Avocado Brainstorming 2018

Towards a Sustainable Future

28 May – 1 June 2018

Fairview Hotel

Tzaneen, South Africa

Report to Sponsors

Prepared by

Mary Lu Arpaia

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EXECUTIVE SUMMARY

The 6th Avocado Brainstorming meeting was held in Tzaneen, South Africa from 28 May through 1 June 2018. One hundred fifty-two individuals representing 12 countries were invited. There were 78 participants representing 11 countries (Australia, Brazil, Chile, Colombia, Israel, Mexico, New Zealand, Peru, South Africa, Spain, and the United States). The Organizing Committee consisted of Mary Lu Arpaia (University of California, Riverside, CA, USA), Zelda Van Rooyen (Westfalia Technological Services, Duweilskloof, South Africa), Alejandro Barrientos Priego (University of Chapingo, Mexico), Francisco Mena (GAMA, Quillota, Chile), Randy Ploetz (University of Florida, Homestead, FL, USA) and Iñaki Hormaza (IHSM La Mayora-CSIC, Malaga, Spain). Westfalia Technological Services provided logistical assistance for the meeting and their help was invaluable.

This meeting would not have been held without sponsorship. There were 4 levels of sponsorship: Platinum (Hass Avocado Board (USA), Westfalia Fruit (South Africa), California Avocado Commission (USA)); Gold (ZZ2 (South Africa), Agricom (Chile) and Allesbeste (South Africa)); Silver (Costa (Australia), Delroy Orchards (Australia), Jasper Farms (Australia), Simpson Farms (Australia), Southern Forest Avocado (Australia), West Pemberton Avocados (Australia), BioGold (South Africa), Halls (South Africa), Index Fresh (USA), SAAGA (South Africa), The Fruit Farm Group (South Africa) and DataHarvest (USA)); and Bronze (Guy Witney (South Africa), Alvi's Drift (South Africa)). Additionally, a US$250 registration fee was required from participants.

One of the organizing committee's goals was to have a broad range of expertise and experience amongst the meeting participants. In particular we wanted to target young researchers to continue to build the foundation for continuity of ideas and sharing of knowledge between those experienced and those new to avocado research. This goal was met. Approximately 32% of the attendees could be considered as early career scientists (graduate student, postdoctoral researcher or less than 10 years avocado experience). Twenty-seven percent of the participants had between 10 to 20 years' experience (mid-career) and 41% of the attendees had greater than 20 years avocado experience. The attendees also represented a broad range of research interest from molecular biology/genetics to applied field orientation.

The meeting consisted of 8 2-hour sessions with ample time for exchange of ideas and discussions in an informal setting plus 2 poster sessions held on the second and fourth day. There were 17 poster abstracts submitted. The technical sessions covered the following topics:

- Providing for the Consumer: Health, Safety, Flavor
- New Technology to Improve Avocado Production
- Challenges to Productivity: Diseases
- Challenges to Productivity: How the Tree Regulates Return Bloom and Crop Load
- Where Theory Meets Practice

- Challenges to Productivity: Genetics, Genomics and Biotechnology
- Meeting the Challenges of the Future
- Tying the Loose Pieces Together – Planning for the Future

Additionally 3 field excursions were offered. The first was a morning trip to Allesbeste Nursery and orchards where the company is experimenting with high density plantings and tree training. The second event was an all-day field trip sponsored by Westfalia Technological Services. This trip included a visit to the original phosphite injection trees, an overview of the soil and land conservation practices, an overview of the company's avocado rootstock selection program and a field trip to see rootstock, cultivar trials and an experimental net planting with the GEM avocado. The final field trip was to Nick Hume's net trial with Lamb Hass, Maluma and Hass as well as a trip to ZZ2's compost operation. The Allesbeste field trip and the final field trip were optional activities but had good participation and were offered at a modest fee to cover transportation costs.

Of most interest to the group, based on feedback from participants, was the discussion of the health benefits of the avocado (presented by Dr. Nikki Ford, Hass Avocado Board, USA), the update of our progress to sequence the avocado (Dr. Aureliano Bombareley, Virginia Polytechnic University, USA), the update on flowering behavior (Dr. David Pattermore, Plant and Food, New Zealand) and Session 7 where perceived needs of the avocado community were discussed and solutions suggested.

One of the overarching goals of the Avocado Brainstorming meeting is to foster collaboration amongst avocado researchers worldwide. The collegiality and free exchange of ideas that occurred at this meeting is testament that this is occurring amongst the participants. Many participants indicated to the organizing committee that due to this meeting they had forged new working relationships with other international avocado researches. These collaboration will ultimately lead to joint research across international borders, open discussions and sharing of ideas amongst researchers interested in targeted topics and an overall greater appreciation of the complexities of avocado research amongst all scientists working in avocado.

At the conclusion of the sessions there was a discussion on where to proceed for future Avocado Brainstorming meetings. A consensus was expressed that holding the meeting off-cycle to the World Avocado Congress continues to be preferred. It was decided to hold the next meeting in 3 years to be mid-point between the Congress in Colombia and the following Congress. We had several suggestions for where to hold the meeting including Brazil, Israel, Netherlands, Spain, and the United States (California). Spain was selected as the preferred site followed by California, Israel, Brazil and the Netherlands. The feasibility of these options is currently being explored.

Included in the following pages are four items: meeting agenda, session summaries prepared by the session chair and co-chair, titles of the posters presented, and a list of attendees. The session summaries are currently incomplete but will be updated when all reports are received.

Avocado Brainstorming 2018

Towards a Sustainable Future

Program Agenda

Avocado Brainstorming 2018
Meeting Agenda

Date	Time	Activity or Session Title/Co-Chairs
27/28 May	Arrival to venue	Lodging provided by meeting; meals on own in hotel
28 May	7:00 a.m.	Breakfast Buffet
	8:00 a.m. – 12:00 p.m.	**Optional TOUR:** Allesbeste Nursery and high density plantings (See attached for more tour details)
	12:00 p.m.	Lunch (Buffet)
	Session 1 2:30 p.m.	Providing for the Consumer: Health, Safety, Flavor *Co-Chairs: Nikki Ford. Lise Korsten, David Obenland*
	4:30 p.m.	Social – High Tea
	Session 2 6:00 p.m.	New Technology to Improve Avocado Production *Co-Chairs: Nicki Taylor, Mark Buhl*
	8:15 p.m.	Light Dinner
29 May	7:00 a.m.	Breakfast Buffet
	Session 3 8:30 a.m.	Challenges to Productivity: Diseases *Co-Chairs: Randy Ploetz, Kerry Everett*
	10:30 a.m.	Break
	Session 4 11:00 a.m.	Challenges to Productivity – How the Tree Regulates Return Bloom and Crop Load *Co-Chairs: Harley Smith, Rodrigo Iturrieta, Vered Irihimovitch*
	1:00 p.m.	Lunch (Buffet)
	Poster Session 1 4:00 p.m.	*Co-Chairs: Neena Mitter, Noelani van den Berg*
	Session 5 6:00 p.m.	Where Theory Meets Practice *Co-Chairs: Francisco Mena, Ben Faber*
	8:15 p.m.	Dinner

Avocado Brainstorming 2018
Meeting Agenda

Date	Time	Activity or Session Title/Co-chairs
30 May	**FIELD DAY**	Sponsored by Westfalia Technological Services (See attached for Field Day details)
31 May	7:00 a.m.	Breakfast Buffet
	Session 6 8:30 a.m.	Challenges to Productivity – Genetics, Genomics and Biotechnology *Co-Chairs: Aureliano Bombareley, Iñaki Hormaza*
	10:30 a.m.	Break
	Session 7 11:00 a.m.	Meeting the Challenges of the Future *Co-Chairs: Mary Lu Arpaia, Zelda Van Rooyen, Tim Spann*
	1:00 p.m.	Lunch (Buffet)
	Poster Session 2 4:00 p.m.	*Co-Chairs: Neena Mitter, Noelani van den Berg*
	Session 8 6:00 p.m.	Tying the Loose Pieces Together – Planning for the Future *Co-Chairs: Jose Chaparro, Nigel Wolstenholme*
	8:15 p.m.	Dinner (3 course)
1 June	7:00 a.m.	Breakfast Buffet
	8:00 a.m. – 12:00 p.m.	**Optional TOUR** and Delegates Depart (See attached for more tour details)

7:15	Groups depart from Fairview Hotel
7:30	Arrive at Westfalia Fruit Estate - African welcome
8:00	Welcome & breakfast - Ramalea Guesthouse
9:15	Groups depart on various tours

	Group one	Group two
9:30	*Westfalia heritage tour*	*Avocado rootstock screening tour*
10:50	Tour rotation / bathroom break	Tour rotation / bathroom break
11:00	Avocado rootstock screening tour	Westfalia heritage tour
12:20	Groups meet at Westfalia Tarining Centre & collect lunch packs	Groups meet at Westfalia Training Centre & collect lunch packs
12:45	Depart to Soekmekaar	Depart to Soekmekaar

	Group one	Group two
14:00	*Visit to Gem® orchard grown under shade net*	*Avocado cultivar & rootstock field trials*
14:45	Tour rotation / bathroom break	Tour rotation / bathroom break
15:00	Avocado cultivar & rootstock field trials	Visit to Gem® orchard grown under shade net
15:45	Groups return to Westfalia Fruit Estate	Groups return to Westfalia Fruit Estate
17:15	Braai under African skies	Braai under African skies

Tour details

Morning

Westfalia heritage tour
- View over Westfalia Avocado Amphitheatre
- Dr Hans Merensky Conservation Heritage
- Orchard visit to a clone of the original mother 'Hass' tree
- Cultivar display

Avocado rootstock screening tour
- Overview of current rootstock screening
- Visit to "killing fields"
- 30 years of rootstock selection- visit to original "super trees"

Afternoon

Visit to Gem® orchard grown under shade net
- Gem avocado attributes & overview
- The pros & cons of avocado production under nets

Avocado cultivar & rootstock field trials
- Field trial where 6 different fruiting cultivars are being tested on 5 different rootstocks
- Field trial where Hass & Gem® are being tested on 11 different rootstocks

Avocado Brainstorming 2018
Optional Technical Tours

28 May 2018 **Optional TOUR**
8:00 a.m. – 12:00 p.m.
Allesbeste Nursery and high density avocado plantings
Estimated cost per person: US$25 - 40; payable by credit card

7:30 a.m.	Assemble in dining room of Fairview Hotel
7:30 a.m.	Overview of Allesbeste Nursery and Concepts of High Density Planting Andre Ernst, Zander Ernst, Abraham de Villiers
9:00 a.m.	Divide participants into 2 groups and depart Fairview Hotel. Stop 1. Allesbeste Nursery Stop 2. Maluma and Hass high density plantings and tree training schemes
10:30 a.m.	Switch groups
12:00 p.m.	Return to Fairview Hotel (arrive approximately 12:30 p.m.)

1 June 2018 **Optional TOUR**
7:30 a.m. – 11:00 a.m.
Provisional Program
Estimated cost per person: US$25 - 40; payable by credit card

7:30 a.m.	Depart Fairview Hotel
7:45 a.m.	Net Structure, Nick Human
8:45 a.m.	Leave for ZZ2
9:30 a.m.	Arrive ZZ2 – View Composting and Compost tea operations
11:00 a.m.	Return to Fairview Hotel or travel to Polokwane Airport

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Summary Reports

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SESSION SUMMARIES

Submitted by Session Moderators

Session 1. Providing for the consumer: Health, safety, and flavor

This session was composed of three presenters: Lise Korsten (University of Pretoria, South Africa), David Obenland (USDA/ARS, USA) and Nikki Ford (Hass Avocado Board, USA)

Overall Summary:

This session covered food safety, flavor and nutrition, three aspects that are of critical importance to the consumer in determining if they will purchase avocados. Food safety is strongly impacting the avocado industry and is an issue that must be dealt with by the research community to help reassure consumers that avocados are safe to eat. Sensory studies are identifying what aspects of flavor are of most importance to the consumer and utilizing a variety of analytical techniques to define determinants of flavor to help improve avocado flavor quality. Consumers are increasingly health-conscious and must be provided accurate information on the nutrient content and potential health benefits of avocados.

Food safety (Korsten)

Food safety has become a critical issue in the processing and marketing of agricultural commodities with incidents involving *Listeria* and *Salmonella* being particularly prominent. Avocados have not been immune from this problem as many recalls involving whole and prepared products have occurred in recent years. The means to easily detect the causal organisms have been developed as have methodologies to determine the microbiome present on avocados. Information on contaminant genomics can be used to determine the effectiveness of preventative controls and to better understand the origin of the organisms. Establishment of a global project to study food safety in avocados, potentially including research on the avocado microbiome, may be a useful approach toward reducing the risk of food-borne illness from avocados.

Avocado flavor (Obenland). Flavor in avocados is a combination of the perception of taste aspects and the influence of volatile components. Texture is an important modifier of these two factors and is especially important in avocados. Consumer studies have identified key aspects of flavor and texture that drive consumer preference but a major challenge is in understanding the determinants of these factors so that likeability to the consumer can be enhanced. Research has identified the formation of aldehydes following tissue homogenization as being the likely cause of grassiness. Since these aldehydes are formed during the process of chewing, however, the change in flavor is dynamic and may not be fully captured using standard static measures of flavor volatile content. Information was shown during the presentation on methodologies using real-time mass spectrometry that may enable a better understanding of this process. Information was also presented on the use of electronic tongue technology to discover non-volatile factors that influence avocado flavor. Experiments utilizing extracts from various avocado genotypes of differing maturities identified differences in the output of the umami (savory) sensor of the electronic tongue that correlated with variations in savory flavor as identified by consumer taste panels. The results from these experiments may lead to the identification of components that are important to determining consumer liking in avocados.

Avocado health benefits (Ford). The Hass Avocado Board (HAB) is an information, research and marketing program, funded by industry dollars but governed by the USDA. HAB's vision is to be the catalyst for fresh avocados being the No. 1 consumed fruit in the U.S. and industry stakeholders being successful. HAB works towards this vision by combining marketing with nutrition research because consumer tracking studies indicate that U.S. consumers purchase avocados for their flavor and because they are good for you. HAB's research program includes focuses on 4 health areas - cardiovascular health, weight management, healthy living and diabetes. Published studies indicate that avocado consumption plays a role in each of these focus areas. The research focuses exclusively on consumption of whole fresh pulp and some of the scientific outcomes may be attributed to additive or synergistic effects of fiber, especially soluble such as pectin, monounsaturated/polyunsaturated fats, folate, lutein, avocation, beta-sitosterol, and flavonoids and other antioxidants. Nutrition research is essential for marketing, due to regulations present in most countries throughout the world. Moreover, nutrition research is used to in food policies which ultimately determine what foods can be purchased through any Federal U.S. program. A new opportunity or challenge is arising with consumers and Federal regulators – sustainable diets. This discussion will affect consumer purchasing and may even be used in Federal food policies.

Session 2. New Technology to Improve Avocado Production

The session consisted of six presenters: Mark Buhl (DataHarvest, USA), Nicky Taylor (University of Pretoria, South Africa), Zander Ernst (Allesbeste, South Africa), Elizabeth Dann (University of Queensland, Australia), Jayeni Hiti Bandaralage (University of Queensland, Australia) and Neena Mitter (University of Queensland, Australia).

Session Synopsis. This was a very diverse session and a wide range of topics were covered from remote sensing and data management to avocado tree training, avocado propagation and finally crop protection. This was to be expected from such a session, as technology impacts every aspect of production. The discussion at the end of the session focused largely on the stem cell culture of avocado and the BioClay-RNAi technology. There was also discussion concerning the habit of the trellised avocado trees to flower from the stem and the persistence of this behavior in older trees and the setting of threshold for management actions using remote sensing.

BlockChain and the Modern Farm/Nursery/Breeder (Buhl). We are firmly in the digital age and making use of the latest technology for data management can change the way in which the avocado industry “does business”. Increasing amounts of data are collected every day throughout the avocado value chain and innovative systems are required to take advantage of this information and streamline operations. One such system that could facilitate this is Blockchain, which can be described as “an incorruptible digital ledger” that can be programmed to record virtually everything of value. Blockchain will aid in the standardization of metrics and the sharing of information from the nursery to the grower and finally to the consumer. This is largely possible as a result of a predetermined set of parameters which are collected by all parties. This will allow for improved traceability in the value chain and facilitate the sharing of information with consumers, which is becoming increasingly important in agriculture, as consumers seek more information on the manner in which their food is produced. It could also allow the assetization of farms and create unique financial models for farm ownership. Technology to manage labor more effectively and efficiently is also becoming available and through the use of smart watches and remote sensing, labor can be used optimally and managed more efficiently to lead to better productivity. This can be achieved through sharing of detailed daily task information on the smart watch and tracking of activities throughout the day.

Remote sensing and Big Data (Taylor). One of the tools that is becoming more readily available to growers is remote sensing data, which has shown enormous promise in improving spatial management of orchards. This data can be collected by satellites, fixed wing airplanes and unmanned aerial vehicles or drones. Farmers in the Western Cape province of South Africa, currently have free access to a platform called Fruitlook where spatial data on evapotranspiration, vegetation indices, biomass accumulation and nitrogen content is available. This platform is sponsored by the provincial agricultural department and is assisting growers manage spatial variation in orchards. Whilst the data from this platform has proved to be extremely useful the large pixel size does limit application and other options need to be explored with better spatial resolution. With better spatial resolution, drones can be used for disease scouting, canopy management, water management, defining management zones on a farm, targeting spraying of pesticides and for security.

When considering the use of “Big Data” in agriculture there are a number of questions that should be asked before it is seen as one of the major solutions to various problems. For example, we need to consider “when does Data become Information and when does Information become Knowledge and when does Knowledge become Wisdom?” How can we move from data towards wisdom that would allow for more sustainable agricultural, and more specifically avocado, production. The grower also needs to be considered and concerted effort needs to be directed towards understanding how much information growers need to make good decisions. Does information overload ever assist in better management or does it just make it more difficult to make a decision? Finally, do we collect “big data” just because we can or is there a specific research question in mind?

Intensive avocado canopy management (Ernst). Allesbeste in Tzaneen have evaluated ultra high density avocado orchards on a trellising system and have recently planted their first commercial orchard. The philosophy behind these plantings is that the closer the trees are planted together, the quicker the full potential of the orchard can be reached in terms of per hectare production. High density also simplifies management, whilst maintaining the complexity of the trees. Current spacing is 5 m x 2.5 m resulting in 800 trees ha-1, with trellis wires spaced 300 mm apart. Branches are tied in an upwards direction rather than downwards. In the first few years after planting this system seems to reduce alternate bearing and allows good light penetration into the canopy, but sunburn needs to be managed and controlled. Flowering occurs from the stem and the covering of these fruit by leaves has improved packout. The keys to the success of this planting system include the microclimate, judicious irrigation management and careful pruning. It is proposed that a tatura training system works best and that training should start in the nursery.

Using image analysis to quantify P.c. symptoms (Dann). Phytophthora infection of trees often occurs without any discernible visual symptoms, however, an analysis of canopy porosity using RGB images obtained with a cell phone from below the canopy is proving useful in diagnosing early symptoms of canopy decline and has been found to be well correlated with the Ciba-Geigy rating chart. Vegetation indices obtained from satellite images are also proving very useful in producing maps of Phytophthora root rot problems for different orchards. In future it is hoped that these maps can be linked to a cell phone app together with multispectral and hyperspectral sensors. Remote sensing is also being used for mapping block yield and predicting yield, which could assist growers with marketing.

Avocado tissue culture using stem cells (Bandaralage). Avocado is a highly recalcitrant plant species and therefore the challenge with tissue culture of avocado is to optimise every stage of production. Success with both nodal and meristem tip culture has been very limited in avocado. The key to successful tissue culture is multiplication and with shoot tip culture, 500 plants can be obtained from a single shoot tip with a method developed by the University of Queensland, within 8-12 months. This has been achieved for the cultivar 'Reed' and optimisation is under way for 'Velvick'. Parts of the propogation methodology have been patented.

BioClay – non GM and non-toxic crop protection platform (Mitter). BioClay can be described as clay nanosheets that can be used for non-GM delivery of RNAi or RNA interference. It provides a means of degrading pathogen RNA and preventing disease. A double stranded RNA is applied to the plant, which is degraded by enzymes on the plant leaf surface. This complex is stable on the leaf surface and can last for at least 30 days on the leaf surface. In addition, it is not integrated into the DNA of the plant and the bioclay can also act as a slow release fertilizer. Protection against a virus has been demonstrated in capsicum but work still needs to be done on avocado.

Session 3. Challenges to Productivity: Diseases

The session consisted of six presenters: Elizabeth Dann (University of Queensland, Australia), Noelani van den Berg (University of Pretoria, South Africa), Randy Ploetz (University of Florida, USA), Clara Priego Prieto (IFAPA-Churriana, Spain), Kerry Everett (Plant and Food, New Zealand) and Noam Alkan (Volcani Research Center, Israel).

In this session the most important avocado diseases were selected for discussion. Importance was determined on the basis of invasiveness (laurel wilt and fusarium dieback), new emerging diseases (brown root rot, caused by *Phellinus noxius*, white root rot, *Rosellinia necatrix*, and nursery root rots, *Calonectria* spp.), and perennial problems (Phytophthora root rot and fruit rots).

Phytophthora root rot: History, impact, status (Dann). Phytophthora root rot (PRR) is caused by *Phytophthora cinnamomi* (PC). PC originated in Asia and has a wide host range (<5000 species). PRR is a disease of nursery and mature trees, resulting in tree decline and plant death. Affected trees set small fruit and yield is reduced. PRR costs Australia an estimated AU $17 million per annum which is about 5% of the value of total production. It is the no. 1 constraint for avocado production in many countries. Other *Phytophthora* species (i.e. *P. citricola*, *P. mengeii*, *P. multivora* and *P. niederhauserii*), and *Phytopythium vexans* also affect avocado. Several rootstocks that have been selected for tolerance and resistance are used widely for PRR management, but an integrated approach that utilizes several tactics (see Pegg wheel) is usually most effective; there is no silver bullet.

Rootstocks – selection, production and use of commercially available material (van den Berg). The selection of superior rootstocks is time-consuming and difficult. There are no molecular tools to select rootstocks, rather rootstocks are selected based on their phenotypic response to PRR. The selection process at WTS is based on mist-bed selection in PC-infested soil followed by field trials. This process takes 10-20 years, and has resulted in 'Latas', the current indutry standard 'Dusa' and several new lines that are in the WTS pipeline. Superior rootstocks usually respond to PRR in one of several different ways. For example, 'Dusa' responds by suppressing the amount of PC that develops after infection. Notably, if superior rootstocks are flooded they are unable to withstand PRR. Noelani's group sequenced the first transcriptome for host response to PC and flooding. Npr1 is a key regulator and salicylic acid is the key pathway 'Dusa' uses to fight PC.

Phosphonates (Dann). There would not be an avocado industry without phosphonates. Aliette was used beginning in the late 1970s, followed by phosphorous acid (PA, the active incredient in Aliette) neutralized with KOH in the 1980s. Tree injection with the latter compound, which was developed by Joe Darvas in 1987, was a crucial breakthrough. In the 1990s, advances were made to optimize the timing of application, based on tree phenology, and beginning in 1998 a service was developed in Australia for monitoring PA levels in roots. PA has a dual mode of action, as it affects PC and also activates plant defences against PRR. Reduced sensitivity to PA has been found in PC, but there is no evidence for reduced efficacy against PRR in the field.

Fusarium dieback and laurel wilt (Ploetz). Ambrosia beetles reside in xylem of woody hosts, but consume fungal symbionts, not wood. Fusarium dieback, now found in RSA, Israel and California, is caused by *Fusarium euwallaceae*, a symbiont of *Euwallacea* nr. *fornicatus*. In avocado, it is not systemic, and generally restricted to outer areas of canopy; it can be managed by removing affected branches. Other trees are much more susceptible than avocado, e.g. *Acer negundo* and *Ricinus communis*. Laurel wilt (LW) is caused by *Raffaelea lauricola* (RL). It and its primary beetle symbiont, *Xyleborus glabratus*, were introduced to the USA from Asia. LW was first found on an avocado relative, redbay, on which it spread rapidly throughout the SE

USA. RL has jumped to other ambrosia beetles, some of which are thought to be important in the avocado pathosystem. LW moves rapidly in avocado orchards via root grafts. LW is most effectively managed by removing affected trees as soon as they develop symptoms (before root graft transmission occurs). Management via cultural or fungicidal measures can be effective, but are not long-term solutions. LW is now in Texas, just north of the Mexican border.

White root rot (Pliego Prieto and van der Berg). White root rot (WRR) is caused by *Rosellinia necatrix* (Rn). It causes yellowing, wilting and eventual death of the tree, and spreads by root grafts. Control is very difficult. As WRR is resistant to common fungicides, tolerant rootstocks are sought in Spain; 22 selections are being evaluated in Rn-infested fields. In transcriptomic analyses, ca 250 genes have been associated with the growth of WRR on avocado roots, some of which are responsible for toxin production, biosynthesis of hormones and potential effectors. In a microarray gene expression analysis, protein inhibitors were upregulated in a tolerant rootstock. Induction of resistance via water stress is being investigated. In RSA, WRR was first detected in apples and pears in the Western Cape. In avocado orchards, it has probably been present for a long time, but unnoticed; it is now in Kwazulu/Natal, Limpopo, and Mpumalunga. The susceptibility of different rootstocks is being evaluated in glasshouse trials, as are biological and chemical control options for WRR.

Brown root rot and trunk rot (Dann). This disease is caused by *Phellinus noxius* (Pn). Pn spreads by root to root contact, and occurs on avocado in the Atherton Tablelands and Bundaberg Childers areas in Australia. Its distribution in fields is usually patchy. Isolating infected (symptomatic and apparently healthy adjacent trees) from non-infected trees is indicated with root barriers at least 1 m deep. Pn has survived for 4+ years after dead avocado trees were removed. Thus, replanting fails. Pn affects over 200 woody hosts, and mulch from infested woodchips should not be used.

Nursery root rots (Dann). These diseases cause rapid death in the nursery, and wilting and death of trees within a year of planting. If a tree is infected in the nursery, it can outgrow the disease if it is well cared for after planting in the field; however, if damage in the nursery is great, trees die. Unlike PRR, this disease causes discrete lesions on feeder roots. Several different nectriaceous fungi can be isolated from roots, only some of which are pathogenic; in general, *Calonectria* and *Dactylonectria* spp. are pathogenic, but *Ilyonectria* and *Gliocladiopsis* spp. are not. A LAMP assay is being optimized.

Botryosphaeria dieback (Ploetz). Several pathogens in the Botryosphaeriaceae are responsible, some of which also cause fruit disease. Symptoms include branch dieback, internal necrosis and graft failure, which is a problem in Israel. Management is very difficult because these fungi are endophytes and do not cause symptoms until plants are predisposed by extreme conditions. There are no good systemic fungicides, although phosphonates are being used in Israel. Pathogen-free scions should be used for propagation.

Post-harvest fruit diseases (Everett and Alkan). In New Zealand, *Colletotrichum acutatum* and *Phomopsis* were less common at the beginning of the season, and more common at the end. In contrast, *Botryosphaeria spp.* were common at the beginning, but declined towards the end. Overall the most common pathogens were *C. acutatum and Phomopsis* sp. The temperature optima for both was c. 18°C. Using *nit* mutants, monthly wound-inoculations of fruit in the orchard suggested that infection occurred only when temperatures were above 18°C. When the cut stem was inoculated, *Phomopsis* did not cause stem-end rots, but *C. acutatum* caused almost 100% infection. Further work is required to confirm how infection occurs in the orchard, and to study the *Phomopsis* sp. infection pathway. In Israel, fruit rots are caused by species of *Colletotrichum*, *Alternaria*, *Lasiodiplodia*, *Phomopsis*, *Neofusicoccum* and *Botryosphaeria*, but *L. theobromae* is the main pathogen. It is an endophyte that causes symptoms on fruit only after they ripen. Using mango as a model, it colonized the phloem asymptomatically. When fruit ripened, the phloem was breached and the fruit flesh was invaded.

Session 4. Challenges to Productivity: Optimizing yield by understanding the physiological events that regulate crop load and the return to bloom

The session consisted of five presenters: Harley Smith (CSIRO, Australia), Rodrigo Iturrieta (University of California, USA), Vered Irihimovitch (Volcani Research Center, Israel), David Pattermore (Plant and Food, New Zealand), Iñaki Hormaza (ISHM, Spain).

Overview (Smith). Avocado is characterized as a low yielding semi-domesticated fruit tree crop due to problems with key yield determinants such as biennial bearing, pollination, flower quality, fruit set and fruit abscission. As yield is a function of genetics x environment x management, there are numerous research opportunities in breeding and the development of new management techniques to improve yield and profitability for avocado industries throughout the world.

Exploring the effects of fruit load on floral induction in 'Hass' alternate bearing avocado (Irihimovitch). 'Hass' fruit load reduces the ability of the buds in the shoot to undergo the floral transition, resulting in biennial flowering and fruit production. Previous studies showed that floral induction occurs during early winter months and correlates with a transient accumulation of transcripts for FLOWERING LOCUS T-like (PaFT) in leaves of off ‘Hass’ trees. Fruit load may indirectly affect PaFT expression, by modulating either carbohydrates and/or the endogenous concentrations of hormones in the leaves known to regulate FT in other species. Results from the Irihimovitch laboratory showed that measurements of the seasonal fluctuations of nonstructural carbohydrates, and a detailed hormonal profiling, revealed that off leaves displayed significantly higher total soluble sugar and cytokinin content, as compared with on leaves. Furthermore, an initial increase in sucrose and perseitol in the leaves, correlated with up–regulation of PaFT and with elevated expression of Trehalose-6-Phosphate Synthase 1 (PaTPS1), a key enzyme regulating carbohydrate availability. A model, interpreting these and other obtained results, in terms of understanding factors regulating return to flowering, was presented. The possible implications of the obtained results, in terms of developing horticultural practices to control 'Hass' flower induction, were also discussed.

Control of flower quality and fruit set in avocado (Hormaza). Fruit set is dependent upon several decisive and sequential developmental events in avocado. First, environmental factors including temperature and humidity regulate pollen tube growth. For example, low temperature slows pollen tube growth whereas high temperature and low humidity accelerate stigmatic degeneration. Second, avocado trees produce up to a million flowers with similar morphology and dichogamy cycle of flowering. However, significant differences are found in flower quality as indicated by carbohydrate and boron levels. As carbohydrate and mineral content is depleted by the high flowering behavior of avocado trees in the spring, winter fertilization is recommended to increase flower quality under Mediterranean climatic conditions. Third, the lack of pollination is a key yield-limiting factor, as honey-bees are inefficient pollinators of avocado flowers. The use of additional pollinating insects, including solitary bees and syrphid flies would act to increase pollination together with delaying flowering or planting later flowering cultivars in the case of Mediterranean climates with low temperatures at the time of bloom. Lastly, additional efforts in evaluating the use of pollinizer varieties is needed to ensure growers the best pollinizer for each production cultivar in different production environments.

Model for fruit abscission avocado (Smith). The irregular bearing of avocado is contributed by a number of factors including fruit set and fruit abscission. During early stages of fruit development, it has been postulated that a high rate of fruitlet abscission (unfertilized and fertilized) occurs in response to vegetative shoot growth (Sedgley 1980). According to Sedgley 1980, the majority of unfertilized fruitlets abscise within the first two weeks after fruit set. Fertilized fruits, ranging from 2.6 to 9.3 mm, abscise within the 15-35 days after fruit set due to the growth of the spring flush. Fruitlet abscission is a multistep process that is initiated by unknown signals that promote fruit growth cessation in a subset of fruit in the tree. After growth cessation, seed senescence occurs followed by the activation of the abscission zone in the pedicel, which leads to the physical separation of the fruit from the tree. Developing a system to better understand the physiological signaling mechanism(s) that mediate fruit growth cessation will provide a platform to develop new management strategies to limit fruit abscission and increase yield.

Sedgley, M (1980) Anatomical investigation of abscissed avocado flowers and fruitlets. Ann. Bott. 46, 771-777.

Impact of fruit presence and sunlight on 'Hass' avocado growth (Iturrieta). Under field conditions, Rodrigo Iturrieta used a single shoot focused phenotyping of the 'Hass' variety to dissect its plasticity into consistent and resilient patterns that explain what is perceived as a whole canopy behavior. Phenotyped at the original research site in California but corroborated in Chile, Israel, Peru and South Africa, the pattern under absence of a growing fruit is of increased vegetative complexity by more flushing and branching events along the single shoot axis while simplicity was observed on fruiting shoots. Reproductive growth was also observed with a reduced frequency and complexity on fruiting shoots. Adding to the previous, he indicated that there is a clear "topography" of these phenotypical events along the single shoot axis and a correlated likelihood of occurrence. Sunlight exposure can modify the phenotype of a fruiting shoot to be closer to that of the non-fruiting counterparts. He advocated for the need of a common language among researchers and an awareness of these patterns in order to precisely link molecular events to actual field phenotypes, share databases and do collaborative research across hemispheres and growing areas.

Avocado Pollination and Pollinizers (Pattemore). D. Pattemore presented an overview of our knowledge on avocado pollination and the use of pollinizers. His presentation was divided into several themes. The first was discussing whether there was any value to having pollinizers. He presented data that suggests that pollen parent may influence dry matter accumulation and fruit persistence after fruit set. Most striking was data collected at the grove level where individual tree yields were monitored over a 6 year period. The main factors that influenced the 6-year average yield included distance to the pollinizer variety and the identity of that closest pollinizer. The New Zealand group has also revisited past work conducted in Israel which examined the number of pollen grains deposited on flowers visited by honey bees. The vast majority of flowers have none or only 1 -2 pollen grains on the stigma which was corroborated by examining the amount of pollen found on the honey bees. The data also shows that the honey bee carries, under New Zealand conditions, more pollen from pollinizer varieties than 'Hass'. The pollen collected by bumblebees was slightly less than that of honey bees and the native flies that were monitored had considerably less. He also showed data on flower visiting insect visits to multiple orchards, which showed considerable variance in insect visitation. The last portion of his presentation dealt with the timing of the female and male flower opening as influenced by temperature. The data corroborates earlier data published by Gad Ish Am et al. in Israel which shows that when temperatures are cool, the opening of the female stage flower is delayed. In his final comments he outlined the challenges that are faced in future research on this subject.

Session 5. Where Theory Meets Practice

The session consisted of four presenters: Ben Faber (University of California, USA), Francisco Mena (GAMA, Chile), Neil Delroy (Jasper Farms, Australia), Tatiana Cantuarias-Avilés (University of São Paulo, Brazil)

This was a Brainstorming session that introduced many of the different field practices that growers are pursuing, in a way integrating the research findings that can be economically justified in the field. The overview of these practices includes those that the grower needs to plan in advance, such as scion and rootstock selection which can affect future pest/disease management, planting density and cost and rate of return on investment. High density plantings generally give a greater Internal Rate of Return, and a higher Net Present Value for projects. Plant costs, availability, and downstream management considerations generally related to the ability to mechanize versus labor costs influence ultimate plant densities.

When it comes to cost, growers must analyze cost per kilogram and not per hectare, usually growers that produce larger crops have higher costs per hectare but the per kilogram cost is much lower. The final analysis of higher densities should evaluate this production cost. In Chile, high densities have proven to be more productive than lower planting densities.

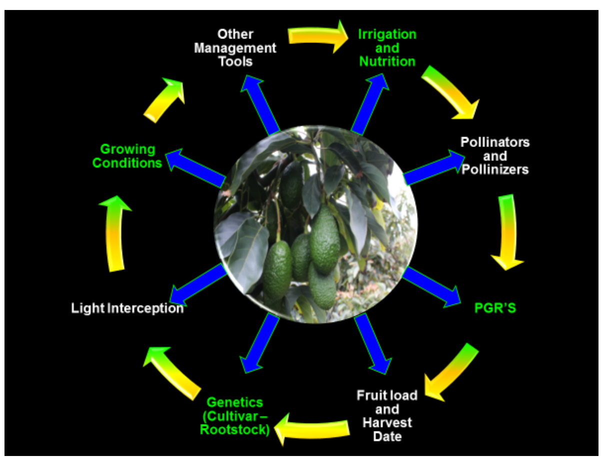
Whether and how many pollinizer varieties are included also needs to be decided pre-planting and is generally dependent on temperatures experienced at flowering.

Cultural management practices such as planting on mounds for improved drainage and use of mulch to improve Phytophthora control are important considerations. Protective structures (high netting for environmental modification) will also affect plant growth, harvest practices and costs. Biostimulants including seaweed, gibberellic acid, uniconazole and even phosphites can affect tree health and fruit production, such as precocity, fruit size and alternate bearing.

Irrigation and nutrient practices will affect tree health, growth and productivity. Crop management practices, including harvest timing, pruning and spray programs can affect yield, fruit size, pest and disease incidence and alternate bearing. Use of pollinators and their management will further affect tree productivity, and this includes how ground cover is managed through weed management, mulching and/or encouragement of insectary plants. Tree growth habit and planting density will affect pruning practices, light interception and ultimately productivity.

Table 1. Production (kg/ha) of 'Hass' avocado planted at varying density in Llay-Llay, Chile. Trees planted in 1997 and 2004.

Year	555 plants per HA (planted 1997)	1,111 plants per HA (planted 2004)
2004	25,571	
2005	15826	
2006	29,428	9,288
2007	12,003	17,711
2008	18,797	4,425
2009	25,092	39,526
2010	16,099	19,395
2011	7,636	31,480
2012	20,815	16,877
2013	25,147	42,548
2014	13,046	18,406
Average Yield	**19,042**	**23,796 (+25%)**



Alternate bearing can be controlled by plant density, pruning practices, use of plant growth regulators and "applying the right quantities of nutrients" at the right phenological stages of tree growth. Moderate annual pruning helps prevent lower production because it improves canopy light interception and helps to renew tree growth without inducing large fruit losses. Canopy architecture is a key consideration to maximizing potentially productive canopy volume. Pruning timing must have flower differentiation in consideration, ever since it might push trees to grow rather than to commit with reproductive development.

Alternate bearing is probably inherent to avocado, but it's possible to keep yields alternating between 16-24 tonnes/ha rather than from 30 to 5.

Soil health is critical for sustainable good yields and practices used in non-irrigated avocado orchards in Brazil were presented. Soil preparation prior to planting includes increasing organic matter content and promoting soil biology by establishing one to three cycles of annual green manure crops during before avocado prior to planting. Soil amendments for acid soils, such as limestone, gypsum and rock dust are also applied. At planting, bacterial/fungal inoculants are applied together with readily available carbon sources, such as humic and fulvic acids. Mounding and mulching with grass and wood chips. The soil inoculants are being produced on site by growers at a relatively cheap cost and are directly applied to the soil beneath the tree canopy during the rainy and hot season. These materials are being used by the main growers of São Paulo and Minas Gerais States and have led to fertilization costs reduction and improvement of tree health. So far, these practices have proved to boost soil microbiological activity in the short-term period. Furthermore, various biological control measures for pests and disease management have been also adapted by local growers for controlling pests and soil-borne pathogens and promoting root growth, such as drone-assisted release of *Trichogrammas* in the orchards, sprayings with *Beauveria bassiana* and *Bacillus thuringiensis* and soil inoculation with *Trichoderma harzianum* and *Bacillus subtilis.*

In the past years the development of different crop management techniques has allowed higher fruit yield per hectare in some of the growing areas. Planting densities have dramatically changed, new areas are being developed for growing avocados, while water quality and availability have become critical issues in many growing areas. Novel and updated research is needed in areas such as nutrition and irrigation to better adapt to this new growing condition.

Session 6. Challenges to Productivity – Genetics, Genomics and Biotechnology.

The session consisted of four presenters: Aureliano Bombarely (Virginia Polytechnic University, USA), Iñaki Hormaza (IHSM, Spain), Sara Mwangi (University of Pretoria, South Africa), Elena Palomo-Rios (IHSM, Spain), Fernando Pliego Alfaro (University of Málaga, Spain).

The goal of the session "Challenges to Productivity – Genetics, Genomics and Biotechnology" was to summarize and put several examples of the current technologies that are being applied to the avocado research. The session was chaired by Prof. Iñaki Hormaza from the IHSM La Mayora, Spain and Dr. Aureliano Bombarely from Virginia Tech, USA on May 29th, 2018 in Tzaneen, South Africa. The session consisted of five presenters: Aureliano Bombarely (Virginia Polytechnic University, USA), Iñaki Hormaza (IHSM, Spain), Sara Mwangi (University of Pretoria, South Africa), Elena Palomo-Rios (IHSM, Spain), Fernando Pliego Alfaro (University of Málaga, Spain):

Characterization of genetic diversity in an avocado panel (Hormaza). Prof. Hormaza described the work of his team about the characterization of avocado cultivars using morphometric and genomic tools. On the morphometric tools, he stressed the importance of having an adequate ontology for the annotation of phenotypic and genomic data. A current project is analyzing different traits described in different sources, such as the UPOV, Bioversity and unpublished sources with more than 1,500 variables. Regarding genomics, there have been advances in the las couple of decades on the use of molecular markers for fingerprinting and diversity analyses but a qualitative change is arriving due to different ongoing sequencing works. In our case, about 10,000 SNPs have been recently developed.

Community resources, genomes and databases (Bombarely). Dr. Bombarely presented the current status of one of the avocado genome sequencing projects. Although several avocado sequencing projects have been developed in the last ten years, they have failed to build a publicly available effective resource for the community. Dr. Bombarely described the initiative developed for the Avocado Sequencing Consortium to produce a publicly available resource for the community. Their assembly is based in a combination of long read PacBio sequencing reads corrected by Illumina short reads and HiC to scaffold them into chromosomes.

Transcriptomic studies of avocado (Mwangi). Dr. Mwangi presented the transcriptome studies by the Avocado research program at the University of Pretoria. The avocado genome consortium was introduced followed by a brief on the genome annotation process. All avocado transcriptomic datasets available in the public domain were highlighted together with their utilisation in the avocado genome functional and structural annotation process.

Avocado transformation and micro-propagation (Pliego-Alfaro and Palomo-Rio). On one hand, Prof. Pliego talked about the micropropagation of avocado material selected for tolerance to *Rosellinia necatrix* discussing the following points: 1. Seedlings derived material can be routinely propapated in solid medium supplemented with 1mg/l benciladenine; 2. Material from adult trees was rejuvenated through pruning and propagated using the protocol of Barceló et al (1999) from Plant Cell Tissue and Organ Culture, 58:11-17. For other hand, Dr. Palomo presented the avocado genetic transformation protocol developed by our group (Palomo-Rios et al. 2012) using avocado somatic embryos is presented. This protocol has been used to analyse the possible use of fluorescent markers, gfp and DsRed, in avocado (Palomo-R√≠os et al. 2017). In addition, four different lines of avocado plants, transformed with pK7WG2-NPR1 plasmid containing the Atnpr1 gene involved in SAR regulation, have been generated. Plants are currently being multiplied to evaluate their response to white root rot.

Ideas for community based projects (Bombarely). Dr. Bombarely closed the session proposing different genomic-based projects that it could developed by the community based in the current challenges. Specifically, he presented the following ideas: 1- Study about how the phenotypic diversity rise on clonal propagated crops using the Hass avocado type as model; 2- Development of a genomic atlas of the avocado variation through the re-sequencing and analysis of 100 avocado varieties; 3- Development of more efficient phenotyping tools that can be shared by the whole community; 4- Modelling of the impact of climate change on avocado production.

Session 7. Meeting the Challenges of the Future

This session had no formal presentations. Rather the audience was divided into 10 groups and each group was assigned a specific question which was formulated following an attendee survey on the perception of issues facing the world avocado industry. The session chairs were: Mary Lu

Arpaia (University of California, USA), Tim Spann (California Avocado Commission, USA), and Zelda van Rooyen (Westfalia Fruit, South Africa).

This session was designed to run as a workshop in order to force the meeting participant to "Brainstorm". The Brainstorming participants were given two days to submit their response to these 2 questions:

a) The top three challenges facing avocado research today; and
b) the top three perceived challenges facing the avocado industry.

Results of the survey were summarized by grouping the various items into the specialist fields categorized for meeting participants:

- Plant Improvement and Genomics
- Productivity and Crop Management
- Quality, Postharvest and Food Safety
- Pests and Diseases
- Genetic Resources
- Profitability and Economic Analysis
- Propagation

At the beginning of the session one of the session chairs (Tim Spann) summarized the results of the survey (Figure 1 and Figure 2) and the meeting participants were then divided into groups and asked to come up with solutions to the "challenges posed" that addressed topics suggested in the top 3 categories. The various groups were purposefully comprised of members whose area of research expertise was not related to the category field they were assigned to. This was done to try and get fresh ideas/solutions to described problems.

Within the top 3 groups, there were several subcategories as listed below. These were used as the basis of each discussion group. Tables 1 – 3 at the end of the report provides the actual comments received by the respondents to the survey.

Plant Improvement and Genetic Resources
- Varietal diversification
- Rootstocks
- Genetic tools
- Genomics
- Climate Adaptation

Productivity and Crop Management
- Water availability, quality and cost
- Alternate bearing and stable production
- Precision agriculture

Quality, Postharvest and Food Safety
- Food safety
- Quality to the consumer

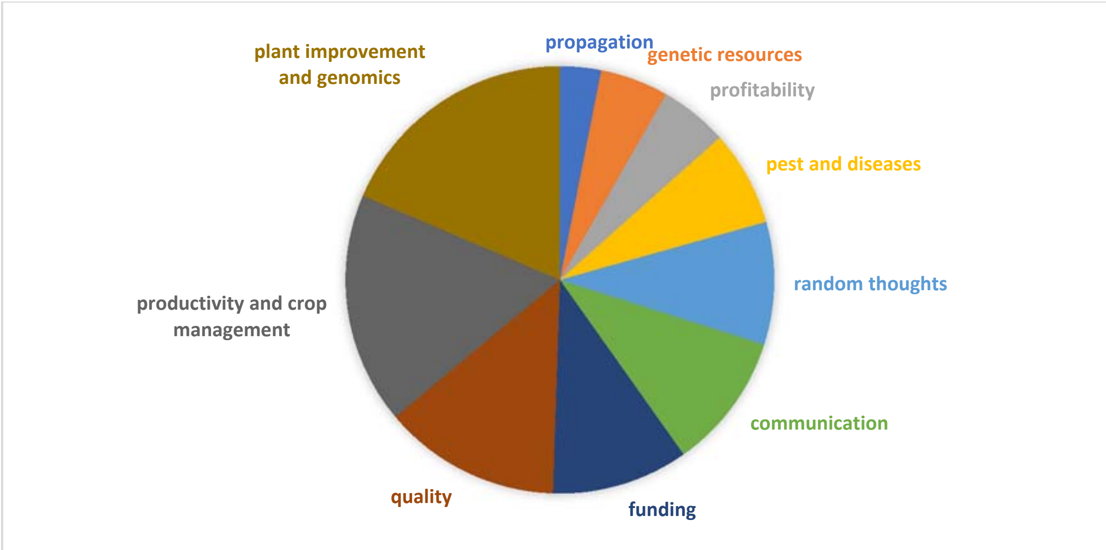


Figure 1. Summary of voluntary poll taken on problems facing both the avocado industry, as well as any research related to avocado.

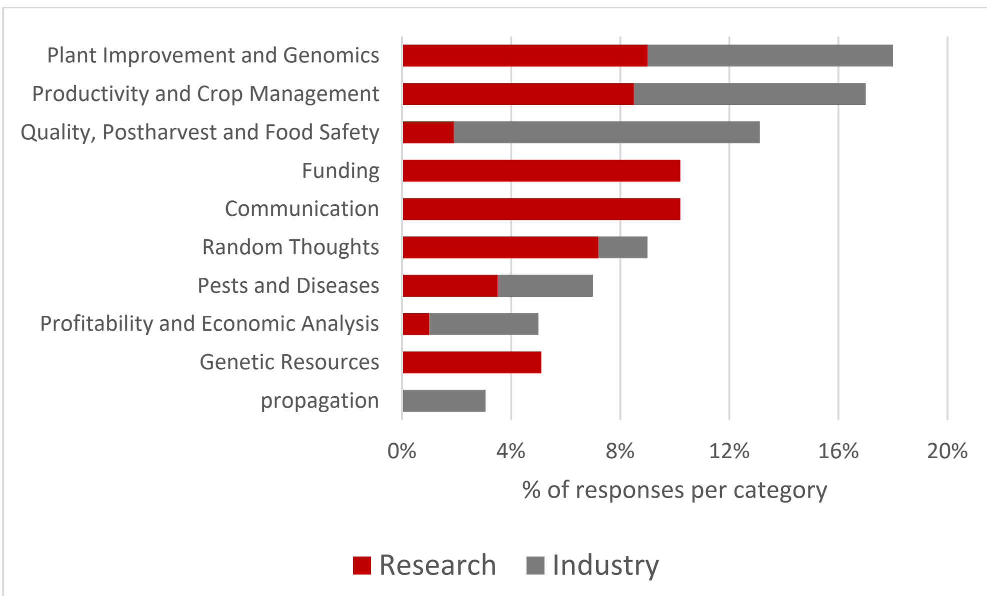


Figure 2. Summary of the number of responses per category differentiating between research and industry concerns.

Group Reports

Group 1. Varietal diversification

Solutions offered: Find a better 'Hass' vs find a "different avocado". The industry needs to start preparing for climatic change and decreasing risk exposure as mono cultures are at high risk for attack by new pests and diseases. Educate and/or increase awareness of what new cultivars could offer the industry and hopefully new funding bodies. Re-evaluate genetic resources –

introduce more wild types. Target specific genes/behaviour. Could breeding be “sped up” using markers?

Group 2. Genomics:

Two questions were asked: - 1) Why? and 2) How? The groups answers were as follows:

1) Breeding speed, cultivar identity and link to others. Old production areas vs new areas – do the cultivars behave differently.
2) Communicate value of genome to growers. What is needed form researchers? What can Block-chain offer e.g. coordination of data, collection. New approach to data analysis and manipulation.

Group 3. Rootstocks:

The discussion group indicated that the speed of production/identification of new rootstock material was a challenge. The group felt that the following items need to be addressed.

- Markers to be developed for phenotypes, and chemical “defence”
- Tissue culture
- Key factors – *Phytophthora cinnamomi* , Salt, Stress, *Rosellinia*, Fruit quality.
- Encourage genetic diversity, community database.
- Which rootstock and cultivar are the best combination.
- Micro-grafting to increase the speed to producing a disease free scion.
- IP Process
- Dwarf – either through genes or silencing “vigor” to simulate a plant growth regulator (PGR) action.
- Priming rootstock for epigenetic change?

Group 4: Breeding Tools

It was felt that this should be approached via Global Communities. For example Super Trees should be handed over to relevant molecular scientists. Genetic markers need to be identified, e.g. Rosellinia an Pc tolerance. The questions remain as to how to transform avocado plant material. RNA interf – “Bioclay”. We want to avoid situations that could lose certain resources – e.g. ASBVd. Genetic modification with the aim of getting “Super Beneficials” was also an option e.g. to identify Trichoderma’s that would be beneficial and would be more acceptable that genetically modifying the crop itself.

Group 5. Climate Adaptation

In South Africa late frosts impact flowering and early frosts affect the fruit already hanging on the tree (pre-harvest). The mode of action of the climate affecting the timing of flower induction. Various different cultivars have different ranges of temperature tolerances and signals. Thought that more work is needed to evaluate various fruiting scions and rootstocks separately and/or the combinations of these two factors. Suggested that mapping the origins of genetic traits would be useful.

Group 6. Alternate Bearing

Several representatives provided the alternate bearing cycles from their respective countries. Israel reports yields of 20-22 tons/hectare vs 8 t/ha and New Zealand reports yields of 8 t/ha vs 0t/ha. Alternate bearing is said to be cultivar specific with 'Hass' being more prone.

Suggestions for modulating alternate bearing include the following:

Decreasing alternate bearing – (high) nitrogen concentration after fruit set was reported as a risk – resulting in a second fruit drop.

Flower thinning was suggested (but not for 'Lamb Hass').

Pruning – with stumping said to result in an increased vegetative state, and thus cutting a maximum of 30% of the canopy was suggested. Israel's recommendation is to cut a maximum of four branches per tree. Further Israel would girdle a branch in one year and then the same branch would be cut out in year two. Spiral girdling was thought to be less harmful. The timing of pruning after flower commitment being critical. Early resulting growth and late pruning not normally having the desired response.

Nutrition – Winter the idea was to increase the carbohydrate status of the tree post season (harvest?). The cold winter (freezing) temperatures to be mitigated by using smudge pots and overhead sprinklers.

Was suggested that fruit are not hung too late. Water shoots to be removed. Delay flowering. Ensure good tree health. Minimize over-shadowing as this decreases the crop. Evaluate high density plantings (?) – the idea being that HDP results in big crops with less alternate bearing (provided no overshadowing).

Group 7: Water Availability and cost

With the increasing cost of water it was predicted that the grower would be forced to charge more for his produce. Luckily it was pointed out that avocados are not thought to be a "thirsty" crop. However, it would still be necessary to secure sufficient water and for this some growers would need to consider desalinization and reverse-osmosis sources. The quality of water was further highlighted as important as the presence and heavy metals and/or Listeria were a real concern. Thus the quality of water going into orchards would need to be tested, as well as monitoring the quality of water leaving an orchard. With respect to quantifying the need of orchards and specific trees it was suggested that perhaps thermal imaging (NDVI) could be used to identify individual tree stress areas in an orchard to improve management. However, the cost of micro management to a "per tree" base was questioned.

There was a suggestion that perhaps in future specific fruiting scions and rootstocks would need to be identified that could tolerate specific conditions – example salinity tolerant rootstocks, and drought tolerant cultivars. If the genetic material didn't exist it was hoped that in future tolerant genes could be introduced (e.g. CRISPER technology).

The (more) extensive use of shade nets over orchards was also thought to require further investigation to quantify any real water savings (if any).

Group 8: Precision Agriculture

Digital/Remote sensing: GIS, drones, mapping sites. In Chile national "information is available on various useful agricultural data like temperatures for example. It was felt that we need more access to data collection tools.

Micro-biomes: Soil mapping needed to managed smaller "pockets" of conditions on farms.

Robotics: Auto soil sample sample collection, and spraying of orchards.

Data: Must be available to growers – e.g. in the form of cellphone applications which could also, for example, send out temperature alerts. Data on servers was felt to be less useful/helpful. Also growers would benefit from being able to track data specific to their own areas/regions.

Lidar: for crop estimates would be useful, but require some calibration in the field.

Data management: to enable "mining" of past and present data. Scale of collection needs to be specified/improved. In Chile (seedling) it was mentioned that data is not precise enough (i.e. decimal points needed).

Automated data collection: Good if used, but must answer a "question".

In summary precision agriculture would be costly and allow for micromanagement – but it was uncertain how "sustainable" this kind of management/precision would be.

Group 9. Fruit quality

1) Operator error – grower, shipper and consumer. Need to standardize the post-harvest protocols (SOPs). Need to monitor points from farm to fork – use technology to ensure standards are adhered to. Use near infrared, for example to monitor TSS. Learn from previous postharvest treatments used. Use markers to identify fruit origin and then use gene expression to confirm correct handling.
2) Endogenous – What genes are expressed postharvest, even when 100/100 correct shipping is protocol followed it is still possible to get poor quality. Finally, how to identify good quality fruit. Taste – focus on cultivars that have consistent good postharvest quality (shipping attributes).

Group 10: Food Safety

Different information available. MRL's tested = old way of testing "safety". Now we need to understand the level at which residues are "relevant" to the consumer. Tests need to be standardized to use an international level – e.g. ISO method for PGR's and PO_3. In terms of traceability we need to implement standards. Evaluate the use of Block chain technology.

Communication: 1) Prepare clear scientific facts and communicate this to the consumer. Consider that "Technical people" are awkward with communicating so need help. 2) Use Working Groups to share information and to prepare for any "Outbreaks" so that there isn't Panic (especially on the side of the consumer).

GENERAL DISCUSSION ON ALL TOPICS

There is real concern about the possible decrease in the MRLs of phosphite residues in various markets (e.g. EU). USA were exempt and in 2016 the MRL level of 75ppm was extended. It was decided that perhaps toxicology studies should be conducted to determine whether phosphite was in fact harmful to animals (and at what levels). It was thought to be ironic that Coca cola is not described as being harmful considering its high phosphonate levels. Further Australia fruit are allowed an MRL of over 500ppm (compared to South Africa at 45ppm).

Canopy management on slopes vs flat land was thought to require "optimization" as protocols for management would be different.

In regard to precision agriculture: a suggestion was made to look into trellising. Fruit were to be counted and traced to be able to give feedback back to the grower. Individual tree tracking would allow for yield mapping and would be useful to orchard management. This would allow investigation of what was causing poor production in certain areas of the orchard – e.g. poor tree health or irrigation problems.

The meeting was asked if the "Brainstorm" exercise was helpful to identify challenges and agreed that it was. It was suggested that perhaps in future the exercise could be carried out at the beginning of the meeting (instead of the end). In addition, it was decided to track whether the problems (and solutions offered) made any differences to research/the industry between meetings- i.e. was any progress made.

Session 8. Tying the Loose Pieces Together – Planning for the Future

Co-Chairs: Jose Chaparro (University of Florida, USA), Nigel Wolstenholme (Retired, South Africa). Prof. Wolstenholme had prepared a summary of challenges facing avocado industry which is included below.

Introduction

These notes, in summary form under various headings, form the background for a presentation (together with Jose Chaparro of the University of Florida) to conclude "Avocado Brainstorming 2018" in Tzaneen, South Africa, 28th May – 1st June, 2018. My emphasis is on the "subtropical" and "highland tropical" avocado industries typified by Mexico, South Africa and Australasia, based mainly on the 'Hass' cultivar. Such environments are more humid and mesic (less stressful climatically and edaphically), and potential tree vigour is high.

Industries in more stressful, semi-arid Mediterranean climates, also based on 'Hass', have much in common, but also much that is different - including salinity, stress and hot, dry summers. Tree vigour is understandably lower, making high density plantings easier to manage.

A 10 to 12 year time span is chosen – "towards 2030". Previous talks by the author (Wolstenholme, 1988, 2001, 2013; Wolstenholme & Whiley, 1992, 1996, 1999) also explored this topic. The book "Avocado: Botany, Production and Uses", 2nd ed. edited by Schaffer, Wolstenholme & Whiley (2013) provides a more scientific background.

The World in 2030

Keeping the big picture in mind requires a vision of what sort of world we will inhabit in 2030. The "knowns", positive and negative, include: -

- Mind-boggling scientific advances in genomics (human and plant), technology in general, the basic core sciences including biology; robotics, medicine; artificial intelligence, transportation etc.
- Climate change, largely anthropogenic in spite of the denialists, is real and driven mainly by rising atmospheric concentrations of C02, and some other gasses including methane. Prospects for keeping the mean temperature rise below 2^{o}C by 2050 are bleak. Greater weather extremes - heat, cold, drought, flood, hurricanes, windstorms etc. will mitigate any benefit from higher photosynthetic rate, and increase plant stress.
- Global problems of poverty, inequality and unemployment will fuel migration (legal and illegal) to first world countries. Africa's population is rising fastest, and will overtake those of China and India in the not too distant future. Africa, however, is a potential world food basket!
- Over-population also fuels unrest, poor governance, religious intolerance, and increasingly, terrorism – which has reached stable democracies. Dissatisfaction of lower middle class people has spawned populist leaders, nationalism, and threats to free trade. Nuclear war no longer seems unthinkable.
- The rise of China has created a sizeable new middle class, and *inter alia* created a huge new market for macadamia nuts, pecan nuts and hopefully by 2030 avocados. To date, however, the new status of avocado as a boom crop was mainly facilitated by the opening of the U.S.A. market.

By 2030, we can reasonably expect the middle classes of India, Japan and some other Asian markets to enjoy avocados. Such countries are less likely than the EU and U.S.A. to allow supermarket dictatorship to make it too difficult for their own growers to compete (unrealistic produce MRL's; high production costs; loss of "chemicals"). Unsustainable pressure on the world's natural resources is already evident - we have exceeded Earth's carrying capacity by a substantial margin. What will the situation be by 2030? Can science and technology mitigate a worst case scenario?

Trends in Agriculture and Horticulture

- **Commodities vs products**. Commodities such as wool, steel and fresh fruit are vulnerable to over-production, static or declining real prices, and a cost-price squeeze. The South African avocado export industry was in this position some 20 years back, when the traditional main European markets were saturated by ca. 650 000 cartons (net 4kg) per week from March through September. This forced survival changes, including mergers, growth by acquisitions, and partnerships, plus new value added products to differentiate from the crowd. It also accelerated the search for new markets, with less dictatorial supermarket chains. For the last 5 to 10 years however, the wheel has turned full circle, with demand now far exceeding supply.
- **Changes in land ownership and operation**. The trend has been toward land lease, or contracting off-farm production to other growers or smallholders. Large estates have become more dominant, with advantages of economies of scale, greater efficiency, and reduction of risk, and the resources to expand into other countries.

- **Globalization, free trade and fickle consumers.** These have been the norm until recently. However, the new U.S.A. administration's "America first" policy is causing uncertainty. Will this unwelcome trend continue? Global fresh produce trade, and the freeing up of the U.S. market for avocado imports, have been largely responsible for the current boom in avocado production and export. Fortunately, there are other large potential markets to be developed. The fickle consumer is currently firmly on the avo bandwagon, not least for dietary value and healthy lifestyle. How long can we maintain this trend?
- **Sustainable farming and safer food trends**. These are well known to responsible growers, most of whom support the basic concepts and thereby commit themselves to the accompanying deluge of form-filling and bureaucratic red tape. This author has always advanced "integrated pest and disease management", and careful use of essential agricultural chemicals. He has been an academic teacher and researcher from 1960 until 1999. In the 1950's and 1960's orchard floor management encouraged cover cropping, and sometimes companion cropping in the non- bearing years. These practices then went out of fashion, for good economic reasons. Today orchard biodiversity is the new norm, in the interests also of soil health, encouragement of beneficial micro- and macrofauna and flora, and soil organic matter conservation and atmospheric carbon sequestration. These trends are sure to continue and must be encouraged. However, this author warns against some practitioners of pseudoscience and over-zealous and expensive programmes to micro-manage the extremely complex soil living component. It is disingenuous to reject modern technological advances and revert to "the old ways". Science has moved on since, for example, the Albrecht approach to soil analysis interpretation. He also regards "organic" farming as expensive, difficult, and pandering to an elite, affluent market, prepared to pay a premium price for scientifically dubious benefits.

The Big Picture Picture: EvoDevo of a Unique Tree Crop

Here I speculate and attempt a synopsis on the questions "what are we dealing with?"; what is remarkable about the avocado tree and its fruit?; how does its evolutionary history impact on the current stage of domestication? In short, we have a remarkable and in many respects a unique evergreen fruit tree, which after a slow start (the fruit has an "acquired taste") is currently experiencing unprecedented popularity and explosive growth.

The avocado fruit is unusual in several respects:

- The mature flesh, especially of cultivars of the Mexican and Guatemalan races and their hybrids, is rich in oil rather than sugars (especially the very sweet fructose, a reward for dispersal agents). Oil percentage (FM basis) varies from 8% to nearly 30% (in late harvested fruits), and around 5% in true West Indian race cultivars. Janzen & Martin (1982) suggested that now extinct megaherbivores with high energy needs dispersed avocados.

- To make 1g of oil is over twice "carbon" (energy) expensive as 1g of sugar. Oily fruits must therefore be very strong "sinks" during development, and yields are low as compared to fruit sugar-accumulating fruit trees. True non-fleshy nuts, with ca 70% oil are logically much smaller and yields much lower. The olive fruit (fleshy like the avocado) has about 20-30% oil in a very small fruit, with a good yield being about 5 t/ha. It is not surprising therefore that avocado trees with large, oil-rich fruits are comparatively low yielders.

- The fruit will not soften on the tree, while firmly attached.
- The harvested fruit has a very high respiration rate (especially 'Maluma'cultivar), requiring prompt cold storage to slow down flesh softening.
- The main translocation sugars in the phloem are C7 sugars, especially perseitol and mannoheptulose (rather than the C6 sugar sucrose). Developing fruits are also unusually high in C7 sugars, which decline in maturing fruits. The probable role of C7 sugars has recently been reviewed by Cowan (2017).

To help understand the avocado tree, I refer to the introductory chapter (Schaffer, Wolstenholme & Whiley, 2013), in the scientific treatise "The Avocado: Botany, Production and Uses", 2nd ed., edited by Schaffer et *al. (*2013b). Presumed adaptive strategies of avocado trees are discussed on page 5, and in Wolstenholme & Whiley (1999).

It is first necessary to note that in evolutionary terms the avocado (*Persea americana*) is a primitive plant. It has been placed in the magnoliid clade, a basal angiosperm lineage near the origin of the flowering plants (Chanderbali *et al.,* 2008), and therefore fortuitously for us has attracted the attention of prominent taxonomic and "evodevo" scientists.

Adaptive Strategies of the Avocado Tree (Schaffer *et al.,* 2012a)

(i) **Vegetative adaptive strategies**

- Tree architecture (Rauh architectural model of Halle *et al.,* 1978), facilitates competition with montane climax forest trees. Reiterative regrowth potential makes possible a rapid and very plastic response to orchard pruning.
- Vegetative growth flushes are episodic, typically with two flushes in the humid subtropics, three in semi-arid winter rainfall climates, up to four in Mexican tropical highlands, and several more in tropical lowland bearing trees.
- In full sunlight in mesic environments, high net photosynthesis rates are possible, resulting in vigorous peripheral growth. In native forests, most vegetative growth is vertical until an emergent canopy is formed.
- Leaves are short-lived (typically 10 – 12 months) and also fairly shade-tolerant (at the expense of flowering and fruiting intensity). Abscissed leaves from healthy trees leave a thick mulch permitting feeder root proliferation.
- The fibrous feeder roots are shallow and also proliterate in well aerated topsoil (high oxygen requirement for root health).
- Feeder roots help to intercept mineralized nutrients from soil organic matter, helping with recycling and hoarding in the tree of often scarce nutrients. Tree growth therefore does not make heavy demands on the soil, and fruiting is comparatively "mineral cheap", depending of course on yield.

(ii) **Reproductive strategies**

- Flowering has a high light requirement and occurs on well-lit peripheral shoots of sufficient age. In native forests, irregular "mast" fruiting occurs (every several years).
- Flowering is intense, especially in "on crop" seasons, and also prolonged, leading to significant differences in fruit age (but, more synchronized in colder climates).
- This primitive heavy flowering can make seemingly wasteful water and nutrient demands on tree resources at a critical time, especially in the humid subtropics.
- Honeybees are not present in native forests. A range of small insects pollinate cohorts of flowers opening successively on days with suitable weather.
- Synchronous alternating dichogamy favours obligate out breeding, but fail-safe self-pollination is common.
- Massive abscission of most flowers and fruitlets occurs, coincident with and after the spring growth flush, reducing initial fruit set to a very low percentage of highly selected fruitlets.
- A final opportunity, and second fruit drop to adjust crop load occurs after the summer growth flush. This is the evolved strategy to prevent catastrophic over-bearing in this energy-demanding fruit (carbon starvation).
- Crop size is positively correlated with flowering intensity in healthy trees. "On" and "off" (alternate) and irregular crop seasons are normal, but the intensity of alternation on can be reduced in well-managed orchards.
- The avocado fruit is strongly dependent on its large seed, and especially the thick, vascularised pachychalazal seed coat, until horticultural maturity. The seed coat at this stage thins, darkens and dies. Very early premature seed coat death can result in small, seedless "cukes", or at a later stage in distinctly smaller fruits and seed size (phenological small fruit problem).
- Fruit softening in "subtropical" cultivars occurs only after harvest (physical separation from the tree) or falling to the ground in the native habitat – a presumed adaptation to extinct megaherbivore dispersal.

Past, Present and Future Avocado Characteristics

Evolutionary adaptations, and extinction of its major megafaunal dispersers some 13000 years ago, still persist in avocado trees (Janzen & Martin, 1982). They have been somewhat modified by humans for at least 9000 years, and especially since vegetative propagation of selected chance seedlings, beginning about 110 years ago. These adaptations can be counter-productive in a modern orchard, especially in mesic invigorating environments. Barlow (2000) includes the avocado as a "ghost of evolution", anachronistic and over-endowed in the modern world.

Some selection, by Native Americans, for larger fruits with smaller seeds and improved flavour undoubtedly occurred, but only since the onset of vegetative propagation could the improved characteristics be preserved. The first major standard of excellence for subtropical avocados was the Mexican X Guatemalan race hybrid 'Fuerte'. Hundreds of cultivars have been selected from chance seedlings or mutations, but only 'Fuerte'and subsequently 'Hass' have stood the test of time. There are also several promising 'Hass'-like selections.

We sum up the purported characteristics of the naturally evolved (**ancient**) avocado, appreciated by meso-Americans from about 9000 years ago:- Large tree size; delayed bearing until emergence from a montane cloud-forest canopy (i.e. a long juvenile period), flowering very profuse but irregular, due to slow carbohydrate reserve build-up (large tree size, small sunlit canopy, high maintenance costs); thus irregular "mast" fruiting; low *average* yield; small fruits of poor quality and relatively large seeds; and no evolved resistance to today's major disease, *Phytophthora cinnamomi* root rot (PRR) which had not as yet reached central America.

Today we have progressed to medium-sized grafted trees with reasonable precocity, profuse and annual flowering, average yield per ha usually in the 10-20t/ha range; a target *average* yield (at least over 4-5 seasons for at least a 5-10 ha block) of 30+ t/ha (seldom attained); moderate seed size; and at least moderate PRR tolerance in selected clonal rootstocks.

So, what of the fully-domesticated avocado of the **Future?** First prize would be a small (2-3m) tree (semi-dwarfed) on a semi-dwarfed rootstock, fully resistant to soil diseases, and conducive to high yield of the scion, plus outstanding fruit quality. High precocity is essential; hopefully flowering intensity would be reduced without compromising average yield. Fruiting would be regular, and average yield/ha would exceed 30t/ha. Fruit taste could be excellent, again hopefully with a lower oil content and a small seed, without compromising yield or fruit size. To achieve these goals, a range of elite cultivars and rootstocks for different growing conditions would be needed.

Main Current Technological Problems

Low average yield. The oil/energy-rich fruit flesh, plus the large nutrient and mineral-rich seed are prime causes of low average yield (Wolstenholme & Whiley, 1999). Collectively they are a powerful sink during the main fruit growth phase, diverting (hijacking) "carbon", metabolites and mobile minerals away from the "shoot" and root components. This can influence the timing of foliar sprays or phosphonate stem injections against PRR (and sufficient boron reaching the relatively weak root sink?).

Potential yield is strongly affected by cultivar, rootstock, climate and soil conditions, PRR and other diseases and pests. At one extreme are the mesic, humid summer rainfall subtropics and moist highland tropics with high quality soils. A good *average* yield of a large mature block over 4 or 5 seasons is 12-15 t/ha, with top growers averaging 20-25 t/ha. A breakeven (profitable) yield would be around 10 t/ha. The more stressful semi-arid usually coastal winter rainfall areas with more marginal soils have corresponding average yields of 8-12 t/ha and 15-20 t/ha for 'Hass'.

Alternate or irregular bearing, with distinct "on" and "off" bearing seasons is often cited as a concern for growers and marketers. The problem is worse in cool growing areas where 'Hass' fruit requires more than one growing season to mature. Late hanging will also accentuate alternate bearing, although less so if half the crop is harvested earlier. Causes are complex and multiple, but horticulturally, "off" seasons are due to less intense flowering and fewer fruiting sites (peripheral shoots), plus lower storage carbohydrate reserves after a heavy crop. Pruning, bioregulant foliar sprays, and adjusted nitrogen fertilization are the main management tools (Salazar-Garcia *et al.,* 2012).

Phytophthora root rot (PRR) remains a problem in high risk situations (high rainfall, and poorly drained/aerated soils). Phosphonates have been used (where registered) since the 1970's, firstly through carefully timed stem injections, plus foliar sprays more recently. They are combined with other management practices promoting root health (e.g. the "Pegg wheel" integrated management concept, which includes PRR tolerant clonal rootstocks such as 'Duke 7', 'Dusa', 'Bounty', 'Velvick', and others in the pipeline (Pegg, 2010). It is currently of great concern that phosphonate MRL's have been set at 50 mg/l in EU markets, or much lower in some German supermarkets. These are unrealistically low for high risk PRR countries, and loss of phosphonates would be a major setback in high risk PRR growing areas.

Too few elite cultivars. 'Hass' is overwhelmingly the cultivar of choice at present, both for local and export markets. This is, in the long term, a cause for concern. Established fruit industries typically rely on a least five elite, well-known cultivars. Avocado cultivars are either purple/black or green-skinned, vary in size, shape and time of maturity, so there is the desired genetic variability. However, there are no other fully tested and widely accepted cultivars for the subtropics, although there are several promising candidates such as 'Hass' lookalikes ('Gem', 'Lamb Hass', 'Carmen' and 'Maluma', *inter alia*). Most new cultivars arise from chance seedlings or mutations, and breeding programmes are difficult, time-consuming, costly, and under threat. The genomic revolution should surely improve the situation in the next 10-12 years.

Too few elite rootstocks. The world avocado industry still relies heavily on seedling rootstocks – often with little experimental evidence. A notable exception is Whiley's detailed study in Australia, which found that the best selected seedling rootstocks e.g 'Velvick' were the equal of clonals, from an overall tree performance point of view (Whiley, & Whiley, 2011). Certain Mexican seedling rootstocks such as 'Zutano' and 'Topa Topa' have poor PRR tolerance and may cause scion overgrowth. In South Africa before the use of clonal 'Duke 7', 'Edranol' seedling stocks proved very susceptible to PRR.

At present, unprecedented demand for nursery trees has seen greater use of seedling stocks, of mainly Guatemalan, hybrid and even the West Indian race. Their comparatively low cost is an attraction, especially for high density plantings. It is inevitable that some will not stand the test of time, being used without research backup. Orchard uniformity may suffer, but rootstock genetic diversity may be beneficial in the event of new diseases. Freedom from sunblotch viroid is non-negotiable.

In South Africa, clonal 'Dusa' and 'Bounty' are currently the most popular, with a few new selections in the pipeline. Continued rootstock testing and selection is vital, as turn-around times are long, and new diseases threaten.

Best practice orchard management. Wide variation exists between different growing environments in tree spacing, training, pruning, tree size and shape, and canopy management. Tree vigour is greater in mesic clilmates and good soils, necessitating wider espacement and tree populations of around 300 to 400 trees per ha (depending on cultivar). More stressful climates and soils result in less vigorous trees, and permit closer spacings of 800 to over 1000 trees per ha for new orchards – sometimes considerably more. The jury is out as to whether such tree densities can be economically justified and maintained. Dedicated training and pruning, and use of growth retardants, e.g. uniconazole, is essential, and even girdling has been used (Whiley e*t al.,* 2013).

These plantings have occurred with little long-term research backup, and with much trial and error and learning on the job. The same applies to pruning and some aspects of managing the vegetative: reproductive balance to best advantage.

Research Priorities

The four-yearly World Avocado Congresses are a sounding board for the health of the world avocado industries. All serious growing countries sponsor and fund research on important practical problems, although it is true that there is often a dearth of experienced researchers and adequate funding. What is encouraging is that basic "blue sky" researches at prestigious research institutes are increasingly choosing avocado as an interesting model crop, e.g. for genetic engineering, genome mapping and sequencing, and basic biochemical, physiological and taxonomic studies, as well as plant pathology and entomology.

Final Thoughts and Conclusions

A SWOT analysis (strengths, weaknesses, opportunities and threats) on the world (or an individual country) avocado industry would find much to admire, ponder, but also be concerned about. The breakneck speed of the current industry growth is both encouraging and frightening, for there is much that could go wrong. The world political and economic scene is fraught with danger. No food commodity industry can grow so rapidly for a long time without a serious implosion. Overproduction is the biggest threat to any commodity based industry. Inevitably mistakes will be made, standards will suffer, prices will decline and there will ultimately be a shakeout. Inefficient growers will go to the wall; efficient ones will prosper in the next cycle. This may be an unpopular viewpoint, but I have seen too many commodity boom/bust cycles not to sound a warning. In the interim, enjoy the ride but invest profits wisely.

Also, under the **threats** column, global climate change appears to be facilitating the spread of new, very worrying invasive pests and diseases. These include the Ambrosia beetle species and their fungal symbionts threatening avocado trees in Florida, California, and Israel, and gaining a foothold in other countries. Also, the spread of other root rot diseases, and potentially serious insect pests such as fruit flies. It is true that there is high genetic variability in wild *Persea* species, for use in imparting tolerance and resistance to new diseases in cultivar and rootstock selection and breeding. Central American countries where these species are native have a responsibility to conserve, protect, study and utilize these potential future industry saviours. Breeding programmes must continue, and developed countries also have a duty to assist with new technology, gene banks, expertise, and not least, assured funding.

To end on an optimistic note, the collegiality of contacts, ideas at national and international congresses, symposia, workshops and brainstorming get-togethers, and the formation of a World Avocado Forum are truly inspiring, and an example to other fruit industries. I also include the free information website provided by the Hofshi Foundation in California. It has been a pleasure to have had an over 40 year association with such a progressive horticultural industry.

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Addendum to Summary Reports.

Session 7. Meeting the Challenges of the Future. Detailed input from Avocado Brainstorming participants on challenges facing the international avocado industry.

Table 1. Details of the various problems thought to challenge avocado research and/or the avocado industry in the future with regard to Plant Improvement and Genetic Resources (Cells are color coded as to whether question is related to industry (grey) or research perspective (blue) or crossover (green)).

Varietal Diversification	**Genomics**	**Rootstocks**	**Breeding Tools**	**Climate Adaptation**
Cultivar diversification	A genome would be swell, like an assembled annotated one.	Dwarf rootstocks, water stress, tolerant rootstocks	How do we speed up breeding programs?	Proactively picking new growing regions and cultivars for a changing climate
Hass "blight" threatens world industry - lack of diversity	Genome availability	Improved rootstocks	Salinity tolerance	Growing avocados in cool climates
Moving on from 'Hass', finding new added value cultivars	Genome sequence for various avocado traits to facilitate breeding more "efficient" avocados plus help understand and solve other issues	Dwarf rootstocks		
New scion varieties to expand consumer choice	Genome sequences with good annotation			
Need more choice: mini avocados, different looks, different flavors	Open sources for genomes resources (sharing information)			
Get new varieties that improve Hass production conditions reducing the amount of inputs.				

Table 2. Details of the various problems thought to challenge avocado research and/or the avocado industry in the future with regard to Quality, Postharvest and Fruit Quality (Cells are color coded as to whether question is related to industry (grey) or research perspective (blue) or crossover (green)).

Alternate bearing and stable production	**Water availability, quality and cost**	**Precision agriculture**
Increasing and stabilizing crop yield	Water management in avocados, understanding water relations and spatial variability in orchards	How to harness new digital/remote sensing image analysis tools to answer important biological questions: need collaboration with data scientists
How do we work on flower quality when only 0.3% set fruit?	To reduce water consumption in irrigated orchards	Considering different production conditions set common grounds for integrated research, that can be funded by various players form Those different conditions.
High variablity in fruit, trees, orchards and management	Water cost/quality	
Canopy Management for optimal production; e.g. tree spacing, pruning method, optimal tree architecture	Securing good quality water	
Increasing and stabilizing crop yield		
Sustainable production		
Irregular bearing		
Consistent high productivity		
Management of trees to maximize yields consistently and sustainably		
Less alternate bearing		
Sustainable management alternatives to allow high production		

Table 3. Details of the various problems thought to challenge avocado research and/or the avocado industry in the future with regard to Productivity and Crop Management (Cells are color coded as to whether question is related to industry (grey) or research perspective (blue)).

Quality to the consumer	**Food Safety**
Fruit quality all the way to the consumer's home	Fruit contamination with PGR, Phosphonate etc?
Confusion of country of origin - too many countries with inconsistent quality	Capacity to deal with disease without causing public panic (eg Listeria contamination) and independent of farmer pride (eg laurel wilt dump and burn to prevent spread)
Delivering quality to the consumer	Coordinating messages and policy around nutritional value and food safety
How to get avocados of the best quality to market	Regulations
How to maintain value/premium?	How and when do postharvest pathogens infect avocado fruit?
How to guarantee quality at supermarket?	What are heavy metals, fungicide, herbicide residues within flesh of fruit at market?
Quality fruit - postharvest issues	

Poster Abstract Titles

Avocado Brainstorming 2018

28 May – 1 June 2018

Poster Abstracts

Investigating soilborne nectriaceous fungi impacting avocado tree establishment in Australia (4457)
Louisa E Parkinson, Roger G Shivas , Elizabeth K Dann

Identification and characterization of polymorphic microsatellite markers to study *Phytophthora cinnamomi* populations
Juanita Engelbrecht, Tuan A. Duong, Noelani van den Berg

Manage Phytophthora Root Rot
Newett, S., Rigden, P., Dann, E. and Thomas, G.

In silico identification of polygalacturonases in *Phytophthora cinnamomi* and polygalacturonase-inhibiting proteins in *Persea americana*
T.M. Miyambo, S.A. Prabhu, F. Joubert, N. van den Berg

Phenotypic variation and fungicide sensitivity of *Phytophthora cinnamomi* isolated from avocado in California
R. J. Belisle, B. McKee, W. Hao, M. L. Arpaia, J. E. Adaskaveg and P. Manosalva

Overcoming Verticillium wilt by identifying resilient avocado rootstocks
Amnon Haberman, Amnon Busatn, Eli Simenski, Leah Tsror and Arnon Dag

Significant *in vitro* antagonism of the laurel wilt pathogen by endophytic fungi from the xylem of avocado does not predict their ability to manage the disease
José Pérez-Martínez, Randy C. Ploetz, Joshua L. Konkol

Current status and management of laurel wilt
Ploetz, R.C., Carrillo, D. , Blanchette, R., Schaffer, B.A., Rollins, J., and Saucedo, J.R.

Effect of crop load on return bloom in New Zealand 'Hass' orchards
Helen Boldingh, Grant Thorp, Nick Gould, Andrew Barnett, Phillip West and Marisa Till

Influence of salinity on ion concentrations in avocado trees
Peggy A. Mauk, Rui Li, Brandon McKee, Mary Lu Arpaia and Patricia Manosalva

How much water do avocado orchards use?
NJ Taylor, E Mazhawu, A Clulow and MJ Savage

Avocado tree water use in New Zealand
Teruko Kaneko, Nick Gould, Phillip West, Mike Clearwater

Dealing with frost-associated damage in avocado cv. 'Hass'
Joshi N.C., Ratner K., Eidelman O., Yadav D., Isaac S., Irihimovitch V. and Charuvi D.

Comparative study of antioxidant activity as a possible mechanism for frost and freeze tolerance in 'Hass' and 'Ettinger' avocado cultivars
Weil Amir, Sofer-Arad Carmit, Bar-Noy Yael, Liran Oded and Rubinovich Lior

Temperature effects on fruitset
Nick Gould, Nicola Haisman, Phillip West and Marisa Till

Technologies and practices to reduce flesh bruising in avocado fruit
Joyce, D., Perkins, M., Mazhar, M., Coates, L., Ainsworth, N., and Hofman, P.

Evaluating high density planting for improving avocado yield and economics
Etaferahu Takele and Sonia I Rios

Meeting Participants

Avocado Brainstorming 2018

Contact List and *Research Interests*

Noam Alkan noamal@agri.gov.il Agricultural Research Organization, Volcani Center P.O.B 15159, HaMaccabim Road 68 Rishon LeZion 7505101, Israel *Pests and Diseases, Quality, Postharvest and Food Safety*	**Mary Lu Arpaia** mlarpaia@ucanr.edu University of California, Dept. of Botany and Plant Sciences, Riverside CA 92521 USA *Plant improvement, quality, postharvest, productivity*
Mark Baker mark@halls.co.za HLHall & Sons, Mataffin Farm, Nelspruit, South Africa *Productivity and crop management, pests and diseases, quality, postharvest and food safety*	**Andries Bester** andries@subtrop.co.za Subtrop, Peace Street 13, Tzaneen, 0850, South Africa *Productivity and Crop Management, Propagation, Plant improvement and Genomics*
Helen Boldingh helen.boldingh@plantandfood.co.nz Helen Boldingh, Plant and Food research, Ruakura, New Zealand *Productivity and Crop Management. Genetic resources and Plant Improvement and Genomics*	**Aureliano Bombarely** aurebg@vt.edu Virginia Tech, Department of Horticulture, Blacksburg, VA 24061 USA *Plant Improvement and Genomics, Genetic Resources, Pest and Diseases*
Therese Bruwer thereseb@westfaliafruit.co.za Westfalia Technological Services, PO Box 1103, Tzaneen, 0850 RSA *Productivity and Crop management, Plant improvement and Genomics, Genetic resources*	**Carlos Caballero** ccaballero@cametrading.com "Camet Trading, Dept of R&D, Av. Alfredo Benavides 768, Of. 601 Miraflores, Lima 18 - Perú *Productivity and Crop Management, Plant Improvement and Genomics, Quality*
Tracey Campbell tracey@halls.co.za HLHall & Sons, Mataffin Farm, Nelspruit, South Africa *Productivity and Crop Management, Plant Improvement and Genomics, Quality*	**Tatiana Cantuarias-Avilés** tatiana.cantuarias@gmail.com University of Sao Paulo, Dept. of Plant Production, Piracicaba SP 13418-900 Brazil *Productivity and Crop Management, Propagation*
Mónica Castro monica.castro@pucv.cl Pontificia Universidad Católica de Valparaíso, Laboratorio de Propagación. Escuela de Agronomía. Quillota, Chile *Genetic Resources, Plant improvement and Genomics, Propagation*	**Jose X. Chaparro** jaguey58@ufl.edu Horticultural Sciences Department University of Florida Gainesville, FL USA *Plant improvement and Genomics*

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Dana Charuvi charuvi@volcani.agri.gov.il Institute of Plant Sciences, ARO- Volcani Center, Rishon LeZion 7505101, Israel *Productivity and Crop Management, Plant Improvement and Genomics, Genetic Resources*	**Liz Dann** e.dann@uq.edu.au QAAFI, University of Queensland, Ecosciences Precinct, GPO Box 267, Brisbane 4001 Pests and Diseases, Productivity and crop management, Postharvest
Neil Delroy neil@agribusiness.com.au Jasper Farms, 13 Adelaide St, Busselton, Western Australia, 6280 *Productivity and Crop Management,Quality, Postharvest*	**Michael du Toit** michael.dutoit@fabi.up.ac.za FABI, University of Pretoria *Pests and Diseases, Plant Improvement and Genomics, Genetic Resources*
Juanita Engelbrecht juanita.engelbrecht@fabi.up.ac.za FABI, University of Pretoria *Pests and Diseases, Plant Improvement and Genomics, Genetic Resources*	**André Ernst** andre@allesbeste.com Allesbeste, P.O. Box 91, Tzaneen 0850, South Africa *Plant Improvement and Genomics, Propagation, Productivity and Crop Management*
Zander Ernst andre@allesbeste.com Allesbeste, P.O. Box 91, Tzaneen 0850, South Africa *Genetic Resources, Productivity and Crop Management, Plant Improvement*	**Kerry Everett** Kerry.Everett@plantandfood.co.nz Plant & Food Research, Mt Albert Research Centre, 120 Mt Albert Road, Auckland 1025, New Zealand *Pests and Diseases, Quality, Postharvest and Food Safety, Plant Improvement and Genomics*
Ben Faber bafaber@ucanr.edu UCCE, 669 County Square Dr. Ventura, CA 93003 *Orchard Management*	**Eric Focht** eric.focht@ucr.edu University of California, Dept. of Botany and Plant Sciences, Riverside CA 92521 USA *Genetic Resources, Plant Improvement and Genomics, Productivity and Crop Management*
Nikki A. Ford nikki@hassavocadoboard.com Hass Avocado Board, 25212 Marguerite Parkway, Suite 250, Mission Viejo CA 92694 USA *Nutrition & flavor; quality, postharvest and food safety; plant improvement and genomics*	**Sakkie Froneman** sakkie@tffgsa.co.za The Fruit Farm Group South Africa, D8 Rosehaugh Road, Schagen, South Africa *Plant Improvement and Genomics, Productivity and Crop Management, Entomology*
Pilar Gil pmgil@uc.cl Pontificia Universidad Católica de Chile, Facultad de Agronomía e Ingeniería Forestal. Vicuña Mackenna 4860, Macul, Santiago *Productivity and crop management, Quality, postharvest and food safety, Pest and diseases*	**Madeline Gleeson** madeleine.gleeson@uqconnect.edu.au Queensland Alliance for Agriculture and Food Innovation, Centre for Horticultural Science, The University of Queensland, Australia *Plant improvement and genomics, propagation, productivity and crop management*

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Paty González-R patricia_gonzalezr@hotmail.com Universidad Autónoma del Estado de México. Carretera Tenancingo-Villa Guerrero Km 1.5, Tenancingo, Estado de México, C.P. 52400 *Plant Improvement and Genomics, Genetic Resources, Productivity and Crop Management*	**Nick Gould** nick.gould@plantandfood.co.nz Plant and Food Research, Te Puke, New Zealand *Productivity and Crop Management*
Amnon Haberman amnon.haberman@mail.huji.ac.il Gilat Research Center, Agricultural Research Organization, Gilat,85280, Israel *Productivity and Crop Management, Plant Improvement and Genomics, Genetic Resources*	**Jesse Hartley** jesse.hartley@fabi.up.ac.za FABI, University of Pretoria *Pests and Diseases, Plant Improvement and Genomics, Genetic Resources*
Jayeni Hiti Bandaralage jayeni.hitibandaralage@uq.net.au Queensland Alliance for Agriculture and Food Innovation, Centre for Horticultural Science, The University of Queensland, Australia *Propagation, Plant improvement and Genomics, Pest and Diseases*	**Eli Hofshi** elisfarmsllc@gmail.com Subtropica Nurseries, Fallbrook, CA 92028 USA *Propagation, Productivity & Crop Management, Genetic resources*
Joseph Hofshi elisfarmsllc@gmail.com Subtropica Nurseries, Fallbrook, CA 92028 USA *Pests and Diseases*	**Iñaki Hormaza** ihormaza@eelm.csic.es IHSM la Mayora, Dept. Subtropical Fruit Crops, Algarrobo, Málaga 29750, Spain *Reproductive biology and genomics*
Vered Irihimovitch veredi@agri.gov.il Volcani Center ARO, Israel *Genetic Resources, Plant Improvement and Genomics, Productivity and Crop Management*	**Rodrigo Iturrieta** rodrigoi@ucr.edu University of California, Dept. of Botany and Plant Sciences, Riverside CA 92521 USA *Productivity and Crop Management, Plant Improvement and Genomics, Genetic Resources*
Daryl Joyce daryl.joyce@daf.qld.gov.au Department of Agriculture and Fisheries, Ecosciences Precinct, 41 Boggo Road, Dutton Park Qld. 4102, Australia *Postharvest biology and technology, Fresh produce supply chains, Plant physiology*	**Kamukota Kaluwa** kk@subtrop.co.za Subtrop / SAAGA *Productivity and Crop Management*
Stefan Kohne stefank@westfaliafruit.co.za Westfalia Technological Services, PO Box 1103, Tzaneen, 0850 RSA *Crop Management, Genetic Resources, Propagation*	**Lise Korsten** Lise.korsten@up.ac.za Dept Plant Science, University of Pretoria, Pretoria 0002, South Africa *Quality, Postharvest and Food Safety, Pests and Diseases*

Sylvie Kremer –Kohne sylvie@haenertsburg,co.za Westfalia Technological Services, PO Box 1103, Tzaneen, 0850 RSA *Crop Management, Genetic Resources, Propagation*	**Peggy Mauk** peggy.mauk@ucr.edu University of California, Dept. of Botany and Plant Sciences, Riverside CA 92521 USA *Productivity and Crop Management, Pest and Diseases, Plant Improvement and Genomics*
Scott McKenzie scott@duroihalls.co.za Du Roi Halls Nursery, White River, Mpumulanga, South Africa *Plant Improvement and Genomics, Propagation, Productivity and Crop Management*	**Francisco Mena** fmena@gama.cl GAMA - Chile *Crop Management, Plant Improvement, Quality, Postharvest and Food Safety*
Sibongile Mhlopphe sibongilem@westfaliafruit.co.za WTS, PO Box 1103, Tzaneen, 0850, South Africa *Genetic Resources, Plant Improvement, Postharvest and Food Safety*	**Dudley Mitchell** hortmanagement@gmail.com Avonova Farms, 23a Macqueen Cr, Bunbury WA6230 *Productivity and Crop Management, Plant Physiology, Fresh Produce Supply Chains*
Neena Mitter n.mitter@uq.edu.au Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Australia *Plant Improvement and Genomics, Propagation, Genetic Resources*	**Tsakani Miyambo** tsakani.miyambo@fabi.up.ac.za University or Pretoria, FABI, Dept. of Microbiology and Plant Pathology, Pretoria 0002, South Africa *Pests and Diseases, Plant Improvement and Genomics, Genetic Resources*
Sarah Mwangi sarah.mwangi@fabi.up.ac.za University or Pretoria, FABI, Dept. of Microbiology and Plant Pathology, Pretoria 0002, South Africa *Genomics*	**Alejandro Navas** anavasa@corpoica.org.co CORPOICA C.I. LA SELVA Km 7, via Rionegro-Las Palmas, Vereda Llanogrande Rionegro Antioquia Colombia *Plant Improvement and Genomics, Productivity and Crop Management, Postharvest and Food Safety*
Simon Newett simon.newett@daf.qld.gov.au Department of Agriculture and Fisheries, Nambour, Queensland, 4560, Australia *Productivity and Crop Management, Pests and Diseases*	**Precious Novela** precious.n@zz2.co.za Bertie van Zyl(Pty)Ltd ZZ2 Farm Boekenhoutbult Jachtpad Mooketsi 0825 *Productivity and Crop Management, Genetic Resources, Quality. Postharvest and Food Safety*
David Obenland david.obenland@ars.usda.gov San Joaquin Valley Agricultural Sciences Center, USDA-ARS, Parlier CA 93648 USA *Quality, Postharvest and Food Safety, Plant Improvement and Genomics, Pests and Diseases*	**Juan Ortuzar** jortuzar@agricom.cl Technical Manager, Agricom, Chile *Plant Improvement and Genomics, Productivity and Crop Management, Postharvest and Food Safety*

Elena Palomo-Ríos epalomorios@uma.es IHSM, CSIC-UMA, Plant Biology Depart., Málaga 29071, Spain *Plant Improvement and Genomics, Propagation, Genetic Resources*	**David Pattemore** david.pattemore@plantandfood.co.nz Plant & Food Research, Bisley Rd., Hamilton 3214, New Zealand *Productivity & Crop Management, Genetic Resources, Quality, Postharvest and Food Safety*
Edouard Périé edouard.perie@plantandfood.co.nz Plant & Food Research, 412 No 1 Road, RD2, Te Puke, 3182, New Zealand *Productivity and Crop Management, Propagation, Plant Improvement and Genomics*	**Pieter Pieterse** pieter@zz2.co.za Bertie van Zyl(Pty)Ltd ZZ2 Farm Boekenhoutbult Jachtpad Mooketsi 0825 *Productivity and Crop Management, Plant Improvement and Genomics, Propagation*
Fernando Pliego-Alfaro ferpliego@uma.es Universidad de Málaga, Dpto. Biología Vegetal, Campus de Teatinos, s/n, 29071 Málaga, , Spain *Plant Improvement and Genomics, Genetic resources, Propagation*	**Clara Pliego Prieto** mclara.pliego@juntadeandalucia.es IFAPA-Churriana Dpto. Cultivo de Tejidos y Biotecnologia. Cortijo de la Cruz s/n 29140, Málaga, Spain *Plant Improvement and Genomics, Genetic resources, Pest and Diseases*
Randy Ploetz kelly12@ufl.edu University of Florida, 18905 SW 280th Street, Homestead FL 33031 *Pests and Diseases, Plant Improvement and Genomics, Genetic Resources*	**Viresh Ramburan** vpramburan@biogold.co.za Biogold International, 19A Electron Avenue, Technopark, Stellenbosch, South Africa *Plant Improvement and Genomics, Propagation, Productivity and Crop Management*
Wouter Retief wouter.r@zz2.co.za Bertie van Zyl(Pty)Ltd ZZ2 Farm Boekenhoutbult Jachtpad Mooketsi 0825 *Productivity and Crop Management, Pest and Diseases, Quality, Postharvest and Food Safety*	**Manuel Rey** mrey@biogold-em.com Biogold EM, Edificio Marie Curie, Parque Tecnológico Cartuja 93, 41092, Sevilla-Spain *Plant Improvement and Genomics, Genetic Resources, Propagation*
Harley Smith Harley.Smith@csiro.au CSIRO Agriculture, Wine Grapes and Horticulture, Waite Campus, Adelaide, SA, Australia *Productivity and Crop Management, Genetic Resources, Plant Improvement and Genomics*	**Tim Spann** tspann@avocado.org California Avocado Commission, 12 Mauchly, Suite L, Irvine, CA 92656 USA *Productivity and Crop Management, Plant Improvement and Genomics, Pests and Diseases*
Juan Carlos Reyes reyesaleman@hotmail.com Universidad Autónoma del Estado de México. Carretera Tenancingo-Villa Guerrero Km 1.5, Tenancingo, Estado de México, C.P. 52400 *Plant Improvement and Genomics, Genetic Resources, Productivity and Crop Management*	**Lior Rubinovich** liorr@migal.org.il Northern R&D, Migal, Galilee Technology Center, P.O. Box 831, Kiryat-Shmona 11016, Israel. *Plant Improvement and Genomics, Propagation, Productivity and Crop Management*

Wilna Stones wilnas@westfaliafruit.co.za Westfalia Technological Services, PO Box 1103, Tzaneen, 0850 RSA *Plant Improvement, Productivity and Crop Management, Propagation, Pests and Diseases*	**Eta Takele** ettakele@ucanr.edu University of California, Cooperative Extension, 21150 Box Springs Road, Moreno Valley, CA 92557, USA *Cost of Production and Profitability Analyses. Economic analyses of best management practices*
Nicky Taylor Nicolette.Taylor@up.ac.za University of Pretoria, Department of Plant and Soil Sciences, Private Bag X20, Hatfield, 0028 *Productivity and Crop Management, Plant Propagation, Plant Improvement and Genomics*	**Noelani van den Berg** noelani.vdberg@fabi.up.ac.za University or Pretoria, FABI, Dept. of Microbiology and Plant Pathology, Pretoria 0002, South Africa *Pests and Diseases, Plant Improvement and Genomics, Genetic Resources*
Zelda van Rooyen zeldavr@westfaliafruit.co.za Westfalia Technological Services, PO Box 1103, Tzaneen, 0850, South Africa *Plant Improvement, Productivity and Crop Management, Postharvest, Pests and Diseases, Genetic Resources*	**Burtie van Zyl** burtie@zz2.co.za Bertie van Zyl(Pty)Ltd ZZ2 Farm Boekenhoutbult Jachtpad Mooketsi 0825 *Plant Improvement and Genomics, Productivity and Crop Management, Quality, Postharvest*
Francois Viljoen fviljoen963@gmail.com University of Pretoria, Plant Pathology Department, Pretoria *Postharvest and, Food Safety, Biomes*	**Phillip West** phillip.west@nzavocado.co.nz NZ Avocado, Tauranga, New Zealand *Genetic Resources, Plant Improvement and Genomics, Propagation, Productivity and Crop Management, Pests and Diseases, Quality, Postharvest and Food Safety*
B. Nigel Wolstenholme nigelw@telkomsa.net 30 Wavell Drive, Wembley, Pietermaritzburg, 3201, South Africa *Productivity and Crop Management, Pest and diseases, quality - postharvest and food safety*	**Taly Zviran** taliz@volcani.agri.gov.il Agricultural Research Organization - the Volcani Center, 68 HaMaccabim Road , P.O.B 15159 Rishon LeZion 7505101, Israel *Plant Improvement and Genomics, Productivity and Crop Management, Genetic Resources*