International Spinach Conference

Melbourne, Australia
1-2 May 2023

TABLE OF CONTENTS

Letter from Organizing Committee..3

Event Facilitators..9

Program and Field Day Sponsors...10-14

Program Itinerary....15-17

Field Day Information..18-20

List of Contributed Abstracts...21-41

Spinach Website..42

UNIVERSITY OF ARKANSAS
DIVISION OF AGRICULTURE

Department of Plant Pathology

UNIVERSITY of ARKANSAS
1871
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May 1, 2023

On behalf of the organizing committee, we would like to welcome everyone to Melbourne, Australia for the 10th International Spinach Conference, dedicated to the international exchange of information for the benefit of the spinach community. This is the first International Spinach Conference we have had the opportunity to host in the Southern Hemisphere. We have a large and diverse international contingent of spinach colleagues, and an exciting program and field day planned. This should be a valuable venue for everyone interested in spinach.

Stuart Grigg is this year's program chairperson and local organizer. We thank Stuart and the team in Australia for their stellar efforts associated with all aspects of the meeting.

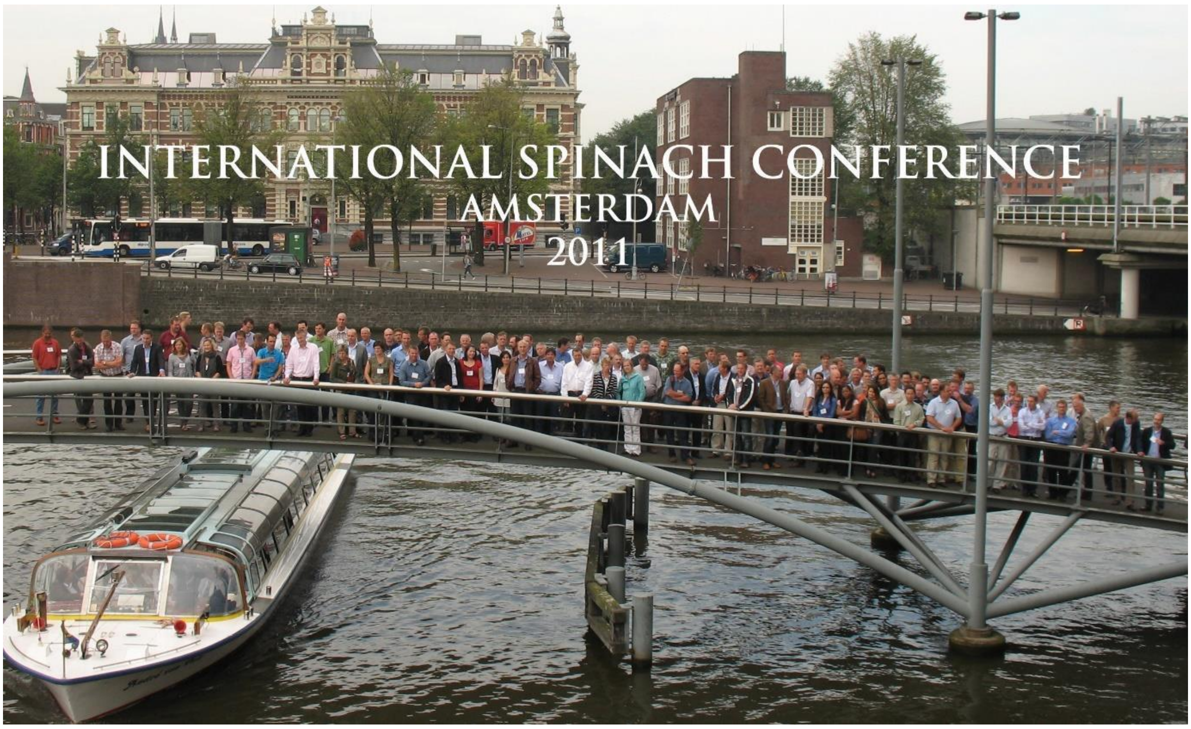
We also would like to thank the many people for their time and effort in convening the meeting, and the dedicated sponsors for their financial support. Without this interest and support, the meeting would not be possible. In particular, many thanks to the Organizing Committee members, including Andrew Bulmer, Bonnie Dawson, Tim Withers, Nathan McIntyre, Kate Grigg, Lindsey du Toit, Maria Isabel Villarroel- Zeballos, Shelby Lane Hanson, and Hannah V. Zima. They deserve the credit for doing the heavy lifting.

Welcome to the meeting and welcome to Melbourne, Australia! We hope everyone enjoys the meeting and finds it productive.

Sincerely,

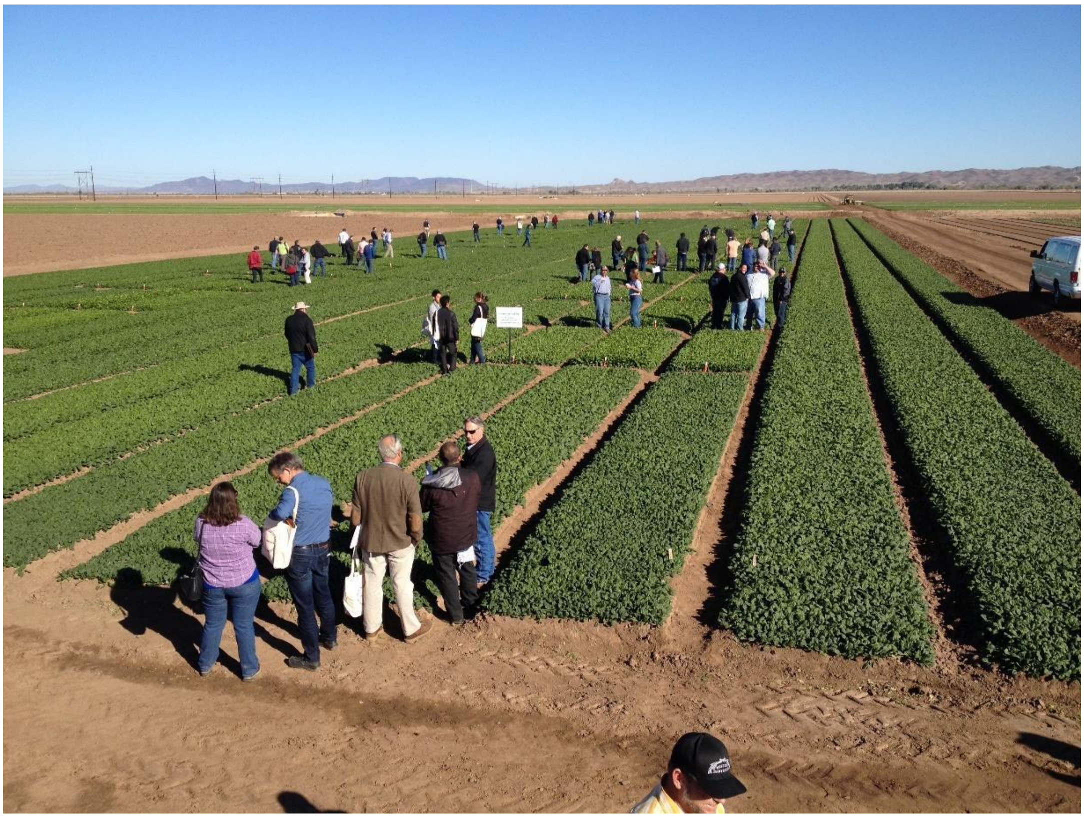
Jim Correll and the Organizing Committee:

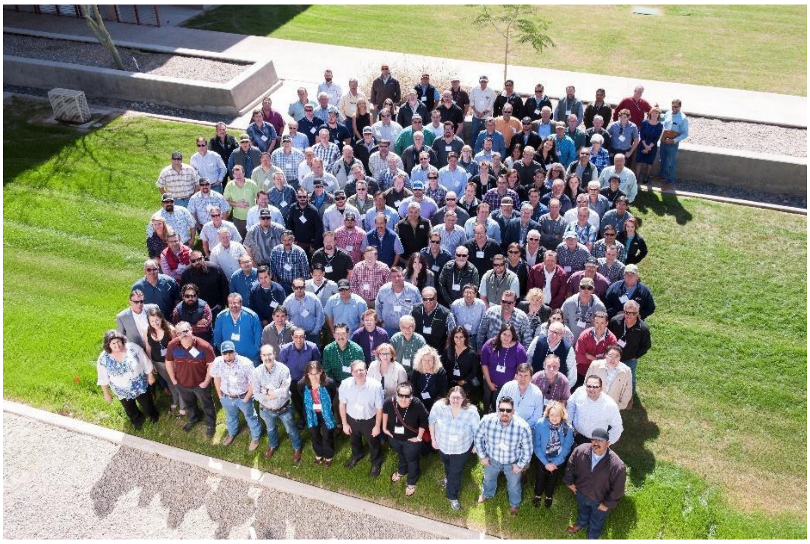
Jim Correll, Stuart Grigg, Lindsey du Toit, Andrew Bulmer, Bonnie Dawson, Tim Withers, Nathan McIntyre, Kate Grigg, Maria I. Villarroel-Zeballos, Shelby Lane Hanson, Hannah Zima


INTERNATIONAL SPINACH CONFERENCE
AMSTERDAM
2011

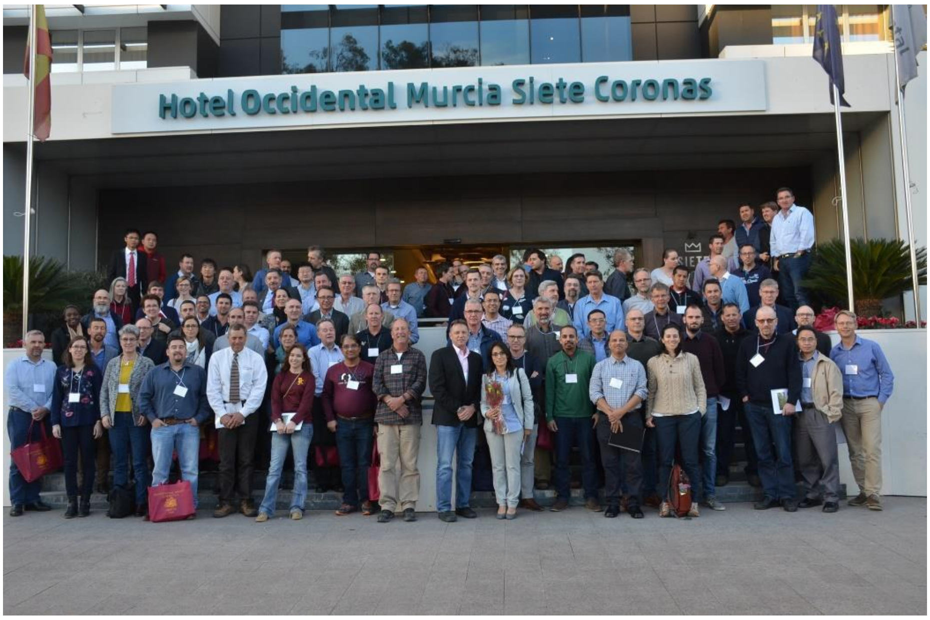
2013 International
Spinach Conference Guangzhou, China

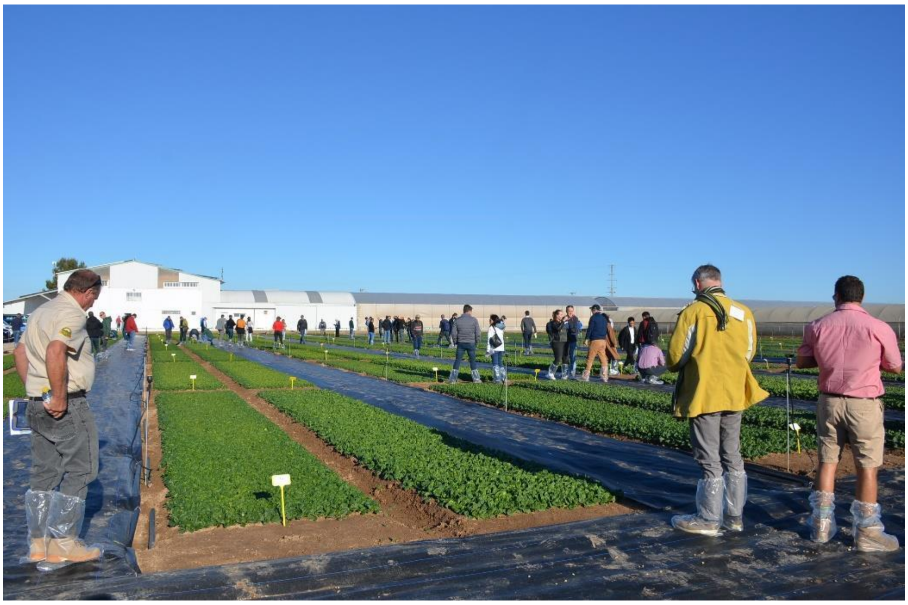
2015 International Spinach Conference
Yuma, Arizona





2018 International
Spinach Conference Murcia, Spain





Welcome to the 2023

International Spinach Conference
Melbourne, Australia

1-2 May 2023

2023 International Spinach Conference
Event Facilitators

East Gippsland Vegetable Innovation Days

Stuart Grigg Ag-Hort Consulting

Bulmer Farms

Food & Fibre Gippsland

National Vegetable Extension Network
VICTORIA - GIPPSLAND

UofA
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2023 International Spinach Conference Program Sponsors

Key Event Sponsors

Hort Innovation

AGRICULTURE VICTORIA

Gold

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Speakers for 10th International Spinach Conference in Melbourne, Australia, 1-2 May 2023

Kaleide Theatre, Building 8, RMIT (Royal Melbourne Institute of Technology) University, 360 Swanston Street, Melbourne

PROGRAM

Monday, 1 May 2023

Time	**Title**
Session Moderator - Jim Correll	

(Please note, only the presenter is listed. For full authorship, see the published abstract in the program)

8:00 - 8:05 am	Welcome to the ISC 2023 on behalf of the Organizing Committee Jim Correll, University of Arkansas
8:05 - 8:15 am	Welcome to Australia, overview of Horticulture Innovation Anthony Kachenko, Horticulture Innovation Australia Limited
8:15 - 8:30 am	Intro and orientation, spinach & the Australian context. Stuart Grigg, Ag-Hort Consulting
8:30 - 8:45 am	A recent history snapshot of Spinach sales growth and performance in Australian supermarkets. Sam Robson, CEO One Harvest
8:45 – 9:00 am	US spinach production and supply chain. A Focus on California Production and Trends Jennifer Clarke, Chair of the California Leafy Greens Research Board
9:00 - 9:15 am	Spinach breeding – meeting grower and consumer needs Amy Groh, Bayer Product Development Breeding
9:15 - 9:30 am	Controlling invertebrate pests of spinach Paul Horne, Entomologist at IPM Technologies
9:30 – 9:45 am	Fresh produce food safety trends, challenges, and opportunities for 2023 Deon Mahoney, International Fresh Produce Association
9:45 – 10:00 am	Environmental management and regulation for vegetable growing in New Zealand Michelle Sands, Natural Resources and Environment | Horticulture New Zealand
10:00 – 10:15 am	Break

10:15 – 10:30 am (2:15 am in Italy)	Cultivation of baby leaf spinach in Italy: an overview on the management of diseases and pests in the European scenario which imposes the reduction of the use of chemicals. Pietro Di Benedetto (Virtual), Dottore Agronomo.
10:30 – 10:45 am	EU spinach production and breeding. Jan de Visser, Pop Vriend Seeds
10:45 – 11:00 am (5:45 pm, March 31 in California, USA)	Efficient nitrogen management and reducing cadmium uptake in spinach production Richard Smith (Virtual), University of California Extension
11:00 – 11:30 am (6:00 pm, March 31 in California, USA)	Virus and soilborne pathogens of spinach in coastal California Steve Koike (Virtual), TriCal Diagnostics
11:30 – 11:45 am	Organic spinach production in the USA Ramy Colfer, True Organics
11:45 -12:15 pm	Panel discussion Stuart Grigg, Sam Robson, Jennifer Clarke, Amy Groh, Deon Mahoney, Ramy Colfer
12:15 – 1:15 pm	Lunch

Session Moderator – Lindsey du Toit

1:15 – 1:45 pm	Disease management in spinach seed crops in the Pacific Northwest USA Lindsey du Toit, Washington State University
1:45 – 2:00 pm	Ecology and management of Stemphylium leaf spot of spinach. Kayla Spawton, Washington State University
2:00 – 2:30 pm	Downy mildew, Stemphylium, and Damping off of spinach. Jim Correll, University of Arkansas
2:30 -2:45 pm	Sentinel field trials to evaluate spinach downy mildew caused by *Peronospora effusa.* Hannah Zima, University of Arkansas
2:45 - 3:00 pm (9:45 pm, March 31 in California, USA)	Transmission of spinach downy mildew via seed and infested leaf debris Steve Klosterman (virtual), USDA/ARS Salinas, CA
3:00 – 3:15 pm	White rust fungicide efficacy Larry Stein, Texas A&M University

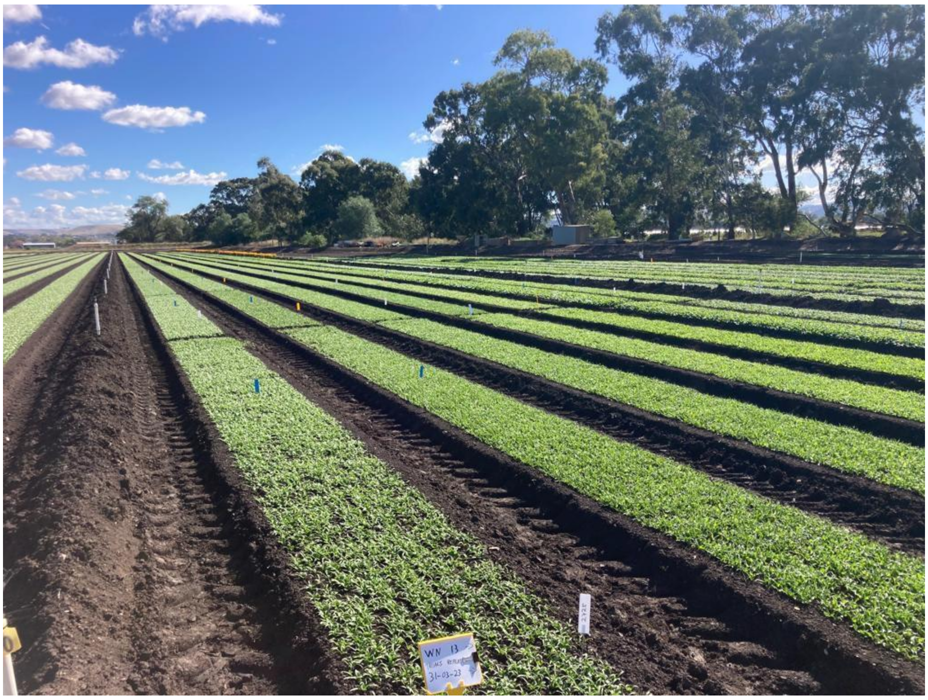
3:15 – 3:30 pm	Beyond salad: Producing spinach seed for grain consumption Carlos Avila, Texas A&M University
3:30 – 4:00 pm	Panel discussion Lindsey du Toit, Jim Correll, Larry Stein, Jan de Visser
5:30 – 7:00 pm	River cruise departure (Yarra River Cruise, Southbank Promenade, Pier 2) Stuart Grigg and Jim Correll

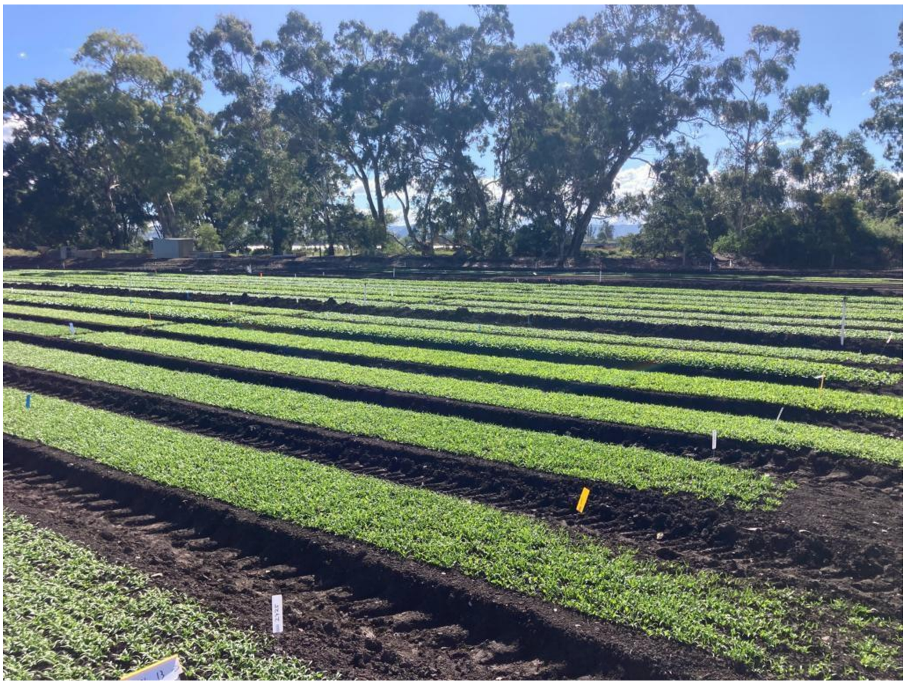
Tuesday, 2 May 2023

Spinach Field Day

9:00 am	Depart for Bacchus Marsh from RMIT (Royal Melbourne Institute of Technology) University - exact location to be announced on 1 May
10:00 am	Arrive at Baccus Marsh (Boratto Farms, Woolpack Rd, Bacchus Marsh) Coffee & morning tea
12:30 pm	Depart Baccus Marsh
1:00 pm	Arrive at Rijk Zwaan location **(**Provenzano Farms, Fisken St, Bacchus Marsh)
1:00 pm	Lunch
2:30 pm	Depart Rijk Zwaan location
4:00 pm	Arrive back at hotel

Field Trial
Melbourne, Australia
1-2 May 2023





10th International Spinach Conference: Spinach Field Day - hosted by Boratto Farms, Woolpack Road, Bacchus Marsh

each cell represents 1 sprinkler gap (approx 10 meters per variety)

	Sprinkler row														
sown 31st March	Sem 2725	Sem 2146	Sem 2157	Sem 2741	Sem 3580	Magnetic	Thanos (5998)	Kona	Rangitoto	Sem 3719	Java	Motutapu	Opulu	Sem 3549	Sem 1470
sown 31st March	Deeno	2953	SP 2956	SP 2958	SP 2961	El Lucio	LSPH 20-0095	El Furio	El Fortonado	El Swing	El Madison	Grant	Nighthawk		
sown 31st March	Tectonite (1714)	Dallas	Apache	Cocopah	Carmel	Flurite (1526)	Sioux	Onyx (1713)	Opal (1718)	Nun 7561	Sculptur	Minkar			
sown 31st March	Jinx	Countryside	Sorento	Gatsby	SPS 071-22	SPS 084-22	SPS 496-8	SPS 056-23	SPS 057-23	Serpans	Nun 7566				
sown 31st March	Auroch	Platypus	Bonnethead	Sunangel	Lizard	Boxfish	Stoat	Yalko	Cabezon	Traverse	Trailboss	Crosstrek	Longhorn	Frontier	
sown 25th March	Montutapu	Opulu	Sem 3549	Palaos	Nighthawk	Jinx	Countryside	Sorrento	Diablo	Gatsby	SPS 071-22	SPS 084-22			
sown 25th March	Magnetic	Thanos (5998)	Kona	Sem 3719	Java	Deeno	SP 2953	SP 2956	SP 2957	SP 2958	SP 2961	SPS 496-8			
	Sprinkler row														
sown 25th March	Sem 2725	Sem 2146	Sem 2740	Sem 2741	Sem 3580										
sown 25th March	Cabezon	Crosstrek	Trailboss	Longhorn	Frontier										
sown 25th March	Trasier	Sunangel	Lizard	Yakalo	Stoat										
sown 25th March	El Fortunado	El Swing	El Furio	Platypus	Bonnethead										
sown 25th March	Sioux	Onyx (1713)	Opal (1718)	El Lucio	LSPH 20-0095										
sown 25th March	Dallas	Apache	Limestone (1664)	Carmel	Flurite (1526)										
sown 25th March	Sculptur	Nun 7561	Nun 7566	Serpans	Tectonite										
	Sprinkler row														
sown 14th April	Fungicide seed coating demo														
sown 14th April	Fungicide seed coating demo														
sown 14th April	Fungicide seed coating demo														
sown 14th April	Fungicide seed coating demo														
sown 6th April	Prodoz demo bed														
sown 6th April	EE Muir & Son's demo														
sown 30th March	Bayer (serinade) demo														
	Sprinkler row														

PROGRAM ABSTRACTS

Welcome to Australia, overview of Horticulture Innovation

Anthony Kachenko

Horticulture Innovation Australia Limited

Anthony is Hort Innovation's General Manager, Production & Sustainability R&D.

Anthony has lived and breathed Australian horticulture for more than 20 years, with extensive experience along the agribusiness value chain. Anthony started with Hort Innovation in 2014 and has held several senior roles, including Head of Research & Development, General Manager of Data & Extension, and General Manager of Stakeholder Experience. Before joining Hort Innovation, Anthony held senior policy and leadership roles at Greenlife Industry Australia (then Nursery & Garden Industry Australia).

In his role at Hort Innovation, Anthony oversees investments focused on production-related R&D, including emerging technology, and leads our company's R&D efforts to navigate industry-wide sustainability opportunities.

Anthony holds a PhD in Agricultural Science, a Masters in Agribusiness, an Honours Degree in Horticultural Science, and a Diploma in Quality Auditing. He is a Member and Graduate of the Australian Institute of Company Directors and is a Chairman and Professional Member of the Australasia-Pacific Extension Network.

Intro and orientation, spinach & the Australian context

Stuart Grigg

Ag-Hort Consulting

Welcome to all and thanks for taking time out of your busy schedules to attend the 10th International Spinach Conference, the first time the conference has been held in the Southern Hemisphere. Huge thanks to Hort Innovation, Vegetable Seeds by Bayer and Agriculture Victoria for their support of this conference

Spinach production and the Australian Context:
At last estimate, Australia punches well above its weight in the world of spinach production and consumption. Globally Australia is the 4th or 5th largest consumer of spinach seed and on a per capita basis, Australian consumers eat more spinach per capita than American consumers, and thus Australia is a very important player in the global spinach market!

Australian spinach production regions and seasonality, production challenges including Downy mildew, the damping off complex, anthracnose, leaf spot disorders, leaf miner, spinach crown mite will all be introduced and consumption data will give light to further discussion during the 10th International Spinach Conference.

Australian spinach specific research is very limited, our production system relies on the expertise of a very few here in Australia linking with international partners and researchers. However some of this international research is not specifically targeted enough to meet some of the Australian challenges. We will learn, listen, engage and be enlightened during the intense day of proceedings to further develop our spinach production sector into the future.

A recent history snapshot of Spinach sales growth and performance in Australian supermarkets

Sam Robson

CEO One Harvest

“A recent historical snapshot of Spinach sales growth & performance in Australian supermarkets.”
We at One Harvest believe spinach is Australia’s favourite vegetable. It’s versatile, nutritious & tasty. Aussie shoppers & consumers think so also. Listen in for some insights into Spinach consumption patterns, volumes & basket affinities.

U.S. Spinach Production and Supply Chain: A Focus on California Production and Trends

Jennifer Clarke

California Leafy Greens Research Board

The U.S. fresh market spinach industry has experienced steady growth in recent years, driven by the increasing demand for this leafy green due to its numerous health benefits. California is the leading spinach producer in the country, thanks to its favorable climate, access to water, and rich soil. In 2022 California produced over 250,000 tons of spinach, valued at $359 million. The California spinach industry is dominated by a few large companies that have invested heavily in modern growing and packaging techniques. These companies have made spinach a popular and easily accessible food item for consumers, resulting in increased demand for spinach. Additionally, the industry has seen a rise in demand for organic spinach due to growing health and environmental concerns. Overall, this presentation will provide an overview of the U.S. fresh market spinach industry, with a particular focus on California production and trends.

Spinach breeding – meeting grower and consumer needs

Amy Groh

Bayer Product Development/Breeding

Controlling invertebrate pests of spinach

Paul Horne

IPM Technologies Pty Ltd, Hurstbridge, Victoria, Australia

There are several pests of spinach that are found in many parts of the world and also some that are local, Australian problems. Examples of pests found in many parts of the world include spinach crown mite (*Tyrophagus similis* or *Rhizoglyphus sp.*) and leaf-mining flies (*Liriomyza spp.*) while of local concern can also be redlegged earth mite (*Halotydeus destructor*), slugs (especially *Deroceras reticulatum*) and caterpillars (including *Helicoverpa sp.*). In Victoria a combination of cultural and biological control methods has proved effective in controlling populations of these pests with minimal reliance on pesticide applications. Critical cultural controls include weed management (particularly broad-leaf weeds), soil preparation and fallow prior to spinach, and the use of sacrificial plantings at key times during the year to promote populations of parasitoid wasps.

Fresh produce food safety trends, challenges, and opportunities in 2023

Deon Mahoney

International Fresh Produce Association, Docklands, Victoria, Australia 3008

Food safety incidents that occur as a result of microbiological contamination of fresh produce are on the rise in Australia and globally. Such instances present a significant public health burden and pose a major cost on the fresh produce industry. That such incidents occur in the 2020's reflects badly upon our industry and its ability to manage food safety, with far reaching impacts on public health, market access, and consumer confidence.

Sources of contamination include agricultural practices during the growing process; contamination during harvest, processing, and packaging; cross-contamination during transportation and storage; and improper handling by consumers.

This presentation will explore recent outbreaks of foodborne illness involving leafy vegetables, with a focus on spinach, and tease out the root causes and specific learnings. It will then seek to delve into issues around the implementation and validation of hazard control strategies, and explore factors impeding the uptake and implementation of effective pre-requisite and food safety programs along the supply chain.

Environmental Management and Regulation for Vegetable Growing in New Zealand

Michelle Sands

Horticulture New Zealand

Vegetable growing significantly contributes to New Zealand's economy and food security. However, intensive growing practices have raised concerns about the environmental impact of vegetable growing, particularly on water quality.

The National Policy Statement for Freshwater Management (NPS-FM) directs regional councils on managing the country's freshwater resources, ensuring sustainable management that meets social, economic, and cultural needs while protecting and improving water quality. The NPS-FM requires regional councils to establish freshwater visions, values, outcomes, and limits. For water quality, this results in the establishment of limits on the cumulative discharges that can be accommodated within sub-catchments to maintain existing water quality or achieve improvements in water quality required to support community freshwater values.

Nitrogen leaching has been a key indicator for setting water quality regulatory limits in NZ, and two methods have been used to determine nitrogen allocation. The "natural capital approach" has calculated the overall nitrogen load at the catchment scale and distributed the load across all productive land. This approach relied on the grass curve for distributing the load, which provided insufficient nitrogen leaching allocation to grow vegetables, leaving growers unable to gain consent for existing activities. The "grandparenting" method allocated nitrogen leaching based on one-time use during a baseline period, preventing crop rotation and intensification and hindering the expansion of vegetable growing required to meet domestic demand for fresh vegetables.

The horticulture sector has been working for several years to develop tailored good management practices that support crop rotation and provide for expansion to meet domestic demand for fresh vegetables.

Cultivation of baby leaf spinach in Italy: an overview on the management of diseases and pests in the European scenario which imposes the reduction of the use of chemicals

Pietro Di Benedetto

Agronomist Freelance – A.N.Te.S.I.A. https://www.antesia.it/

- Overview of greenhouse cultivation critical point: up to 5-6 cultivation cycles are carried out in the greenhouse each year, causing a rapid deterioration of soil fertility
- The impact of EU farm to Fork in the European Agriculture. European markets demand perfect products, at the same time politics impose ever greater limitations on the use of synthetic active substances
- The principal disease and virus observed in Italy
- The principal pests which limit baby spinach production
- The integration of Good Agricultural Practices and Integrated Pest Management. Good practices and Bacs can help produce with less chemical means.
- Discussion

EU spinach production and breeding

“Down Under”

Jan de Visser

KWS Vegetables, Middenweg 52, 1619 BN Andijk, The Netherlands

A root cause analysis of the challenges we are facing in spinach production and, therefore, in spinach breeding, these days.

Still in the dark? Maybe the presentation will cast light into the darkness; See you in Melbourne, Victoria, Australia!

P.S. This is a teaser, not an abstract…

Efficient nitrogen management and reducing cadmium uptake in spinach production

Richard Smith, Emeritus Farm Advisor
University of California Cooperative Extension, Salinas, CA 93901

Improving the efficiency of nitrogen (N) management in spinach production has greater urgency in the coastal production district of California (Salinas to Santa Maria Valleys). In April 2021, the Central Coast Regional Water Quality Control Board passes Ag Order 4.0 which for the first-time established limits on the use of N fertilizer use. The A minus R metric in which A is the quantity of applied N and R is the quantity of N that is removed from the field, is being used to determine compliance. The A minus R equation is subject to limits that ratchet down over the next several years. Spinach is a particularly challenging vegetable to improve N use efficiency. Although it the amount of N uptake by spinach is modest, 90 – 130 lbs N/A, the uptake curve is commonly compressed into a 14-day period following crop establishment. As a result, spinach needs robust quantities of N in the soil for a short period of time. However, the effective rooting depth of spinach is in the top 4 – 12 inches of soil. Good water management is needed to maintain nitrate-N in this narrow zone of soil. A combination of good water management and other cultural practices to help growers comply with the new regulations.

There are areas in the Salinas Valley that have high levels of naturally occurring cadmium (Cd) in the soil. Spinach takes up higher quantities of cadmium than other vegetables, and when grown on the high Cd bearing soils, can result in unacceptably high levels of Cd in the marketable product. In order to minimize Cd uptake by spinach, it is important to avoid soils with levels of Cd >1.0 ppm. Cultural practices can also be employed to reduce Cd uptake by spinach: fertilizing with high levels of zinc, keeping soil pH's above 7.0, applying compost, using irrigation water with low levels of chloride and by using spinach varieties that take up low quantities of Cd.

Virus and soilborne pathogens of spinach in coastal California

Steven Koike

TriCal Diagnostics, Hollister CA 95023

The central coast region of California is home to an extensive fresh market spinach industry, where the crop is subject to a number of virus and soilborne fungal pathogens. However, despite the large number of planted acres, long growing season, and adjacent and/or back-to- back plantings, these pathogens have had limited economic impacts for California growers. Virus pathogens occurring in this coastal area include the following: Beet curly top virus (BCTV), Beet necrotic yellow vein virus (BNYVV), Cucumber mosaic virus (CMV), Impatiens necrotic spot virus (INSV), Tobacco rattle virus (TRV), and Tomato spotted wilt virus (TSWV). Of interest is the increasing incidence of INSV in spinach. Small, insignificant outbreaks of INSV in spinach periodically have occurred since 2006. However, in 2021 and 2022, the virus was detected in a number of fields and with higher incidence. This development is very likely connected to the widespread and extensive damage that INSV is inflicting on neighboring lettuce crops. Soilborne fungal pathogens include the following: *Fusarium oxysporum*, *Phytophthora cryptogea*, *Pythium ultimum*, *Rhizoctonia solani*, and *Verticillium dahliae*. *Pythium*, *Fusarium*, and *Rhizoctonia* are most often found to cause spinach damping- off and root rot diseases. It is unclear whether the *Fusarium* that causes root rot in California is related to *Fusarium* isolates that cause spinach Fusarium wilt. While *Verticillium* can be isolated from spinach grown in this region, such plants show no symptoms because the crop is always harvested at a very young physiological stage. Currently, Phytophthora root rot poses no economic threat to spinach but is misdiagnosed as Fusarium or Rhizoctonia root rot. *Phytophthora cryptogea* has recently been documented on lettuce in the Salinas Valley, so incidence of this pathogen on spinach should be monitored for the common spinach-lettuce crop rotations.

Organic Spinach Production in the USA

Ramy Colfer, VP Research & Development / Agronomy

True Organic Products, Spreckels CA 93962

Organic spinach production is a major fraction of total spinach produced in the United States. I review some of the dollar values of organically produced crops in the key counties in California that produce organic spinach and specifically focus on organic spinach production in Monterey County in California, USA. I will discuss key challenges encountered in organic spinach production and discuss general approaches to managing these problems. I will briefly review pest management, disease management, weed management, and nutrient management in organically produced spinach in California and Arizona, USA.

Disease Management in Spinach Seed Crops in the Pacific Northwest USA

Lindsey du Toit

Washington State University

Western Washington and western Oregon are the only regions of the USA with climatic conditions suitable for production of high-quality spinach seed. Approximately 2,000 ha (5,000 acres) of spinach seed crops in this region produce ≤20% of the global supply of spinach seed annually for western markets. Even with favorable growing conditions, seed growers in this region must implement integrated disease management programs to limit losses to various spinach pathogens, including some that can be seedborne and seed transmitted. The challenge is intensified by the fact that: 1) most spinach seed crops are for hybrid production, which necessitates planting two proprietary parent (inbred) lines in each crop that can differ in susceptibility to spinach pathogens, 2) there is a need for minimum isolation distances between crops of this wind-pollinated species, and 3) seed growers have little to no choice of parent lines to plant since seed crops are grown on contract with seed companies using proprietary parent lines. This presentation reviews the main diseases affecting spinach seed production in the USA, including damping-off from *Rhizoctonia* and *Pythium* species (particularly in cool, wet springs); the foliar diseases Cladosporium leaf spot (favored by cool, wet conditions after canopy closure), Stemphylium leaf spot (favored by warm, wet conditions after canopy closure, and exacerbated by pollen shed), downy mildew (favored by cool, wet conditions), and cucumber mosaic (favored by the presence of aphid vectors, with a greater risk of seed infection for certain parent lines); and the vascular diseases Fusarium wilt (favored by acid soils) and Verticillium wilt (particularly when spinach is grown in rotation with other susceptible crops such as potato). Cultural, chemical, and resistance management practices implemented through the season will be reviewed, including use of a soil bioassay to quantify the risk of races 1 and 2 of Fusarium wilt, and to optimize field selection for reduced risk of Fusarium wilt and Verticillium wilt; screening spinach parent lines to assess susceptibility to races 1 and 2 of Fusarium wilt; soil preparation for optimum soil tilth and drainage; soil amendment with agricultural limestone to increase pH of the acidic soils of this region that are highly favorable to spinach Fusarium wilt; seed, drench, and foliar fungicide treatments for damping-off pathogens, downy mildew, and leaf spot fungi using relevant fungicide modes of action (Fungicide Resistance Action Committee = FRAC groups); timing and methods of fungicide application for optimum efficacy; and scouting, diagnosis, and rogueing of symptomatic plants. Investment by seed growers and the seed industry in research on spinach production issues continues to provide an invaluable cornerstone to the economic and logistical sustainability of spinach seed production in the Pacific Northwest USA.

Ecology and management of Stemphylium leaf spot of spinach

Kayla Spawton, Tobin Peever, and Lindsey du Toit

Washington State University

Stemphylium leaf spot of spinach has re-emerged as a disease of economic concern for fresh market, processing, and seed production. The two main causal agents, *Stemphylium beticola* and *S. vesicarium*, are seedborne and seed transmitted. The overall objective of this study was to improve our understanding of the biology and epidemiology of the pathogens, and to refine management options for the disease by: 1) identifying the *Stemphylium* species associated with the disease in the USA and colonizing spinach seed worldwide, 2) determining the prevalence of resistance to strobilurin fungicides (azoxystrobin and pyraclostrobin) that have been used widely for control of Stemphylium leaf spot, 3) evaluating the potential significance of seedborne *S. vesicarium* in outbreaks of Stemphylium leaf spot, 4) screening spinach cultivars for resistance to *S. vesicarium*, and 5) sequencing the genome of *S. beticola* to complement those already available for *S. vesicarium*. Only isolates of *S. beticola, S. vesicarium*, and *S. drummondii* were pathogenic to spinach. None of seven other *Stemphylium* species associated with spinach seed proved pathogenic to spinach. Resistance to strobilurin fungicides was found in all spinach isolates of *S. vesicarium* screened from three countries, but in none of the *S. beticola* isolates screened. Resistance in *S. vesicarium* was perfectly correlated with presence of the target site G143A mutation in the *cytochrome b* gene, suggesting that this may be the sole mechanism of resistance in this fungus. Genetic diversity, measured as number of multilocus genotypes (MLGs) and unique MLGs, varied widely among *S. vesicarium* populations from seed lots grown in major spinach seed production countries of the world: Denmark, France, the Netherlands, New Zealand, and the USA. Diversity was inversely correlated with the proportion of isolates colonizing seed that were pathogenic to spinach. In contrast, *S. vesicarium* sampled from symptomatic spinach leaves in two Texas crops were uniformly pathogenic and less diverse than populations isolated from the seed used to plant each crop. Cultivars with excellent resistance to *S. vesicarium* were identified for both fresh market and processing spinach production. Two genomes of *S. beticola* from spinach were sequenced, marking the third species of *Stemphylium* with a sequenced genome. These genomes will facilitate genetic comparison of the two main species that cause Stemphylium leaf spot of spinach, and facilitate development of molecular tools to study the biology of these fungi. This study has provided valuable new understanding of Stemphylium leaf spot of spinach, with direct implications for improved management of this re-emerging disease.

Downy mildew, Stemphylium, and damping off of spinach

Correll, J. C., Feng, C., Liu, B. Zima, H. V.[1], and Villarroel-Zeballos, M.
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Diseases remain a major constraint in both conventional and organic spinach production, and are the focus of most spinach breeding efforts. Downy mildew (DM), caused by *Peronospora effusa* (Pfs), Stempylium leaf spot, caused by *S. versicarium* and *S. beticola*, and damping off caused by several Pythium species (*P. ultimum, P. aphanidermatum*, and *P. dissoticum*) and *Fusarium oxysporum* f. sp. *spinaciae* often are the predominant diseases affecting production. DM remains one of the most predominate diseases throughout the world. New races continue to emerge and currently there are 19 described races. Although there are some cultivars that have resistance to races 1-19, many cultivars are susceptible to one or more of the known races. Although DM disease pressure continues to be problematic, overall disease pressure has been lower in the past 4-5 years, likely due to the incorporation of relatively new resistance genes. Efforts continue to examine the molecular mechanism of the development of new races. Stemphylium leaf spot on spinach is highly dependent on a number of variables, including temperature and free moisture. Molecular tools have been developed to distinguish the two species involved in the leaf spot directly from plant tissue, which can help in disease management. Pythium species typically cause pre-emergence damping off, but can also cause post-emergence damping off on young seedlings. *F. oxysporum* f. sp. *spinaciae* causes post emergence damping off 7-14 days after emergence.

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Sentinel field trials to evaluate spinach downy mildew caused by *Peronospora effusa*

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Downy mildew of spinach, caused by *Peronospora effusa*, remains one of the major constraints in both conventional and organic spinach production, and is a focus of most spinach breeding efforts. Over the past 30 years, new races of the pathogen have been able to overcome newly-deployed resistant cultivars, with 19 races currently described. The International Working Group on *Peronospora* (IWGP) functions to identify, verify, nominate, and communicate the appearance of new races through a series of criteria. Although the greenhouse assays are very valuable to identify races and novel strains, determining how cultivars perform under field conditions with naturally-occurring inoculum helps in "ground truthing" cultivar performance under field conditions. Sentinel plots were established in field trials in the Salinas, California and Yuma, Arizona Valleys between 2015 and 2023. The trials included three replications of 70 commercial cultivars with a wide range of genetic resistance to the downy mildew pathogen. The trials were rated for downy mildew disease incidence (DI) and compared across cultivars and across years. Although the cultivars used in the trials have changed over the years, several have been included in most trials. Disease pressure was moderate to severe depending on the year and location with 15 to 69 of the 70 cultivars rated as susceptible (DI > 9.0%). The mean DI of the three most susceptible cultivars ranged from 70.6 - 97.7% in Salinas, CA and 57.8 – 97.8% in Yuma, AZ between the 2015 and 2023 years. Continued evaluation of genetically diverse cultivars can provide valuable information for examining pathogen diversity.

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Transmission of spinach downy mildew via seed and infested leaf debris

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Spinach downy mildew, caused by the oomycete pathogen *Peronospora effusa*, is a worldwide constraint on spinach production. The role of airborne sporangia in the disease cycle of *P. effusa* is well established, but the role of the sexual oospores of *P. effusa* is less clear. Surveys of modern spinach seed lot samples since 2014 have revealed the presence of oospores in 19% of the lots. To evaluate seed transmission of spinach downy mildew via oospores in this study, we used glass isolator chambers to grow out oospore-infested spinach seed and non-infested seeds mixed with oospore-infested crop debris in two independent experiments. Downy mildew diseased spinach plants were found 37 days after planting in the chambers that contained one of two oospore-infested seed lots in the first experiment, and 34 days after planting in the second experiment. Isolator chambers with seeds coated with oospore-infested leaf debri also gave rise to downy mildew diseased spinach plants in both experiments. Spinach plants in glass chambers initiated from seeds without oospores did not show downy mildew symptoms. Similar findings were obtained using the same seed lot samples in a third experiment conducted in a growth chamber. Grow out tests with oospore-infested seed of two cultivars revealed the characteristic *Peronospora* sporangiophores growing from one seedling of each cultivar. The results provide evidence that oospore-infested plant debris in soil can cause downy mildew and further evidence of seed transmission of downy mildew in spinach via oospores.

White rust fungicide efficacy

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White rust, caused by *Albugo occidentalis*, was first reported in Texas in the U.S., but is now found in most spinach producing states east of the Rocky Mountains. There have been recent finds in Mexico and some other countries, but to date it is found limitedly outside the U.S. At one time Texas had over 30,000 acres of spinach, but white rust became a major problem. No doubt the resistance found and developed by Dr. Teddy Morelock, University of Arkansas, has greatly improved the ability to live with this disease. The disease causes white, blister-like pustules to form on the lower side of the leaf. In advanced stages, the white lesions form on the upper side of the leaf. Generally, the upper surface will only be chlorotic. Plants infected with the white rust fungus are weak and collapse quickly if environmental conditions are favorable for disease development. Current control recommendations are 10 to 12 ounces of Ridomil Gold at planting, using tolerant varieties, and effective fungicide 30 days after planting if warm and wet conditions are the norm. Dr. Frank Dainello began evaluating the efficacy of fungicides for white rust control in the 1990s and this work continues today. Some of the fungicides recommended today were tested as product numbers in our trials. Two of those products were Quadris (azoxystrobin, group 11 and Cabrio (pyraclostrobin) with Cabrio continuing to be the most effective product. A new numbered product we started looking at in 2020 was BAS 751, Veltyma, (Mefentrifluconazole + Pyraclostrobin) which has given very good control. We began testing LifeGard, *Bacillus mycoides* isolate J+, a biological plant activator, in 2017 and this has become the standard first spray on many commercial fields. Over the last 6 years, we have looked at 75 treatment options which include many products and product rotations. Products which work well in a rotational scheme to control white rust include LifeGard, Cabrio, Merivon, Reason, Presidio + Prophyt, Oso, and Miravis Prime.

Beyond Salad: Producing Spinach Seed for Grain Consumption

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Spinach production is constantly challenged by endemic diseases that significantly reduce producers' income. Even when resistant cultivars and cultural practices are used, mild disease damage can happen, negatively affecting quality and therefore reducing its commercial value. In contrast, under those conditions, spinach could still produce seed for grain with valuable nutritional content that can fetch premium prices for the gluten-free niche markets. This project evaluated grain production as an additional source of income by assessing yield potential, nutritional quality, and economic feasibility. A total of ~200 USDA-NPGS accessions were evaluated. For all nineteen amino acids evaluated, a wide range in content was observed. E.g. aspartic acid population mean was 106.5 nmol/g with a minimum of 36.2 nmol/g and a maximum of 353.9 nmol/g. Similar results were observed for all eight minerals evaluated. E.g. K population mean was 9,998.1 mg/kg with a minimum of 3,227 mg/kg and a maximum of 24,770 mg/Kg. High diversity can be used to improve nutritional content in spinach seed. Furthermore, protein digestibility tests indicate that spinach provides ~50% of all amino acids required in the diet as compared with Amaranth and Quinoa protein in grain that provided ~20% of all amino acid required. Therefore, indicating spinach grain has a higher nutritional content as compared with highly demanded Amaranth and Quinoa grains. Finally, a partial budgeting approach was used to assess the economic feasibility of producing spinach seeds for grain. The added costs totaled $218.71/ac, including custom harvesting ($24/ac), an additional application of fertilizers ($17.36/ac) and fungicide ($62.54/ac), extra irrigation costs ($60.63), and $54.18/ac in associated interest on production expenses. The break-even price of seeds was estimated to be equal to $0.20/lbs when the average experimental yield was considered (i.e., 1,089lbs/ac). Therefore, producing seed for grain can expand the farmer portfolio, increased farmed acreage and fringe products.

Spinach Website Directory

www.spinach.uark.edu

Australian Glossary for International Travelers

A Cold One – Beer
Accadacca – How Aussies refer to Australian band ACDC
Ankle Biter – Child
Arvo – Afternoon (**S'Arvo** – this afternoon!)
Aussie Salute – Wave to scare the flies
Avo – Avocado
Bail – To cancel plans. 'Bruce bailed' = Bruce isn't going to turn up.
Barbie – Barbecue
Bathers – Swimsuit
Beauty! – Great! Most often exclaimed as "You Beauty"
Billabong – A pond in a dry riverbed
Billy – Teapot (In the Outback on the fire)
Bloody – Very. Used to extenuate a point
Bloody oath – yes or its true. "You right mate?"… "Bloody Oath"
Bludger – Someone who's lazy, generally also who relies on others (when it's someone who relies on the state they're often called a 'dole bludger')
Bogan – This word is used for people who are, well let's say, rednecks. Or, if you like, just call your friends a bogan when they are acting weird.
Booze Bus – Police vehicle used to catch drunk drivers
Bottle-O – Bottle Shop, basically a place to buy alcohol
Brekky – Breakfast
Brolly – Umbrella
Bruce – An Aussie Bloke
Bucks – A colloquial term for dollars in Australia
Budgie Smugglers – Speedos
Bush – "Out in the bush" – "he's gone bush" In the countryside away from civilisation
Cab Sav – Cabernet Sauvignon
Cactus – Dead, Broken
Choc A Bloc – Full
Choccy Biccy – Chocolate Biscuit
Chook – Chicken
Chrissie – Christmas
Ciggy – a Cigarette
Clucky – feeling maternal
Cobber – Very good friend. 'Alright me 'ol cobber'.
Coldie – Beer. 'Come over for a few coldie's mate.'
Coppers – Policemen
Crack the shits – Getting angry at someone or something
Crikey – an expression of surprise
Crook – Being ill or angry; 'Don't go crook on me for getting crook'
Dag – Someone who's a bit of a nerd or geek.
Daks – Trousers. 'Tracky daks' = sweatpants (tracksuit pants)
Deadset – True
Defo – Definitely
Devo – Devastated
Drongo – a Fool, 'Don't be a drongo mate'
Dry as a dead dingo's **donger** – I need a beer
Dunny – Toilet
Durry – Cigarette

Esky – An insulated container that keeps things cold (usually beers)
Facey – Facebook
Fair Dinkum – 'Fair Dinkum?' … 'Fair Dinkum!' = Honestly? … Yeah honestly!
Fair suck - was coined by struggling Australian families who shared droppings of tomato sauce to flavor their meat. Such was the hard life that all they wanted was an equitable suck
Flannie / Flanno – flannelette shirt
Flat out – Really busy – "Flat out like a lizard drinking" – As busy as a bee
Footy – Football (AFL / Aussie Rules)
Frothy – Beer
F*ck Me Dead – that's unfortunate, that surprises me
Furphy – rumours or stories that are improbable or absurd
G'day – Hello
Galah – an Australian cockatoo with a reputation for not being bright, hence a galah is also a stupid person.
Gnarly – awesome – often used by surfers
Going off – busy, lots of people / angry person "he's going off"
Good On Ya – Good work
Goon – the best invention ever produced by mankind. Goon is a cheap, boxed wine that will inevitably become an integral part of your Australian backpacking experience.
Hard yakka – Hard work
Heaps – loads, lots, many
Hoon – Hooligan (normally driving badly!)**Lappy** – Laptop
Larrikin – Someone who's always up for a laugh, bit of a harmless prankster
Legless – Someone who is really drunk
Lollies – Sweets
Maccas – McDonalds
Manchester – Sheets / Linen etc. If you're from England, finding a department within a shop called Manchester could seriously confuse you.
Mongrel – Someone who's a bit of a dick
Mozzie – Mosquito
No Drama – No problem / it's ok
No Worries – No problem / it's ok
No Wucka's – A truly Aussie way to say 'no worries'
Nuddy – Naked
O – put an "o" at the end of any word makes it Australian. For example, bottle – bottle shop, arvo – afternoon, spino – spinach enthusiast.
Outback – The interior of Australia, "The Outback" is more remote than those areas named "the bush"
Pash – to kiss
Piece of Piss – easy
Piss Off – go away, get lost
Piss Up – a party, a get together and in Australia – most social occasions
Pissed – Intoxicated, Drunk
Pissed Off – Annoyed
Rack Off – The less offensive way to tell someone to 'F Off'!
Rapt – Very happy
Reckon – for sure. 'You Reckon?'… 'I reckon!'
Rellie / Rello – Relatives
Ripper – 'You little ripper' = That's fantastic mate!
Rooted – Tired or Broken

Runners – Trainers, Sneakers
Sanger – Sandwich
Servo – Service Station / Garage
Shark biscuit – kids at the beach
Sheila – A woman
Shoot Through – To leave
Sick – awesome; 'that's really sick mate'
Sickie – a sick day off work, or 'to pull a sickie' would be to take a day off when you aren't actually sick
Skull – To down a beer
Slab – A carton of beers
Snag – Sausage
Stoked – Happy, Pleased
Straya – Australia
Strewth – An exclamation of surprise
Stubby – a bottle of beer
Stubby Holder – Used so your hands don't get cold when holding your beer, or to stop your hands making your beer warm!
Stuffed – Tired
Sunnies – Sunglasses
Swag – Single bed you can roll up, a bit like a sleeping bag.
Tea – Dinner
Tinny – Can of beer or small boat
Thongs – Flip Flops. Do not be alarmed if your new found Australian friend asks you to wear thongs to the beach. They are most likely expressing their concern of the hot sand on your delicate feet.
True Blue – Genuinely Australian
Tucker – Food. 'Bush Tucker' tends to be food found in the Outback such as witchety grubs
U-IE – to take a U-Turn when driving
Up Yourself – Stuck up
Woop Woop – middle of nowhere "he lives out woop woop"
Ya – You
Yous – (youse) plural of you!