Final Report

Vegetable Knowledge Transfer at the 2018 International Spinach Conference

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EGVID Pty Ltd

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Vegetable Knowledge Transfer at the 2018 International Spinach Conference – VG17004

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Content

Content 3
Summary 4
Keywords 5
Introduction 6
Methodology 7
Outputs 9
Outcomes 10
Monitoring and evaluation 12
Recommendations 14
Suggestions for the Hort Innovation concept funnel 14
Refereed scientific publications 17
References 18
Intellectual property, commercialisation and confidentiality 19
Acknowledgements 20
Appendices 21
Appendix 1 - Itinerary 21
Appendix 2 – Tour notes and Visits 22
Appendix 3 – International Spinach Portal 41
Appendix 4 - Articles, media releases and social media. 42

Summary

An Australian continent attended the 2018 International Spinach Conference (ISC) in Murcia Spain with the aim of to increasing the capacity of Australian Spinach producers, to improve their production efficiency, product quality and help build the production capacity of the Australian Vegetable Industry. The tour was to aid in the identification of new practices, technologies, varietal improvements, and to allow producers to understand many of the global challenges and research opportunities from world leading growers, researchers and breeders attending from USA and Europe. Combined, these two countries produce around 1,000,000 tonnes of Baby Spinach per annum (Europe - 550,000 tonnes per annum and the US - 400,000 tonnes per annum) with approximately 62,500 hectares under production. The two regions are dominant world producers of Baby Spinach and are highly regarded and respected for their research into new varieties, pest and disease risks, and food safety programs and on farm production techniques.

As well as attending the 2018 International Spinach Conference the contingent visited Spanish producers supplying the European market, looked at sustainable vegetable production techniques with composting one of the focuses, attended spinach breeder trials, viewed the use of floating crop covers, research trails and processing facilities and technologies. Seeing first-hand new on-farm practices, applied technology, varietal developments and research opportunities from Europe and the US, that could be adopted in the Australian production systems. The delegates enjoyed a positive tour experience that will "assist the development for the Australian spinach industry" through sharing their thoughts, highlights and learnings amongst Australian producers, processors and researchers.

The delegates had first-hand experience that will progress with the adoption of varieties and facilitate further development of "international networks" with researchers, breeders and producers to help support and "identify new technologies/research for further investment" making possible the future development of Australian specific research projects.

Delegates attended the seed company stations of Rijk Zwaan, Enza Zaden, Pop Vriend and Nunhems where they gained first-hand knowledge regarding current, new and developmental varieties with specific focuses around genetic and phenotypic traits. Discussions included Downy Mildew resistances, leaf spot tolerances, leaf traits and varietal scheduling.

Delegates also gained first-hand knowledge around global production challenges including Downy Mildew evolution, management and breeding, grower challenges around leaf spot and damping off disorders, seed production and associated inoculum loading, automation and technology, nutrition management and soil health including the use of composting.

Downy Mildew resistance continues to be the main breeding focus with new isolates continuing to evolve mostly due to spinach production within the organic sector where pathogen management options are limited. Some presentations at the International Spinach Conference focused on leaf spot pathogens and seed inoculum levels, the delegation was very interested in seed hygiene and potential seed inoculum loadings.

Automation and mechanisation was a highlight of the tour with an exceptional tour of Emmett Espania. The visit to this very cost focused business was an eye opener for the touring group. Covered cropping viewed at G's and crop covers at Intercrop also challenges some of the Australian production system. The Spanish production system also sees a high degree of regulation around nutrition management with the use of compost or organic pallets is focus of cropping. Environmental regulations were observed to be very stringent.

Project dissemination has and is occurring back through the attendee's own grower networks immediately upon their return in late February. Media communication networks including a YouTube video, articles for Vegetables Australia magazine, on AusVeg weekly update has been published, and presenting project outcomes to the Australian industry via discussion groups and appropriate HIA advisory panel is in the planning.

Keywords

HIA	Hort Innovations Australia
EGVID	East Gippsland Vegetable Innovation Days
ISC	International Spinach Conference
DM	Downy Mildew
IWGP	International Working Group, Peronospora

Introduction

To enable productivity increases for the Australian spinach industry, it is important to gain first hand research knowledge and insights from the world's leading producers. Combined, Europe and the US produce around 1,000,000 tonnes of Baby Spinach per annum (Europe - 550,000 tonnes per annum and the US - 400,000 tonnes per annum) with approximately 62,500 hectares under production per year. These two regions are dominant world producers of Baby Spinach and are highly regarded and respected for their research into new varieties; pest and disease risks; food safety programs and on farm production techniques.

In comparison, the Australian vegetable industry is large and diverse. There were 2,466 vegetable growing businesses paying the national vegetable levy in 2014-15, accounting for an estimated 68% of vegetable-growing farms. These farms are located in all regions of the country and represent over 130 different vegetable crops. The value of Australian vegetable production in 2015-16 was estimated at $3.5 billion. The greatest number of outdoor vegetable growing businesses are in NSW (at 24% of total), followed closely by Queensland (23%) and Victoria (19%), then South Australia (14%), Western Australia (12%), Tasmania (7%) and the Northern Territory (1.5%). For undercover vegetable growing, this order remains the same.

Spinach is mainly produced in Victoria with the three regions of Greater Melbourne, Latrobe Gippsland and North West responsible for 5,196t of production. Tasmania and Queensland are the other states principally producing Spinach with some growers producing smaller amounts in WA.

Some Australian Industry and Spanish producers and processors have established an ongoing and long lasting professional relationship with their counterparts overseas, this conference has allowed the development of a greater relationship with many top Australian producers and international contacts. This strong network has been integral in providing technology transfer and information exchange for important issues such as Downy Mildew management, Food Safety and variety selections and can only be further developed and enhanced.

Up until now there has not been an official Australian contingent attend the International Spinach conference either in Europe, China or the US however, various lone producers and associated industry members have attended various events (Amsterdam 2011, China 2014, Yuma 2015, San Antonio 2016). With spinach production and consumption continuing to grow in Australia and the crop becoming mainstream it was very timely that an Australian delegation attended in order to continue the growth of the Spinach in Australian vegetable sector. The delegation was exposed to new and different technology, varietal, pest and disease advancement all of which is vital to continuation of the development of the Australian baby spinach sector.

Due to the similarities in production systems, climate and topography, throughout much of Europe and the US (especially Spain during winter) the Australian sector had a great opportunity to learn not only at the conference but also in the field.

Methodology

The 2018 International Spinach Conference tour was to Murcia, Spain, the heart of the winter spinach production area for Europe and specifically the UK. Included were visits to farms, processing plants, attendance for two days to the International Spinach Conference, and facilitated meetings with researchers, processor/marketers and others involved in the industry. Refer to Appendix 1 for a detailed break-up of the day-to-day visits.

The tour was jointly led by Andrew Bulmer, Managing Director Bulmer Farms and Agronomist Stuart Grigg (directors of the East Gippsland Vegetable Innovation Days - EGVID). Andrew and Stuart were responsible for program development, coordinating applicant selection and delivery of the project extension, R&D and evaluation components.

November 2017 was the expression of interest period. Once completed the parties were asked to complete an application form that would assist in the selection of those most suited for the tour. The project reference group of Andrew Bulmer, Stuart Grigg and Sam Turner of HIA assessed the applicants based on the following criteria:

- What crops does your business produce?
- As this tour specifically focuses on Spinach production, approximately what proportion of your business income is derived from spinach production? .....%
- Have you ever travelled internationally to study/observe any crop production practices or attended international conferences? If so, did you use some of the observed techniques in driving improvements in your business (provide a few of examples)?
- How do you see attending the International Spinach Conference 2018, grower and seed company tours will benefit your business?
- How will you assist with disseminating the findings of the Vegetable Knowledge Transfer at the 2018 International Spinach Conference to growers within your region/network?
- Are you prepared to take notes on tour and provide these notes to tour leaders for use in HIA reporting process?

The development of the tour program was largely completed by Stuart Grigg. Through previous attendance of the conference since 2011, he has developed long-lasting relationships built on mutual respect with the University of Arkansas who facilitate the International Spinach Conference, Washington State University, Texas A & M AgriLife Extension Service, Enza Zaden, Rijk Zwaan, Pop Vriend, Seminis/Monsanto, G's, Intercrop, and others with whom the contingent met on the tour. Through these contacts, arrangements were made for farm walks at peak harvest time along with tours of key processing facilities. Strong linkages to researchers and research facilities in Spain provided comprehensive information on new varieties; production techniques; and pest and disease risks and management.

A number of conversations with our Spanish and European contacts facilitated Australian delegation's attendance to both the 2018 International Spinach Conference and the greater Murcia region. Rijk Zwaan, Enza Zaden, Pop Vriend and Nunhem's/Bayer hosted us at their breeding stations and planned demonstration days and sites specifically for our group including current and pipe line varieties of Spinach and Lettuce.

The tour identified new on farm practices, applied technology and research opportunities from Europe and more specially Spain, that could be adopted in the Australian production systems and shared amongst Australian producers, processors and researchers. These messages will be extended through a network coordinated by the co tour leaders Andrew Bulmer, Managing Director Bulmer Farms and Agronomist Stuart Grigg, with the assistance of tour participants. The target audience for this communication will be producers, processors and researchers throughout the Australian industry using the existing industry communication channels developed and maintained by Hort innovation and AusVeg.

The information will be made available via a number of communication channels, including:

- a YouTube video of the conference proceedings, tours and some attendee feedback;
- two articles in Vegetables Australia and Hortlink industry magazine on the outcomes of the tour;
- A brief update for inclusion in the AusVeg weekly emailed update;
- An update to be include on the Soil Wealth website;
- A presentation to the Industry Strategic Investment Advisory Panel;
- Attendees will be encouraged to verbally transfer knowledge to other spinach producers in their regions;
- Information published on social media during and after the tour.

Outputs

The 2018 International Spinach Conference tour has provided the following outputs:

- 14 Industry producers and industry representatives participated in the study tour;
- This report on the outcomes of the study tour;
- a YouTube video of the conference proceedings, tours and some attendee feedback;
- two articles in Vegetables Australia and Hortlink industry magazine on the outcomes of the tour (Appendix 4);
- A brief update for inclusion in the AusVeg weekly emailed update (Appendix 4);
- An update to be included on the Soil Wealth website;
- A presentation to the Industry Strategic Investment Advisory Panel;
- 3 applications into the Hort Innovation concept funnel;
- Information published on social media during and after the tour (Appendix 4);
- Australian spinach research presented to global audience at the International Spinach Conference by Len Tesoriero (Senior Plant Pathologist, Biosecurity Research).
- Tour notes and photos (Appendix 4)

Outcomes

Outcomes from the 2018 International Spinach Conference tour included:

- Key learnings and reporting on the Spanish Industry production including quality parameters and yield vs product specifications;
- Increased understanding of key world markets;
- Updated linkages with key researchers in Europe and the US;
- Improved understanding and reporting of the latest research outcomes and production techniques of the global spinach Industry;
- Analysis of the applicability of Spinach industry research and industry practice for the Australian production system, culminating in new research, extension and adaptation focused on productivity gains; yield increases; and other economic efficiencies.;
- Generation of ideas from state-of-the-art concepts and techniques viewed in Spinach, for adoption on farm and across the production cycle in Australia;
- Growth in skills, capacity and understanding of participants through learnings and exposure to leading world research and production systems.
- Industry research, development and extension program, leveraging applicable research and industry experience viewed in Spain.

The spinach production industry throughout Australia will be the beneficiaries of this project. The industry is made up of an estimated 100 Industry producers and associated processors and while the industry continues to grow in terms of production, processing and ultimately consumption we all need to challenge processes used in order to maintain this growth and meet and exceed consumer expectations.

The immediate audience for the project was 14 producers, processors and industry service providers who participated in the tour. They were able to assess the farm practices, research, ideas and learnings from European spinach production and research presented at the International Spinach Conference 2018 in context of the Australian production, processing and marketing environment.

The experience of these participants has been used to identify the important themes and messages of the tour that has been and continues to be extended to the whole Australian Industry.

These messages have been extended through a network coordinated by Agronomist Stuart Grigg, with the assistance of tour participants. The target audience of these communications is producers, processors and researchers throughout the Australian spinach industry using the existing industry communication channels developed and maintained by AusVeg, RMCG, Applied Horticultural Research, EGVID and Horticulture Innovation Australia.

- A report on the outcomes of the study tour;
- A YouTube video of the conference proceedings, tours and some attendee feedback;
- Two articles in Vegetables Australia and Hortlink industry magazine on the outcomes of the tour;
- A brief update for inclusion in the AusVeg weekly emailed update;
- An update to be included on the Soil Wealth website;
- A presentation to the Industry Strategic Investment Advisory Panel;
- 3 applications into the Hort Innovation concept funnel;
- Information published on social media during and after the tour;
- Australian spinach research presented to global audience at the International Spinach Conference by Len Tesoriero (Senior Plant Pathologist, Biosecurity Research) - (YouTube recording).

The tour to Spain and attendance the 2018 International Spinach Conference provided participants with immediate benefits. Benefits to the Australian Spinach production industry will be both medium and longer term following completion of the report, articles and dissemination (medium term, approximately

4-10 weeks) and longer term where possible areas of research are considered. Possible research topics have been discussed with attendees and recommendations made to benefit whole of industry.

Monitoring and evaluation

Our evaluations aimed to gather information on the changes in knowledge, attitude, skills and aspirations of the participants with a series of combined pre and post questionnaires.

The evaluation framework **used the following key questions to identify:**

- Noting the gaps and possible areas for individual and whole of industry improvements based on sites toured and presentations at the 2018 International Spinach Conference.
- Information to be delivered more widely to the Australian Spinach production industry
- The development of 3 Horticulture Innovation project proposals and;
- Assess the value of information to be extended to the Australian Spinach industry.

The project has been evaluated by participants via a participant survey. Each farm visit, seed company visit, presentation at the International Spinach Conference 2018 had participants taking notes using one of the appropriate documents.

Key participant evaluation questions:

1. How do you rate the quality of the information presented?
2. How do you rate the usefulness of the information presented?
3. What were the key messages?
4. How do you rate your understanding of the topic before this presentation?
5. How do you rate your understanding of the topic after the presentation?
6. What is the likelihood of you using some of this information in your business in the future?
7. What key messages/learnings did you take on board from each presentation? Two participants each took specific notes on each presentation at the 2018 ISC which can be found in Appendix 2.

Below is a selection of delegate tour highlights and quotes:

"The chance to meet other growers both local to Australia and International. This was a great opportunity for myself being new to the industry and the learnings I have taken from this experience to further my knowledge in the industry is over whelming".

"Tours around the conference to seed companies to look at variety trials and to talk to plant breeders were excellent.

This was a great opportunity to ask breeders specific questions and provide feed to them about Australian growing conditions and the traits desirable for our country.

Travelling with a great cross section of people from the Australian Industry including producers, processors, researchers, agronomists and service providers was excellent. Knowledge was widely shared and significant relationships built which can only help our industry".

"While there is plenty of take-home learnings, another very important 'take home' is the developing business relationships built with others while on this tour. Being a medium size operation, I was able to meet and get to know some of the biggest spinach growers in Australia. Over the course of the week, while learning how operations were handled in Spain, we got a better understanding of our own industry, with shared information, challenges, and solutions, to a level that just can't be achieved in a day. It is tours like this that are invaluable to our industry".

"With other growers – through the connection formed on this trip I anticipate further discussion to be had".

A selection of key learnings from the tour delegates below:

"The vase number of new varieties of spinach becoming available and the higher number of these that have a better Race resistance".

"Learning about the importance of soil hygiene and a healthy microbial population in defense against many soil pathogens. I learnt about how strains of downy mildew are created and how we can avoid pressuring it to evolve. Also that it's important to take notice of which race may be present to learn about their favoured conditions.

It was interesting to see how the European and U.K. Markets had developed conventionally and organically, and the regulations surrounding rowing processes like nitrogen use and herbicide use as the MRL's of certain crops have been changed to the point of zero detection.

Seeing some netting crop covers and glass houses were interesting, it showed how their markets have pressured them to ensure security by making large investments.

A better understanding of race resistance and variety selections depending on the likelihood of a particular strain being present".

"Innovation in harvesting technology and systems from UK spinach grower Emmet's.

De-risking of production by utilizing crop covers and hot house productions systems.

Environmental drivers in Europe have significant constraints on production. Requiring low Nitrate levels, environmental plantings, tree shelter breaks etc.

See production is challenging for baby leaf spinach. Australia has relatively small demand globally which may post supply risk in the future.

Spinach see will not get cheaper due to increasing global demand and difficulties in seed production.

Little genetic variation exists in spinach presenting issues for plant breeders and disease resistance".

"Australian producers need to be judicious with their use of varieties to prolong mildew resistance".

"Australian spinach consumption is growing. The organic trend is growing. We are still to develop technologies in terms of harvesting and process.".

"Regarding technology and techniques, I believe that we are slightly behind regarding implementing technology, our techniques will improve with this".

"Manage all Downy Mildew issues with best management practices at the forefront to minimise risk of DM spread".

"Australia's spinach industry appears to be on par with other countries. With the exception of breeding and our QA programs, which have a strong emphasis on on-farm foreign body control. While our labour is still very expensive (up to double) compared to the rest of the world but places like Spain pay far more for land and water. The USA (for what I've seen when traveling overseas) still surpasses all other countries for size of production and for the least cost".

"A better understanding of the organic sector".

Recommendations

Suggestions for the Hort Innovation concept funnel

Peronospora effusa (Downy Mildew) race and isolate testing (by far the most widely recommended research requirement Australian producers require):

As the tour participants further learnt, Downy Mildew pathogen evolution, varietal race resistance and management techniques require a multi-faceted management approach. Some production systems challenge such as the multi-faceted approach required for DM management (such as organics where fungicide use is greatly limited) leading to pathogen evolution and subsequent pathogen mutation around of genetic resistances. With spinach crops produced in geographically isolated countries around the world, pathogen evolution is subject to different climactic drivers and subsequently the DM pathogen can develop & evolve differently. Different DM isolates have been detected in Europe, the US and more recently have been reported in Australia. Currently, as the pathogen evolves and overcomes breeding resistances here in Australia, seed companies send these collected isolates to Europe or the US and to their own pathology testing stations. The distance to send these live samples is very challenging as samples must cross the equator, can be held up in quarantine and must be sent packed cold. Many samples simply fail to make it and others once tested remain the property of the breeding company. Australian producers may be kept in the dark as to exactly what DM race or isolate has been collected (if the sample makes it), be fed limited information and variable information can be received from different sources. It is recommended research be undertaken to understand exactly which DM races are present in Australia by using the "*Genetic basis of resistance to downy mildew in spinach*"

Genetic basis of resistance to downy mildew in spinach

Variety	*P. effusa* race															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Viroflay	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Resistoflay	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Califlay	-	+	-	+	-	+	+	-	-	+	-	-	+	-	+	-
Clermont	-	-	-	-	+	+	+	+	+	+	+	+	+	+	-	+
Campania	-	-	-	-	-	+	-	+	+	+	-	+	+	+	-	-
Boeing	-	-	-	-	-	-	-	+	-	+	-	+	-	+	-	-
Lion	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Lazio	-	-	-	-	-	-	-	-	-	-	+	+	+	+	-	+
Whale	-	-	-	+	-	+	+	-	-	+	-	-	+	-	+	-
Pigeon	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+
Caladonia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Meerkat	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+

+ = Pathogen can infect

- = Pathogen cannot infect

Hypothesized to be 6 (or more) resistance loci

16 races of the pathogen

Resistance consistent with classic R-gene response

This grouping of internationally agreed varieties is used to assess DM race presence and can assist determining of a new DM isolate when outbreaks occur. This varietal group is amended each time a new DM race is denominated by the IWGP. An ongoing project where by outbreaks are collected in Australia and sent to a grow out testing station would be of great benefit to industry as growers could then make informed varietal selections knowing exactly which DM races are occurring in their location. The testing station would then be able to bulk up the DM pathogen for dissemination to international pathology assessment or further work could be undertaken in Australia to genetically test for new, Australian specific DM isolates. Part of this work could include Australia being represented in the IWGP to facilitate greater international knowledge transfer from international research.

Leaf Spot disease and damping off pathogen testing and management

Leaf spotting diseases and damping off of spinach continue to become an increasing concern globally with Anthracnose (*Colletotrichum dematium*), Stemphylium leaf spot (*Stemphylium botryosum*), Cercospora leaf spot (*Cercospora beticola*) being three of the main leaf spot pathogens identified and Pythium (*Pythium sp.*), Phytophthora (*Phytophthora sp.*), *Rhizoctonia solani* (AG2-2) and *Fusarium oxysporum* f.sp. *spinaciae* the most common damping off pathogens. These pathogens are also becoming more commonly observed and identified by pathology services in Australia. Pathogens may be coming

from a range of sources including the cropping system where more intensive spinach rotations are occurring, spinach seed once again due to more intensive production and limited management techniques in the growing system or from other crops. Australian producers require further identification of these pathogens, their distribution and subsequent management techniques. With spinach production continuing to increase on the back of sustained increasing consumer demand these production challenges are only going to increase.

Automation and mechanization (including foreign body identification and removal):

The touring party was exposed to some excellent automation in spinach production at the tour of Emmett Espania. This business focuses on production costs, efficiencies, quality and all European producers have stringent food safety programs including foreign body management. Cost management and automation is a major focus for Australian producers but foreign bodies continue to place considerable pressures on Australian producers. Foreign bodies have traditionally been managed via the use of human labour however challenges with labour costs and availabilities are placing more requirements on potential automation developments. Continued technological developments to detect and remove these foreign bodies in field both prior to harvest and post-harvest are of utmost importance. Improved removal of these foreign bodies and technology efficiencies will lead to improved consumer satisfaction, greater growth of the sector and producer efficiencies where cost challenges are consistent.

Feedback and thoughts from the delegates regarding further research

Having an Australian Based breeding program for the conditions and challenges we face in the spinach growing sector in this country.

“Testing the mildew races cheaply and fast in Australia

Methods of reducing the foreign bodies (detection etc)

Quick cheap tests of pathogenic microbial populations in soils”.

“Adopting innovation technology around new harvesting equipment and bulk spinach handing systems”.

“Harvesting technology, this will reduce cost of production

Variety trials of different locations

Leaf spot disease (anthracnose, stemphalium)

Effects of different cover crops in different regions. How can this add value to spinach?”.

“Australia needs to have better research facilities to identify Australian isolate of Downy Mildew

Breeding for damping off tolerant/resistant spinach in Australia

Identify Australia isolates within Australian DM”.

“Keeping up with Downy Mildew resistance

California seed association has a committee to devote research funds to spinach to educate seed producers and seed dealers; this should flow on to Australia”.

“From the conference – a different look at food safety with a stronger emphasis on the follow up/knowledge test of stronger education program

An actual check for which strain of downy mildew we have in a particular area of Australia

Further research into leaf spotting diseases, prevention and treatment particularly for those that are just on Australia's doorstep and could dramatically affect our industry.

Continued research into soil-borne disease to prevent harvesting gaps in the industry, particularly at certain times of the year".

Refereed scientific publications

Journal article

Orange, V., Apple, G.S., Banana, L.F., 2013. The nutritional profile of fruit varieties in Australia. *Journal of Horticultural Research* **163**, 51–59.

Whole book

Lettuce, I., Tomato, B.R., 2014. The Base Elements of a Salad (second edition). Vegetable Publishing, Melbourne.

Chapter in a book or Paper in conference proceedings

Broccoli, G., Capsicum, R.G., 2013. Growing fruits and vegetables. In: Peach, J.S., Avocado, R.D. (Eds.), Introduction to Australian Horticulture. Horticulture Publishing, Sydney, pp. 281–304.

References

Refer to Appendix 3.

Intellectual property, commercialisation and confidentiality

No IP, commercialisation or confidentiality issues to report.

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G's Fresh – Chris Abram and Charles Shropshire

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Nunhams/Bayer – Chris Pertile and Vicente Garin Olague

Lefroy Valley – Nick Laminski

Pop Vriend – Marcel Blowmendall

University of Arkansas – Dr Jim Correll, Shelby Lane Hanson and Kim Keeney

Appendices

Appendix 1 - Itinerary

Detailed day-to-day itinerary		
Date	**Location**	**Activity /Visits**
Sunday 11 February	G's Fresh – spinach production for the UK market (counter seasonal production). Alicante - Murcia	Travel to G's Alicante head office. Meeting with Gareth Holder & Charles Shropshire & farm tour including composting, irrigation management in an arid production region & floating crop covers in Spain Travel to Murcia for week long visits, tour & conference
Monday 12 February	Intercrop - spinach production for the UK market (counter seasonal production). Enza Zaden – organised spinach tour of current & new varieties. Lettuce trial also to be viewed (trials set up especially for Australian contingent).	Intercrop head office, meeting with Mark Fletcher & Jafar Golnabi. spinach production, food safety requirements of the UK market. Enza meeting & breeder trial tour with Enza team & Ettienne Schultz (Enza Australia)
Tuesday 13 February	Rijk Zwaan – organised spinach tour of current & new varieties. Vitacress – farm tour, counter seasonal UK production. International Spinach Conference opening	Rijk Zwaan meeting with Spanish team lead by Santiago (colleague of Wim in 't Groen RZ Crop Co-ordinator Spinach) Farm tour, spinach production.
Wednesday 14 February	International Spinach Conference Len Tesoriero presentation to global audience regarding research in Australian Spinach production challenges	Day 1 - Conference preceding's, research presentations
Thursday 15 February	International Spinach Conference Conference dinner	Day 2 - Research tour. Spinach tours, research presentations & field trials Dinner as planned by conference organisers.
Friday 16 February	Emmitts &/or Primaflor farm tour Nunhams/Bayer – organised spinach tour of current & new varieties	Farm tour, spinach production. Sustainable production on soils with limited organic matter. Breeder station

Appendix 2 – Tour notes and Visits

Monday, February 12, 2018 Grower visits

G's Fresh – spinach production for the UK market (counter seasonal production).

- Cropping celery, lettuce, spinach, other baby leaf crops, citrus and tomatoes
- Annual rainfall around 240mm vs evaporation of 700mm!
- G's Espania started in 1986, now growing on 4000 hectares
- Produce harvested for the UK market is transported by road for 2 ½ days back to the UK
- Production aims for 75 tonnes of Spinach per week
- Soil is plastic covered in summer to solarize and sterilize the soil
- Calcerious soils with a pH of 7.2
- Labour costs are $7.50 euros per hour
- Main issues are DM in Wild Rocket, thrips, Leaf Spot in spinach
- Crop fences used to keep foreign bodies out
- Crops sown with seed spiders, harvested with Ortomec harvesters and controlled traffic used.
- Water costs approx. $650 euro per megaliter (mix of bore, desalinated & piped water)
- New environmental standards being adopted.
- Crops tested monthly for nitrate levels – leaching, runoff impact etc
- Compost applied annually at 15-20 tonnes per hectare
- Compost made from green waste, cow & chicken manure
- Some protected cropping in the form of plastic tunnels is used to primarily produce beet/chard crops

Intercrop - spinach production for the UK market (counter seasonal production).

- Production runs October to May
- Production focuses on spinach & lettuce
- Spinach production targeted at 100tn per week
- Main production issues are DM and “Skirt Spot”
- Zero tolerance to foreign bodies (Plastic, from mulch, is the main foreign body contaminant)
- Two spotters in front of harvest
- Producing 2 crops spinach per annum on the same ground (no rotation)
- Manure compost used for fertilizer
- Intercrop supplies bulk material to UK factories for packing
- Netting is used for hail and temperature control - frost protection
- 25% of spinach crops and 50% of lettuce crops are covered with netting for insurance of supply against hail
- Some wind rub is observed on leaf from crops covers
- Hoops are used over some crops to carry netting above crops
- Hoops are carried into crops and installed by hand
- Yield improve the under nets by 10%

- Crops are 2-4 days quicker to mature under netting
- The pre-emergent herbicide Lenacil is used on spinach

Tuesday, February 13, 2018
Seed Company visits

Rijk Zwaan – organised spinach tour of current & new varieties. Lettuce varieties also on show.

- Spinach is a major focus of RZ as is lettuce, brassicas and they are moving into celery breeding
- DM is the main breeding focus however other issues also important
- Focus now on DM packages of 1-17 (UA 10/14 will denominated shortly)
- Focus on breeding for tolerance to leaf disease for European countries – Anthracnose is the most important
- Stemphylium Leaf Spot is starting to be an increasing problem as well as Cladosporium.
- Damping off – was not an issue in Spain.
- 1 DM isolate specific to Australian has been identified, it probably won't be denominated. (isolate is different to 17)
- RZ have several Varieties resistant to DM race 17
- Parakeet and Kolibri were 2 varieties focused on for summer production in Australia.

Enza Zaden – organised spinach tour of current & new varieties. Lettuce trial also to be viewed (trials set up especially for Australian contingent).

- Spinach is a major breeding focus with DM the main issue
- "Skirt Spot" *(Helmin sporium)* was mentioned as another breeding focus however damping off is more important
- Also breed lettuce, celery, rocket and more
- Enza Zaden focus on breeding and not sales using sales businesses to undertake these tasks
- One variety, Tundra, is a focus with its improved Pythium tolerance (nematodes were also mentioned as influential with Pythium infections)
- Australian growers can request seed viability tests for seed as after 2-3 years seed viability is known to drop 5-10% every 6 months
- Acadia and Tundra are the main Enza Zaden varieties used in the US
- Enza Zaden is 2 year away from having varieties resistant to DM races 1-17

Wednesday February 14, 2018
International Spinach Conference Proceedings

Spinach seed production in the Pacific Northwest USA. Lindsey du Toit, Washington State University

- 1ha seed = 10ha baby leaf – big requirement on soil for seed
- Long daylengths (ie high latitude) & dry summers needed for seed production
- 10-15 year rotations & 1-2 miles between crops (wind pollinated)
- DM resistance from both parents
- RoNeet herbicide used in production (other options - Spinade, Dual, Asulox, Fusilade)
- Seed all fungicide treated F300 or mefanoxum, thiram
- More leaf spot issues turning up in seed crops – *comments from growers re leaf spots becoming more prevalent!! Where are spots coming from in leaf production??*
- herbicides, seed coating fungicides, Lime & pH all influence crop susceptibility to fusarium.

Can French Coastal areas be a new solution for spinach seed production? Anthony Gorin, Haden Seeds

Should we be asking where seed is grown – possibility of disease in seed?

- Extensive seed production of many other crops currently occurs in this region
- In 2016, 248 hectares of spinach seed was produced – minor crop
- Current spinach seed production regions are in central France where average temperatures are higher than other spinach seed production regions around the globe
- Average temperatures of French coastal regions are much more in line with Danish & US climates in spinach seed production regions
- French coastal regions are wetter than Danish seed production regions – seed drying will be necessary should seed production occur in French Coastal regions

Spinach seed production in New Zealand. Jay Schafer, Schafer Ag Services

- Comments re leaf spot issues
- Counter seasonal spinach seed production, similar latitude to Oregon in the US
- Production areas increasing, currently at 5% of global production
- Shielded boom used between seed rows
- Blond seed generally means seed was dry at the end of production likely free of disease (only 2 fungicides available for disease control). Dark seed usually got wet prior to harvest & more likely to be carrying disease.

Spinach production in the European Union.

Alec Roberts, Tozer Seed Co.

- US is the biggest seed purchaser by far with Australia, China and Europe (Spain, Italy, UK, France) following.
- Spinach sales have increased by 90% from 2013 to 2016
- Tighter rotations for spinach cropping – possibly increasing levels of spot in soil & crops. Ways of dealing with spotting issues:
- Breeding, better seed production areas, seed treatments, rotations, crop protectants, climactic influences in the cropping system
- New Rojo Caliante red mustard – 10-20% more glucocinolate levels = better fumigant properties.

Conventional and organic spinach production in the US; Perspective from an organic grower / shipper.

Ramy Colfer, Earthbound Farm DanoneWave

- Earthbound Farms crops 5200 ha of organics
- Spinach is king for production, 40% of Earthbound Farms production
- Spinach is 2nd on the list of products with chemical residues leading to more demand for organic spinach.
- Copper used for DM control as well as geographic isolation & cultural management techniques
- Earthbound Farms uses varieties of spinach with different DM race resistances – if DM enters a crop hopefully only 1 variety is lost
- Organic spinach production assumes 30% crop losses to DM with a 50% higher total production cost
- Actigard – available in the US for Systemic Acquired Resistance (SAR) in conventional spinach production, needed in organics
- Haven't found any organic products effective against DM

California Seed Association's Organic Spinach Committee's (CSAOSC) Support of the Organic Spinach Community.

Dale Krolikowski and Donna Boggs, Germain's Seed Technology and California Seed Association

- Web address - Calseed.org
    - Funds are available for research in spinach
    - Looking to develop standardised seed testing for DM oospores on seed
- 30% of US salads are produced organically
- Seed producers and seed dealers fund the CSAOSC
- Funding has been used to research managing cadmium levels in soil and subsequent crop uptake and DM

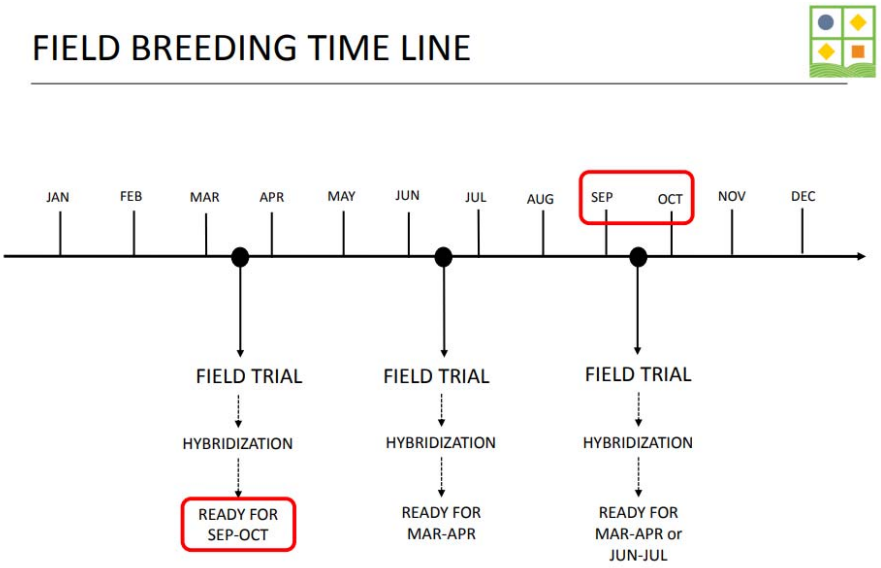
Developing a new spinach breeding program for California.

E. Charles Brummer, Allen Van Deynze, Juliana Osorio-Marin, Rachel Greenhut, Steve Klosterman, Steve Koike, Richard Smith. University of California, Davis.

- Main objective is to produce high quality spinach varieties for conventional and organic

production

- Varieties selected for low cadmium uptake
- Both OP and hybrid cultivars produced
- Isolator chambers are used to hold up to 100-200 plants. Small seed production
- Segregation populations to genetically map major downy mildew genes
- Asian lines are genetically closer to European lines
- Dutch and Arkansas lines have more closely related germplasm



Water challenges in vegetable production in California.

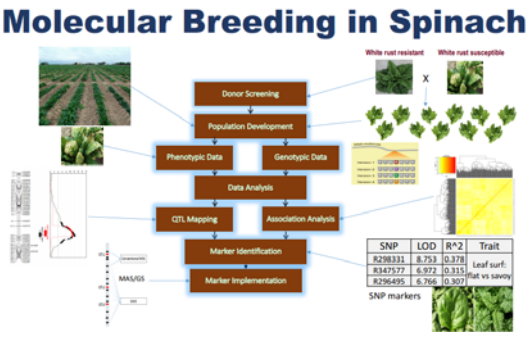
Amy L. White, MPP, Two Girls Ranch, LLC

- Flooding and groundwater management is a major challenge in California
- $7.5 billion has been proposed to help fix the water issue but to date the funds have not been made available not for lack of trying. Issues have been around proving the public benefit for moneys spent.
- For vegetable production a 12 month exclusion on paddocks follows flooding.

Genetic diversity, genome-wide association study and genomic selection in spinach.

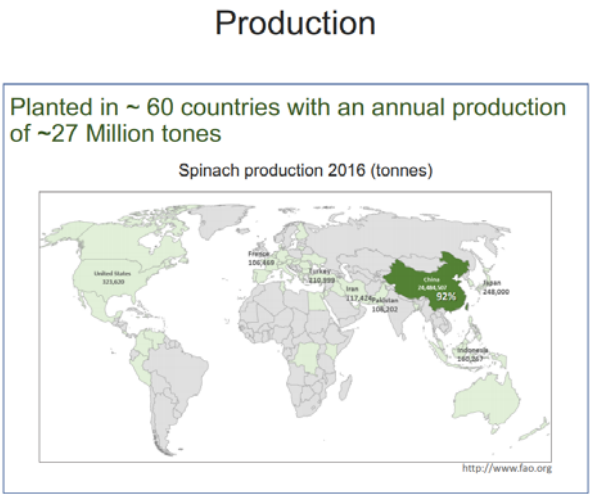
Ainong Shi, Jun Qin, Yuejin Weng, Jim Correll, Chunda Feng, Gehendra Bhattarai, Waltram Ravelombola, Bazgha Zia, Wei Zhou, and Beiquan Mou. University of Arkansas, Fayetteville, AR USDA-ARS, Salinas, CA

- Male and female lines need for production
- Very limited genetic diversity available for breeding
- Diversity leads to resistance
- Spinach has 6 genes – breeders combine multiple genes for resistance to multiple traits
- Worldwide genetic spinach material is limited representing a serious risk to this crop



Spinach genome and its transcriptome variation provide insights into evolution, domestication and important nutrient traits. Zhangjun Fei, Cornell University

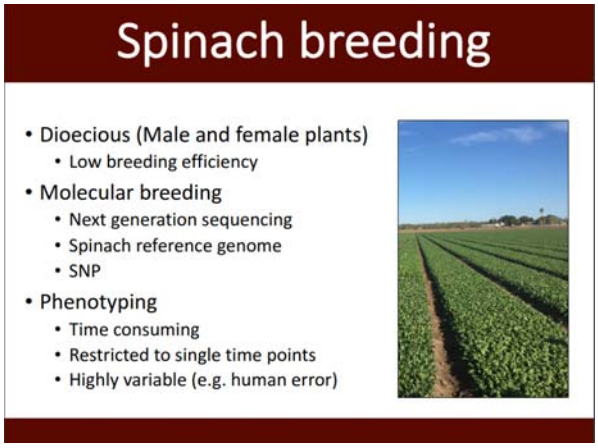
- Draft genome of spinach using high throughput illumine sequences.
- Genome is highly repetitive with 74% of its content being transposable elements.
- Genome syntenic analysis between spinach and sugar beet suggests inter and intra-chromosome rearrangement during the caryphyllales genome evolution.
- 60 countries grow spinach worldwide, 26.7 million tonnes in 2016
- 91.8% of spinach is grown in China (bunching types)



Combining high-throughput genotyping and phenotyping to improve spinach breeding efficiency.

Carlos A. Avila, Juan Enciso, Jinha Jung, Thiago Marconi, and Henry Awika

- Manual phenotyping is time consuming and open to human error
- Using drones and visual imaging is much quicker to assess each new genotype and removes the human error
- Able to monitor growth patterns, maturity and yield from the air speeding up the breeding system
- Using collected data to evaluate and rank bermplasm based on specific breeding goals (disease, bolting, colour, yield etc)



Molecular markers for spinach sex determination gene.

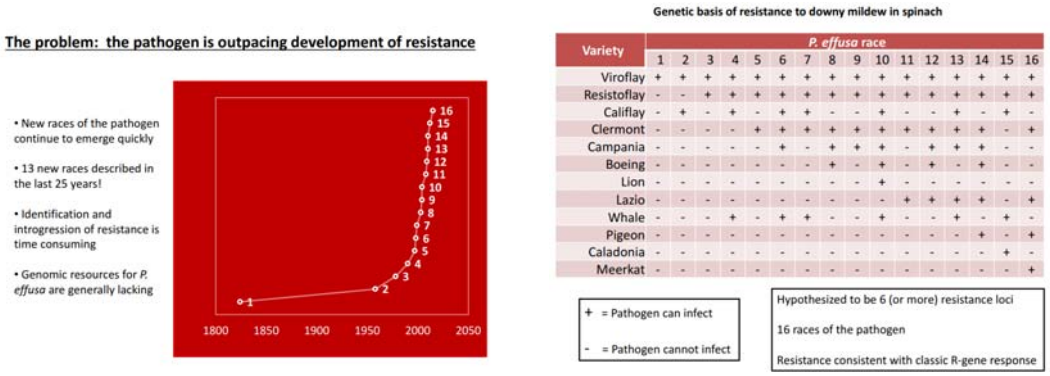
C***hunda Feng, Bo Liu, Braham Dhillon, Maria Isabel Villarroel-Zeballos, Burt Bluhm, Ainong Shi, James Correll. University of Arkansas, Fayetteville, AR***

- Spinach plants can be dioecious (either male or female plants), monecious (male and female flowers on the same plant) or gynomonecious (female and hermaphroditic flowers on the one plant)
- Not many molecular markers for spinach sex determination gene available
- 6 PCR markers have been developed for Spinach sex determination gene
- Useful for breeders

A reference genome sequence for Peronospora effusa: towards the molecular dissection of race specificity.

Burt Bluhm, Chunda Feng, Jim Correll. University of Arkansas, Fayetteville, AR

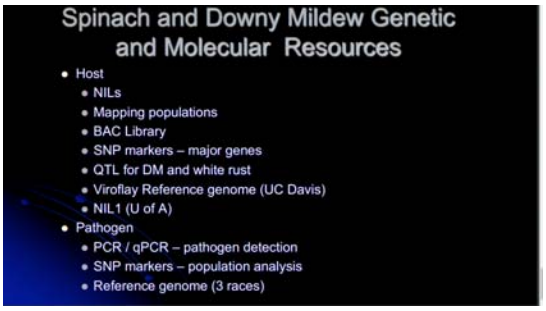
- New races of the pathogen continue to emerge quickly
- 13 new races described in the last 25 years!
- Identifying the specific genone for each DM race will greatly improve breeding efficiencies and understand resistance breeding
- Identification and introgression of resistance is time consuming
- Draft genome sequences (partial) were created for Races 12, 13, and 14 of P. effusa
- The draft genomes were sufficient to identify putative effectors, SNPs, and other genes of interest (e.g., CAZymes)
- The three draft genomes shared a high level of synteny, with considerable rearrangements
- Evidence for Loss of Heterozygousity was observed in the Race 14 isolate
- More complete assemblies would reveal additional genes of interest, including possible race-specific genes or structural variations
- Future genome sequencing efforts will focus on generating hybrid assemblies from short and long read sequencing technologies



Overview of downy mildew disease resistance and race diversity.

Jim Correll and Chunda Feng, University of Arkansas, Fayetteville, AR

- Hugh change in demand and spinach cropping has created high pressure for DM to adapt
- DM is an obligate, oomycete fungus difficult to grow in the lab and can sporulate up to 120°F!
- To distinguish a races presence, different, known varieties with known DM resistances are inoculated with DM spores and susceptibility is observed
- Many isolates of DM occur, economically important isolates are denominated races.
- Research is working on host/pathogen interactions, DNA sequencing and molecular detection for DM on seed

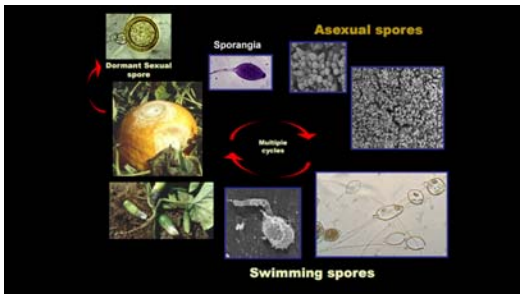


Whole genome variation in 2016 field populations of spinach downy mildew.

Kurt Lamour, Sandesh Shrestha, Bo Liu, Chunda Feng, and Jim Correll University of Tennessee and the University of Arkansas

- Obligate pathogen = difficult to study
- Heterothallic = must outcross to make sexual spores
- Oomycete = fungal-like
- DM has multiple life cycles
- No obvious correlation between genotypes and race types
- A novel genotypically diverse population of DM appeared in 2016 in Arizona and California
- Sex is important role to produce novel inoculum
- Clonal lineages from 2015 were almost absent from 2016

- Clonal reproduction in DM is unique



Oospore production, viability, and incidence on spinach seed.

Shyam Kandel, Beiquan Mou, Sridhara G. Kunjeti, Krishna V. Subbarao, Steven J. Klosterman, USDA/ARS, Salinas, CA

- 19% of seedlots tested hosted DM oospores, of these 59% were viable (Kunjeti et al, 2016)!!
- DM spores can remain dormant for 200 years
- DM spores are difficult to detect on seed
- DM spores can germinate on crop roots, this presents a new paradigm in DM research

Seed health protocol development for spinach downy mildew.

Sierra L. Hartney and Philip Brown, Sakata Seed, Mt. Vernon, WA

- The International Seed Testing Association (ISTA) adopts and publishes seed testing procedures
- The International Seed Health Initiative – Vegetables (ISHI-V) develops and validates seed testing protocols
- Oospores can survive harsh conditions for 1-3 years

Evaluation of oospores on spinach seed.

Bo Liu, Chunda Feng, Jim Correll, University of Arkansas, Fayetteville, AR

- 38% of seedlots contained DM oospores
- 4 types of oospores were detected on the seed surfaces
- Live oospores on seed might be responsible for spreading disease

- Same or similar DM races were identified in different places, countries at the same time (Feng et al., 2014)
- Oospores are viable
- Question whether DM races could be originating in seed production systems then being spread globally as sometimes DM pops up in diff areas at similar times
    - Mostly pop up in organics – seed not treated with metalaxyl
- New races generally in US first, heaps of organics

Numbers of Oospores on commercial seeds.

Lot#	Cultivars	Oospores / 1 g seed	Oospores / ha
1006	Cultivar-1	230.5	25,824,580
1007	Cultivar-1	144.4	16,178,175
-	Cultivar-2	2.8	313,704
1022	Cultivar-8	74.7	8,369,181
1023	Cultivar-8	14.5	1,624,540
1024	Cultivar-8	12.2	1,366,854
1026	Cultivar-8	57.7	6,464,548

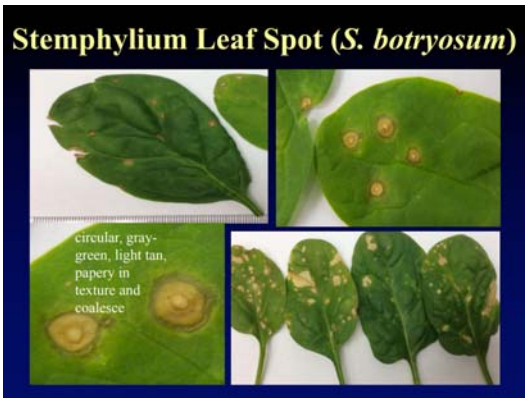
Characterization of spinach leaf spot pathogens and fungicide efficacy.

Liu, B., Feng, C., Cochran, K., Stein, L., du Toit, L. J., and Correll, J. C., University of Arkansas, Fayetteville, AR, and Texas A&M University

- Over 50 field samples were collected from 50 different areas & incubated to recover fungal & bacterial colonies
- Collected samples – grown at:
    - 22-24°C
    - Samples kept wet for 48 plus hours
- Found Anthracnose 61% (water-soaked edges), Stemphyllium 40% (insipid ring inside lesion), Cercospora 13% (red edge to lesion)
- Minor issues observed with other Anthracnose sp. & Myrothecium Leaf Spot
- Bravo, Dithane, Cabrio & Merivon – effective fungicides.
- Bacterial colonies were recovered from samples but none pathogenic on spinach

Major Leaf Spot Pathogens and Symptoms

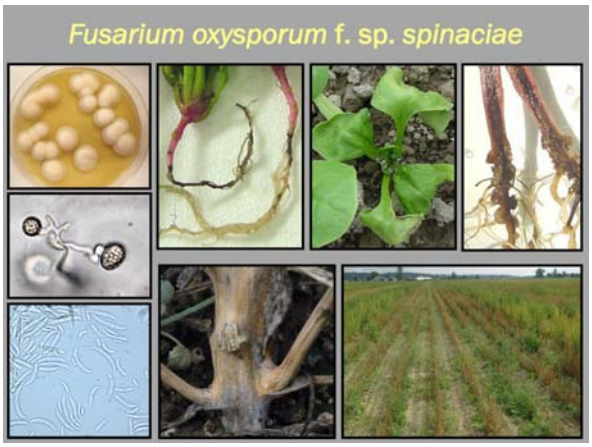
- Anthracnose
    - *Colletotrichum dematium*
- Stemphylium leaf spot
    - *Stemphylium botryosum*
- Cercospora leaf spot
    - *Cercospora beticola*



Determining the genetic basis of pathogenicity of Fusarium oxysporum f. sp. spinaciae on spinach.

Alex Batson, Tobin Peever, and Lindsey du Toit, Washington State University

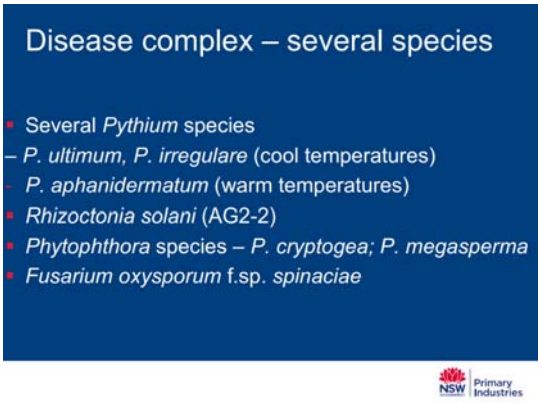
- Fusarium o. s. is highly persistent in soils, general crop rotations for seed production are 10-12 years
- Fusarium o. s. more prolific in acid soils
    - Proline (soil drench/foliar) & Myrtec (applied to seed)
    - Lime
- Pathogen can gain/loose genes when alive! Change from pathogenic to nonpathogenic!
- Can come from soil, plant, seed
- Not all isolates pathogenic to spinach
- Spinach germplasm being screened for Fus resistance as well as WB & DM?
- Could mix with mefanoxam if chasing DM



Soilborne disease management in Australia. Len Tesoriero

- Disease complexes most common rather than single species issues.
- Pythium control is achievable using chemical treatments
- No significant control of Rhizoctonia
    - Some control using strobilurin fingicides

- Suggested control options:
    - Avoid herbicides
    - Use fresh seed
    - Compost to improve soil health
- Seed coating/priming



Rhizoctonia: seedling disease or web blight in Texas spinach?

Cochran, K.A., Spurlock, T.N., Stein, L., and Drury, D., Texas A&M

- Rhizoctonia is ubiquitous in the soil
- Common symptoms:
    - patches of stunted/yellow crop through paddock
    - typical blackened, water-soaked lesions on stems and leaves
    - lesions on can also occur on the taproot
- strobilurins control this pathogen

A multidisciplinary approach to improve damping-off tolerance in spinach.

K.J.H. (Kim) Magnée, S.P.C. (Steven) Groot, J. (Joeke) Postma, E.T. (Edith) Lammerts van Bueren, O.E. (Olga) Scholten, Wageningen University & Research, Netherlands

- Working with PV & Sakata on the damping off issue
- 90% of US damping off caused by Pythium (Phytophthora, Fusarium and Rhizoctonia also cause damping off)
- Seedlots can see different incidence rates, better seed vigour will provide improved

damping off tolerance

- Waterlogging, high temperature, low oxygen, frequent spinach production increase damping off severity
- Not just inoculum levels influencing levels of damping off but also soil structure.

Development of a spinach white rust management strategy in Texas Larry A. Stein, Texas A&M

- In 1937 white rust became the major production problem in US. Continuing through the 60's
- 72 breeding efforts between Arkansas saw field resistance built into new varieties
- WR results in yellow lesions on leaf and white rust lesions initially occurring on the underside of the leaf
- Metalaxyl is used in furrow at seeding – 10lb/ac (efficacy lasts 20-25 days)
- Most affective fungicide – Cabrio rotated with presidio & prophyt and/or merivon (Cabrio best)
- Ranman also effective
- Lifegard works to some degree in organics also another new product coming along
- Organic product Oso used but not organically approved
- Still researching resistant varieties especially in Texas

White rust: beyond borders.

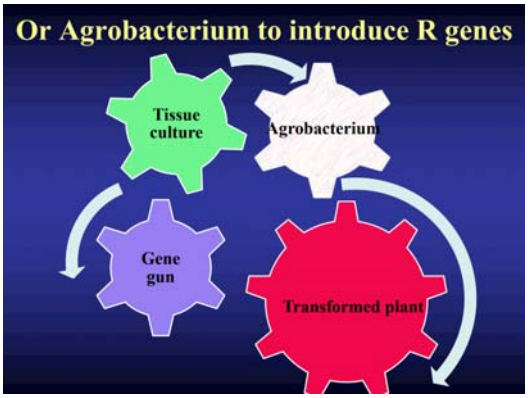
Jim Correll, Chunda Feng, Ainong Shi, University of Arkansas, Fayetteville, AR

- WR is an oomycete fungus, now found in 4 countries (Mexico, Turkey, US, Greece)
- In the US only found in Texas, Arkansas, Colorado, East Coast
- There is no genetic resistance but field tolerance
- Varietal screening for field tolerance occurs in Texas
- Since WR first developed in Texas it has not spread to the major spinach production region of California!

Tissue culture approaches for spinach research on disease resistance.

Maria Isabel Villarroel-Zeballos, Braham Deep Singh Dhillon, Chunda Feng, Jim Correll, University of Arkansas, Fayetteville, AR

- Insert DM resistance genes into susceptible varieties via the use of a gene gun, tissue cutlture or agrobacterium to assess the resistance gene
- Grow out & assess new plants for genes present and resistance to race of DM
- Growth medium is critical



Spinach genome sequence overview including NIL1 and candidate resistance genes.

Braham Deep Singh Dhillon, Chunda Feng, Ainong Shi, Quighua Pan, and Jim Correll, University of Arkansas, Fayetteville, AR

- DM, Pythium, phytophthora, WR, DM in brassicas all oomycetes
- Many gene resistances originate from wild sources
- 6 loci known to be used for resistance breeding – seed companies not telling us how many other loci being used in breeding
- Each loci marked & can be tracked in the genome to quickly determine a new varieties genetic resistance
- Need to use differential set to assess DM races in Australia (slide 4.2, 8/14)

Evaluation of natamycin seed treatments for Stemphylium botryosum and other necrotrophic fungi on spinach seed.

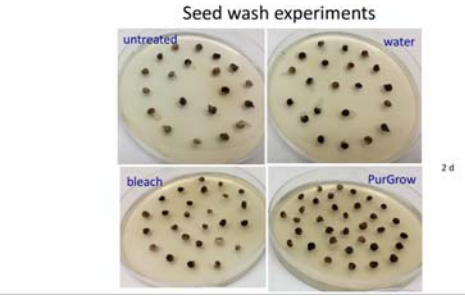
Lindsey du Toit and Michael Derie, Washington State University

- Many seed treatments available to conventional growers
    - For Stemphyllium control - best options pyracostrobin & boscalid
- Natamycin from Streptomyces natalensis
    - Only works on true fungi not DM (oomycetes)
    - No resistance risk
    - Some phytotoxicity
    - Controls Verticillium, Stemphyllium, Alternaria
    - Doesn't antagonise beneficial fungi
- 0.5 to 1.5g/kg seed most effective

PurGrow: a novel methodology for cleaning seed and managing diseases. Chunda Feng and Jim Correll, University of Arkansas, Fayetteville, AR

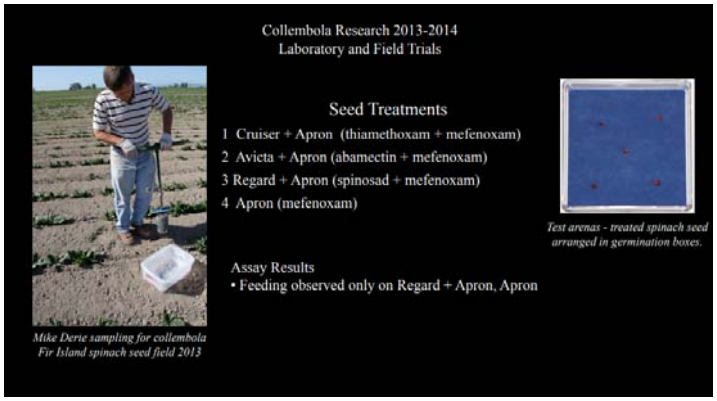
- Tested for seed cleaning and management of spinach diseases
- Purgrow can be used for oomycete control
    - better than bleach
    - Surface disinfectant
    - 5 minute exposure – quick kill of oospores
    - Can't cure infected leaf tissue but can remove inoculum so new leaves grow out not affected

- Also works on Anthracnose & Stemphyllium
- Further research to determine if PurGrow can it be used in irrigation, soil cleaning, on leaf?
- Not sure if PurGrow will be available in organics



Subterranean collembola, a challenging pest of spinach seed production. Beverly Gerdeman, G. Hollis Spitler, and Lynell Tanigoshi, Washington State University

- Subterranean collembola = Springtails
    - Will feed on some soil fungi
    - Can cause some plant damage in high numbers
    - Spring issue
    - Assist with decomposing soil organic matter
    - Damage only noted when numbers are high
    - Inside seed once pericarp breaks, feed on leaf/cotyledon tissue & Prue root hairs
    - Thimathoxin & abamectin control pressures
    - Bifenthrin also works well
    - Crop moisture management can be used to suppress populations
    - Can use beet slices to monitor numbers – attractant. Place on soil surface, cover, assess in 2-3 days



Food safety strategies for preventing the contamination of spinach with foodborne pathogens-A Texas and global approach.

Marcel Valdez, Texas A&M University

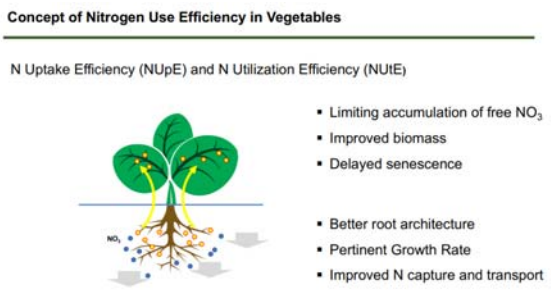
- In 2007 the US & Europe signed a food safety agreement emphasizing the ongoing need for a strong food safety education program to continue to improve food safety
- Strong education plan that teaches workers hygiene and the importance of food safety practices

- Strong delivery method that incorporates different learning styles
- Evaluation method that measures at least some level of knowledge gained

Insights into nitrogen assimilation and oxalic acid metabolism in spinach

Vijay Joshi Texas A&M AgriLife Research, Texas

- Most rapid period of nitrogen requirement is from vegetative phase to reproductive period – period of high crop growth
- Match nitrogen application with periods of demand
- Root architecture is a key for increasing nitrogen use efficiency
- Oxalate is accumulated in spinach & can reduce Calcium availability when consumed by humans
    - Anti-nutrient effect once consumed
    - Spinach crops fed with higher nitrate levels will have higher oxalate levels
- Organic system typically has less NO3 accumulation than conventional likely due to different nitrogen sources in the production system



Sakata Field Trial

- Field day involved sowing of all spinach breeding companies commercial and near commercial spinach varieties in the one field for comparison under identical conditions.
- The team spent some time with John Meeuwsen (Spinach breeder from Seminis/Monsanto) learning of his breeding focus:
    - DM resistance again the main breeding focus
    - The laboratory finds the DM resistance genes then breeding teams job is to combine the genetic resistance into a salable variety

Emmett's Espania – counter seasonal production for the UK market

Richard Clarke, manager Emmett Murcia Agricultura S.L.

- Cropping Kale, Leeks & Spinach
- The company doesn't own any land
- All production costs are kept to a minimum:
    - Soil cultivation (1 rip & 1 rotary hoe)
    - Fertilizer (organic pellets, base fertiliser & top dressing with calcium nitrate if necessary)
    - Growing on the flat using as much ground as possible – no furrows
    - Spray 2 bays at once
    - Adapted air seeder which can hold 1 pallet of spinach seed at a time in the hopper,

48 rows, 50mm appart

- Fungicide applications are minimsied and based around Ridomil Gold, Previcur, Switch, Signum, Fontelis and Copper
- Pre-emergent herbicide – Venzar
- Harvest occurs in bulk into 3tn bins with walking floors
- In the pack shed bulk spinach is minimally processed removing contaminants, cotyledons etc and packed into crates for shipping to the UK where processing occurs
- This business is cost focused, set up to produce a commodity crop

Pop Vriend – personal tour of new development lines (Spinach & Chard)

- The tour group had a personal walk through the spinach trials
- DM resistance is the number one focus
- Damping off tolerance is also a focus with damping off issues being more widely experienced globally
- PV was involved in the original expedition to explore the origins of the spinach plant and hence has access to the genetic collected greatly assisting the breeding focus and DM resistance
- PV prioritises the investment in a broad range of projects which has to date worked in their favour.
- PV are working on developing horizontal resistance as opposed to single gene resistance alone
- Leaf spot resistance is challenging the ability to select for good downy resistance. Europe is

now seeing increasing incidence of leaf spots, this means breeding for two important traits at the same time is much more difficult

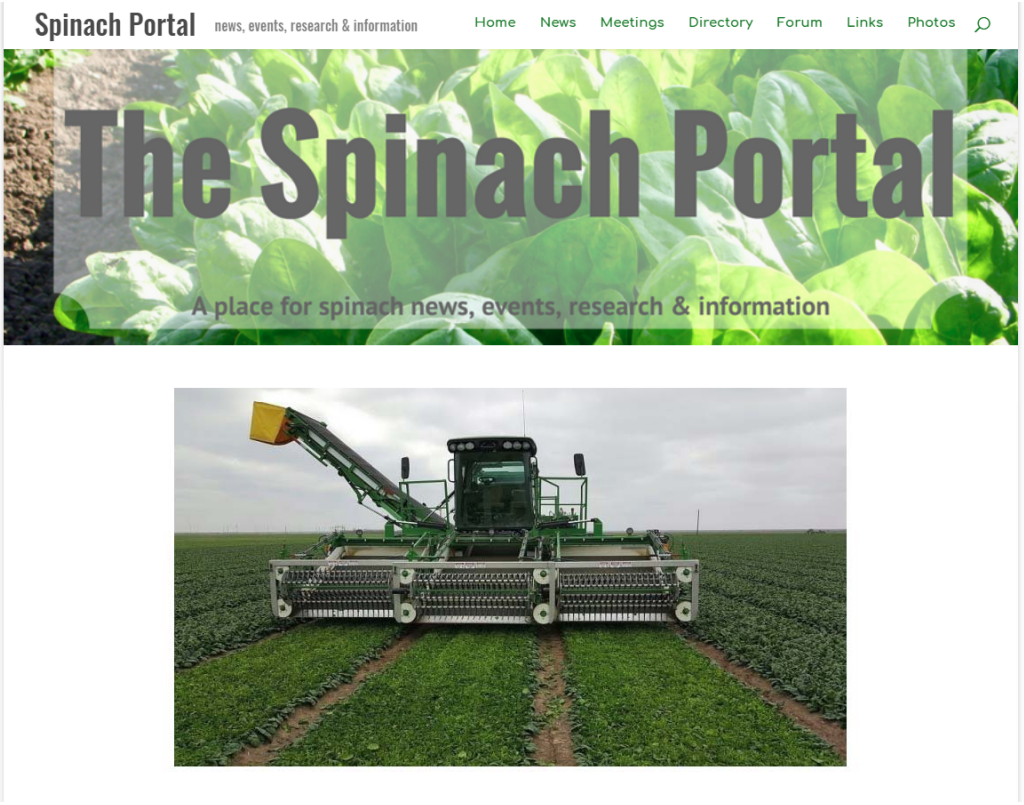
- The use of genetic markers however is having great advantages in developing new lines quicker and cheaper. Once the genome is better understood we may hopefully see mildew become less of an issue

Nunhams/Bayer – organised spinach tour of current & new varieties

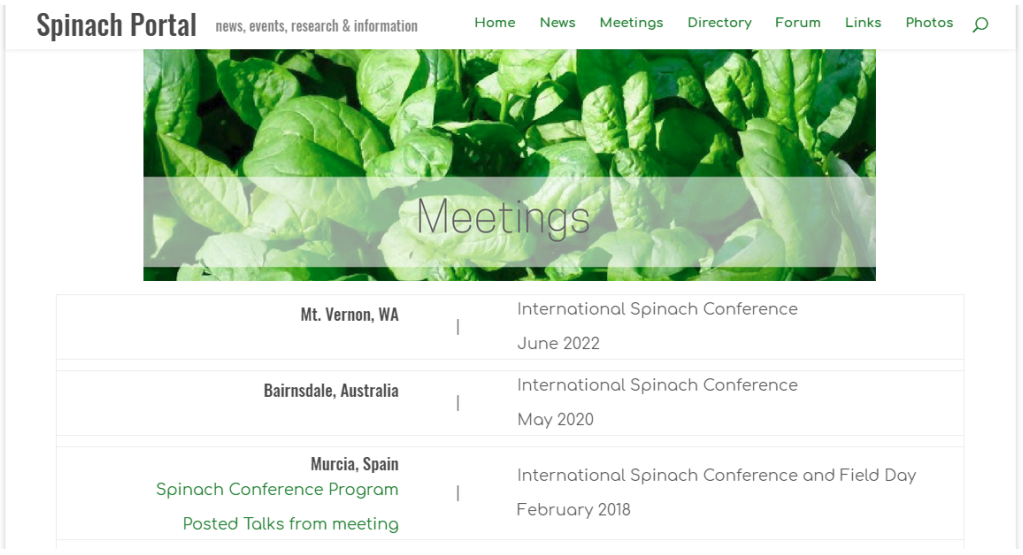
- DM resistance and leaf traits are the main breeding focus
- No known resistance to damping off pathogens hence no ability to breed for resistance – needs to be a focus of research
- Breeders use screening trials to select out DM susceptible varieties
- Fleece used to germinate crops, even crops up, reduce water requirements and increase night temperatures but must be removed before crops stretch
- Many varieties coming through have resistance to the new proposed DM race, race 17
- Typically, Nunhems varieties are rounder leaf types but DM resistances are very strong

Appendix 3 – International Spinach Portal

The International Spinach conference has a dedicated portal, follow https://spinach.uark.edu/



Reference material, slides and relevant information from the Mercia conference can be seen under the 'Meetings' tab, by following the link "Posted talks from meeting"



Appendix 4 - Articles, media releases and social media.

Article – AusVeg

27 FEB 2018

AUSVEG Weekly Update – 27 February 2018

In this edition: Videos on levy investment and IPM, grower tour recaps, free training workshops and more!

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Home › News & Media › Latest News › Spinach growers plug in to global industry at International Spinach Conference

27 FEB 2018

Spinach growers plug in to global industry at International Spinach Conference

Australian spinach growers, agronomists and researchers have made vital linkages with the global industry and accessed international research and development through a study tour to the International Spinach Conference in Murcia, Spain.

Coordinated by the team behind the East Gippsland Vegetable Innovation Days (EGVID) and made possible through a strategic levy investment under the Hort Innovation Vegetable Fund, the study tour ran from 10 February to 18 February and was led by 2017 Australian Farmer of the Year Andrew Bulmer and agronomist Stuart Grigg (Stuart Grigg Ag-Hort Consulting).

As well as attending the International Spinach Conference, the group of 14 participants also visited industry sites, including:

- British growers producing spinach and other crops in Spain counter-seasonally to the British growing season at G's España SL, Intercrop and Emmett; and
- Extensive seed company trials at Rijk Zwaan, Enza Zaden (marketed in Australia by South Pacific Seeds), Pop Vriend (marketed in Australia by Lefroy Valley), and Bayer (under the Nunhems brand).

As well as these site visits, there were many other highlights from the tour. The group gained close-up experience of bulk-harvested baby spinach in the field, learned about production challenges in the harsh southern Spanish climate, visited trials of new and exciting spinach varieties including many new varieties with resistance to all currently named races of *Perinospora effusa* (downy mildew) 1-16, and listened to over 30 scientific and agronomic presentations specifically focused on spinach breeding and production.

Growers interested in seeing some snapshots of the tour can look at the image gallery below or check out the live tweets posted during the mission at the EGVID Twitter (@2017EGVID).

As part of the project, an extensive report will be compiled in coming months and be made available to industry, so keep an eye out for more information.

IMAGE GALLERY: HIGHLIGHTS OF SPINACH STUDY TOUR TO SPAIN

A selection of photos from the levy-funded study tour to the International Spinach Conference in Murcia, Spain and other spinach industry site visits.

This post appeared in the AUSVEG Weekly Update published 27 February 2018.

Hort Innovation | VEGETABLE FUND
This project has been funded by Hort Innovation using the vegetable research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

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Article – Len Tesoriero

Disease management features at international spinach conference

Len Tesoriero

A group of Australian growers and industry representatives recently attended the 4th biennial international spinach conference in Mercia, Spain. Among the wide range of topics presented they heard about research on key diseases with a strong emphasis on those affecting crops across Europe and North America. Some of these diseases pose a significant biosecurity risk to Australian producers while others are already affecting local crops.

Worldwide the most economically important disease of spinach is Downy Mildew caused by the fungus-like oomycete, Peronospora effusa. Managing this disease with resistant spinach varieties has been largely successful and seed companies globally devote considerable effort to incorporating resistance genes into their commercial varieties. There were several presentations on recent studies that are mapping the genetic code of the pathogen as well as finding genetic markers for resistance genes in spinach plants. This will hopefully facilitate breeding of new disease-resistant varieties. Unfortunately controlling spinach downy mildew has become more challenging in recent years largely because of the emergences of new pathogenic races that overcome resistance genes in available commercial varieties. There are currently 16 known races and new ones are appearing at an ever increasing rate, including a recent outbreak of a potentially new one in Australia. Access to resistant spinach varieties is critical given the rapid production cycle of baby spinach crops – as quick as 21 days from seeding in warmer months thus making it less desirable to use chemical management options. Organic producers (50% of production in California and worth $US150M) are solely reliant on availability of resistant varieties. Identifying new races of the pathogen is currently laborious given that the pathogen has to be inoculated onto a panel of varieties with known resistance genes and kept under environmental conditions that favour disease development. P. effusa also has some features that make it difficult to work with; in particular it can't be cultured away from spinach plants so any experimental work has to be done with spores collected from an infected plant. Unfortunately, the common spores causing the typical downy growth under leaves (sporangia) are short-lived and most attempts to send them to Europe from Australia for race-tying have failed. This leaves Australian spinach producers vulnerable as it requires an international effort to confirm new races and breeders rely on races to be officially characterised before including them in their breeding programs. Therefore access to a local race testing service would be of great assistance to the industry in Australia, at least until the development of genetic tests which are still some years from being ready.

One point of controversy regarding spinach downy mildew is that several researchers have shown that the sexual spores (oospores) of P. effusa can be detected on the surface of commercial seed. Some in the industry have argued that there are insignificant risks with seed-borne infection of this pathogen. However, detection rates were surprisingly high with oospores found in nearly one-fifth of 168 seed lots. Moreover about half of these oospores were shown to be able to germinate and therefore serve as primary inoculum to initiate disease. Standardised testing protocols are now being developed and should be available soon through a global regulatory body, the International Seed Federation. Adoption of these protocols should reduce risks for global spread of new races.

Downy mildew was not the only disease discussed at the conference. Len Tesoriero presented Australian research on integrated management of spinach damping-off caused by Pythium species and Rhizoctonia solani. He reported that metalaxyl-M seed dressing was effective for controlling Pythium species but no chemical or biological treatments to date have been successful for reducing Rhizoctonia rot. Earlier applications of such treatments (prior to sowing) are currently being investigated as a way to suppress Rhizoctonia. A Dutch research student spoke of a similar integrated approach to this disease with an emphasis on seed vigour as a critical component in increasing tolerance to damping-off. A Texan researcher spoke about a different R. solani strain that causes an aerial blight in addition to a root and crown rot of bunching spinach. Lindsey du Toit from Washington State spoke on developing a new genetic

test for detection of Fusarium wilt of spinach. Although Fusarium wilt occurs in Australia it appears to only be important in some areas of Victoria where it interacts with other damping-off pathogens causing a disease complex. Fusarium wilt is more important in bunching spinach and seed production as it develops more slowly than the damping-off pathogens. Lindsey also spoke of a seed treatment with a bacterial metabolite called natamycin which was combined with a proprietary seed priming treatment to suppress development of the common leaf spot pathogen, Stemphylium botryosum as well as vascular wilt pathogens, Verticillium spp. and Fusarium. One caveat of this work was that longer priming durations and higher natamycin levels caused adverse effects on seed germination. It's also possible that different varieties or physiological ages of seed might respond differently to priming durations so additional testing is currently being carried out.

One disease of some biosecurity concern to Australian producers is spinach white rust (white blister). It is caused by Albugo occidentalis, an oomycete relative to the downy mildews. It has been a problem to spinach production in Texas since the late 1930s and spread to other US states such as Arkansas and along the Atlantic coast. However, it has been detected more recently in Greece (2013), Mexico (2017) and Turkey (2018). If it were to spread to a seed production area then it would become a significant biosecurity risk to Australia as it can spread with seed.

From a plant pathologist's standpoint this international spinach conference provided a wealth of information about the current research being conducted around the world and where knowledge gaps or threats may pose disease risks to Australian growers. Hopefully this increased awareness can be used to mitigate these risks.

The international Spinach study tour project is funded by Hort Innovation using the vegetable R&D levy and contributions from the Australian government.

Figure 1. Downy mildew affected spinach (above) and resistant variety (below) in a demonstration plot

Figure 2. Underside of downy mildew infected spinach leaf with white spore masses

Figure 3. New Pop Vriend spinach varieties displayed for the Australian delegation

Figure 4. Australian delegation members viewing Rijk Zwaan spinach varieties

Article – Stuart Grigg and Carl Young

Australia visits the 2018 International Spinach Conference, Mercia, Spain.

WRITTEN BY STUART GRIGG AND CARL YOUNG
PHOTO ABOVE: Crop covers – Intercrop Espania

February 14th and 15th saw the International Spinach Conference converge on the Northern Hemisphere's winter vegetable growing hub of Murcia Spain. A contingent of 14 spinach enthusiasts from Australia comprising growers and industry representatives attend the conference and associated production tour facilitated by EGVID Pty Ltd. The largest spinach stake holders globally attended the International Spinach Conference which has previously been held in the US, Europe and China to discuss the latest trends and issues the industry faces.

Murcia is well suited to winter vegetable production being predominantly dry and with far greater daylight hours than British growing regions. For this reason, many of the British growers produce crops in this region and export to the UK and much of Europe during the cooler months.

The tour comprised of three distinct focuses: grower visits, viewing of seed company trial plots and attendance at the International Spinach Conference.

Grower visits to G's Espania, Intercrop Espania and Emmett Espania challenged the touring party and a number of their Australian production techniques. The Spanish soils have been cropped heavily for many years and with heavy regulations around nutrient use, composting is a major focus with high quality composts produced from a mixture of cow manure and palm fronds. The use of protected cropping at G's and floating crop covers at Intercrop enable these producers to give their customers certainty around supply and manage the impact of adverse weather events.

Automation and investment in the production system at Emmett was an absolute highlight with minimal soil cultivation and nutrient use, minimum labour units, bulk harvesting and a real focus on production costs and eye opener. The Australian contingent particularly enjoyed and benefited from the farm visits where questions directed at the large producers regarding their trade secrets were answered surprisingly without much hesitation.

Visits to the trial fields at Rijk Zwaan, Enza Zaden, Pop Vriend and Nunhems/Bayer exposed the touring party to breeder focuses and challenges. Downy Mildew (*Peronospora effusa*) remains the main breeding focus internationally largely due to challenges managing this rapidly evolving pathogen in the organic sector. Conversations around Downy Mildew isolates and the likelihood of a new race, race 17, being denominated in the near future further alerted the touring party to the continued breeding focus and production challenges. This further highlighted the need for multifaceted management approaches for this pathogen rather than relying on genetics alone especially with resistance genetics becoming more challenging to access.

Leaf spot pathogen resistance and management was a topic of conversation not only with spinach breeders but also Spanish producers and an area of research presented at the International Spinach Conference. Many of the leaf spots Anthracnose (*Colletotrichum dematium*), Stemphylium (*Stemphylium botryosum)* and Cercospora (*Cercospora beticola*) are becoming more of a challenge to manage both in the seed and leaf production systems. Presentations around inoculum levels on spinach seed, management of these inoculum levels and management of these pathogens in crop give Australian producers some reassurance these issues are being researched internationally with some solutions to the issues available, should these pathogens become an increasing production issue in Australia.

NSW based pathologist Len Tesoriero accompanied the touring party, soaking up the hottest topics of the International Spinach Conference, particularly about the life cycle and interaction of spinach resistance genes to Downy Mildew, and recount in laymen's terms findings to the rest of the group.

The touring group is very grateful to the support of Elders, E.E. Muir & Sons, Nunhems, Rijk Zwaan and EGVID Pty Ltd. Thank you also to EGVID's Stuart Grigg and Andrew Bulmer for their thorough organisation and management of the tour.

One of biggest benefits of the trip was the opportunity for networking within our own group, with every state of Australia represented, a wealth of experience and knowledge was present and shared communally.

The international Spinach study tour project is funded by Hort Innovation using the vegetable R&D levy and contributions from the Australian government.

Bulk Spinach harvest – Emmett Espania

Spinach processing – Emmett Espania

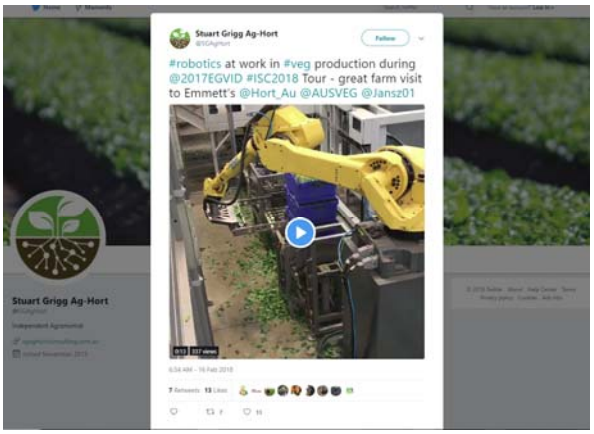
Protected cropping – G's Espania

Spinach current and trial varieties – Nunhems/Bayer breeding station

Touring party gets a briefing in spinach breeding – Rijk Zwaan

Social Media

Links to short videos



https://twitter.com/SGAgHort/status/964508173573947392

https://twitter.com/SGAgHort/status/964120558072774659

https://twitter.com/SGAgHort/status/963285089240141825

EGVID 2017 Retweeted

AUSVEG @AUSVEG · 24 Nov 2017

Are you an Australian #spinach enthusiast? Join a study tour to the 2018 International Spinach Conference in Spain from 9-18 Feb with the @2017EGVID team, Andrew Bulmer + @SGAgHort! For info see bit.ly/2zUPZhE @Hort_Au

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EGVID 2017 @2017EGVID · 21 Nov 2017

Produce spinach? We want you to attend our tour to Murcia, Spain Feb 2018 to tour producers, breeders, processors & coinciding with the International Spinach Conference @Hort_Au @SGAgHort @AndrewBulmer01 #spinach #vegetable #growers #internationalspinachconference #ISC2018 #Spain

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Stuart Grigg Ag-Hort @SGAgHort · Feb 13

@2017EGVID #ISC2018 Tour - Leaf Spot diseases one of España major growing challenges. Also an issue in Texas - one of the presentations Wed fosuses on this issue. @Hort_Au @AUSVEG

1

Stuart Grigg Ag-Hort @SGAgHort · Feb 13

@2017EGVID #ISC2018 Tour @intercrop in España - Tks for your time Jafar, enjoyed by all. @Hort_Au @AUSVEG

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Noel jansz @Jansz01 · Feb 15

Len tesoriero presenting at the international spinach conference #ISC2018 @AUSVEG @Hort_Au @nswdpi

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EGVID 2017 @2017EGVID · Feb 13

Great morning @RijkZwaan with @RPSaladSolution #spinachinSpain

3 5