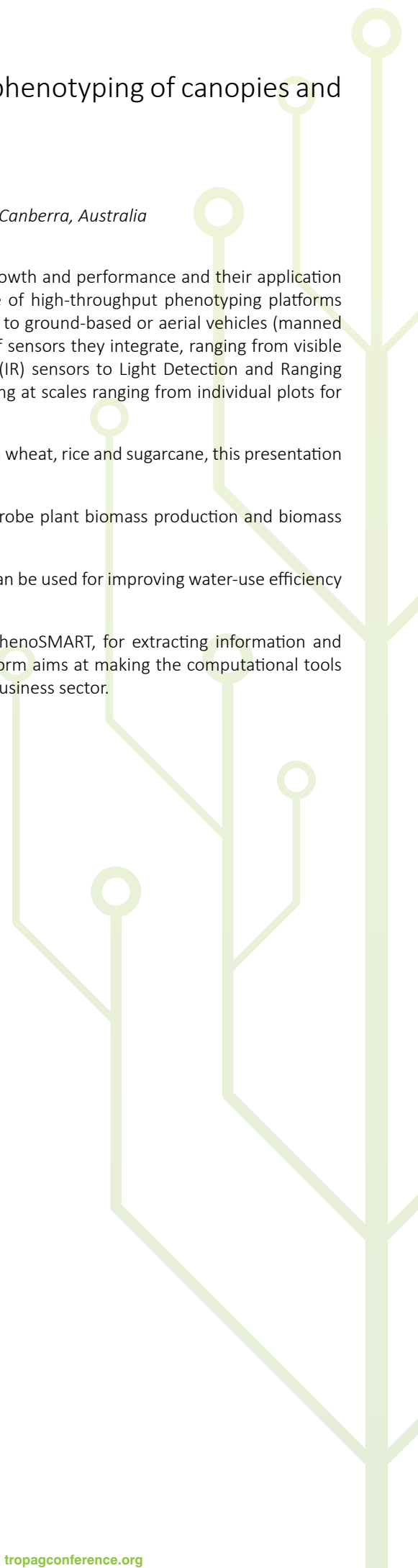
¹CSIRO Agriculture & Food, Canberra, Australia, ²Australian Plant Phenomics Facility, Canberra, Australia

Phenotyping is key to understanding the physiological and genetic bases of plant growth and performance and their application for crop improvement. To increase our capacity at measuring plant traits, a range of high-throughput phenotyping platforms have been engineered ranging from automated systems in controlled environments to ground-based or aerial vehicles (manned or unmanned) in the field. The commonality in all these platforms is the plethora of sensors they integrate, ranging from visible imaging sensors (RGB) to imaging spectroscopy sensors or from thermal infrared (IR) sensors to Light Detection and Ranging (LiDAR) sensors. The availability of these platforms is today transforming phenotyping at scales ranging from individual plots for breeding and physiological studies to entire farms to characterize agro-eco-systems.

Through examples taken from research conducted across CSIRO Agriculture & Food in wheat, rice and sugarcane, this presentation will focus on:

- 1 Exploring how LiDAR and aerial RGB technologies can be used to effectively probe plant biomass production and biomass distribution in cereals and sugarcane; and,
- 2 How the dynamic measurement of canopy temperature using IR technologies can be used for improving water-use efficiency in wheat.

The Australian Plant Phenomics Facility's Collaborative e-infrastructure platform phenoSMART, for extracting information and value from the data collected, will also be illustrated in this presentation. The platform aims at making the computational tools developed by Research groups across Australia available to others and/or the Agro-business sector.



262 How would Google farm?

Prof Alex Thomasson^{1,2}, Prof Craig Baillie²

¹Texas A&M University, College Station, United States, ²University of Southern Queensland, Toowoomba, Australia

Meeting the world's food and fiber needs in the 21st century while maintaining farm profitability requires exploiting data-centric technologies. Google has spearheaded fully autonomous vehicles on our roadways, and were they to enter farming, they would likely first amass all pertinent data and implement artificial intelligence (AI) so the data could dictate how to proceed. A self-driving car uses sensors and AI to see, hear, read, understand, decide, and act – just like human drivers. As Google revolutionizes mobility, the same opportunity exists in agriculture. Precision agriculture took hold with the advent of GPS, which provided position data and along with GIS enabled mapping of field variability. New sensors have enabled mapping of more field properties. VRT has enabled input applications to be varied in real time according to field position. Advances in analytics like AI are enabling complex modeling among numerous field properties and key output metrics like yield. The “Internet of Agriculture” – stationary sensor networks and ubiquitous sensors on field equipment, coupled with wireless networks and cloud-based data handling – has provided voluminous data that enable AI-based modeling. Automation is enabling real-time control of vehicles and implements in the field. UAVs are being used as sensor platforms to provide images indicative of field variability. Field robots are being developed for more complex agricultural tasks. We are beginning to learn how to combine advancements in precision agriculture with those in plant genetics to optimize G x E relationships, and this is critical work for the future of agriculture.

263 Autonomous adaptive precision irrigation for broad-acre agriculture

Dr Joseph Foley¹, Dr Alison McCarthy¹, Dr Malcolm Gillies¹

¹NCEA, University of Southern Queensland, Toowoomba, Australia

For over twenty years, the National Centre for Engineering in Agriculture (NCEA) at the University of Southern Queensland has been measuring furrow, centre pivot, and lateral move irrigation events, and providing management advice to optimise irrigation events. The commercial IriMate surface irrigation improvement process of measurement, modelling, performance assessment, and provision of event management advice has been used by consultants and irrigation industry personnel in about 1000 assessments across five states in Australia where wholefarm irrigation efficiency ranges from 40 to 95%. As irrigation labour availability in hot and remote broadacre irrigation regions in Australia reduces, growers are now implementing alternative means to irrigate their large fields. Areas of automated furrow and overhead broadacre irrigation are rapidly expanding using commercial providers of remotely controlled gates and valves. Current research activity by the NCEA at USQ, funded by the Commonwealth Department of Agriculture and Water Resources under the Rural R&D for Profit's Smarter Irrigation for Profit project across four sites and three different crops, is implementing precision adaptive irrigation using the crop-model based VARIwise control system (McCarthy et al 2011) so as to autonomously optimise hydraulic control of irrigation events and crop outcomes. This minimises tiresome and tedious irrigation event management, and allows easier remote implementation of optimised irrigation control across large fields in remote rural regions with aging workforces. Installation of autonomous precision adaptive irrigation management systems, ensures optimal performance for every event, improved water productivity, and easier work environments for growers.

264 Seeking energy independence

Assoc Prof Bernadette McCabe¹

¹*National Centre for Engineering in Agriculture, University of Southern Queensland, Toowoomba, Australia*

The use of renewable energy and developing equipment which runs on alternative forms such as hybrid technology or biofuels is a growing trend as we move toward more sustainable agricultural systems. The use of biodiesel, wind and solar energy; and electricity and gas generated from biogas are important renewables being implemented globally at various scales. From an international perspective, farmers' consideration for using or increasing renewable energy seems to be independent of the size of their operations but rather stem from their desire for farms to be energy independent. The energy independent farm seeks to cater for its own energy needs and creates a self-sustaining environment which buffers against fluctuating energy prices and the resulting negative impact it has on farm incomes.

This presentation will provide an overview of existing on farm energy efficiency practices which are at the core to the operation of any farming enterprise. It will then introduce the defining features of an energy independent farm and how the key components integrate to provide an overarching sustainable agricultural plan. Key operational models which exist world-wide will be used as case studies and the potential translation to Australian farming contexts will be explored. Some key aspects covered will include the use of energy crops, whole of crop utilisation, waste, spoilage and losses.

265 Animal sensing will take the industry back 100 years

Assoc Prof Mark Trotter, Derek Bailey², Jamie Barwick³

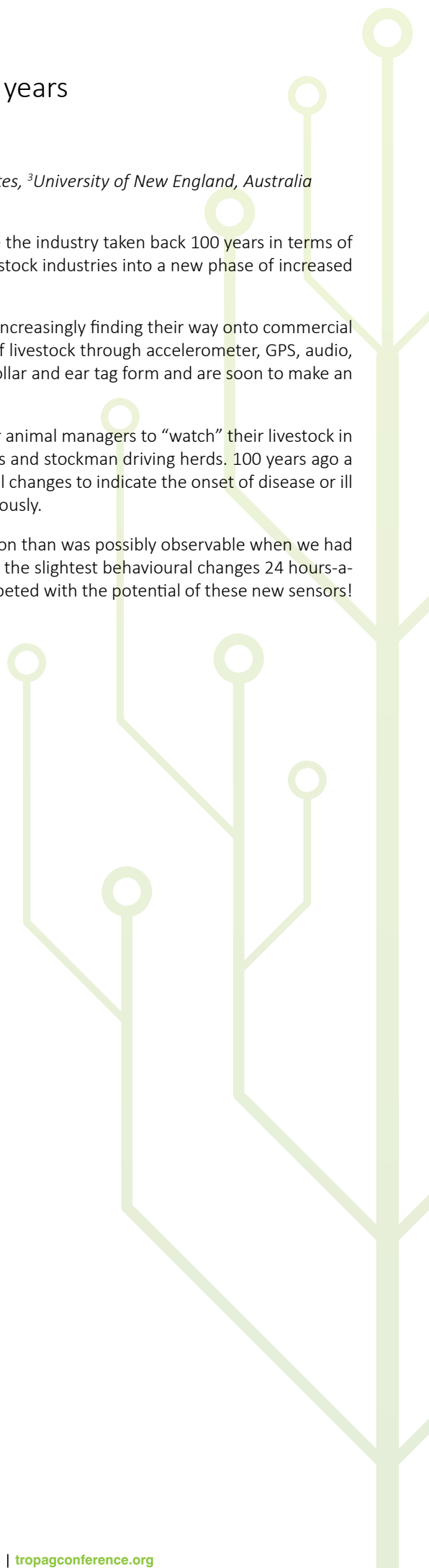
¹Central Queensland University, Australia, ²New Mexico State University, United States, ³University of New England, Australia

There is a quiet revolution happening in the livestock sector that will ultimately see the industry taken back 100 years in terms of its capabilities. It doesn't sound great, but this innovation will also catapult the livestock industries into a new phase of increased production efficiency, sustainability and animal welfare credibility.

On-animal sensing systems have been in development for many years but are now increasingly finding their way onto commercial farms. These systems provide fine-scale behavioural information on the activities of livestock through accelerometer, GPS, audio, proximity and other sensors. They are currently available for the dairy industry in collar and ear tag form and are soon to make an appearance in the extensive grazing sector.

They will take the industry back 100 years because they provide the opportunity for animal managers to "watch" their livestock in a way that hasn't been economically viable since we had shepherds following flocks and stockman driving herds. 100 years ago a dairy farmer might at best have owned 20 cows and closely watched for behavioural changes to indicate the onset of disease or ill health that needed treating. These sensors can now do this remotely and autonomously.

This new generation of animal sensing systems will actually provide more information than was possibly observable when we had shepherd and stockman managing small numbers. With the ability to monitor even the slightest behavioural changes 24 hours-a-day, 7 days-a-week not even the most dedicated shepherd boy could not have competed with the potential of these new sensors!



266 Field robotics in agriculture

Mark Calleija¹

Australian Centre for Field Robotics, The University of Sydney, NSW, Australia

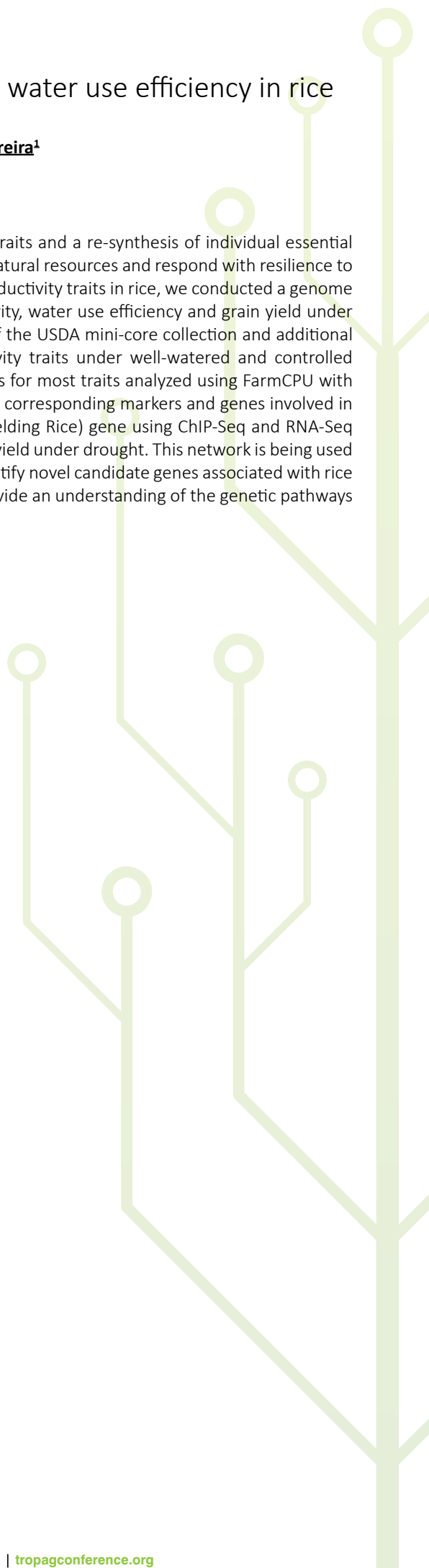
Field robots are outdoor automated mobile platforms that can operate 24/7 in all weather conditions. Over the last five years' field robotic capabilities have dramatically increased because of advances in machine learning, power systems, additive manufacturing, sensing and machine computation. Their impact has been felt in mining, stevedoring, infrastructure monitoring and lately in agriculture. In this talk we will present the current status on three agriculture field robotics projects at the Australian Centre for Field Robotics. The first is with the horticulture industry and in particular our work on robotics, sensing and machine learning techniques that aims to help the vegetable industry increase crop productivity through precision agriculture. The second is our work within the tree crop industry and in particular how sensing and robotics is being used to undertake precision crop monitoring, and the challenges encountered because of different tree structures and fruit/nut types. The third project will look at robotics for the grazing livestock industry and the in particular the objective of undertaking autonomous large scale monitoring of the land and animals.

267 Systems genetic studies of photosynthesis and water use efficiency in rice

Anuj Kumar¹, Supratim Basu¹, Chirag Gupta¹, Sara Yingling¹, Julie Thomas¹, **Andy Pereira¹**

¹University of Arkansas, Fayetteville, United States

Improvement of crops for the future, requires the genetic dissection of complex traits and a re-synthesis of individual essential components, to reconstruct crops that produce more under the limitations of the natural resources and respond with resilience to the challenging environment. To identify the landscape of genes contributing to productivity traits in rice, we conducted a genome wide association (GWA) analysis of component traits for photosynthesis, productivity, water use efficiency and grain yield under well-watered and controlled drought conditions. A diverse rice panel comprising of the USDA mini-core collection and additional genotypes were phenotyped in the greenhouse and field for multiple productivity traits under well-watered and controlled drought. GWA of the diverse panel using ~200,000 SNPs identified candidate genes for most traits analyzed using FarmCPU with potentially fewer errors in mapping. To integrate information on productivity traits, corresponding markers and genes involved in trait expression we created a gene regulatory network around the HYR (Higher Yielding Rice) gene using ChIP-Seq and RNA-Seq data from HYR expressing genotypes that showed higher photosynthesis, WUE and yield under drought. This network is being used to integrate information from rice GWA data, to support functional analysis and identify novel candidate genes associated with rice productivity and drought resistance. Our ongoing studies will be described that provide an understanding of the genetic pathways and physiological processes involved in productivity of rice under drought.



268 Development of rice varieties for multiple abiotic – stress tolerance in the Mekong region and Australia

Prof Shu Fukai¹, Dr Jaquie Mitchell¹

¹*University of Queensland, St Lucia, Australia*

Rice requires a large amount of water, and if ample water is not available it can be severely affected by water stress. In the Mekong region of Thailand, Laos and Cambodia, the rainfed lowland rice ecosystem is dominant. In this system, the crop relies on rainfall in the wet season, and is often subjected to intermittent and terminal drought but also submergence after heavy rainfall events. Climate change is thought to be exacerbating the occurrence of drought and flood. Selection methods are well established for development of drought tolerant varieties, and several varieties adapted to both drought and flood have been released.

For the Australian rice industry, lack of irrigation water as well as cold weather prior to and around flowering are major limiting factors for sustainable production. Aerobic rice is practised in northern Australia, but severe cold prevents its use in the main rice growing area in the country. We have established screening methods for selection of genotypes tolerant to both cold and aerobic conditions. Physiological traits and QTLs that confer cold tolerance have been identified. Cold donors were also identified, crosses made with elite Australian varieties, and advanced materials with cold tolerance are being tested under both flooded and aerobic conditions.

The use of seed drills replacing traditional hand transplanting or broadcasting in the Mekong region and replacing aerial sowing in Australia is contributing to minimizing the water shortage effect on rice production. Development of varieties adapted to multiple abiotic stress tolerance should further assist the rice industries.

269 Mapping, mining and tracking tools to locate and harness climate resilience in rice

Dr Tobias Kretzschmar¹

¹IRRI, Metro Manila, Philippines

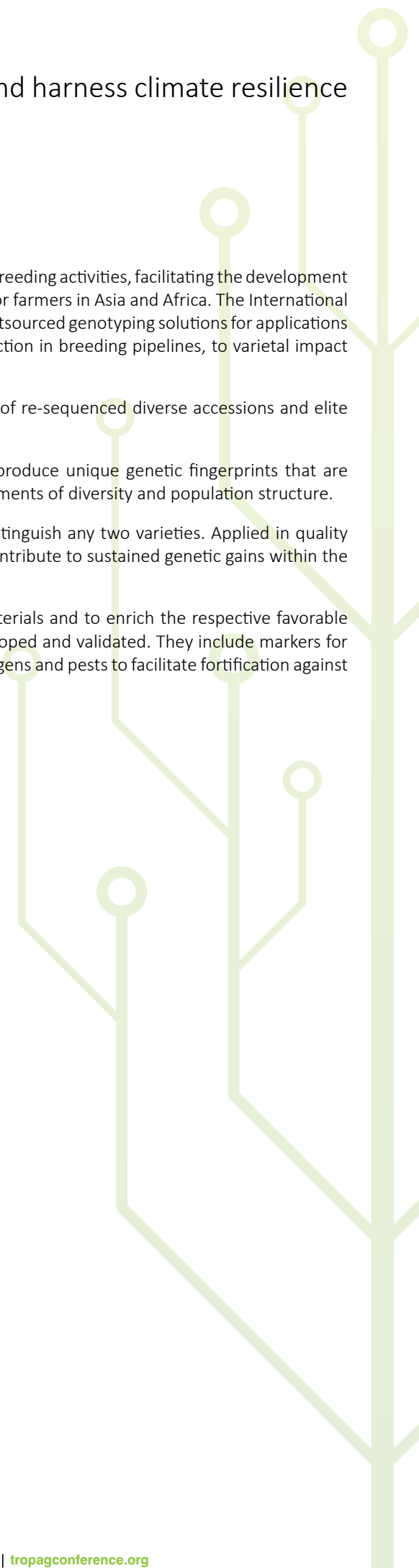
SNP-based genotyping approaches have become indispensable tools in modern rice breeding activities, facilitating the development of climate-change ready rice for increased food and income security of resource-poor farmers in Asia and Africa. The International Rice Research Institute (IRRI) offers and deploys a diverse portfolio of in-house and outsourced genotyping solutions for applications that range from trait mobilization in pre-breeding pools, over marker assisted selection in breeding pipelines, to varietal impact assessment in the farmer's field.

On the high-density end IRRI governs over a global genetic resource of thousands of re-sequenced diverse accessions and elite breeding lines for trait discovery and the mining of favorable alleles.

In the medium-density range fixed array- and amplicon-based platforms reliably produce unique genetic fingerprints that are suitable for mapping purposes, association studies, genomic predictions and assessments of diversity and population structure.

At the low-density end purity SNP sets have been optimized to unambiguously distinguish any two varieties. Applied in quality control to confirm hybridity of crosses and to assess the purity of materials, they contribute to sustained genetic gains within the IRRI breeding programs and ensure clean seed production.

For efficient introgression of high value QTLs of demonstrated effect into elite materials and to enrich the respective favorable alleles in relevant breeding pools, a range of trait-specific markers have been developed and validated. They include markers for tolerance of drought and submergence, as well as for resistance against major pathogens and pests to facilitate fortification against climate extremes and the associated increased disease pressure.



270 Climate-smart rice production for Australia and Asia

Assoc Prof Andrew Borrell¹, Dr Mai Van Trinh², Professor Udaya Sekhar Nagothu³

¹The University of Queensland, Warwick, Australia, ²Vietnam Academy of Agricultural Sciences, Hanoi, Vietnam, ³Norwegian Institute of Bioeconomy Research, As, Norway

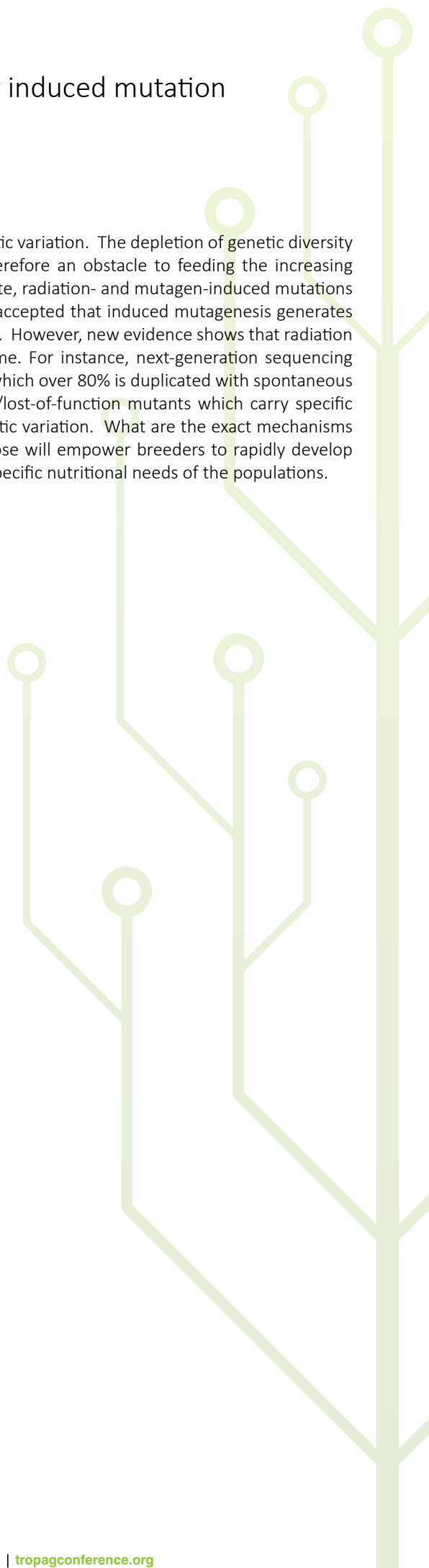
The Earth is a water-scarce planet. Feeding more people with less water is a major challenge facing humanity. The development of water-saving technologies for rice production in northern Australia and Asia will be presented, including case studies from Australia, Indonesia, India and Vietnam. Early research in northern Australia found that it is not necessary to flood rice to obtain high grain yield and quality. Saturated soil culture (SSC), a system of growing rice on raised beds with water maintained in the furrows, used about 32% less water in the wet and dry seasons compared with traditional flooded production. SSC was subsequently evaluated in Indonesia, with similar benefits found. Smallholder rice farmers in Vietnam face considerable risk, and require rice-based cropping systems that are more resilient to the negative impacts of drought and salinity. Five key climate-smart measures for rice production have recently been identified and tested in Vietnam. These include salinity-tolerant rice varieties, slow-release nitrogen fertilisers, organic fertilisers that reduce greenhouse gas emissions, climate-smart crop rotations, water-saving irrigation strategies, and a range of genetic, management and economic solutions. Significant environmental benefits were also identified. For example, methane emissions were reduced 5-fold using 'alternate wetting and drying' irrigation compared with traditional flooded rice. The potential application of these measures to northern Australia will also be discussed.

271 Generating useful genetic variation in crops by induced mutation

Apichart Vanavichit¹

¹*Rice Science Center, Thailand*

The success of conventional breeding and selection relies heavily on available genetic variation. The depletion of genetic diversity is, therefore, a crucial limiting factor to next generation plant breeding, and therefore an obstacle to feeding the increasing world. While spontaneous mutation adds new alleles to the gene pool at a slow rate, radiation- and mutagen-induced mutations rapidly trigger structural and nucleotide changes in the genome. It is commonly accepted that induced mutagenesis generates random alteration on DNA sequences and structural changes at genome-wide scale. However, new evidence shows that radiation mutagenesis generates specific local lesions and structural changes in the genome. For instance, next-generation sequencing revealed that irradiation generates a high density of single nucleotide variation of which over 80% is duplicated with spontaneous variation. In addition, selection under stresses may generate more specific gain/lost-of-function mutants which carry specific genomic changes and allelic variation similar to what can be found in natural genetic variation. What are the exact mechanisms allowing the rapid generation of genetic variation remain unclear. Identifying those will empower breeders to rapidly develop better plant varieties to cope with the imminent climate changes and respond to specific nutritional needs of the populations.



272 Iron tolerance in rice

Prof Antonio Costa De Oliveira¹, Dr Camila Pegoraro¹, Dr Luciano Maia¹, Dr Railson Santos¹, Miss Vivian Viana¹

¹Federal University of Pelotas, Pelotas, Brazil

Plant breeders are faced with bigger challenges since world's population continues to grow and climate changes threaten to reduce crop yields. Not only higher yields are needed but abiotic stress tolerances needed to be added to the genetic background of cultivars. This major task will require a deeper understanding of stress responses in plants as well as the identification of genes that will provide the strength needed for a resilient ideotype. Iron excess, salinity and cold are major stresses affecting rice worldwide. Our group has been working on abiotic stress responses and their regulation as a strategy to find genotypes with better yields. Microarray and RNA seq experiments, as well as bioinformatics tools have been used to identify novel candidates for marker assisted selection. The mechanisms underlying stress tolerance point to a complex regulation system and feedback control by WRKY transcription factors.

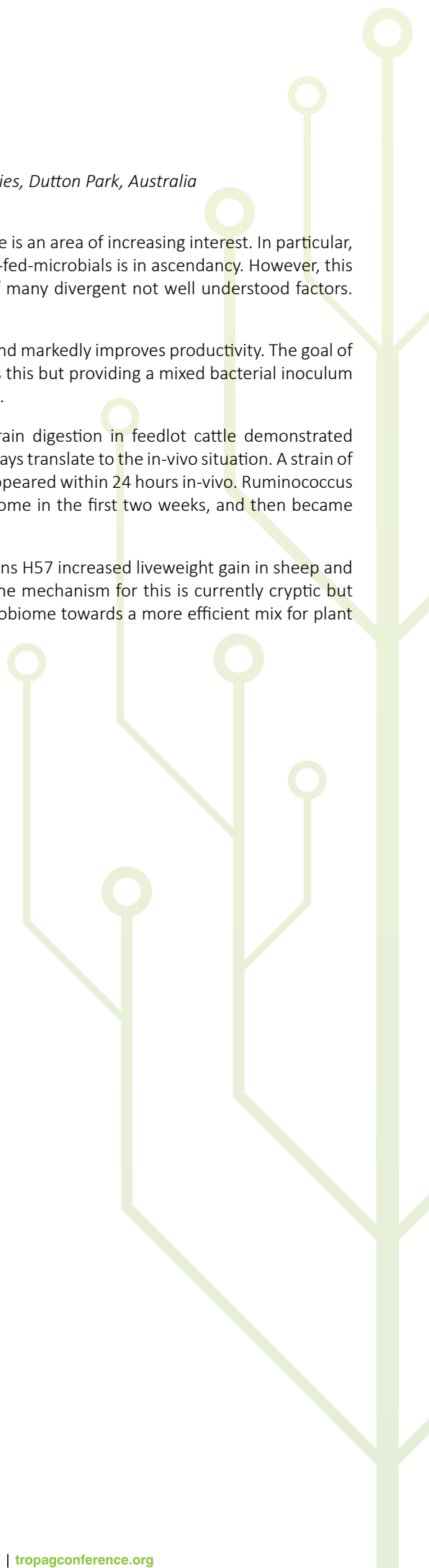
273 Microbial manipulation of rumen efficiency

Assoc Prof Athol Klieve¹, Ms Diane Ouwerkerk², Dr Rosalind Gilbert²

¹University of Queensland, Gatton, Australia, ²Department of Agriculture and Fisheries, Dutton Park, Australia

Improving the efficiency of rumen function through manipulation of the microbiome is an area of increasing interest. In particular, introducing new species or bolstering existing microbial populations through direct-fed-microbials is in ascendency. However, this is not a “one size fits all” strategy, but is very complex involving the interaction of many divergent not well understood factors. Three considerations will be discussed:

1. Consider additional benefits. An inoculum produced by DAF detoxifies leucaena and markedly improves productivity. The goal of the inoculum is to detoxify a nutritious feed plant. One species of bacteria achieves this but providing a mixed bacterial inoculum selected for leucaena degradation also improves the digestion of leucaena biomass.
2. Consider the diet and tailor strategies accordingly. A probiotic to enhance grain digestion in feedlot cattle demonstrated interesting interactions with feed and highlighted that laboratory findings do not always translate to the in-vivo situation. A strain of *Butyrivibrio fibrisolvens*, isolated as the most efficient utilizer of starch in-vitro, disappeared within 24 hours in-vivo. *Ruminococcus bromii* isolated from cattle fed barley, used as a probiotic, dominated the microbiome in the first two weeks, and then became undetectable.
3. Consider cryptic mechanisms. When used as a probiotic, *Bacillus amyloliquefaciens* H57 increased liveweight gain in sheep and calves. However, these effects occur without H57 establishing in the rumen. So, the mechanism for this is currently cryptic but may be attributed to H57 spores carrying anti-microbials that shift the rumen microbiome towards a more efficient mix for plant fibre digestion.



274 Estimating the efficiency of rumen microbial protein synthesis in cattle grazing tropical pastures, and implications for animal performance

Dr Maree Bowen¹

¹*Department of Agriculture and Fisheries, Queensland, Rockhampton, Australia*

In cattle grazing tropical pastures most of the metabolisable protein available is from rumen microbial crude protein (MCP) synthesis. We have developed a new method for estimating MCP production in grazing cattle. It involves continuous intravenous jugular infusion of chromium (Cr)-EDTA and measurement of both Cr and purine derivative (PD) concentrations in spot urine samples to estimate urine output, and, thereby, total PD excretion. In addition, we have determined a lower estimate of endogenous PD excretion, for *Bos indicus* compared with *B. taurus* cattle, which is required to calculate MCP flow. A major study with *B. indicus* steers grazing a range of tropical pasture types confirmed data from pen studies with hay diets, showing that the efficiency of MCP synthesis (EMPS) in steers consuming tropical grass pastures was low and limited by rumen degradable protein (RDP) supply from the pasture. In situations of high RDP, in grazing and pen studies, there was very low conversion efficiency of RDP to MCP (0.24-0.40). A better understanding of the mechanisms associated with endogenous nitrogen recycling, and the metabolisable protein required under various circumstances, will enable better elucidation of how changes to EMPS will affect animal growth, in practice. In the grazing study, tropical legumes provided adequate RDP to meet the needs of rumen microbes and this may provide the best strategy to increase EMPS and animal performance. A study on commercial cattle properties has confirmed that the inclusion of adapted perennial legumes in tropical pastures dramatically improves animal performance as well as profitability.

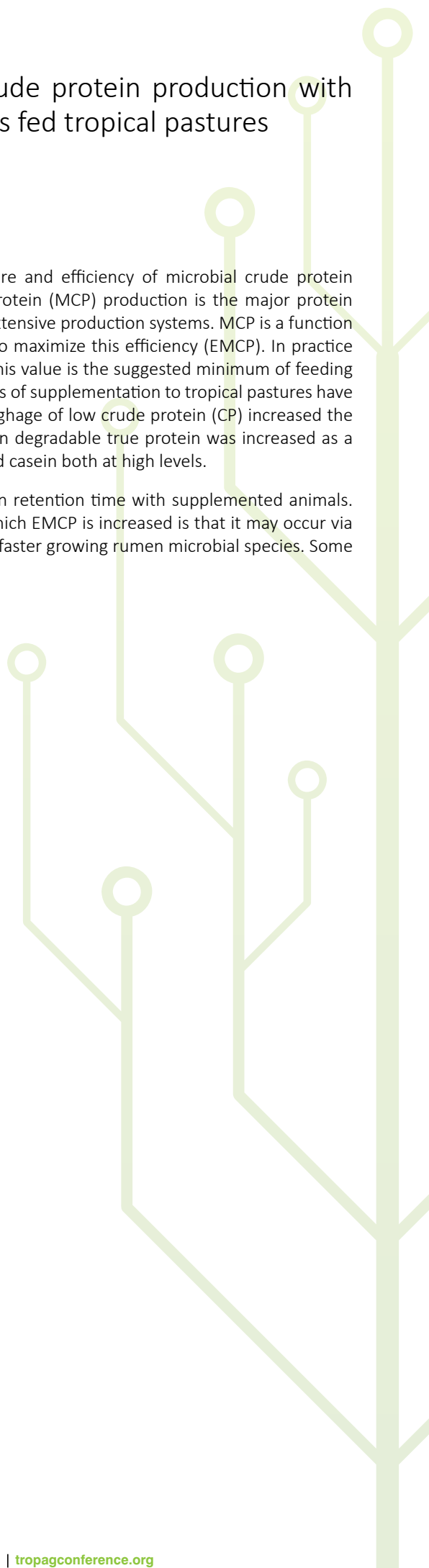
275 The relationship of efficiency of microbial crude protein production with rumen microbial community structure in steers fed tropical pastures

Dr Karen Harper¹

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A better understanding of the factors that govern microbial community structure and efficiency of microbial crude protein production (EMCP) in tropical production systems is required. Microbial crude protein (MCP) production is the major protein supply to the host, and can provide close to 100% of the protein requirements in extensive production systems. MCP is a function of the ME intake and EMCP, therefore an important strategy to optimize MCP is to maximize this efficiency (EMCP). In practice EMCP of Northern Australian native pastures rarely exceeds 130g MCP/kg DOM. This value is the suggested minimum of feeding standards when rumen degradable nitrogen is adequate (S.R.A. 2007). Various forms of supplementation to tropical pastures have provided only limited improvements in EMCP values. Two studies with a basal roughage of low crude protein (CP) increased the EMCP (to approximately 167g MCP/kg DOM) in Brahman-cross steers when rumen degradable true protein was increased as a supplement. Panjaitan et al. (2015) used spirulina algae and Bowen et al. 2016 used casein both at high levels.

These improvements in EMCP were often associated with decreases in the rumen retention time with supplemented animals. Rumen dilution rate has a major effect on microbial growth. The principle upon which EMCP is increased is that it may occur via simple mass action effects on growth and/or changes in the rumen microbiome to faster growing rumen microbial species. Some examples of these changes are outlined.



276 Changing the interplay between gut and host to improve production efficiency of ruminants

Prof Roger Hegarty¹

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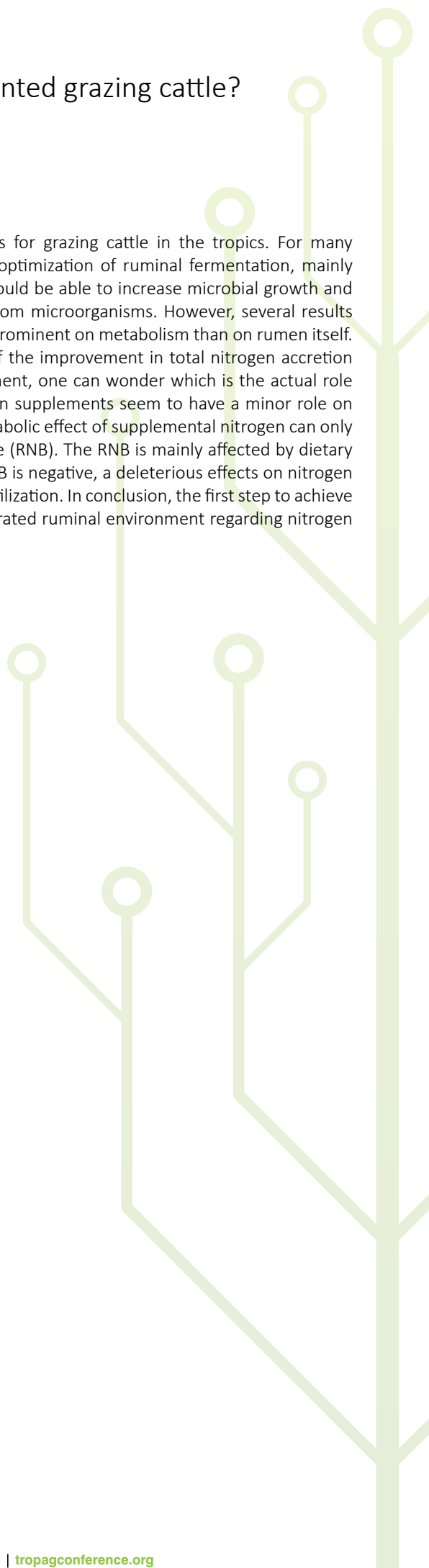
Increasingly, the gut biome is recognised as influencing the host and the host as influencing the gut biome. This awareness creates opportunities to manage both microbe and host to increase the overall efficiency and productivity of the animal. Early life interventions to affect the establishing biome have shown efficacy in changing ruminal ecology but proved less effective in delivering sustained change in the yield of microbial products and productivity of the host. Targeted biome manipulations such as elimination of rumen ciliate protozoa have shown lasting improvements in protein availability that can be advantageous in low protein tropical grazing systems. Manipulating the host to influence the retention time of digesta by means from animal breeding to dietary additives (eg. cysteamine) and diet structure can predictably change fermentation. This presents an example of regulating the biology of the host to favourably change ruminal nutrient yield to better match host animal nutrient requirements, reducing inefficiencies in the rumen (eg. energy loss in methane) and in the host (eg. energy:amino acid imbalance). New approaches to manage the gut biome directly, or by influencing host biology to modify the ruminal conditions, offer promise to improve production efficiency of rumen microbes and of the host ruminant.

277 What is the actual role of rumen for supplemented grazing cattle?

Prof Edenio Detmann¹, Prof Mário Paulino¹, Prof Sebastião Valadares Filho¹

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Protein has been recognized as the most important component in supplements for grazing cattle in the tropics. For many years, the technical arguments regarding supplementation have been based on optimization of ruminal fermentation, mainly fiber degradation. Theoretically, a rumen degradable nitrogen supplementation would be able to increase microbial growth and improve both energy supply from fiber, and metabolizable protein (MP) supply from microorganisms. However, several results obtained in Brazil have pointed out that effects of nitrogen supplements are more prominent on metabolism than on rumen itself. The improvements in microbial nitrogen supply respond for approximately 20% of the improvement in total nitrogen accretion in the animal body obtained by using nitrogen supplementation. From this statement, one can wonder which is the actual role of the rumen when supplements are supplied for grazing cattle. Although nitrogen supplements seem to have a minor role on improvement of MP supply from microbial protein, any significant and positive metabolic effect of supplemental nitrogen can only be achieved after ruminal environment is equilibrated concerning nitrogen balance (RNB). The RNB is mainly affected by dietary availability of nitrogen and shows no correlation with dietary energy. When the RNB is negative, a deleterious effects on nitrogen status in the animal body occurs, which, in turn, will decrease the efficiency of MP utilization. In conclusion, the first step to achieve better metabolic efficiencies in grazing cattle in the tropics is to provide an equilibrated ruminal environment regarding nitrogen availability.



278 Live yeast supplementation improves rumen fibre degradation in cattle grazing tropical pastures throughout the year

Mr. Dannylo Sousa¹, Ms Cassiele Oliveira¹, Mr. Johnny Souza¹, Dr. Eric Chevaux², Dr. Lucas Mari³, **Dr Luis Silva^{1,4}**

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The effect of live yeast (LY- *Saccharomyces cerevisiae* CNCM I-1077) on in situ fiber digestibility and rumen cellulolytic bacteria population of grazing Nellore cattle was evaluated throughout the year. Eight rumen cannulated steers were used in a 2x4 factorial arrangement of treatments: with or without LY, and seasons of the year (spring, summer, fall, and winter). The product was given daily, in capsules, via rumen cannula, in order to provide 8×10^9 CFU. Animals were kept on a rotational grazing system receiving mineral supplementation. Every 45 d, in situ rumen fibre digestibility (NDFD) of 5 reference forages was determined after 24h incubation. A composite sample of the rumen contents was collected for DNA extraction and real-time PCR quantification of four cellulolytic bacteria species: *Butyrivibrio fibrisolvens*, *Fibrobacter succinogenes*, *Ruminococcus flavefaciens*, and *Ruminococcus albus*. Although pasture composition varied greatly throughout the year, there was no LY*season interaction ($P > 0.20$). Supplementation with LY increased 24h-NDFD by 6.3% for bermudagrass hay ($P = 0.02$), 4.1% for palisade grass ($P = 0.01$), 4.9% for guineagrass ($P = 0.03$), 13% for sugarcane silage ($P = 0.02$), and 6.9% for corn silage ($P = 0.04$). Among the four rumen bacteria evaluated, *R. flavefaciens* was the most prevalent, and LY supplementation increased by 78% ($P < 0.01$) the relative population of *R. flavefaciens* in the rumen. The effect of LY on *R. flavefaciens* was more pronounced during the summer and spring (LY*season interaction, $P = 0.10$). Supplementation with LY increased rumen population of *R. flavefaciens* and fibre digestibility of roughages in steers grazing tropical pastures.

279 Regulation and advancing GM technologies

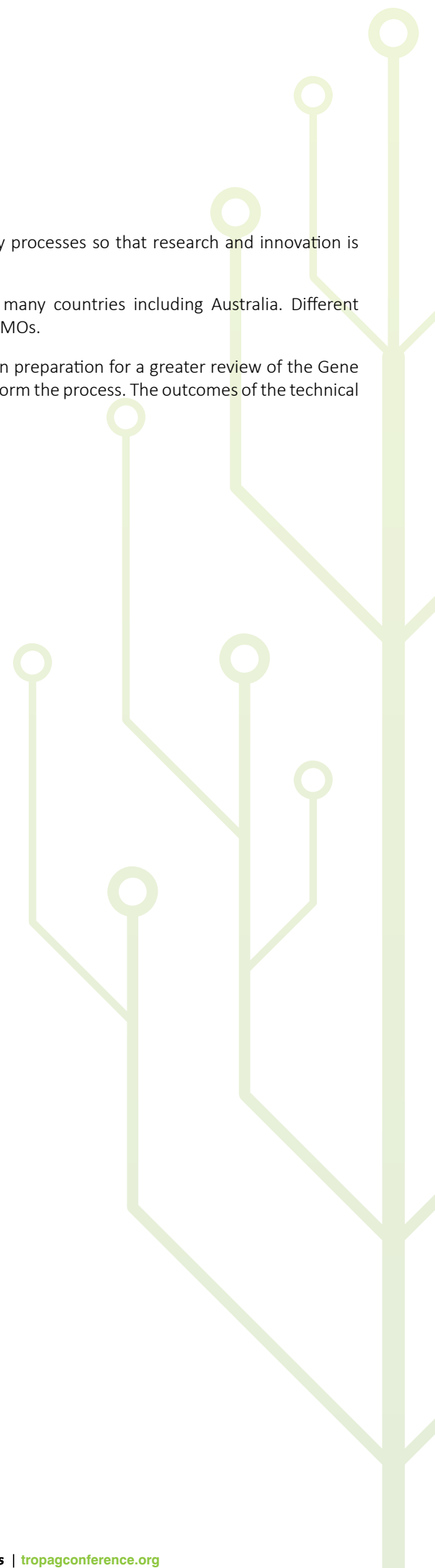
Dr Raj Bhula¹

¹*Office of the Gene Technology Regulator, Canberra, Australia*

Technology is moving at a pace that requires adaptable legislation and regulatory processes so that research and innovation is supported.

New plant breeding technologies are challenging legal definitions of GMOs in many countries including Australia. Different regulatory frameworks at an international level can impact on the acceptance of GMOs.

The OGTR has conducted a technical review of the Gene Technology Regulations in preparation for a greater review of the Gene Technology scheme. Submissions to the review of the regulations have helped to inform the process. The outcomes of the technical review will be presented.



280 Regulatory oversight of new breeding innovations in the US

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The US “Coordinated Framework for the Regulation of Biotechnology” promulgated in the 1980s, is technically agnostic towards the breeding method under review. According to the Office of Science and Technology Policy, “Exercise of oversight ... should be based on the risk posed by the introduction and should not turn on the fact that an organism has been modified by a particular process or technique”. In practice, this is not what happens. The US Department of Agriculture (USDA) regulatory oversight for genetically engineered (GE) plants is triggered by the dependence of any genetic modification upon a plant pest or potential to become a plant pest. The dependence of older GE techniques on pest- and virus-derived genetic components resulted in a de facto process-based regulatory regime of GE plants by the USDA’s Animal and Plant Health Inspection Service. The trigger for the US Food and Drug Administration (FDA) mandatory premarket evaluation of GE animals is those animals whose genome has been intentionally modified by recombinant DNA (rDNA) techniques, including the entire lineage of animals that contain the modification. All GE animals are captured under these provisions, regardless of their intended use. Thus, although the regulatory evaluation is based on the product, the FDA draft guidance suggests any intentional alteration of an animal’s genome would trigger regulatory oversight. As a result, plants with no novel DNA sequences produced using genome editing would likely be exempt from regulatory oversight, whereas any animals with intentional genome modifications would face mandatory premarket FDA evaluation.

281 Regulation of new breeding innovations – Implications for the grain trade

Ms Rosemary Richards¹

¹*Grain Trade Australia, Royal Exchange, Australia*

The Australian grains industry will potentially benefit from research utilising innovative plant breeding technologies to enhance the productive capacity of Australian grain producers. The uses of such innovative technologies are expanding as they are adaptable to large variety of crops and often more economical.

A major challenge for the global grain trade is the lack of consistency in regulations regarding innovative breeding technologies globally. Harmonisation of regulations is required to provide certainty to the grain trade.

The grain trade requires a clear policy framework to facilitate the efficient movement of grain around the world. The absence of a consistent policy framework is likely to result in a lack of alignment in regulatory approaches in exporting and importing countries. This will potentially lead to trade disruption with subsequent increased costs and risks.

The Australian industry works with global partners, through the International Grain Trade Coalition, to achieve international alignment and frameworks that will minimise trade disruptions. Alignment and regulatory coherence will assist governments to avoid unnecessarily eroding the value of the innovation and/or driving up costs and complexity in the global food system.

Grain Trade Australia (GTA) is the focal point for the commercial grains industry within Australia. It facilitates trade and works to provide an efficient, equitable and open trading environment by providing leadership, advocacy and commercial services to the Australian grain value chain.



300 The Mediterranean Diet: A healthy and traditional dietary pattern embedded in a sustainable food system

Prof Lluís Serra-Majem^{1,2,3}

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The Mediterranean diet should be understood not only as a set of foods but also as a cultural model that involves the way foods are selected, produced, processed and distributed. The Mediterranean dietary pattern is presented not only as a cultural model but also as a healthy and environmentally friendly model.

The recognition by UNESCO, with the consequent increased visibility and acceptance of the Mediterranean diet around the world, along with better and more scientific evidence regarding its benefits and effectiveness on longevity, quality of life and disease prevention, has taken this dietary pattern to an unprecedented historical moment. This is a favorable situation that could possibly enable the strengthening of the Mediterranean diet around the world, thus potentiating improvements in global health indicators and in a reduction of environmental impact by production and transportation of food resources.

To this end, the Mediterranean diet should be seen for what it is: an extremely and incomparable healthy, affordable and environmentally sustainable food model, as well as an ancient cultural heritage that confers identity and belonging. From the heart to the earth through the road of culture, the Mediterranean diet is a cultural heritage that looks to the future. With the leadership of the new international organization –The International Foundation of the Mediterranean Diet (IFMeD) www.ifmed.org – the future is over. IFMeD aims to raise public awareness of healthy and sustainable nutrition, making it a central issue, and to promote the international cooperation agreements with actors both public and private stakeholders to support and pursue the values and benefits of the Mediterranean diet.

Key words: Mediterranean Diet, sustainability, health benefits, culture, UNESCO, environment.

301 The changing face of horticulture: Hello tomorrow!

Prof Neena Mitter¹

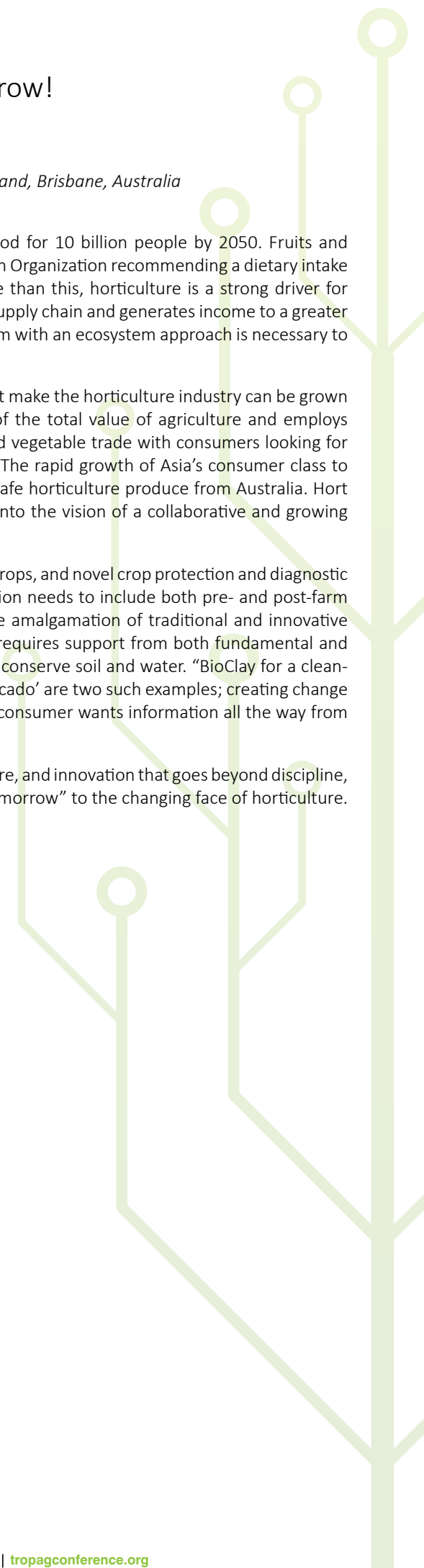
¹*Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Brisbane, Australia*

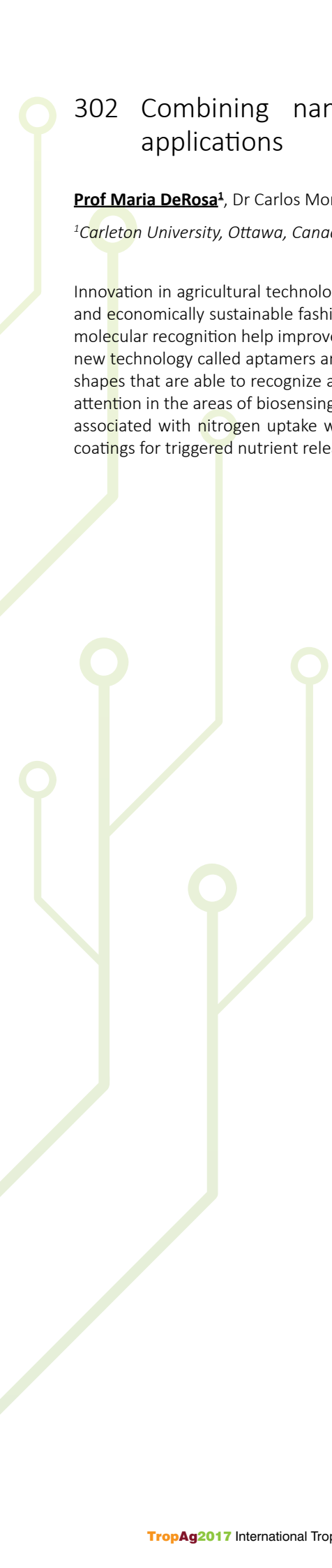
A vibrant and sustainable horticulture industry is a must to provide nutritional food for 10 billion people by 2050. Fruits and vegetables are critical to address the so-called 'hidden hunger', with the World Health Organization recommending a dietary intake of more than 400g of fruits and vegetables per day to prevent malnutrition. More than this, horticulture is a strong driver for economic growth. It creates jobs, supports a wide range of agri-businesses across the supply chain and generates income to a greater degree than any other agricultural crop. A sustainable horticultural production system with an ecosystem approach is necessary to adapt to changing social, political, economic and environmental impacts.

The diversity of fruits, vegetables, nuts, herbs, medicinal plants and ornamentals that make the horticulture industry can be grown across varied agro-ecological zones. In Australia, horticulture accounts for ~18% of the total value of agriculture and employs around 61,000 people. A 'new world order' is emerging in the global fresh fruit and vegetable trade with consumers looking for 'value' over 'volume'. These changes are not years away, they are happening now. The rapid growth of Asia's consumer class to an estimated 3.2 billion by 2030 will drive demand for premium, high-quality and safe horticulture produce from Australia. Hort Innovation Australia's initiatives such as 'Taste Australia' and 'Hort Frontiers' feed into the vision of a collaborative and growing horticulture industry.

Robotics, precision farming, protected cropping, drone technology, new unexplored crops, and novel crop protection and diagnostic platforms are some of the key tenets for the 'horticulture of tomorrow'. The equation needs to include both pre- and post-farm gate operations all the way from production to market and trade investments. The amalgamation of traditional and innovative frameworks are crucial for a proactive industry ready to embrace the future. This requires support from both fundamental and applied science. It is imperative that new innovations reduce pesticide misuse and conserve soil and water. "BioClay for a clean-green and safe crop protection" and "Plant stem cell based clonal propagation of avocado" are two such examples; creating change that counts. This is becoming increasingly relevant as the well-informed millennial consumer wants information all the way from growing conditions to shop-front.

Recognising different pathways to success, guiding young minds to deliver for the future, and innovation that goes beyond discipline, organisations, governments, industries and geographies are vital to saying "Hello Tomorrow" to the changing face of horticulture.





302 Combining nanotechnology and molecular recognition for fertilizer applications

Prof Maria DeRosa¹, Dr Carlos Monreal²

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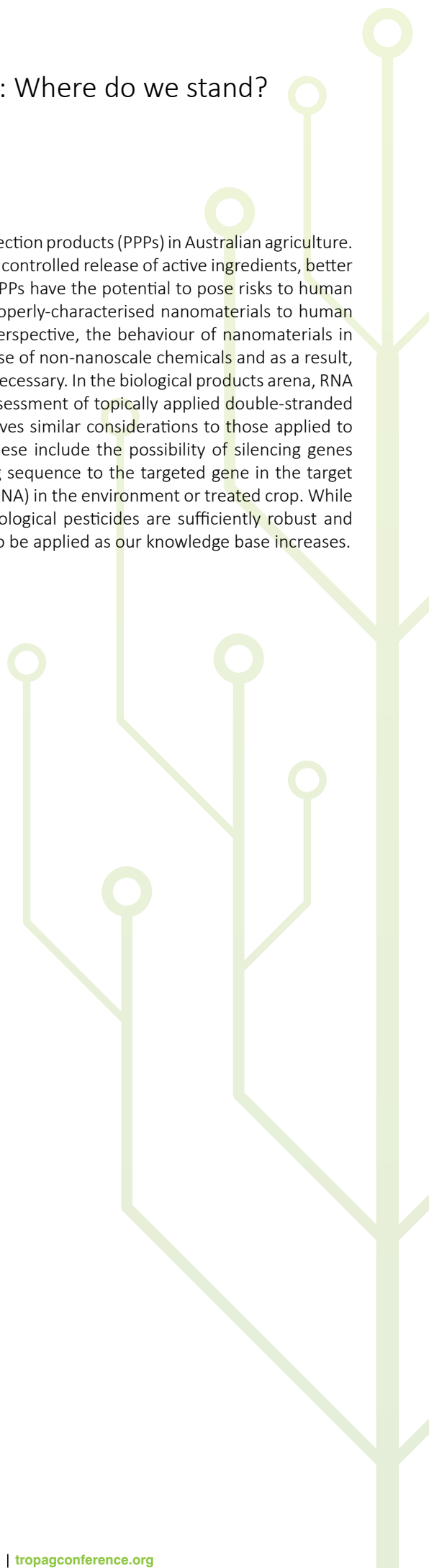
Innovation in agricultural technology will be a critical element in the effort to achieve global food security in an environmentally and economically sustainable fashion. This presentation will examine the question: Can the combination of nanotechnology and molecular recognition help improve the nutrient use efficiency of fertilizers? The presentation will focus specifically on a relatively new technology called aptamers and their agricultural applications. Aptamers are synthetic nucleic acids that fold into nanoscale shapes that are able to recognize and bind to a target molecule of interest. This innovative form of bionanotechnology is gaining attention in the areas of biosensing and controlled delivery. Our efforts in the development of aptamers for specific root exudates associated with nitrogen uptake will be described. Also, our work in the development of aptamer-based nanoscale polymeric coatings for triggered nutrient release will be presented.

303 Regulatory science and agricultural innovation: Where do we stand?

Dr Phil Reeves¹

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Nanotechnology and biotechnology advances will lead to many innovative plant protection products (PPPs) in Australian agriculture. The benefits of such PPPs will include increased product stability, enhanced efficacy, controlled release of active ingredients, better targeting of pest species, and reduced environmental footprints. However, novel PPPs have the potential to pose risks to human health and the environment. The current procedures for assessing the risks of properly-characterised nanomaterials to human health are considered to be adequate. From an environmental risk assessment perspective, the behaviour of nanomaterials in both terrestrial and aquatic environments can be very different compared with those of non-nanoscale chemicals and as a result, modifications to the conventional risk-assessment approach for nanomaterials are necessary. In the biological products arena, RNA interference (RNAi) is a major focus of R&D activities globally. Although the risk assessment of topically applied double-stranded RNA (dsRNA) designed to induce a targeted RNAi response to a pest species involves similar considerations to those applied to other conventional chemical pesticides, additional considerations are needed. These include the possibility of silencing genes (either target or non-target genes) in non-target organisms having an overlapping sequence to the targeted gene in the target organism, and the fate and any possible effect of remnant small-interfering RNA (siRNA) in the environment or treated crop. While the existing regulatory frameworks for the safety assessment of chemical and biological pesticides are sufficiently robust and flexible to be broadly applicable to novel PPPs, appropriate refinements will need to be applied as our knowledge base increases.



304 A nanobiotechnology approach to protect plants from abiotic stress

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¹University of California, Riverside, Riverside, United States

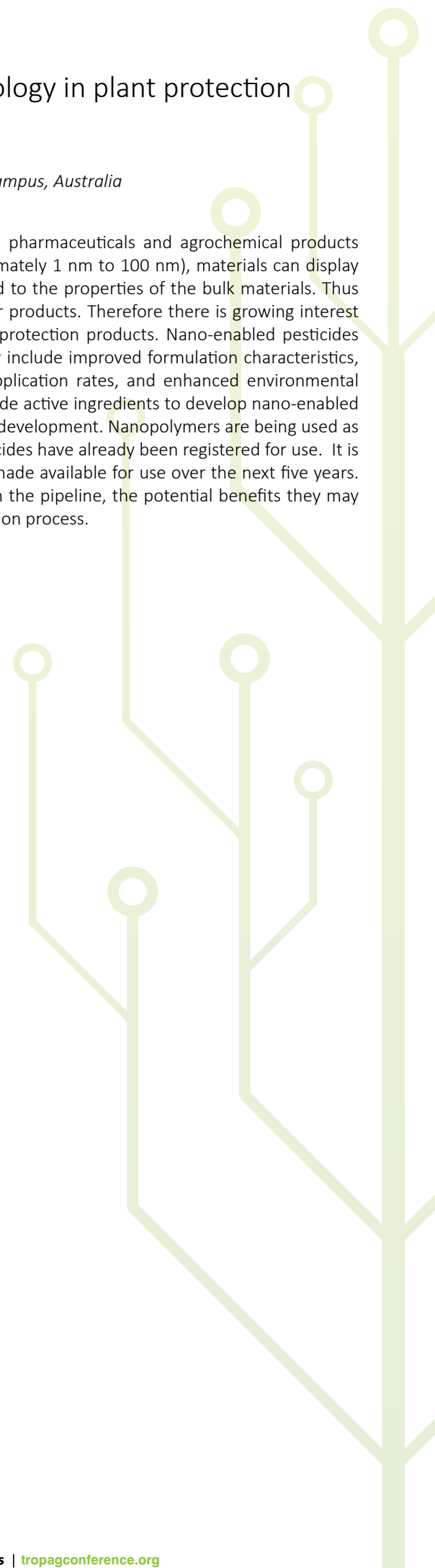
Plant abiotic stress leads to accumulation of reactive oxygen species (ROS) and consequent decrease in photosynthetic performance. We demonstrate that a plant nanobiotechnology approach of interfacing negatively charged, sub-11 nm, spherical cerium oxide nanoparticles (nanoceria) with chloroplasts in vivo augments ROS scavenging and photosynthesis of *Arabidopsis thaliana* plants under excess light, heat, dark chilling, and salinity stress. Poly (acrylic acid) nanoceria (PNC) with a hydrodynamic diameter of 10.3 ± 0.6 nm (lower than the maximum plant cell wall porosity) and zeta potential of -16.9 ± 2.7 mV, preferentially localize inside chloroplasts of leaf mesophyll cells than positively charged nanoceria of similar size. Nanoceria are transported into chloroplasts via non-endocytic pathways, influenced by the electrochemical gradient of the plasma membrane potential. PNC having Ce³⁺/Ce⁴⁺ ratios of $35.0\% \pm 2.2\%$ augment plant ROS scavenging including superoxide anion and hydroxyl radicals, for the latter ROS there is no known plant enzyme scavenger. Plants with embedded PNC that were exposed to abiotic stress have enhanced quantum yield of photosystem II, carbon assimilation rates, and Rubisco carboxylation rates relative to plants without nanoparticles. PNC improve both quantum yield of photochemistry and carbon assimilation rates under excess light but only the carboxylation reactions under heat and dark chilling. Anionic spherical PNC with low Ce³⁺/Ce⁴⁺ ratios can be used both as a tool to study the impact of oxidative stress on plant function and to protect plants from abiotic stress.

305 Nano-enabled pesticides: An emerging technology in plant protection

Dr Rai Kookana¹

¹CSIRO Land and Water, Waite Campus, Australia, ²University of Adelaide, Waite Campus, Australia

Nanotechnology is increasingly being used to develop new and more effective pharmaceuticals and agrochemical products (Nanofertilisers and Nanopesticides). At the nanoscale (the size range of approximately 1 nm to 100 nm), materials can display very different or additional physical, chemical and biological properties compared to the properties of the bulk materials. Thus nanotechnology can help deliver more effective and/or environmentally friendlier products. Therefore there is growing interest in deliberate applications of nanotechnology in the development of new plant protection products. Nano-enabled pesticides promise many benefits over conventional pesticide products. These benefits may include improved formulation characteristics, easier application, better targeting of pest species, increased efficacy, lower application rates, and enhanced environmental safety. For example, dendrimer technology is being applied to a number of pesticide active ingredients to develop nano-enabled pesticides with enhanced efficacy and some products are in an advanced stage of development. Nanopolymers are being used as carriers for targeted delivery of pesticides and a few such nano-enabled pesticides have already been registered for use. It is expected that an increasing number of nano-enabled pesticide products will be made available for use over the next five years. This presentation will provide an overview of types of nano-enabled pesticides in the pipeline, the potential benefits they may offer and the challenges they may pose to the regulatory agencies during registration process.



306 Nanoparticles for animal healthcare

Prof Chengzhong Yu¹

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Agriculture has played a crucial role in addressing the Humanity's top problems in our future. Conventional technologies used in agriculture have limitations to increase the productivity and may cause ecosystems damages. The long-term negative effects of farming such as irrigation, fertilizers and pesticides are persistent and have to be solved using interdisciplinary approaches. Nanotechnology holds great promise in sustainable agriculture, nevertheless current efforts are devoted significantly to "high-end" areas such as nano-medicine and cancer therapy, leaving "weak momentum" for nano-scientists working in agriculture sector that has huge needs and big impact in society. It is critical for chemists and materials scientists to provide enabling solutions in agriculture through multidisciplinary collaboration.

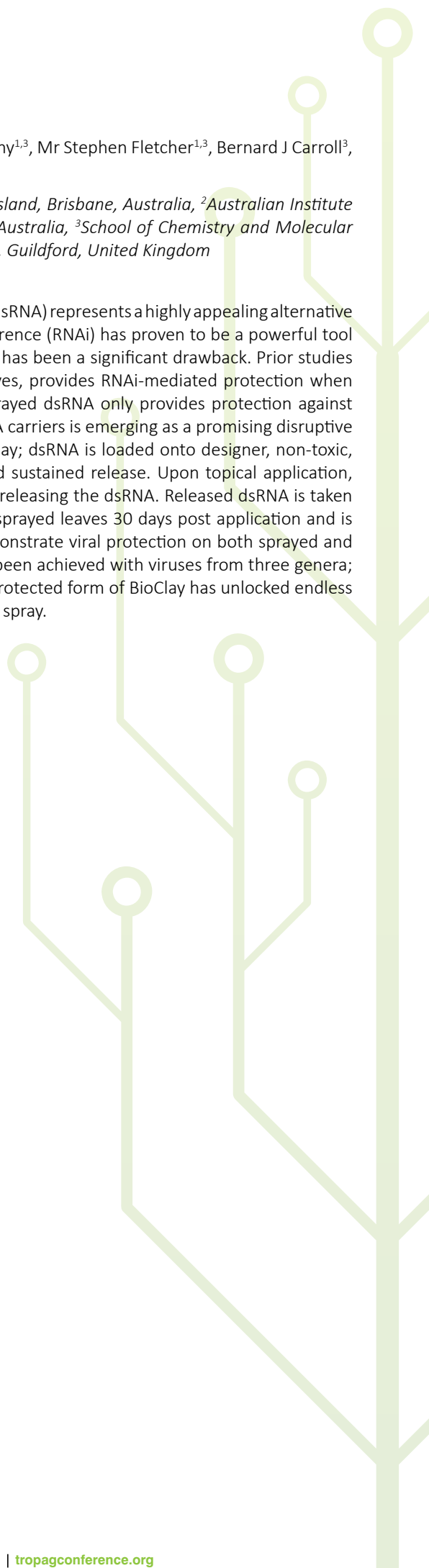
In this presentation, our recent progresses on functional nanomaterials in animal healthcare will be introduced. We report that silica nanoparticles with rough surfaces have enhanced adhesion towards various surfaces, thus can be used for antibacterial protein delivery, DNA vaccine and nano-pesticide formulation. Conventional silica materials have been used as adjuvants in vaccine formulation, however their adjuvanticity is limited. We demonstrate that by tuning the composition, surface roughness and nanoparticle symmetry, the rationally designed silica nanoparticles can be used as novel adjuvants and carriers which stimulate potent and tunable immune response. Our nanotechnologies applicable in other agriculture sectors will also be reviewed.

307 BioClay for crop protection against viruses

Miss Elizabeth Worrall¹, Dr Karl Robinson¹, Peng Li², Mr Ritesh Jain¹, Christelle Taochy^{1,3}, Mr Stephen Fletcher^{1,3}, Bernard J Carroll³, GQ (Max) Lu^{2,4}, Zhi Ping Xu², Professor Neena Mitter¹

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Protecting crop plants against viruses by topical application of double-stranded RNA (dsRNA) represents a highly appealing alternative to virus resistant transgenic crops or pesticides targeting virus vectors. RNA-interference (RNAi) has proven to be a powerful tool to combat crop viruses, however societal acceptance of genetically modified crops has been a significant drawback. Prior studies have demonstrated that homologous dsRNA, exogenously applied onto plant leaves, provides RNAi-mediated protection when virally challenged. However, the instability of dsRNA is a major bottleneck, as sprayed dsRNA only provides protection against viruses for up to 5 days. The innovative approach of utilizing nanoparticles as dsRNA carriers is emerging as a promising disruptive technology that is environmentally sustainable and easy-to-adopt. Coined as BioClay; dsRNA is loaded onto designer, non-toxic, degradable layered double hydroxide (LDH) nanosheets for improved stability and sustained release. Upon topical application, LDH slowly degrades under the presence of moisture and carbon dioxide, thereby releasing the dsRNA. Released dsRNA is taken up by plant cells and silences homologous viral RNA. BioClay can be detected on sprayed leaves 30 days post application and is resistant to washing. Importantly, plants virally challenged 20 days post spray demonstrate viral protection on both sprayed and newly emerged, unsprayed leaves. RNAi-mediated protection utilizing BioClay has been achieved with viruses from three genera; Cucumovirus, Tobamovirus and Potyvirus. Exogenous application of dsRNA in the protected form of BioClay has unlocked endless opportunities to protect crops from pests and pathogens as a clean and green crop spray.



308 Constraints on photosynthetic efficiency in C4 crops, with special references to sugarcane

Prof Rowan Sage¹

¹*Ecology and Evolution Department, University of Toronto, Toronto, Canada*

C4 photosynthesis exhibits superior productivity and resource use efficiency in warm, high light environments of low latitude. As a consequence, the most productive crops are C4. While there has been much emphasis on engineering photosynthetic improvements in C3 crops, including the introduction of the C4 pathway into rice, there is less emphasis on improving C4 photosynthesis. In comparison with C3 photosynthesis, there may be greater opportunities for improving photosynthesis in C4 species due to the addition of the C4 cycle. For example, enhancing C4 cycle activity could improve CO₂ delivery to Rubisco in the bundle sheath cells, thereby enhancing carboxylation efficiency and photosynthesis at lower stomatal conductance. C4 crops designed to have higher carboxylation efficiency at lower stomatal conductance would therefore have much higher water use efficiency, a premium advantage in the dry tropics. Low temperatures also impair C4 photosynthesis, due to bottlenecks imposed by either Rubisco or pyruvate-P-dikinase activity. Overcoming these limitations, for example, by introducing isoforms of limiting enzymes from cold-tolerant C4 species such as *Miscanthus*, could improve performance of tropical C4 crops in upland locations. In the case of sugar cane, its photosynthesis rate is often limited by nitrogen supply, due to reduced N application to enhance sugar allocation to storage. Maize by contrast, has a 50% higher nitrogen use efficiency (NUE) than sugarcane, possibly due to less structural investment in the maize leaf. By mimicking the maize pattern, it may be possible to substantially enhance photosynthetic NUE in sugar cane, and with it, sucrose yield.

309 Licence to farm: Why nitrogen use efficiency matters and how we can achieve it in sugarcane

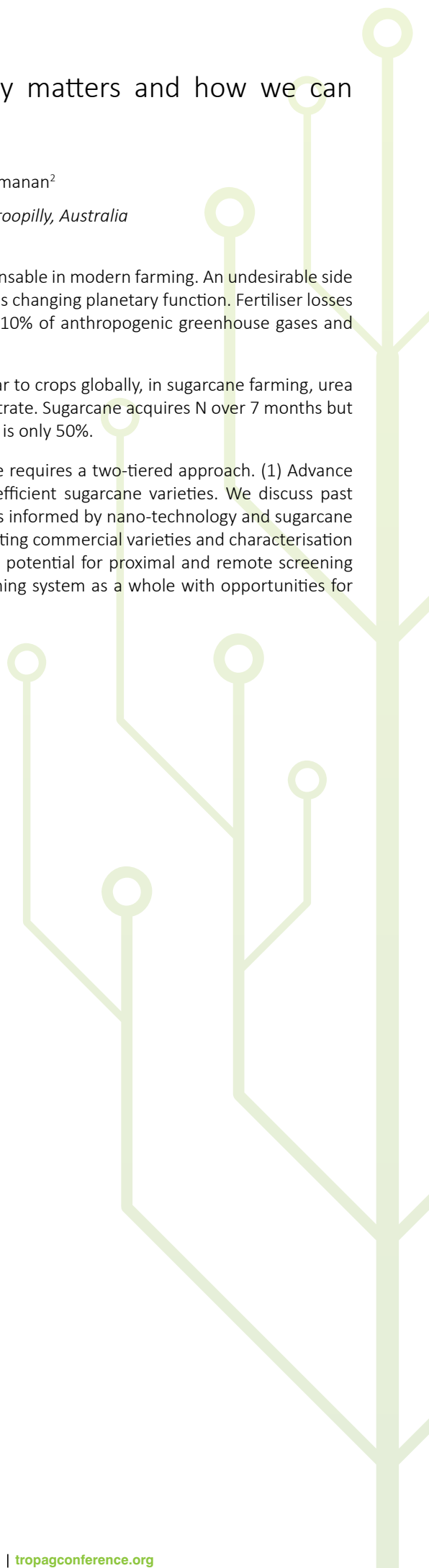
Prof Susanne Schmidt¹, Dr Nicole Robinson¹, Dr Richard Brackin¹, Dr Prakash Lakshmanan²

¹The University of Queensland, St Lucia, Australia, ²Sugar Research Australia, Indooroopilly, Australia

High crop yields are only realised with nutrient sufficiency and fertilisers are indispensable in modern farming. An undesirable side effect is pollution and the increased presence of reactive nitrogen and phosphorus is changing planetary function. Fertiliser losses pollute soil, water and air, cause algae blooms and coastal dead zones, generate 10% of anthropogenic greenhouse gases and deplete biodiversity, e.g. via coral-predating starfish in the Great Barrier Reef.

At the heart is the mismatch between fertiliser availability and crop demand. Similar to crops globally, in sugarcane farming, urea is applied and rapidly converted to ammonium and highly mobile and loss-prone nitrate. Sugarcane acquires N over 7 months but wet season rainfall and irrigation drive N losses in the early season and N efficiency is only 50%.

To meet the N influx reduction target for the GBR lagoon, transformational change requires a two-tiered approach. (1) Advance understanding of soil N processes and efficient N supply, and (2) breed N use efficient sugarcane varieties. We discuss past research with commercial urea formulations, and current next-generation fertilisers informed by nano-technology and sugarcane physiology. We present an update on evaluation of genetic variation in N use in existing commercial varieties and characterisation of N-use linked traits including canopy closure, specific leaf N, and N uptake with potential for proximal and remote screening for efficient N use in sugarcane breeding programmes. Lastly, we discuss the farming system as a whole with opportunities for biological N fixation and nutrient repurposing to achieve nutrient stewardship.



310 Control of sugar and fibre: Insights from the sugarcane transcriptome analyses

Dr Prathima Perumal Thirugnanasambandam^{1,2}, Dr Nam Van Hoang³, Dr Agnelo Furtado¹, Dr Frikkie C Botha⁴, Dr Robert Henry¹

¹QAAFI, Brisbane, Australia, ²ICAR-Sugarcane Breeding Institute, Coimbatore,, India, ³College of Agriculture and Forestry, Hue University, Hue, Vietnam, ⁴Sugar Research Australia, Indooroopilly, Australia

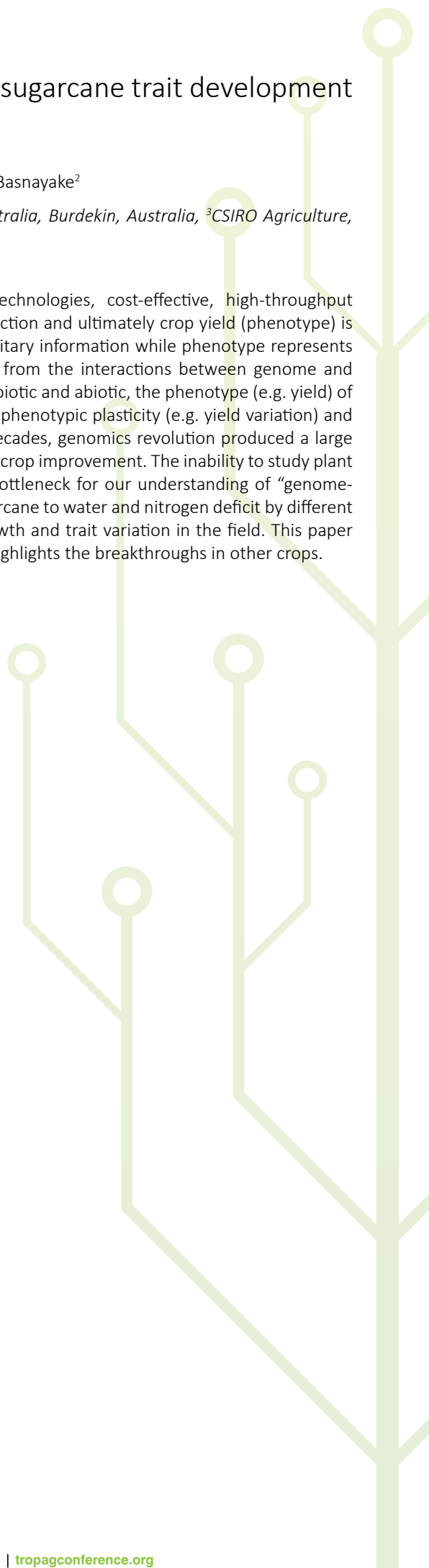
Sucrose and fibre traits in sugarcane share a very dynamic relationship depending largely upon the genetic makeup of genotypes and growth environment. To investigate the molecular basis of carbon flux into sucrose and fibre that makes genotypes high sugared or high fibred, or dual purposed, an extensive transcriptomics study was undertaken using a set of sugarcane genotypes differing in sugar and fibre contents. RNA-Seq was used for sequencing whole transcriptomes from top and bottom internodes of 20 genotypes at 12 months of planting. Differential gene expression (DGE) analyses were performed using 40 transcriptomes using publicly available sugarcane genomic resources including sugarcane EST database (SUCEST) and *Saccharum officinarum* gene indices (SOGI), in addition to a long-read sugarcane transcriptome reference database, SUGIT. Results of DGE analysis for sucrose revealed a complex network of transcripts associated with growth, defence, vacuole, sucrose and fibre related genes, for instance, with SUGIT database, 18543 differentially expressed transcripts were obtained while DGE analysis for fibre resulted in 4818 transcripts differentially expressed. Sucrose might play a significant regulatory role in controlling expression of several thousand genes including those related to fibre rather than merely being a storage sugar of the culms. Further the high sugar genotypes were not always low fibred and fibre might to an extent provide structural framework for maintaining high sugar levels as seen by the high expression of fibre related genes. The study also suggests that there could exist certain threshold levels of sugar or fibre contents beyond which an inverse relation would occur.

311 Application of high-throughput phenomics for sugarcane trait development and variety improvement

Dr Prakash Lakshmanan¹, Dr Sijesh Natarajan², Dr Scott Chapman³, Dr Jayampathi Basnayake²

¹*Sugar Research Australia, Indooroopilly, Brisbane, Australia*, ²*Sugar Research Australia, Burdekin, Australia*, ³*CSIRO Agriculture, Brisbane, Australia*

With the recent advancements in sensor, computational and automation technologies, cost-effective, high-throughput quantitative phenotyping to link the genotype and environment to plant form, function and ultimately crop yield (phenotype) is becoming a reality in many crops. The genotype of a plant consists of all its hereditary information while phenotype represents the morphological, physiological, growth and developmental attributes resulting from the interactions between genome and environment. Because of the large spatio-temporal variation in environment, both biotic and abiotic, the phenotype (e.g. yield) of an individual can be very plastic. Understanding the mechanism underpinning the phenotypic plasticity (e.g. yield variation) and its determinants remains the major bottleneck for breeding. Over the past two decades, genomics revolution produced a large body of genome sequence and gene expression data but it is largely unexploited for crop improvement. The inability to study plant functions dynamically in large genetic populations in the field remains the real bottleneck for our understanding of “genome-phenome” relationships. Recently we studied genetic variation for response of sugarcane to water and nitrogen deficit by different phenotyping technologies. They successfully discriminated test genotypes for growth and trait variation in the field. This paper reviews the status and the potential applications of phenomics in sugarcane, and highlights the breakthroughs in other crops.



312 Sensitivity and plasticity of sugarcane leaf metabolism during stress

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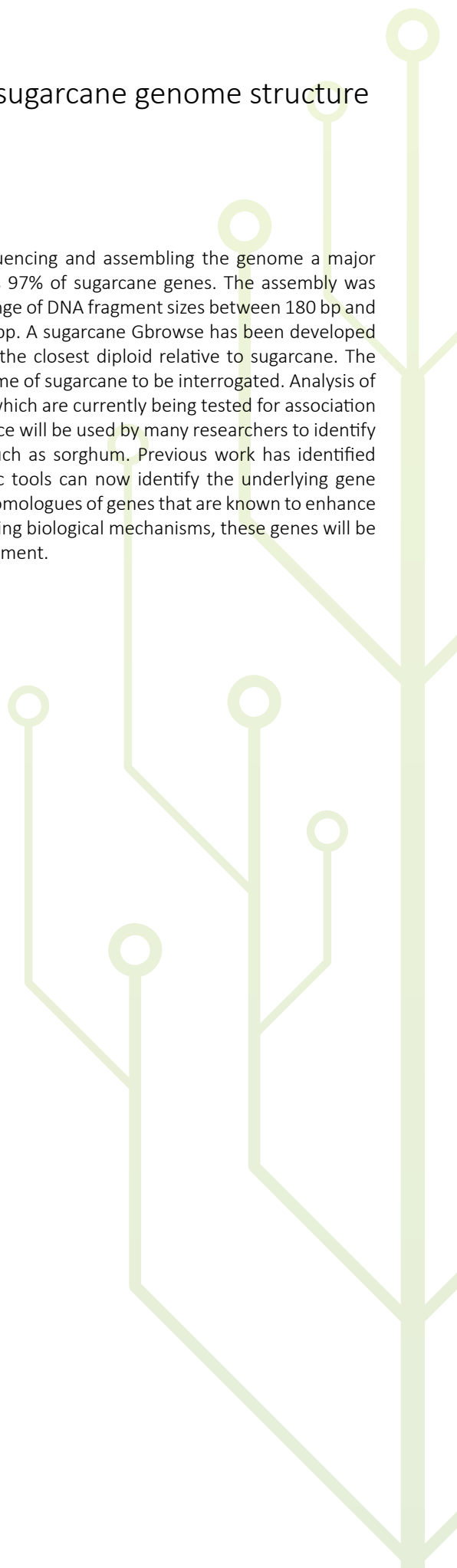
Yield improvements in sugarcane have been negligible in the past three decades as breeders cope with new pests and diseases, as well as changing environmental conditions. Sugarcane production is increasingly forced into more marginal, higher stress environments. Generally, we have a limited understanding of the molecular mechanisms that underpin the crop's response to stress. A good understanding of these biochemical mechanisms, and associated gene expression, supports and encourages the development of sugarcane breeding and management strategies. In this study the metabolic impacts of stresses on sugarcane leaves are described, with emphasis on the C₄ spatial separation of carbon fixation and decarboxylation. In all C₄-species, PEP carboxylase (PEPC) in the mesophyll is the primary enzyme of CO₂ fixation. The product of PEPC, oxaloacetate (C₄-organic acid), is then shuttled to the bundle sheath cells where CO₂ is released via a decarboxylation reaction. There are three different pathways through which this shuttling and decarboxylation can occur and plants are classified based on the dominant pathway. We have used transcriptome and proteome data to reconstruct the carbon fixation pathways, light reactions and mitochondrial pathways in sugarcane leaves at different stages of development and stress. We show there is variation and flexibility in shuttling and decarboxylation pathways under the different physiological conditions. In the light reactions, the photosystem II (PSII) component of the electron transport chain is particularly sensitive to stress. These changes in photosynthetic activity also coincide with major shifts in carbon partitioning.

313 Using genomic sequencing to understand the sugarcane genome structure

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Sugarcane has a complex polyploid hybrid genome of 10 Gbp which makes sequencing and assembling the genome a major challenge. Despite this we have generated a sugarcane assembly that represents 97% of sugarcane genes. The assembly was generated using both whole genome shotgun (WGS) sequence generated from a range of DNA fragment sizes between 180 bp and 32,000 bp, and PacBio long read technology with an average read length of 7282 bp. A sugarcane Gbrowse has been developed which aligns the sugarcane assembly to the current sorghum genome sequence the closest diploid relative to sugarcane. The Gbrowse allows the multiple alleles of genes that are present in the polyploid genome of sugarcane to be interrogated. Analysis of this data has identified large numbers of single nucleotide polymorphisms (SNPs), which are currently being tested for association with desirable traits amongst a population of plant lines. A defined genome sequence will be used by many researchers to identify the basis of traits and to capitalise on knowledge of traits from related crops such as sorghum. Previous work has identified quantitative trait loci (QTL) for traits such as biomass in sugarcane. Bioinformatic tools can now identify the underlying gene sequences from the sugarcane genome sequence. In a similar way, the sugarcane homologues of genes that are known to enhance productivity in other species can now be identified. In addition to revealing underlying biological mechanisms, these genes will be valuable as targets for selection or genetic modification to enhance variety development.



314 The role of animal welfare in tropical beef production

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Over the past 10-15 years consumers have become more vocal regarding the conditions in which their food is raised than ever before. Common on farm practices that still need attention from an animal welfare perspective include painful procedures (castration, dehorning, branding), stressful routine management practices (weaning, handling and transportation) animal health (respiratory disease, lameness, parasites) and environmental (heat stress, parasites and drought) effects. The goal of this talk is to provide a brief overview of the most relevant welfare issues to tropical animal production with a focus on transportation, lameness and castration. It is well known that all of these practices/conditions cause some degree of stress/pain in cattle and can have large economic consequences to producers. Behavioural and physiological techniques for welfare assessment on farm as well as characterizing the problem and identifying some potential mitigation strategies for each of the focus issues will be discussed. Finally, the identification of future industry needs and knowledge gaps will be outlined.

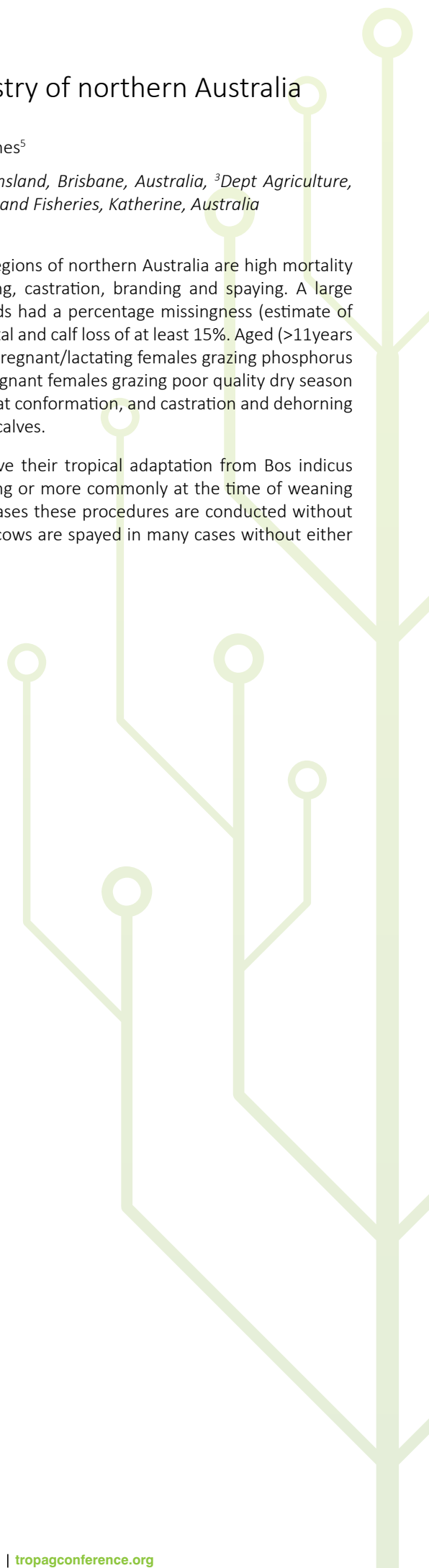
315 Animal welfare issues in the grazing beef industry of northern Australia

Michael McGowan⁴, Geoffry Fordyce², Dave Smith³, Kieren McCosker⁴, Tamsin Barnes⁵

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The major property-level animal welfare issues in the extensive beef production regions of northern Australia are high mortality rates in breeding females and young calves, and pain associated with dehorning, castration, branding and spaying. A large epidemiological study of commercial beef breeding herds found that 25% of herds had a percentage missingness (estimate of mortality) of pregnant cows of at least 12%, and 25% of herds had a percentage foetal and calf loss of at least 15%. Aged (>11years old) cows, cows calving during the mid-dry season or in poor body condition, late pregnant/lactating females grazing phosphorus deficient pastures during the wet season (with the associated risk of botulism), pregnant females grazing poor quality dry season pastures, dystocia, mustering late pregnant-early lactating cows, poor udder and teat conformation, and castration and dehorning are important factors associated with increased mortality in breeding females and calves.

Most calves born in northern Australia need to be dehorned because they derive their tropical adaptation from *Bos indicus* genotypes. Dehorning and castration are conducted either at the time of branding or more commonly at the time of weaning when many calves will be at least 6 months of age. Currently in the majority of cases these procedures are conducted without either local anaesthesia or systemic analgesia. Similarly, surplus heifers and aged cows are spayed in many cases without either local anaesthesia or systemic analgesia.



316 Proteomics to detect biomarkers of pain and inflammation in cattle

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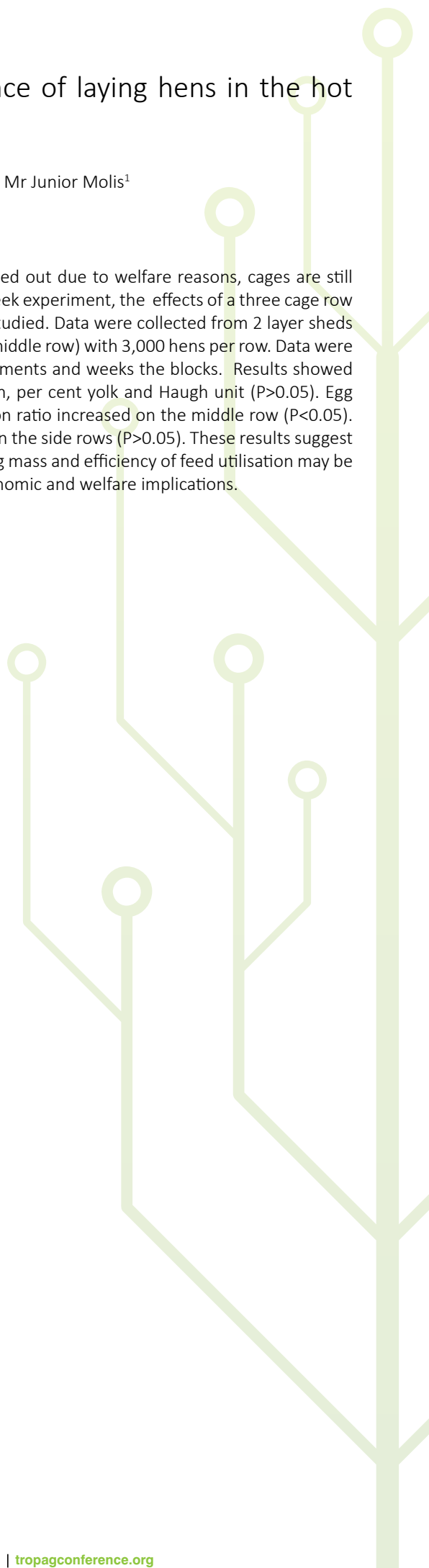
Cattle are routinely subjected to painful surgical husbandry procedures, such as castration and dehorning. Quantifying the effectiveness of pain relief interventions during these procedures is challenging, due to the subjectivity and complexity of pain perception in animals and the inherent tendency for prey species to suppress their behavioural responses. Therefore, there are obvious limitations in the use of behavioural observations and routine biochemical or immunological assays restricted to individual targets (e.g. plasma cortisol) for detecting and quantifying the response to pain and stress. One approach, increasingly used in human biomedicine, is to develop an array of plasma biomarkers, which collectively respond to a stimulus. Next generation mass spectrometry techniques, such as SWATH-MS, can be applied to quantitative profiling of proteins (proteomics), lipids (lipidomics) and metabolites (metabolomics) in an unbiased manner and enable simultaneous evaluation of hundreds to thousands of various markers in virtually unlimited number of samples and thus provide more holistic representation of the physiological change. SWATH-MS analysis requires one off construction of spectral libraries which can be expanded as the project develops and shared between laboratories. In this study, SWATH-MS approach has been applied to monitor proteins that form a part of the systemic response to pain and inflammation and are putative targets of analgesic drugs. We describe the development of the foundational data and tools that do not only permit more thorough understanding of pain and inflammation in cattle but also have a potential to advance veterinary medicine in a manner that has not been possible before.

317 Cage row arrangement affects the performance of laying hens in the hot humid tropics

Dr Siaka Diarra¹, Mrs Ranita Devi¹, Mrs Samantha Rogers¹, Ms Papayaia Vaeluagas¹, Mr Junior Molis¹

¹*School of Agriculture and Food Technology, Apia, Samoa*

Although the traditional cage system of housing laying hens is gradually being phased out due to welfare reasons, cages are still common in most developing tropical countries in different arrangements. In a 12-week experiment, the effects of a three cage row arrangement on hen-day production and egg qualities of Shaver Brown hens was studied. Data were collected from 2 layer sheds housing 9,000 hens in a 3-cage row arrangement (southern row, northern row and middle row) with 3,000 hens per row. Data were analysed for a randomized complete block design where cage rows were the treatments and weeks the blocks. Results showed no significant effects of cage row arrangement on feed intake, hen-day production, per cent yolk and Haugh unit ($P>0.05$). Egg weight, egg mass and per cent shell were significantly reduced and feed conversion ratio increased on the middle row ($P<0.05$). Egg weight, egg mass, per cent shell and feed conversion ratio did not differ between the side rows ($P>0.05$). These results suggest that battery cage row arrangement may not affect the rate of lay but egg weight, egg mass and efficiency of feed utilisation may be adversely affected in hens housed in the middle row. These findings have both economic and welfare implications.



318 Applications of endocrine physiology concepts to evaluate stress and welfare of production livestock

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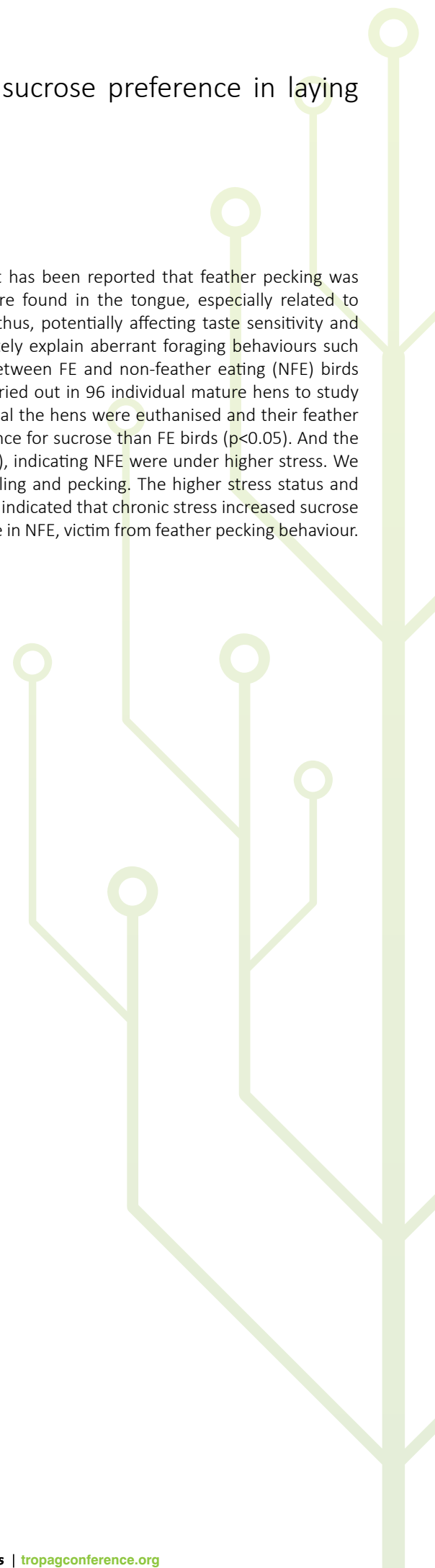
Animal health and welfare are important components of quality livestock production in Australia and welfare is carefully monitored by high standard rules and regulations. Stress is a physiological process which enables animals to respond to changes in their environment however long-term activation of the physiological stress response during exposure to noxious stimulus (e.g. climate change, physical mismanagement) could lead to negative impacts on the animal's health and well-being. The stress endocrine system (hypothalamo-pituitary adrenal-HPA axis) is responsible for regulating the physiological stress response in animals. Secretion of stress hormones or glucocorticoids alter gene expression that may be needed for immune response and energy supply for increased metabolic demand while animals face-off with stressors. The HPA axis normally operates within homeostasis range however prolonged exposure to physical and environmental stressors causes the physiological stress response to turn maladaptive, causing negative effects on reproduction, immune function, satiety and behaviour. Simply put, it is essential to monitor stress in production livestock so that producers and consumers are aware that the animals are "happy=physiological wellness". Recent innovations in the emerging field of non-invasive stress endocrinology have improved laboratory techniques that can rapidly and reliably quantify stress hormones in animals through measurements of steroids in non-invasive biological samples such as faeces, wool and hair. My research lab runs under the thematic area of "Stress Physiology" and through this presentation I will describe and discuss the recent applications of non-invasive endocrinology for stress assessments in production livestock to monitor health and welfare.

319 Feather-eating is related to stress level and sucrose preference in laying hens

Mr Sungbo Cho¹, Dr Eugeni Roura¹

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

Feather pecking behaviour in laying hens may be associated with stress level. It has been reported that feather pecking was positively correlated with plasma corticosterone. Stress hormone receptors were found in the tongue, especially related to Tas1r3-expressing taste cells (a common receptor for sweet and umami taste), thus, potentially affecting taste sensitivity and diet selection. We hypothesized that these effects on diet selection may ultimately explain aberrant foraging behaviours such as feather pecking/eating (FE). Therefore, we compared corticosterone levels between FE and non-feather eating (NFE) birds using a non-invasive method: egg albumin analysis. A double choice test was carried out in 96 individual mature hens to study their nutrient preferences including sucrose (at 1, 5 or 17%). At the end of the trial the hens were euthanised and their feather consumption assessed by necropsy. NFE hens showed significantly higher preference for sucrose than FE birds ($p < 0.05$). And the corticosterone level was higher in non-feather eaters than feather eaters ($p < 0.05$), indicating NFE were under higher stress. We speculate that the higher level of stress relates to being objective of feather pulling and pecking. The higher stress status and sucrose preference in NFE are consistent with stress experiments in rodents which indicated that chronic stress increased sucrose consumption. Therefore, higher stress status might be related to a sucrose appetite in NFE, victim from feather pecking behaviour.



320 Tropical rice: Challenges for quality

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¹University of Queensland, University Of Queensland, Australia

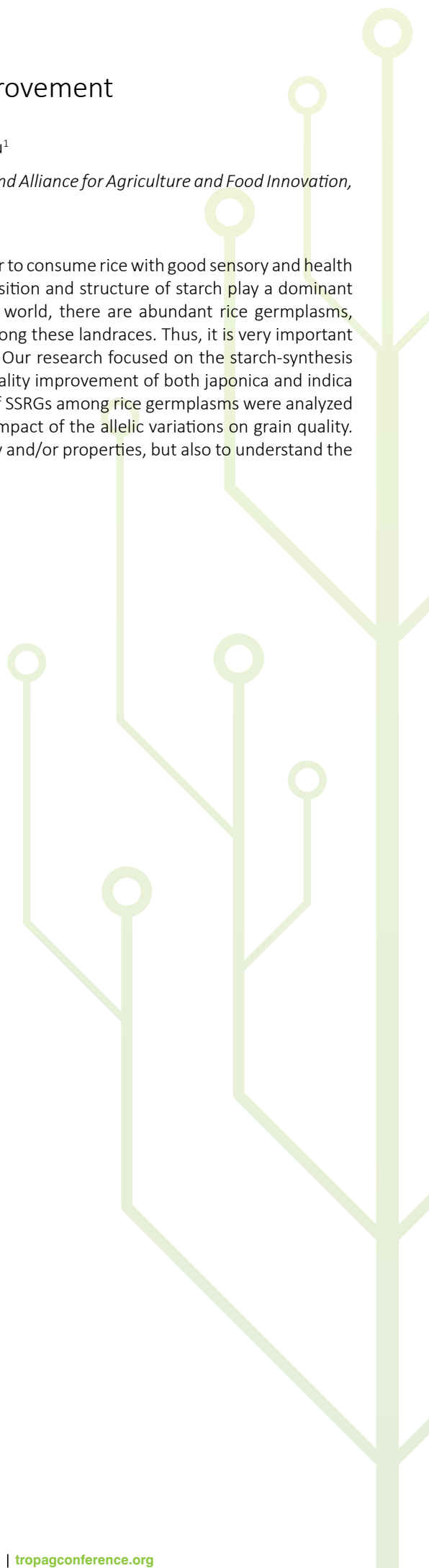
Aromatic rice commands the highest prices in both domestic and international markets because consumers prize both the mouth-watering aroma and delicate flavour of the rice. The major aromatic compound in fragrant rice is 2-acetyl 1-pyrroline (2AP). Using a panel of 380 diverse varieties of rice, metabolomics profiling of volatile compounds from the grain, and genome wide association with 33000 single nucleotide polymorphisms (SNPs), the objectives of this study were to identify (i) sensory traits that describe jasmine rice; (ii) the volatile compounds that define those sensory traits, and (iii) genetic markers for those compounds. The sensory descriptors fell into three clusters, with Cluster 1 describing high quality jasmine rice, Cluster 3 describing non-fragrant rice, and lower quality jasmine rices falling between the descriptors in Clusters 1 and 2. The compounds that most strongly discriminated the high quality jasmine rices from the other samples were 2AP and four other compounds, two of which required high resolution platforms to reveal their molecular structure and annotation. These five compounds associate with the same SNP on chromosome 8, several are fragrant with a low odour threshold, and they provide new information about the pathway of 2AP synthesis. Three QTL were found that associate with high or low amounts of the five compounds. Another 20 metabolites associated either positively or negatively with high quality jasmine fragrance. Significant genetic associations could be found for some of these compounds. By combining these platforms, we deliver new and valuable tools to breeders for selecting highly fragrant rice.

321 Starches in rice endosperm: Diversity and improvement

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Rice is one of the most important foods in the oriental world, and more peoples prefer to consume rice with good sensory and health characteristics. Starch is the major component of rice endosperm, and the composition and structure of starch play a dominant role in the quality of the rice grains, as well as their industry application. In the world, there are abundant rice germplasms, including lots of local landraces, and the grain quality variation occurred widely among these landraces. Thus, it is very important to mine novel alleles of starch quality-related genes for rice quality improvement. Our research focused on the starch-synthesis related genes (SSRGs), and carried out to mine novel diversity of such genes for quality improvement of both japonica and indica rice cultivars. By using re-sequencing and related approaches, the allelic variation of SSRGs among rice germplasms were analyzed and several new alleles were mined. Our results showed that there has a certain impact of the allelic variations on grain quality. The results will be very useful not only to breed new rice cultivars with good sensory and/or properties, but also to understand the genetic diversity of grain quality in rice.



322 Opportunities and challenges of establishing a northern rice industry

Mr Russell Ford¹

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Most of the world's rice is grown under tropical or sub-tropical conditions as found in Northern Australia for much of the year.

Past experiences in North Australia has shown that much of the development to a successful rice industry has been limited by pests, disease, suitable varieties and lack of infrastructure.

The latest efforts in growing rice in Northern Australia have mainly been focused on growing rice in an Alternate Wetting and Drying (AWD) growing system, where a dryer surface helps alleviate problems from bird pressure and works in with many of the current farming systems such as sugar cane and pulses.

The opportunity exists to deliver a Northern rice farming system that can deliver a profitable option for inclusion in agriculture across North Australia. Reliability of rainfall and water, along with heat and suitable soils, are key drivers in finding a suitable system for Northern Rice. Overcoming some of the challenges and delivering a safe and balanced Rice Recipe for the North is the focus over the next few years.

323 Designing tropical rice for improved nutrition and palatability

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¹The University of Queensland, Brisbane, Australia, ²Yangzhou University, Yangzhou, China, ³Beijing Technology & Business University, Beijing, China

The quality trait which has received the most attention from rice breeders has been yield. Nutritional quality is also important, especially slow digestibility (higher resistant starch). Current rices with very slow digestibility are high-amylose types, which have unacceptable palatability. Rice digestibility is strongly dependent on the starch chain length distribution, especially having more longer amylopectin chains and more shorter amylose chains (e.g. [1-3]). Long amylose chains give low palatability, for reasons that are becoming understood on a molecular basis [4, 5]. This new knowledge is available for rice breeders and molecular biotechnologists (including new technologies [6-7]) to select and develop improved rice varieties for tropical agriculture. This can include both new types of wild rice [8], as well as conventional domesticated varieties grown in tropical conditions.

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[6] C. Li, RG Gilbert, *Planta* 243(2016) 13.

[7] C. Li, ... RG Gilbert, *PLoS One* 10 (2015) e0125507.

[8] T. Tikapunya, ... R.J. Henry, RG Gilbert, *Carbohydrate Polymers* 172 (2017) 213.

324 Australian wild rice: Diverse and tasty

Mr Ali Mohammad Moner¹, Ms Tiparat Tikapunya¹, Mrs Hayba Badro¹, Mrs Marta Brozynska¹, Mr Agnelo Furtado¹, H Symth¹, QQ Liu², R G Gilbert¹, Prof Robert Henry¹

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Australian wild rices include A genome populations that are the closest relatives of domesticated rice. Genome sequencing has indicated that the Australian taxa are part of sister clades to the other A genome species diverging in the last 1.5-3 million years. Recent analysis has examined diversity in the Australian populations at the genome level and explored grain quality traits. This research has confirmed the presence of novel diversity at the genome, starch structure and quality trait level. Grain size is within the normal ranges of domesticated rices. The amylose content of the grains is generally very high with a diversity of starch fine structures, some of which are significantly different from those of domesticated rices and thus may have advantageous nutritional properties. Genome analysis has confirmed the presence of novel starch biosynthesis genes. Sensory evaluation suggests that these rices are attractive for consumption in their present form as wild rices and will be useful as source of extensive and novel diversity for domesticated rice improvement.

325 Where the rubber meets the road: Implementing molecular marker technologies in the Australian rice breeding program

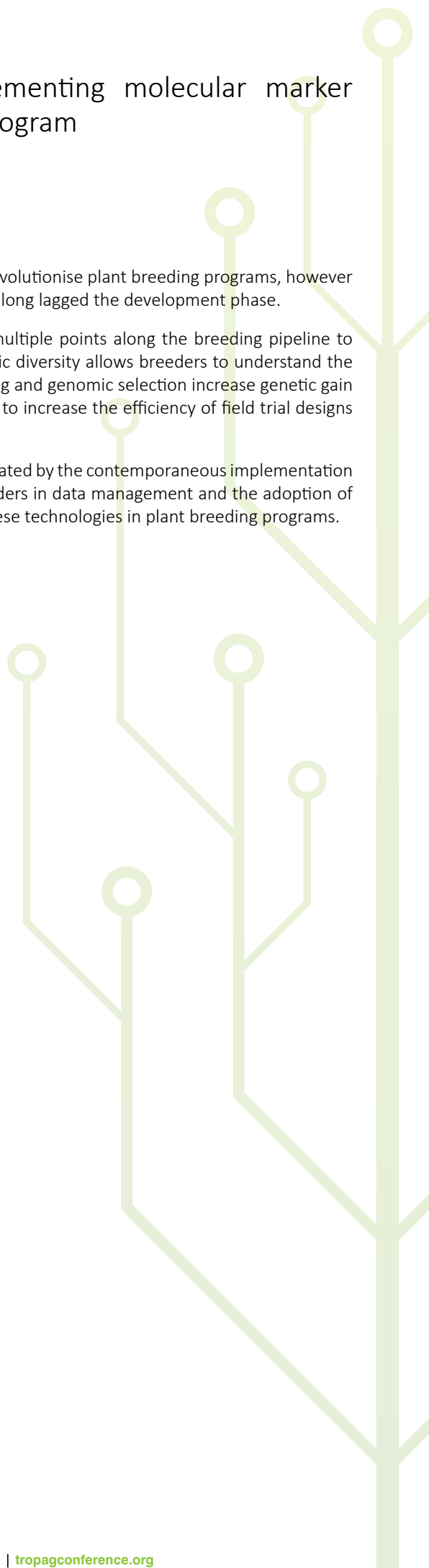
Dr Ben Ovenden¹

¹*Nsw Department of Primary Industries, Yanco, Australia*

The rapid emergence of new molecular marker technologies has the potential to revolutionise plant breeding programs, however the incorporation of these new technologies into variety development systems has long lagged the development phase.

The Australian rice breeding program has integrated molecular technologies at multiple points along the breeding pipeline to increase breeding efficiency and genetic gain. Molecular characterisation of genetic diversity allows breeders to understand the potential as well as limitations of breeding germplasm. Marker assisted backcrossing and genomic selection increase genetic gain during breeding line development. Whole genome profile information is also used to increase the efficiency of field trial designs and pure seed production.

Implementation of marker technologies in the rice breeding program has been facilitated by the contemporaneous implementation of a data management system to manage genetic information. Training plant breeders in data management and the adoption of new marker technologies is an opportunity to more fully realise the potential of these technologies in plant breeding programs.



326 The role of Australia's genebanks and crop wild relatives in all our futures

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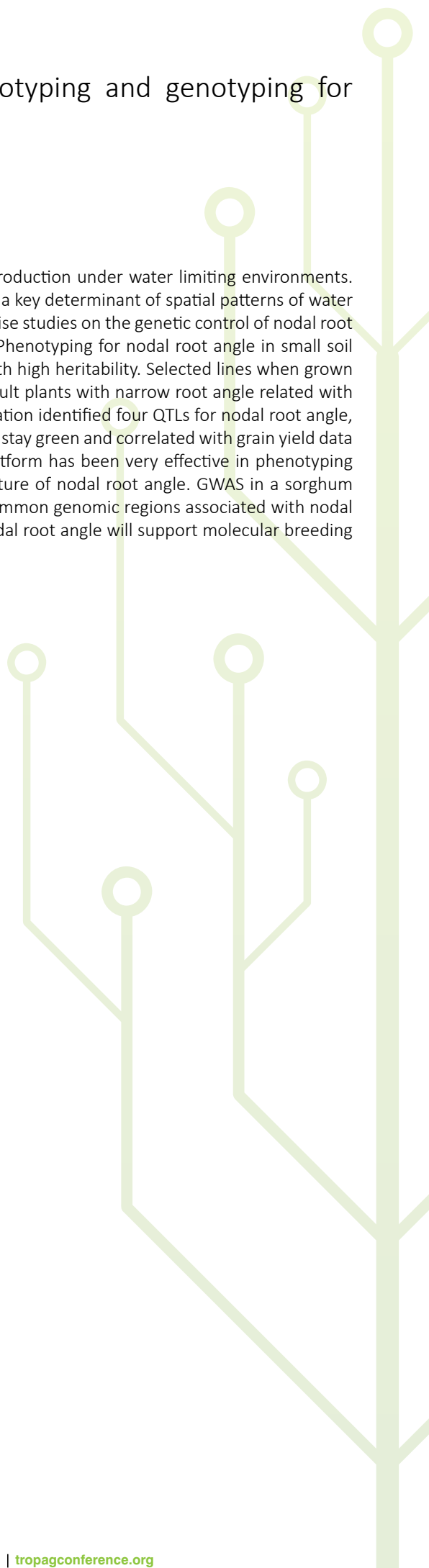
Plant breeders need as much diversity as they can get to develop the more productive, resilient and nutritious varieties that are needed to feed the growing world population under pressures such as reduced arable land and the expected effects of climate change. Through history much of this genetic diversity has been provided by landrace and heirloom varieties, however, a much wider diversity of traits exist 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. Although no major food crops originated in Australia, there is a rich diversity of wild relatives of banana, cotton, macadamia, millets, mungbean, pigeonpea, rice, sorghum, soybean and yam. These CWR are predominantly spread across the tropical regions of northern Australia, with a recent gap analysis of CWR diversity showing they are underrepresented in the world's genebanks. The Australian Grains Genebank has collections of many of these CWR species, and has a collaborative program to collect and conserve the priority species, identified during the gap analyses so the representative diversity is conserved. Once they have been evaluated, these CWR will provide valuable traits for improved productivity under a range of biotic and abiotic constraints.

327 Drought proofing sorghum: Multiscale phenotyping and genotyping for nodal root angle

Dr Vijaya Singh¹

¹QAAFI-CPS, Brisbane, Australia

Genetic improvement of drought resistance in sorghum is essential to enhance production under water limiting environments. Recent research has demonstrated that the angle of the first flush of nodal roots is a key determinant of spatial patterns of water acquisition in mature plants and can improve drought adaptation. Here we summarise studies on the genetic control of nodal root angle in sorghum seedlings and its effects on water extraction of mature plants. Phenotyping for nodal root angle in small soil filled chambers at seedling stage indicated extensive genetic variation (15°-50°) with high heritability. Selected lines when grown in large chambers were predictive of the amount and timing of water uptake in adult plants with narrow root angle related with deep root development. Further phenotyping and genotyping of a mapping population identified four QTLs for nodal root angle, which explained 58.2% of phenotypic variance. These QTLs co-located with QTLs for stay green and correlated with grain yield data from breeding trials in the field. The new, more high-throughput phenotyping platform has been very effective in phenotyping multiple complementary populations to elucidate the underlying genetic architecture of nodal root angle. GWAS in a sorghum NAM population, a Diversity Panel and elite breeding populations has identified common genomic regions associated with nodal root angle. It is anticipated that the identification of genetic regions controlling nodal root angle will support molecular breeding for drought adaptation by manipulation of root traits.



328 Interoperable infrastructure – A vision for DivSeek

Mr Robert Davey¹

¹*Earlham Institute, United Kingdom*

The academic and commercial crop research communities are becoming increasingly reliant on, and responsible for, larger and more complex datasets. These data range from highly-curated centralised resources managed by dedicated specialists to heterogeneous bundles of tabular, image, or binary files that are generated and stored by individual researchers, breeders, or collaborative groups. Integration of these multi-scale resources will be vital to meet the demands of scientists and breeders, making the vast corpus of knowledge accessible so that intuitive data representation and effective data interrogation is possible. However, data integration is notoriously challenging, with much research having been undertaken in the last 20 years to generate standards to form common ways of consistently describing research, computational infrastructure to house and disseminate data, and software tools to facilitate complex analysis and visualisation. To bring these efforts to the forefront of crop research, a strongly coordinated and openly collaborative effort is required.

329 Speed breeding to accelerate gene bank deposits into farmer fields

Dr Lee Hickey¹, Ms Amy Watson¹, Mr Adnan Riaz¹, Mr Eric Dinglasan¹, Ms Dilani Jambuthenne¹, Dr Olga Afanasenko², Dr Olga Mitrofanova³, Dr Kai Voss-Fels¹, Dr Evans Lagudah⁴, Dr Sambasivum Periyannan^{1,4}, Prof Ian Godwin⁵

¹The University of Queensland, Queensland Alliance for Agriculture and Food Innovation, St Lucia, Australia, ²Department of Plant Resistance to Diseases, All-Russian Research Institute for Plant Protection, St Petersburg, Russia, ³N. I. Vavilov Institute of Plant Genetic Resources, St Petersburg, Russia, ⁴Commonwealth Scientific and Industrial Research Organization (CSIRO), Agriculture & Food, Canberra, Australia, ⁵The University of Queensland, School of Agriculture and Food Science (SAFS), St Lucia, Australia

The human population is expected to reach nine billion by the year 2050, and will strain global resources. Modern plant breeding and a switch to monoculture cropping has greatly improved yield and quality, but lack of genetic variation has left crops vulnerable to rapidly evolving diseases and climate change. Fortunately, diverse landraces selected and grown by farmers prior to modern breeding are preserved in numerous gene banks around the world. Yet despite the potential, they are tremendously underutilised. The lack of information available for accessions, lack of high-throughput phenotyping methods, and the lengthy time required to effectively backcross target traits into adapted germplasm, has presented major challenges and provide little incentive for plant breeders to utilise these genetic resources. A new method for rapid generation advance, called 'speed breeding', uses extended photoperiods and controlled temperature to accelerate the growth of plants, enabling up to 6 generations of spring wheat, barley and chickpea per year and four generations of canola. This creates an exciting opportunity to harness genetic diversity lying dormant in gene banks and introduce new alleles into modern breeding germplasm pools. We present some case studies that integrate the use of speed breeding, genomics and phenotyping tools to speed up the discovery and utilisation of novel genes for resistance to major foliar disease of wheat using a collection of gene bank accessions sourced from the N. I. Vavilov Institute of Plant Genetic Resources (VIR) in St Petersburg, Russia.



330 The genomics of rice genetic resources

Prof Robert Henry¹

¹*The University of Queensland, Brisbane, St Lucia, Australia*

Rice is a key global food crop with a well characterised genome. However much can be gained from the use of genomics to further explore the wider rice gene pool. The A genome *Oryza* species comprise a primary gene pool for rice. Recent genome sequencing has demonstrated that domesticated japonica, indica and aus rices are derived from separate wild genepools. This is despite key domestication genes having a common ancestry. Sequencing and re-sequencing of wild A genome species has revealed extensive genetic diversity in wild populations in Australia, Asia and Africa. South American populations remain poorly characterized. Chloroplast and nuclear genomes show different evolutionary histories in the wild populations. Divergence and introgression are evident with hybrid populations being identified in the wild demonstrating active evolution of these taxa. De novo sequencing of wild *Oryza* allows these processes to be characterized. Understanding these processes may be useful in supporting rice improvement and better utilizing genetic resources. *Oryza* species that are more distantly related to domesticated rice also represent an important genetic resource with many traits of interest.

331 Unlocking genomic diversity without assembly or alignment

Mr Kevin Murray¹, Dr Christfried Webers^{1,2}, Dr Cheng Soon Ong^{1,2}, Dr Justin Borevitz¹, **Dr Norman Warthmann¹**

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Gene and seed banks preserve the germplasm of the world. The phenotypic and genotypic diversity in those repositories has been exploited in the past and will be key for future-proofing our ecosystems and agricultural production.

Entire genebank collections are currently being interrogated by DNA sequencing in order to unravel population structure and kinship and to enable approaches to associate genotype with phenotype. Accelerated progress in sorting through the samples and improving the associated metadata requires computationally efficient, bias-free approaches and whole genome sequencing data. Current best practices are dependent on alignment to reference genomes, which are often unavailable, inappropriate, and in any case can introduce bias.

Rapid and unbiased estimation of genetic relatedness by assembly- and alignment-free methods has the potential to overcome this reference genome bias, to detect mix-ups early, and to verify that biological replicates belong to the same genetic lineage before conclusions are drawn using mislabelled, or misidentified samples. We present one such method: kWIP, the k-mer Weighted Inner Product (kWIP), an assembly-, and alignment-free estimator of genetic similarity. kWIP combines a probabilistic data structure with a novel metric, the weighted inner product (WIP), to efficiently calculate pairwise similarity between sequencing runs from k-mer counts. It produces a distance matrix, which can be further analysed and visualised. No prior knowledge of the underlying genomes is required and applications include detecting sample identity and mix-up, non-obvious genomic variation, and population structure.

kWIP is written in C++, licensed under the GNU GPL, and is available from <https://github.com/kdmurray91/kwip>

