Pulses for Dryland Environments

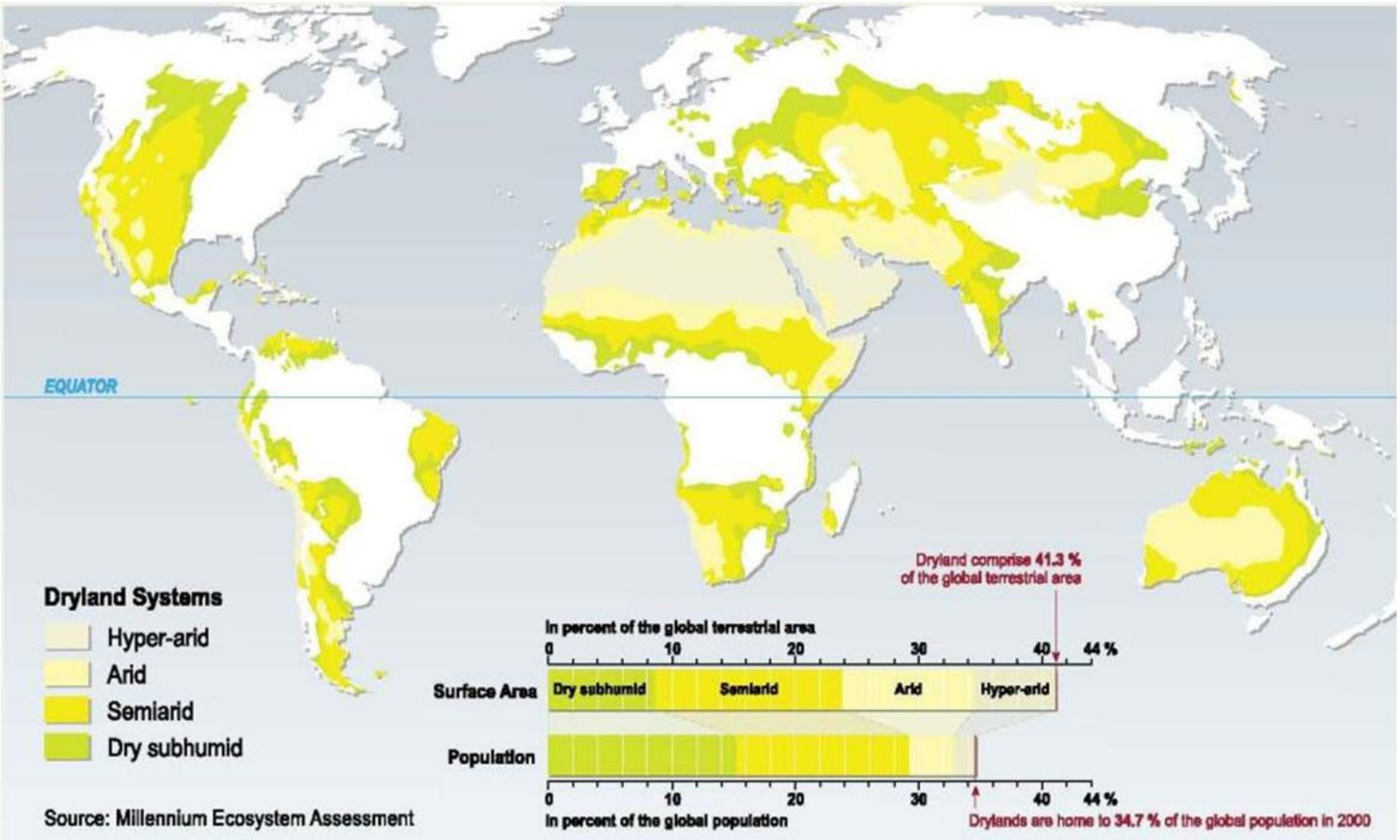
Professor Kadambot H.M Siddique
Hackett Professor of Agriculture Chair and Director
The UWA Institute of Agriculture,
The University of Western Australia
T: +61 8 6488 7012 • M: +61 411 155 396
E: kadambot.siddique@uwa.edu.au

22 June 2022

Outline of presentation

- Background- global scenario
- Effects of pulses in cropping system
- Australian pulse production
- Adaptation of pulses to drylands
- Conclusions

World drylands



What are Pulses?

- Represent over sixty species of "grain legumes"
- Dry grain that is typically boiled and eaten
- A traditional crop in agriculture systems and a staple food in diets around the world

World-wide Origin of Pulses

THE UNIVERSITY OF WESTERN AUSTRALIA

Middle East and Mediterranean Region

Chickpea, faba bean, field pea, lentil

Americas

Common bean, lima bean, scarlet runner bean, tepary bean, peanuts

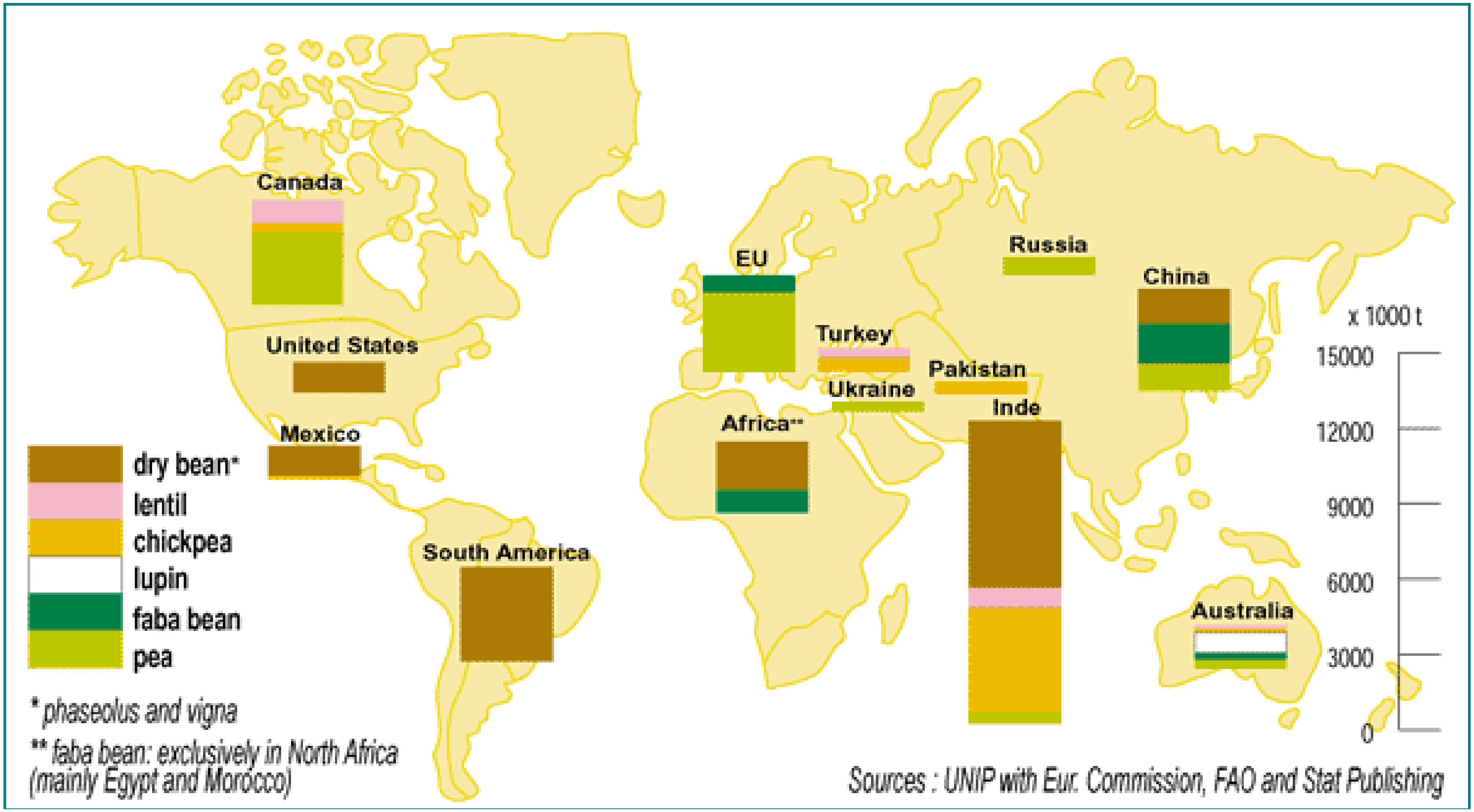
Africa

Cowpea (Blackeye pea), lablab, pigeon pea

Asia

Adzuki bean, mung bean, black gram, soybean

Pulses – World Scene



Why Pulses Important?

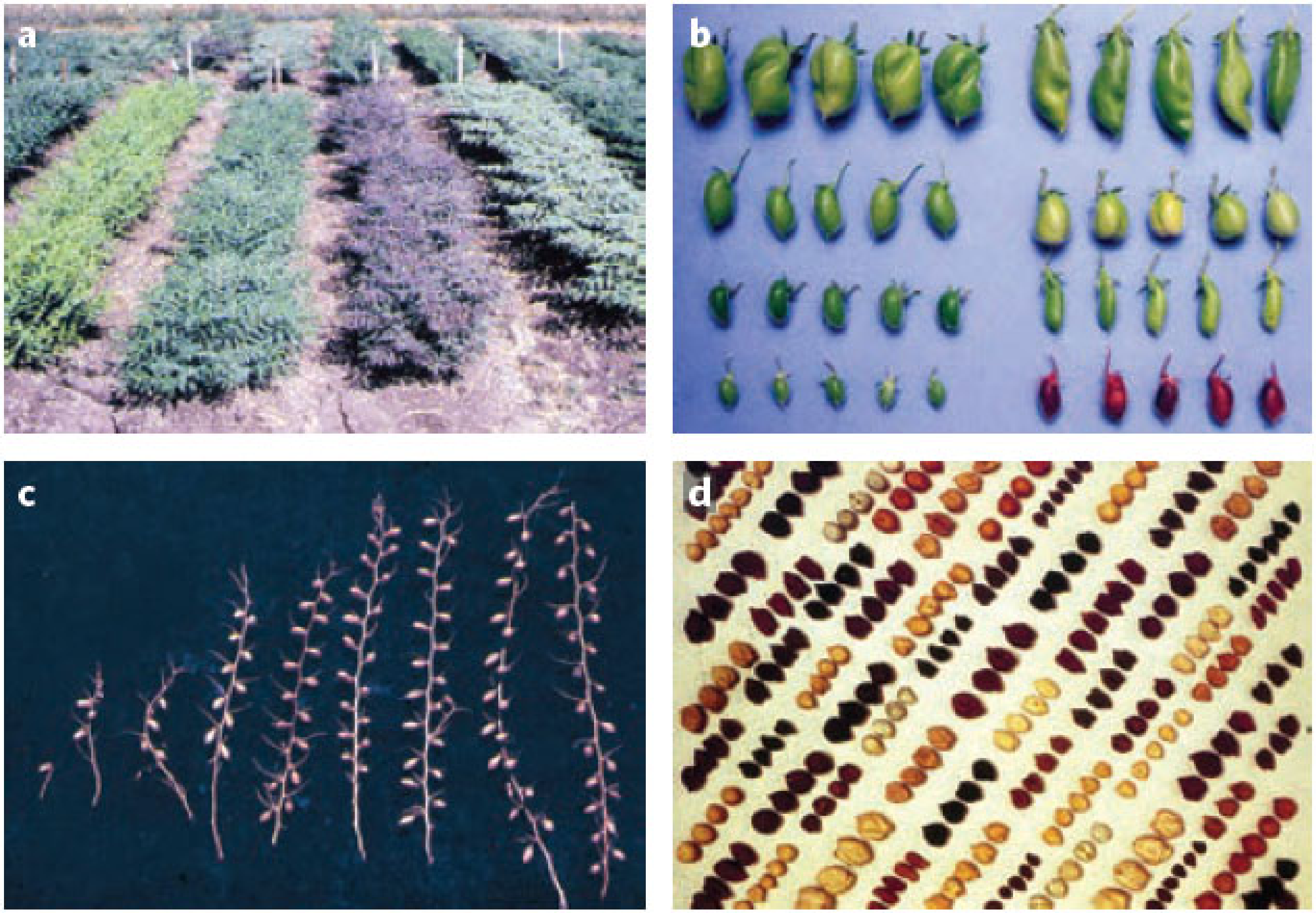
1. A nutrient-rich food that enhances **dietary quality.**
2. Promote gut health and function for improved **human health**
3. Legume crops fix atmospheric nitrogen (N) for improved **sustainability** of cropping systems.
4. Provide farmers with diverse crop options to mitigate risk to ***climate change***
5. Ensure **food and nutritional security** for a growing global population

Diverse parts of plant are eaten

Source: Irvin Widders

Diverse Market Classes within each Species

Source: Irvin Widders



Phenotypic variability in chickpea germplasm conserved at ICRISAT, India.

a, Variation in canopy development and leaf colour in chickpea germplasm in the field.

b, Variation in pod size and pod colour.

c, Variation in pod development and pod numbers on chickpea branches.

d, Variation in seed size and colour in chickpea germplasm collection.

Images courtesy of Hari Upadhyaya

THE UNIVERSITY OF WESTERN AUSTRALIA

2016

INTERNATIONAL YEAR OF PULSES

nutritious seeds for a sustainable future

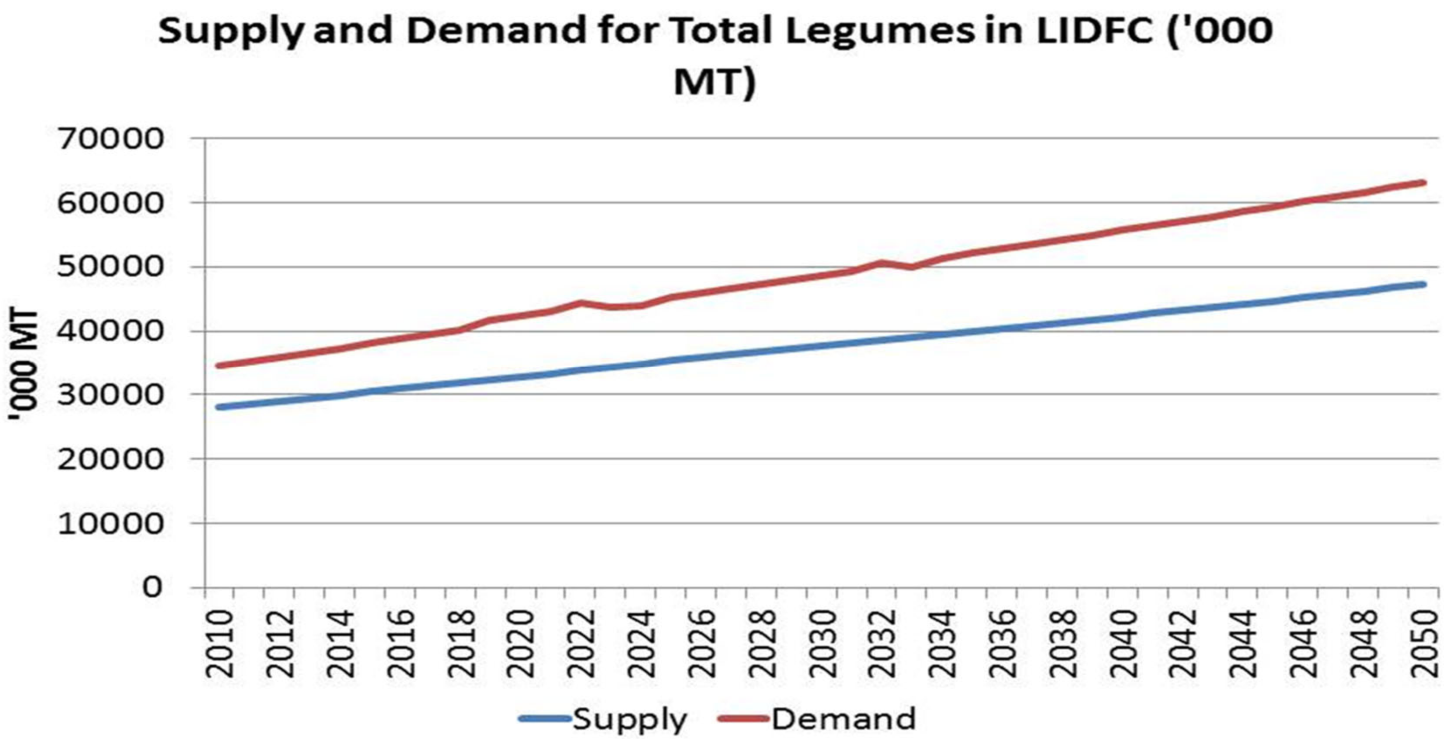
Food and Agriculture Organization of the United Nations

fao.org/pulses-2016 | pulses-2016@fao.org | #IYP2016

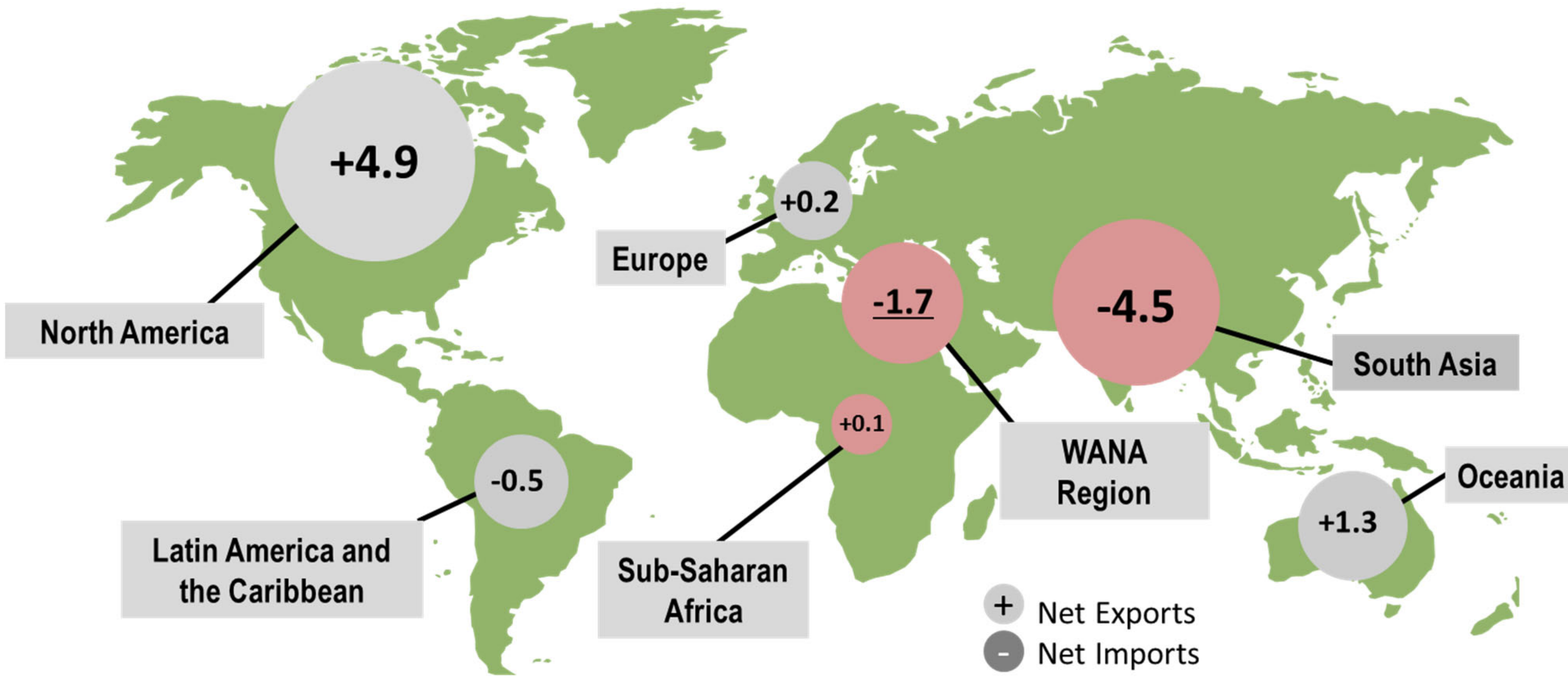
Production sufficiency in pulses is a concern in some regions

THE UNIVERSITY OF WESTERN AUSTRALIA

Asia accounts for 45% of the global pulses production and remains a major producer, importer and consumer



Global pulse trade : about 12 million tons (2014)



Sources: FAOSTAT (2011)

Source: ICARDA

Diversifying crop rotations enhances agroecosystem services and resilience

Advances in Agronomy
ISSN 0065-2113
https://doi.org/10.1016/bs.agron.2022.02.007

Chang Liu[a,k], Daniel Plaza-Bonilla[b], Jeffrey A. Coulter[c], H. Randy Kutcher[d], Hugh J. Beckie[e], Li Wang[f], Jean-Baptiste Floc'h[g], Chantal Hamel[h], Kadambot H.M. Siddique[i], Lingling Li[a,k,*], and Yantai Gan[j,†,*]

[a]State Key Laboratory of Aridland Crop Science, Gansu Agricultural University, Lanzhou, China
[b]Department of Crop and Forest Sciences, Agrotecnio-CERCA Center, Universitat de Lleida, Lleida, Spain
[c]Department of Agronomy and Plant Genetics, University of Minnesota, St. Paul, MN, United States
[d]College of Agriculture and Bioresources, 51 Campus Drive, University of Saskatchewan, Saskatoon, Canada
[e]School of Agriculture and Environment, The University of Western Australia, Perth, WA, Australia
[f]College of Life and Environmental Science, Wenzhou University, Chashan University town, Wenzhou, Zhejiang, China
[g]Biodiversity Centre of Université de Montréal, Québec, Canada
[h]Agriculture and Agri-Food Canada, Québec Research and Development Centre, Québec, Canada
[i]The UWA Institute of Agriculture, The University of Western Australia, Perth, WA, Australia
[j]Agriculture and Agri-Food Canada, Swift Current Research and Development Centre, Swift Current, SK, Canada
[k]College of Agronomy, Gansu Agricultural University, Lanzhou, China
*Corresponding authors: e-mail address: lill@gsau.edu.cn; ubc_soil@outlook.com

Pulse crops in cropping systems

The beneficial role of pulse crops in cropping systems. Pulse crops can be typically no-till planted (a) in rotation with cereals, with (b) numerous nodules on plant roots that fix N2 from the atmosphere, leading to significant benefits to the cropping systems, such as (c) reducing the use of inorganic N fertilizer, increasing soil organic carbon, and decreasing the carbon footprint of agroecosystems

Land Degrad Dev. 2018;**29**:4348–4361.

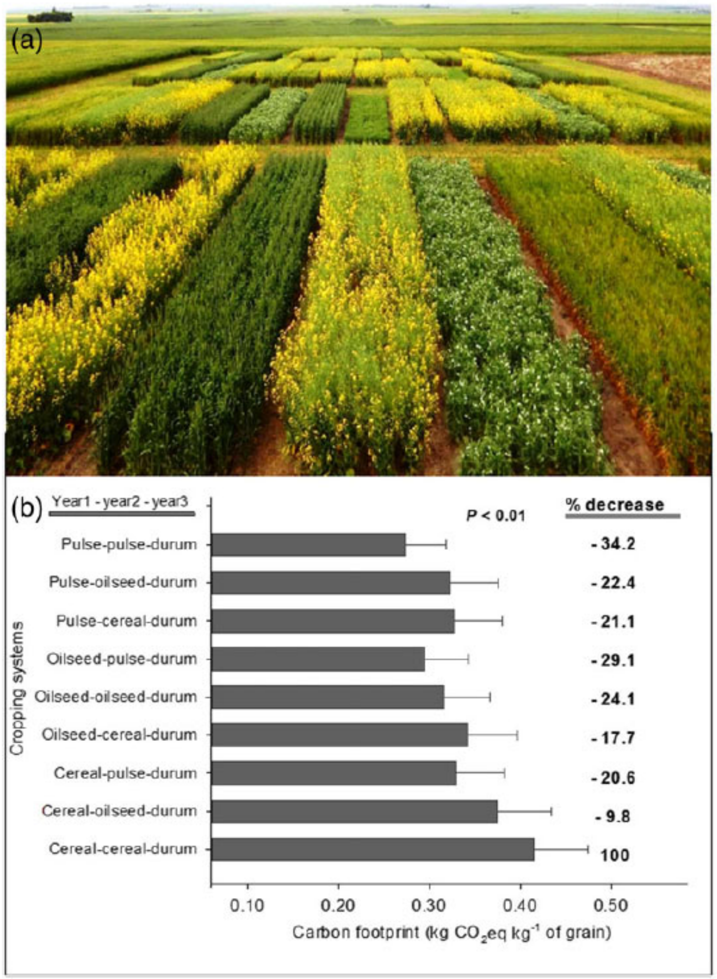
Legume fixed N or fertilizer N for food production

Region	Source & estimated annual N input million ton N/year	
		
Asia & middle East	19	47
Europe	3	14
North America	8	14
Africa	3	5
South America	10	6
Australia	4	1
Total Global	**47**	**87**

value ≈>US$50 billion

Source: Herridge *et al* (2008) *Plant & Soil* 311:1-18 Peoples *et al* (2009) *Nitrogen Fixation in Crop Production: Agronomy Monograph 52*, pp.349-385

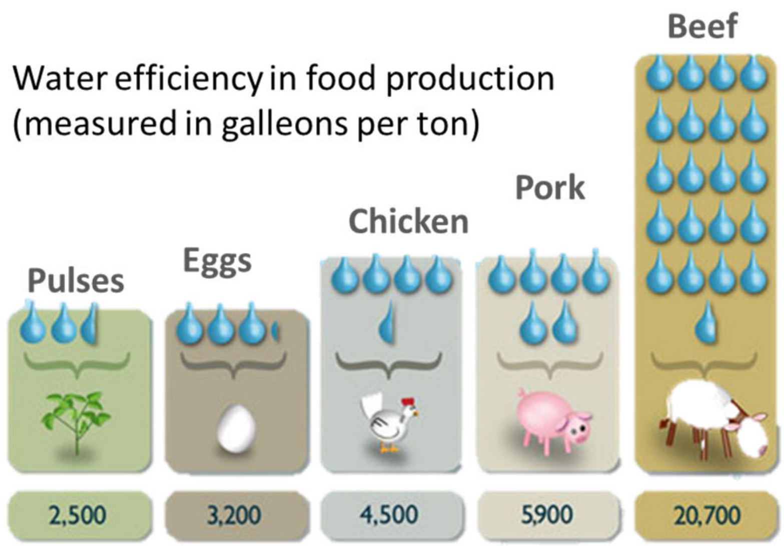
Pulse crops in cropping systems

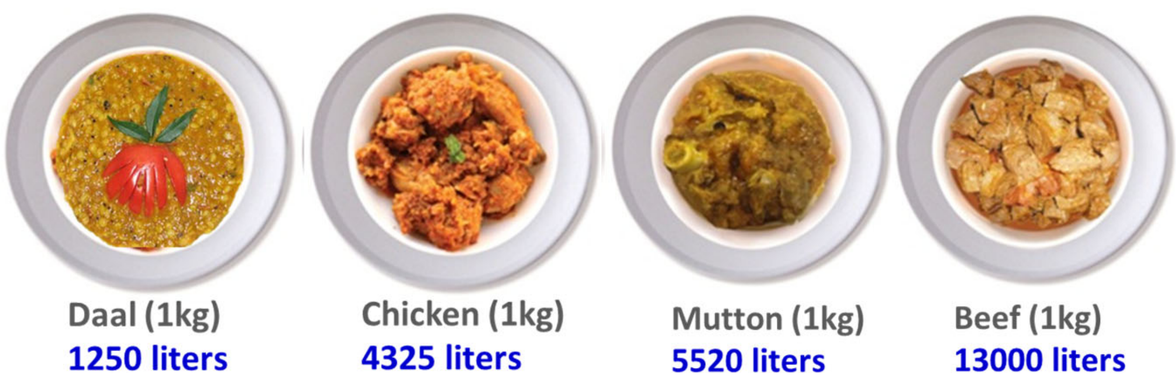


Diversifying cropping systems (a) are used to replace conventional cereal-based monoculture systems, leading to (b) reduced carbon footprint of durum wheat in the Northern Great Plains of North America

Land Degrad Dev. 2018;**29**:4348–4361.

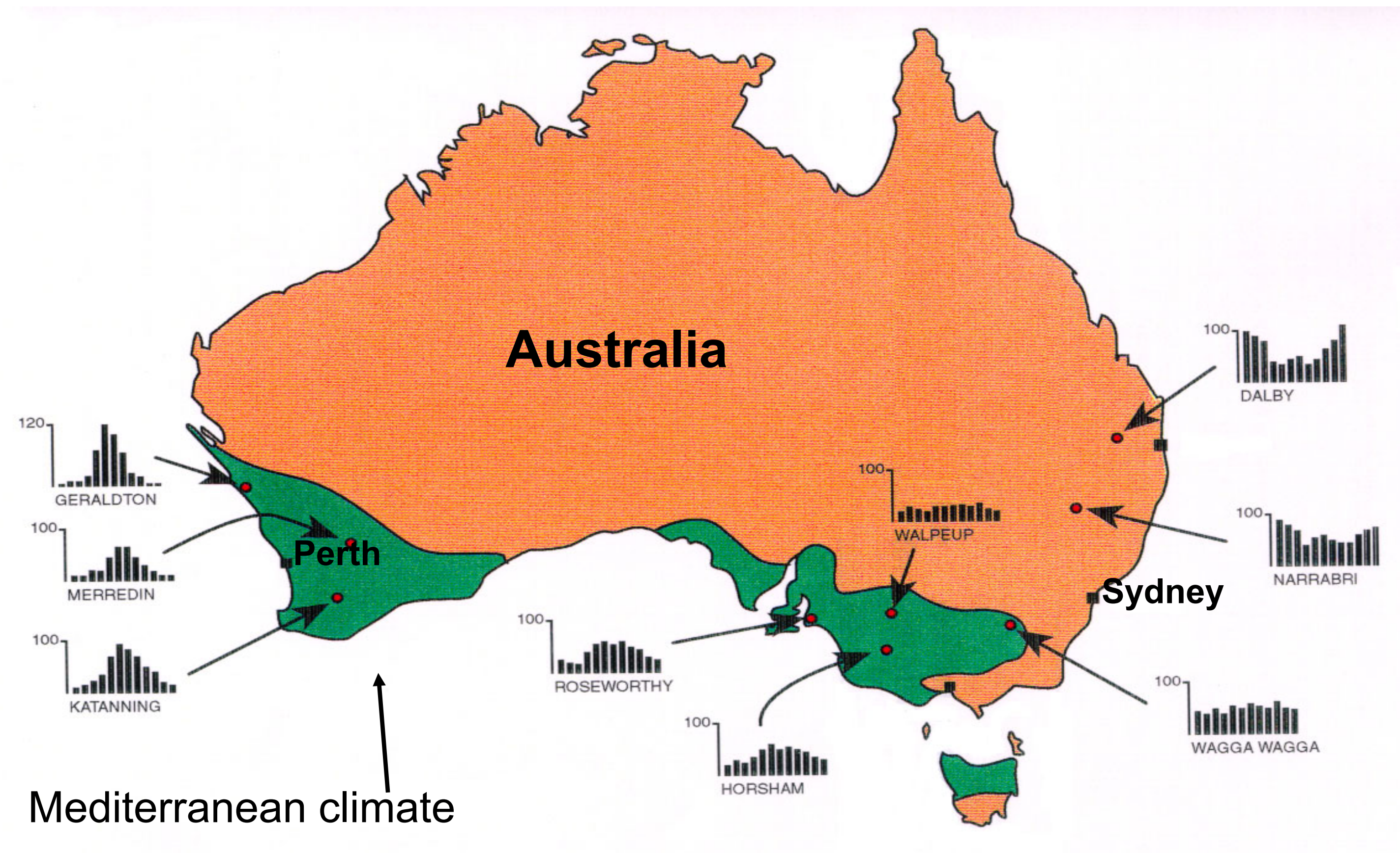
Pulses are climate smart crops with less water requirements





Source: ICARDA

Mediterranean Australia

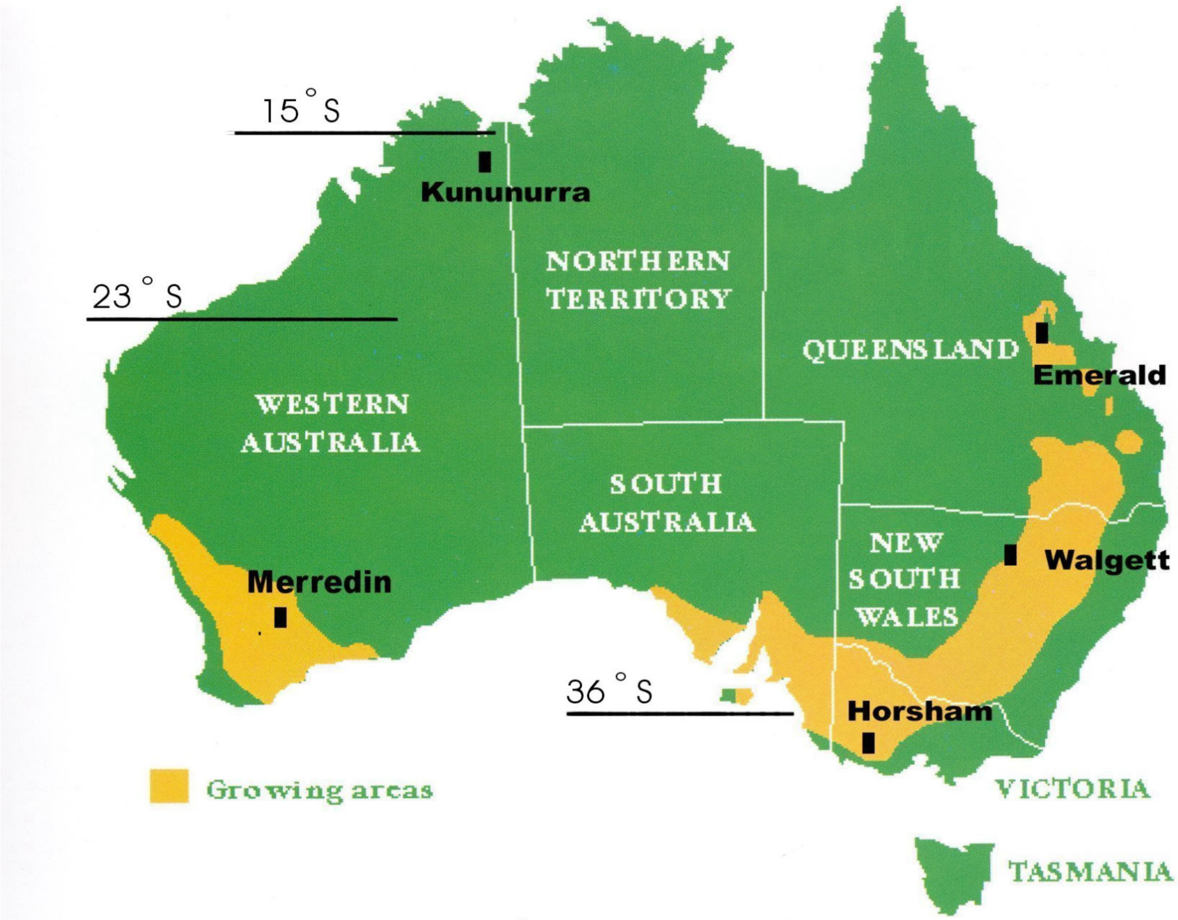


Challenges for the Australian Agriculture

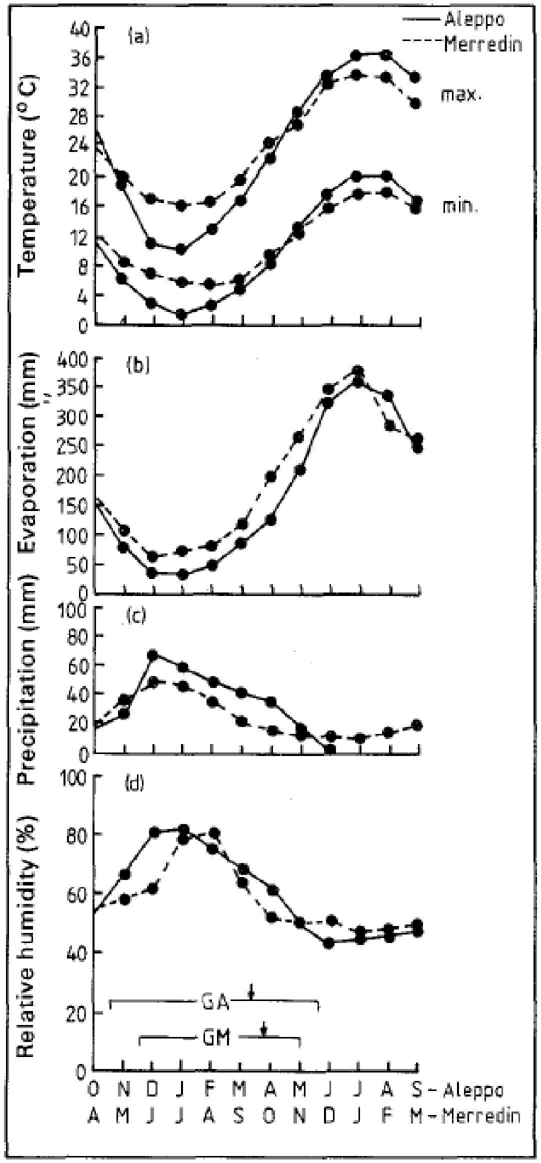
THE UNIVERSITY OF WESTERN AUSTRALIA

- Global competition is increasing from lower cost emerging producers
- The agricultural industry has to diversify its products range (including high value products) to meet new & emerging demands
- Escalating Fossil fuel prices and input costs
- Climate change and variability
- Become faster at adopting new technologies

Climatic regions suitable for pulses in Australia



Knights and Siddique, 2003



Comparison of mediterranean environments: (•——•) Aleppo, Syria, and (•----•) Merredin, W.A.

(a) Temperature: maximum and minimum - mean of 15 years.

(b) Pan evaporation: mean of 15 years.

(c) Precipitation: mean of 15 years for Aleppo and 68 years for Merredin.

(d) Relative humidity: mean of 15 years for Aleppo and 9 years for Merredin.

Normal growing season, GA, Aleppo, and GM, Merredin. Arrow indicates normal flowering time.

Siddique and Sedgley 1986

Field Crops Research, 9 (1984) 193—203
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

EFFECT OF PLANT DENSITY ON GROWTH AND HARVEST INDEX OF BRANCHES IN CHICKPEA (*CICER ARIETINUM* L.)

K.H.M. SIDDIQUE, R.H. SEDGLEY and C. MARSHALL[1]
Department of Agronomy, School of Agriculture, University of Western Australia, Nedlands 6009, W.A. (Australia)
[1] Present address: School of Biology, UCNW, Bangor, Gwynedd (Great Britain)

Field Crops Research, 12 (1985) 251—269
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

THE EFFECT OF REDUCED BRANCHING ON YIELD AND WATER USE OF CHICKPEA (*CICER ARIETINUM* L.) IN A MEDITERRANEAN TYPE ENVIRONMENT

K.H.M. SIDDIQUE and R.H. SEDGLEY
Agronomy Group, School of Agriculture, University of Western Australia, Nedlands 6009, W.A. (Australia)

Aust. J. Agric. Res., 1986, **37**, 245–61

Chickpea (*Cicer arietinum* L.), a Potential Grain Legume for South-Western Australia: Seasonal Growth and Yield

K. H. M. Siddique[A,B] *and R. H. Sedgley*[A]
[A] Agronomy Group, School of Agriculture, University of Western Australia, Nedlands, W.A. 6009.
[B] Plant Research Division, Western Australian Department of Agriculture,
Baron-Hay Court, South Perth, W.A. 6151.

Aust. J. Agric. Res., 1986, **37**, 599–610

Canopy Development Modifies the Water Economy of Chickpea (*Cicer arietinum* L.) in South-western Australia

K. H. M. Siddique[A,B] *and R. H. Sedgley*[A]
[A] Agronomy Group, School of Agriculture, University of Western Australia, Nedlands, W.A. 6009.
[B] Plant Research Division, Western Australian Department of Agriculture, Baron-Hay Court, South Perth, W.A. 6151.

Australian Pulses by Commodity
2014-2021

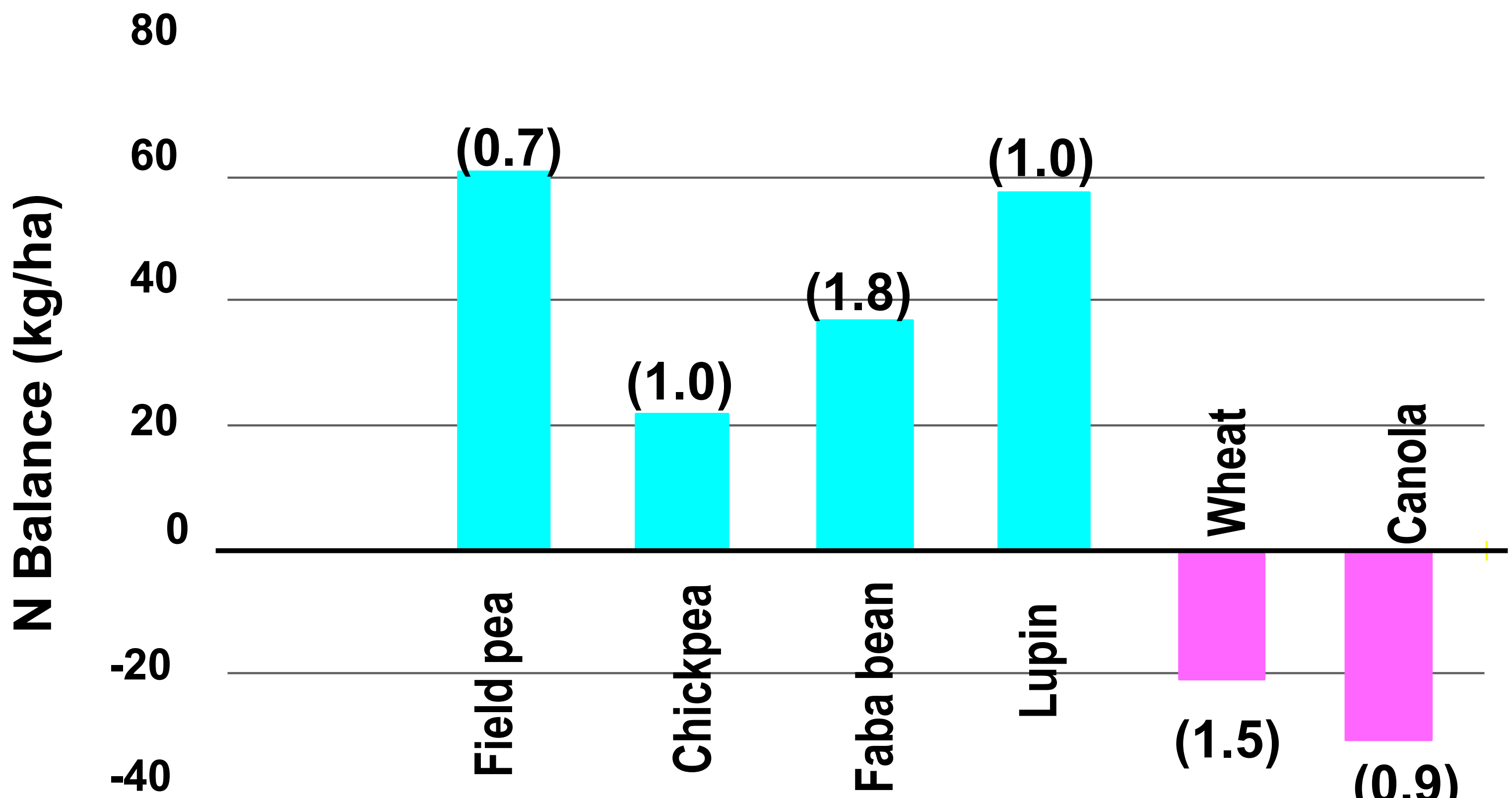
THE UNIVERSITY OF WESTERN AUSTRALIA

000's Tonnes	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
Chickpeas	555	875	2004	998	205	235	733
Lupins	549	652	1031	714	799	591	774
Faba beans	284	301	484	416	233	313	510
Field peas	290	205	415	317	160	210	294
Lentils	242	182	680	543	359	526	782
Total Pulses	**1,959**	**2,342**	**4,720**	**3,105**	**1,819**	**1,913**	**3,093**

Beneficial effects of legumes

- Overall cropping system productivity
- Addition of fixed nitrogen
- Effect on soil organic matter
- Availability of other nutrients
- Effect on biotic stresses

Rotational benefits of grain legumes, Goomalling, WA



Figures in parentheses indicate seed yields (t/ha)

Source (McNeill and Unkovich, unpublished)

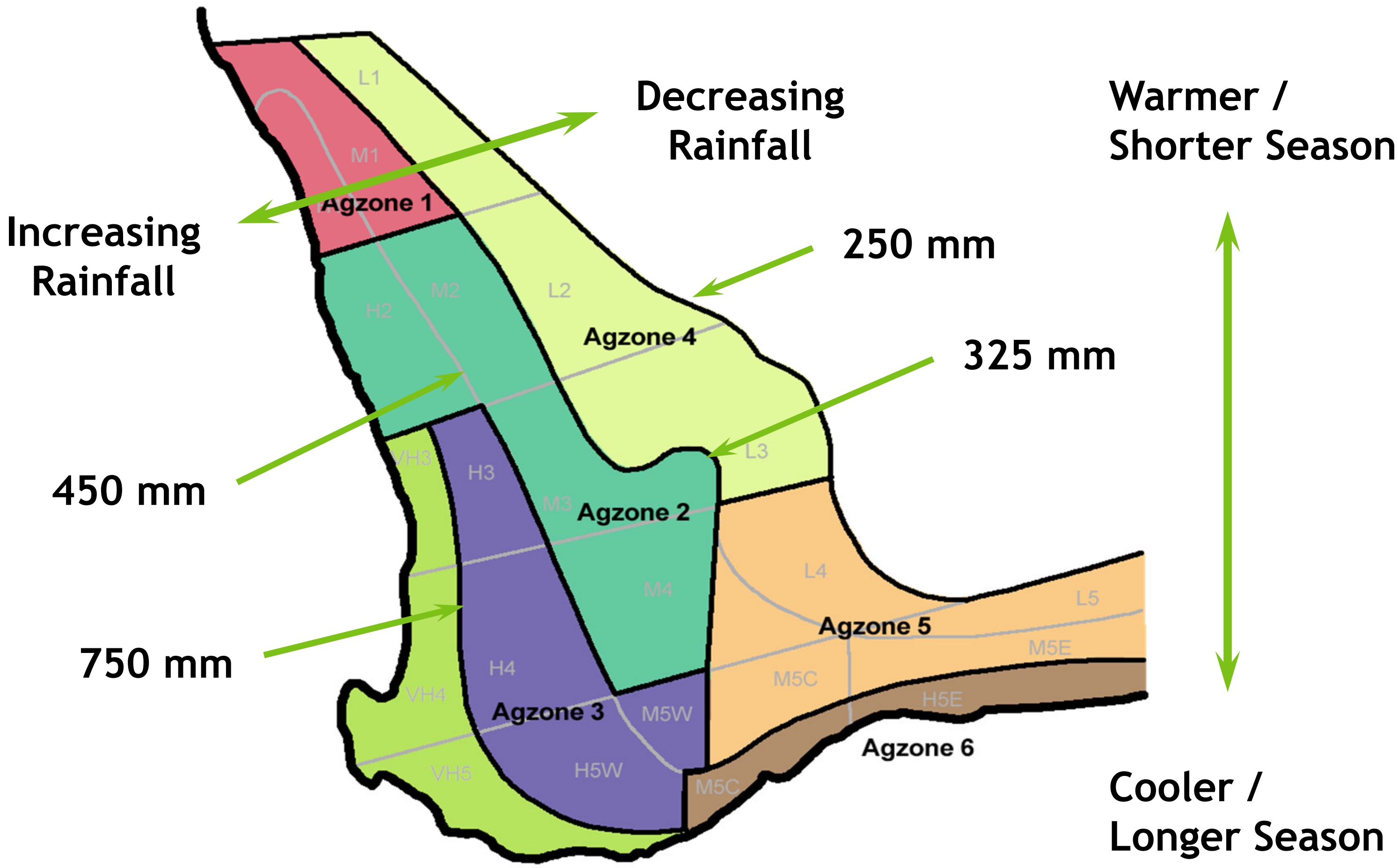
Effect of the previous rotation on incidence of take-all and grain yield of wheat in South Australia

THE UNIVERSITY OF WESTERN AUSTRALIA

Previous crop	% wheat plants with take-all	Grain yield of wheat (t ha^{-1})
Wheat	54	3.3
Lupin	15	4.8

THE UNIVERSITY OF WESTERN AUSTRALIA

Agro Ecological Zones or Ag-zones



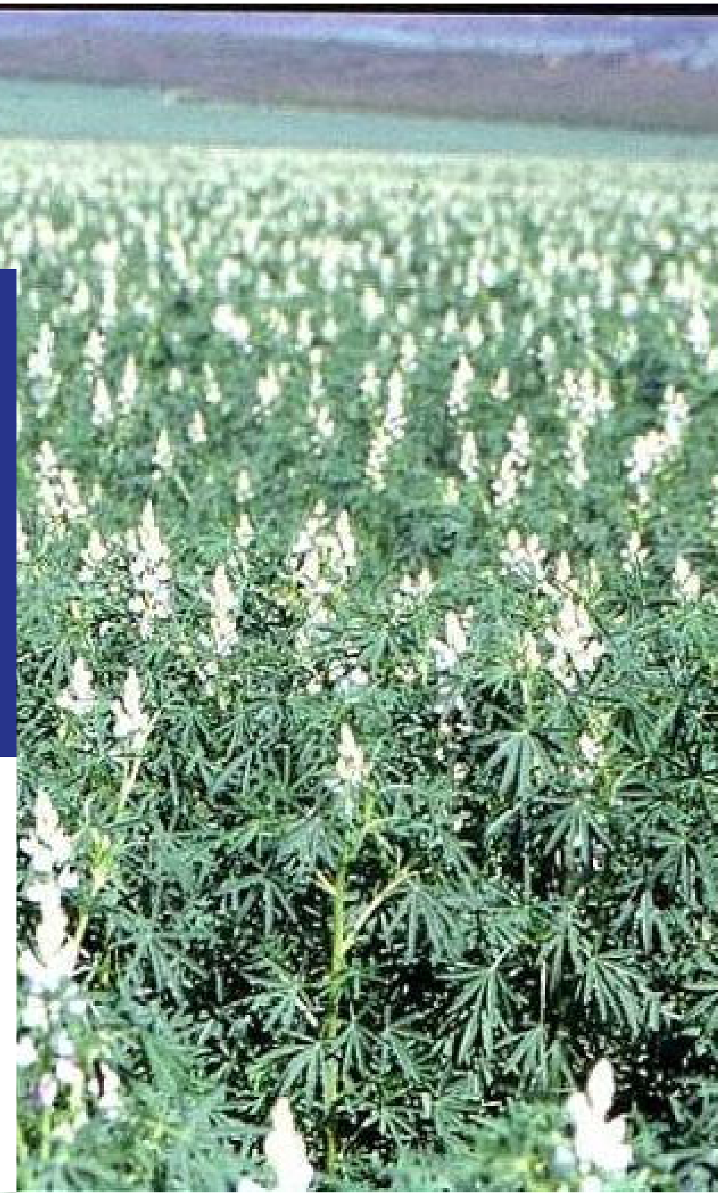
Lupin Industry

- Narrow-leafed lupin has become the major pulse crop in Australia over the past 35 years with > 75% of production in WA
- Smaller industries in NSW, SA and Vic
- Lupins are mainly adapted to coarse-textured, acidic to neutral soils common in WA
- Benefits include improved soil nitrogen, organic matter content, better weed management, reduced level of disease, and increased diversity of cash income

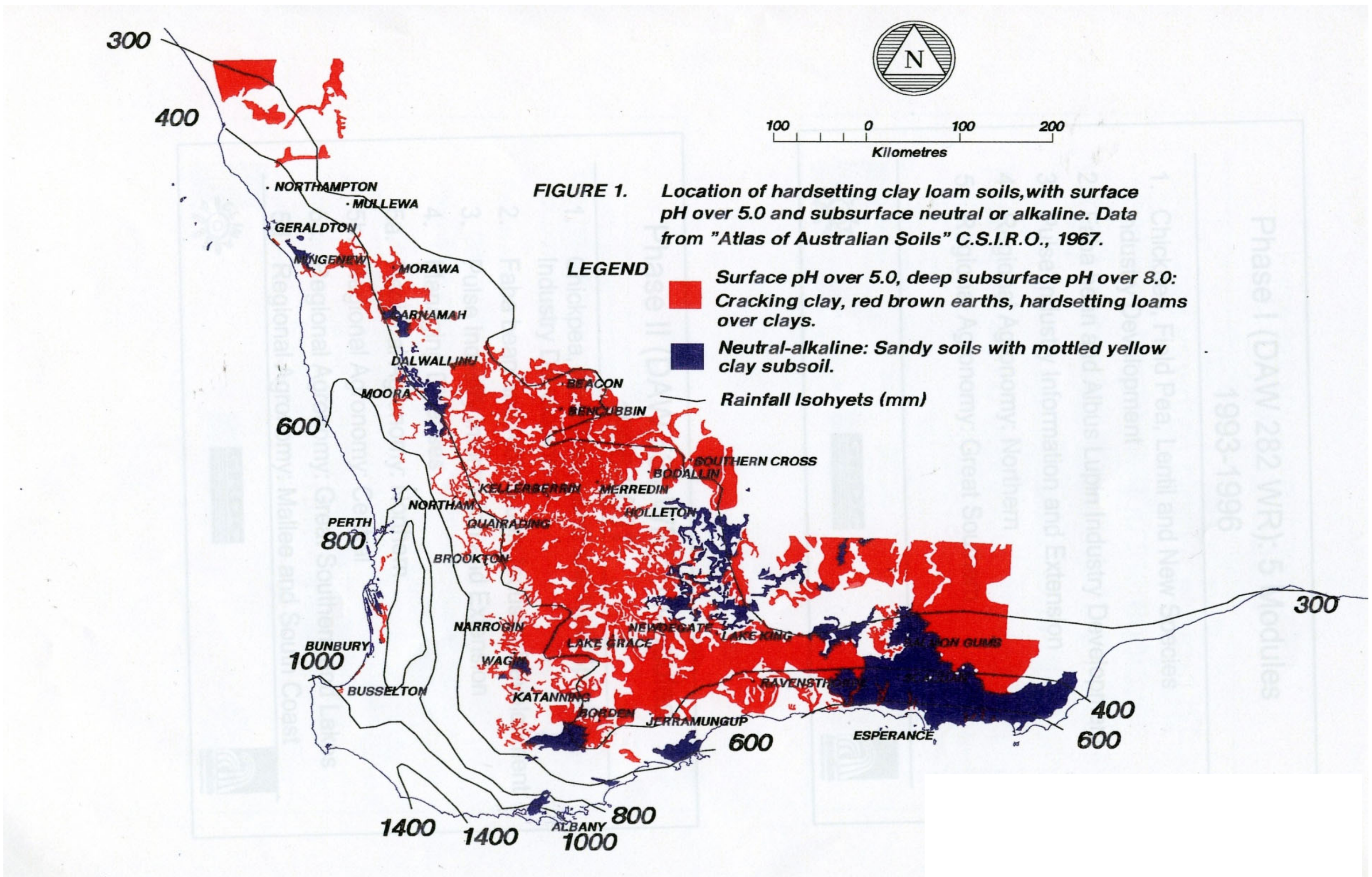
THE UNIVERSITY OF WESTERN AUSTRALIA

Major constraints to lupin production

- Low price of grain relative to canola and other grain legumes
- Variable and low yields in many regional environments
- Fungal diseases (anthracnose and root rot)
- Aphid damage and virus infection
- Herbicide resistant weeds in lupin-cereal rotation



Soil types suitable for pulses in WA



Pulse Species

Field pea (*Pisum sativum)*
Faba bean (*Vicia faba*)
Common vetch (*Vicia sativa*)
Lathyrus cicera
Lathyrus sativus
Lathyrus ochrus
Narbon bean (*Vicia narbonensis*)
Desi chickpea (*Cicer arietinum*)
Lentil (*Lens culinaris*)
Albus lupin (*Lupinus albus*)
Bitter vetch (*Vicia ervilia*)
Kabuli chickpea (*Cicer arietinum*)

Aims

- To study the adaptation of a wide range of cool season grain legumes (pulses) to low-rainfall Mediterranean-type environments of southern Australia

- To identify morphological and physiological traits associated with the adaptation of pulse species to these environments

Pulses experimental sites in south-western Australia

No of sites: 46 **Years: (1994, 1995 and 1996)**

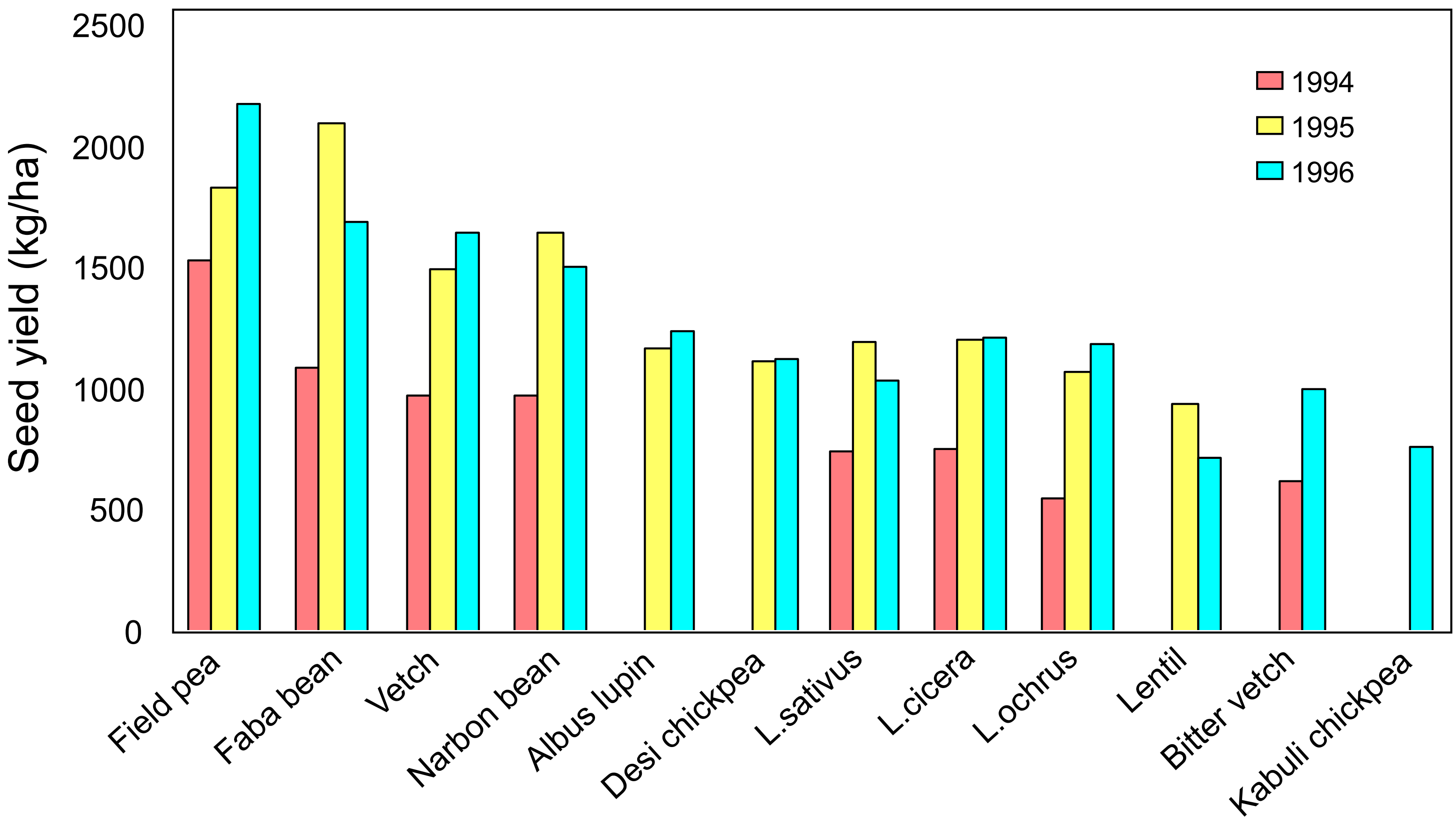
Siddique *et al.* (1999) Aust. J. Agric. Res. 50, 375-387

Pulse species x environment interaction

Fixed effects	Wald statistic	Degrees of freedom	P value
Species	72.2	11	>0.001
pH (0-10 cm)	118.2	1	>0.001
Species. pH (0-10 cm)	31.8	11	>0.001
pH (30-40 cm)	13.5	1	>0.001
Rainfall	19.3	1	>0.001
Year	5.5	2	0.064
Site	331.9	23	>0.001

Siddique *et al.* (1999) Aust. J. Agric. Res. 50, 375-387

Mean seed yields of pulse species in WA



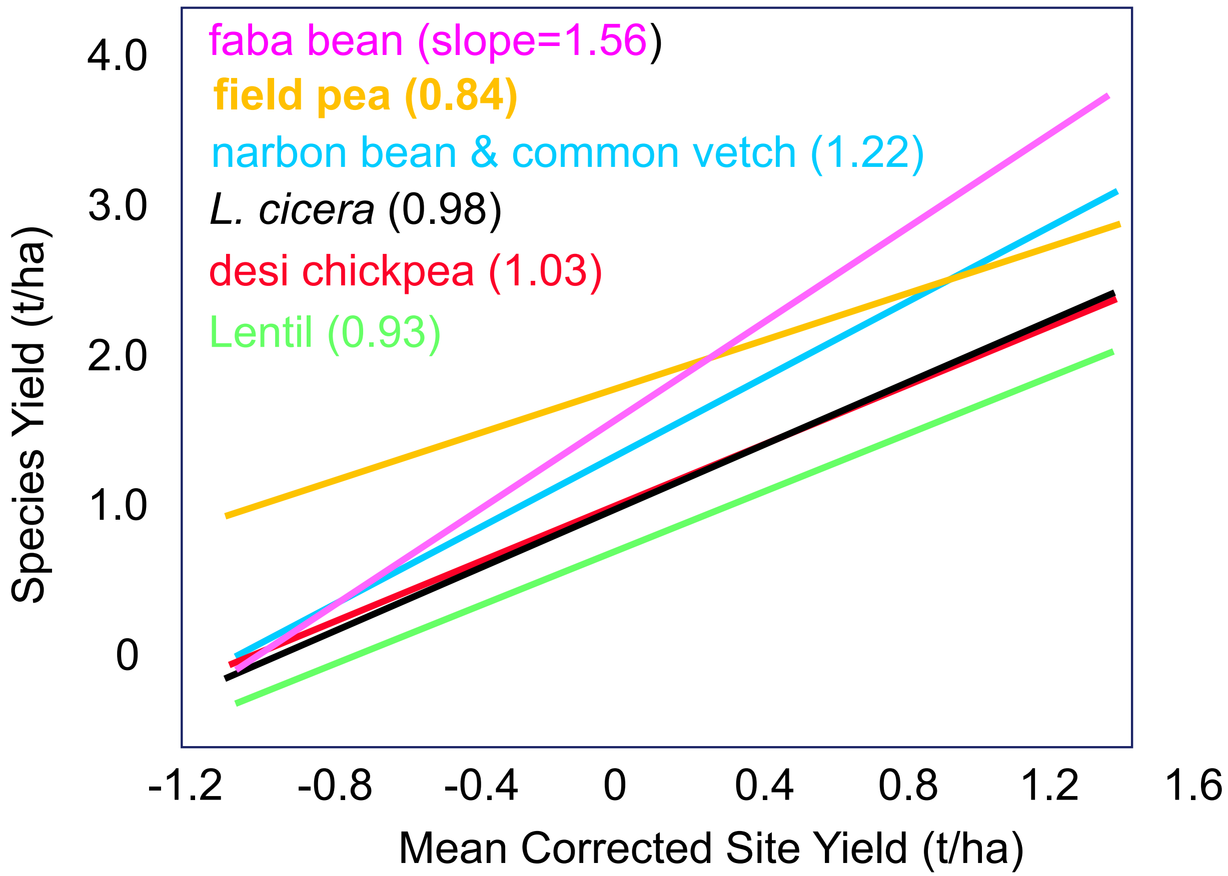
Siddique *et al.* (1999) Aust. J. Agric. Res. 50, 375-387

The University of Western Australia

Soil pH, clay content and rainfall were the environmental factors identified as the most important in determining seed yields of most species studied

Faba bean & soil types

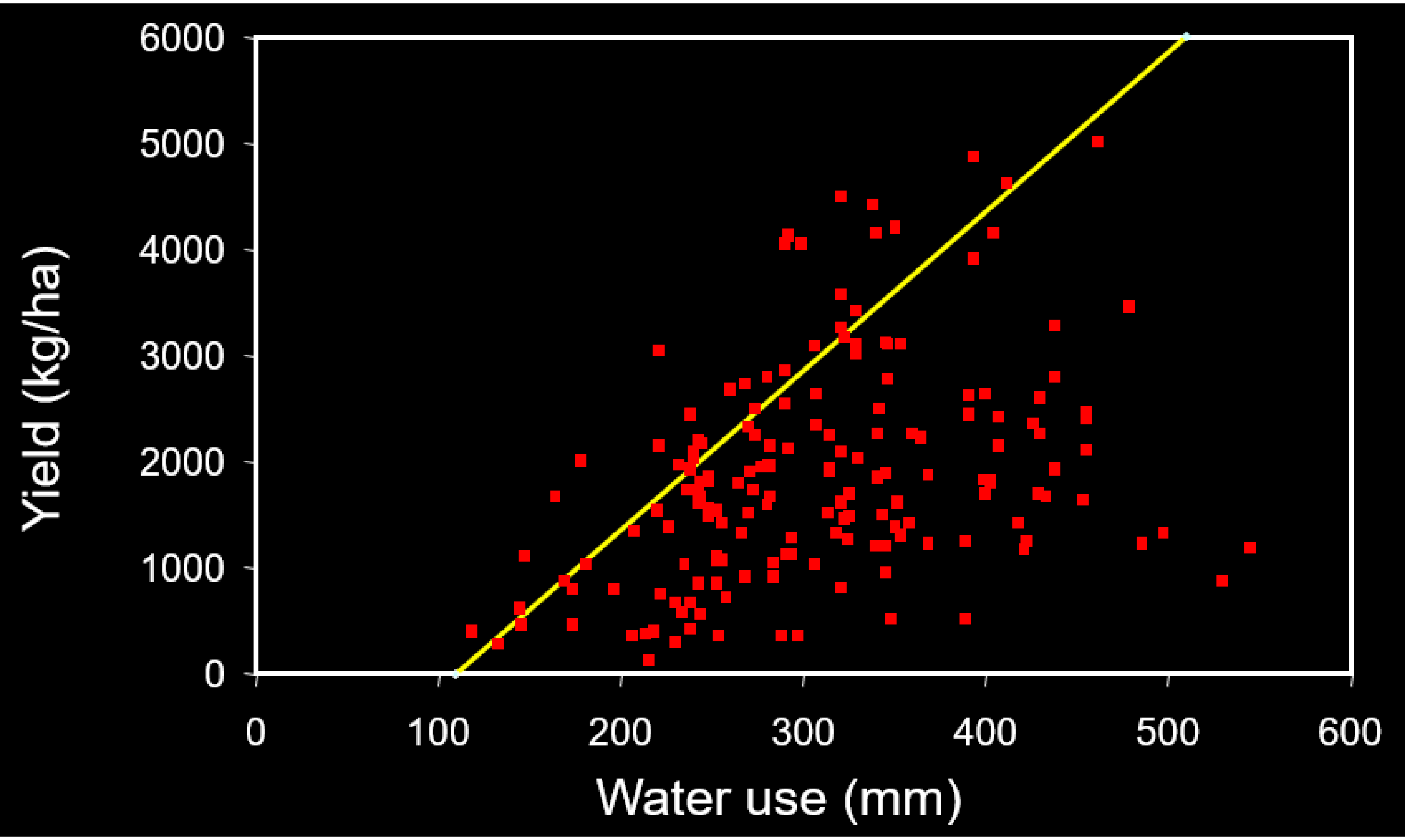
Pulse species x environment interaction



Siddique *et al.* (1999) Aust. J. Agric. Res. 50, 375-387

THE UNIVERSITY OF WESTERN AUSTRALIA

Water use efficiency of faba bean



Potential yield = [estimated crop water use (mm) - 110 mm] x 15 kg/ha/mm

Siddique *et al.* (2001) Europ J. Agron. 15, 267-280

Pulse species x environment interaction

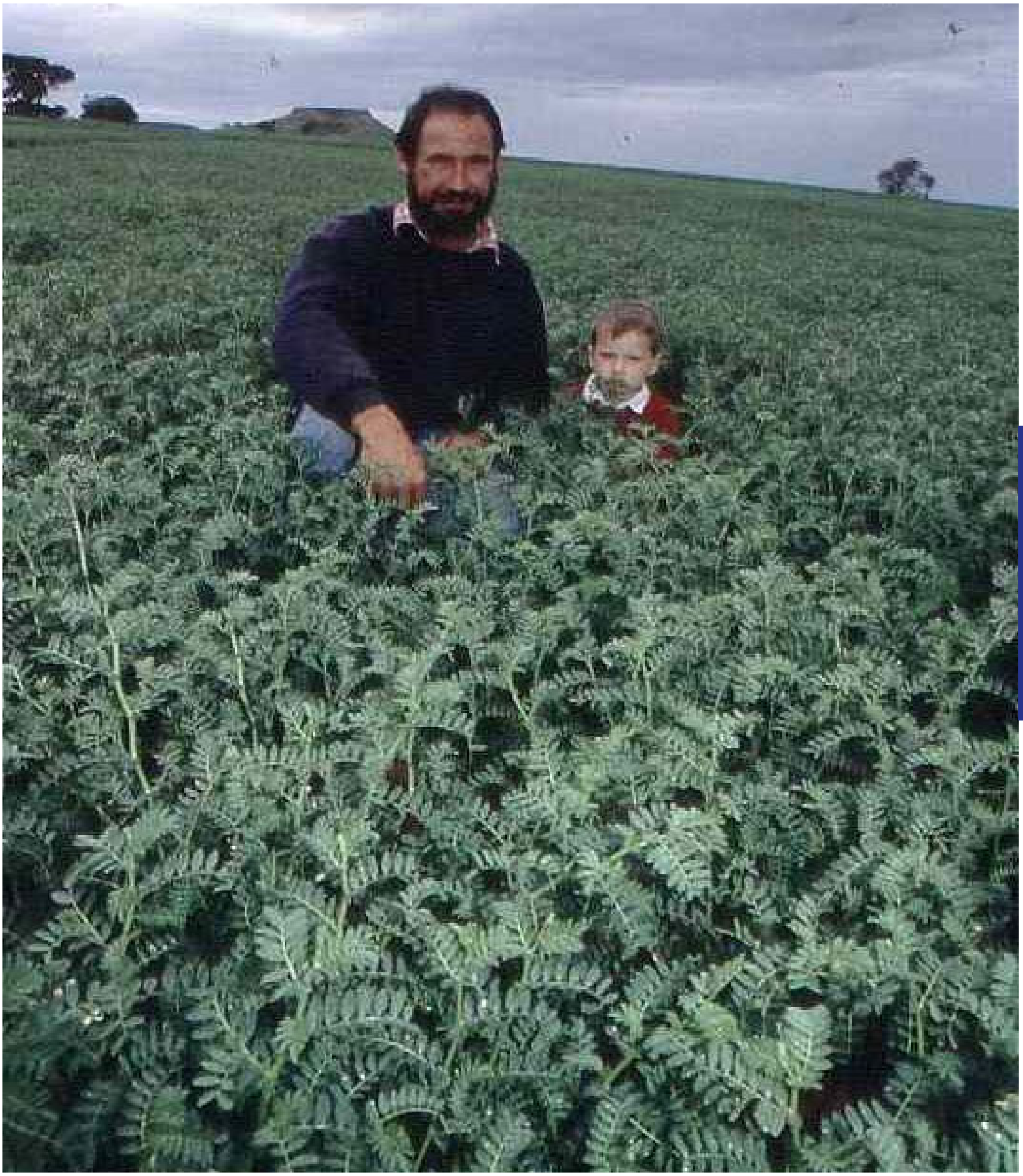
THE UNIVERSITY OF WESTERN AUSTRALIA

- The major traits of adaptation for grain legume species producing large yields in short season Mediterranean-type environments are early flowering, pod and seed set before the onset of terminal drought

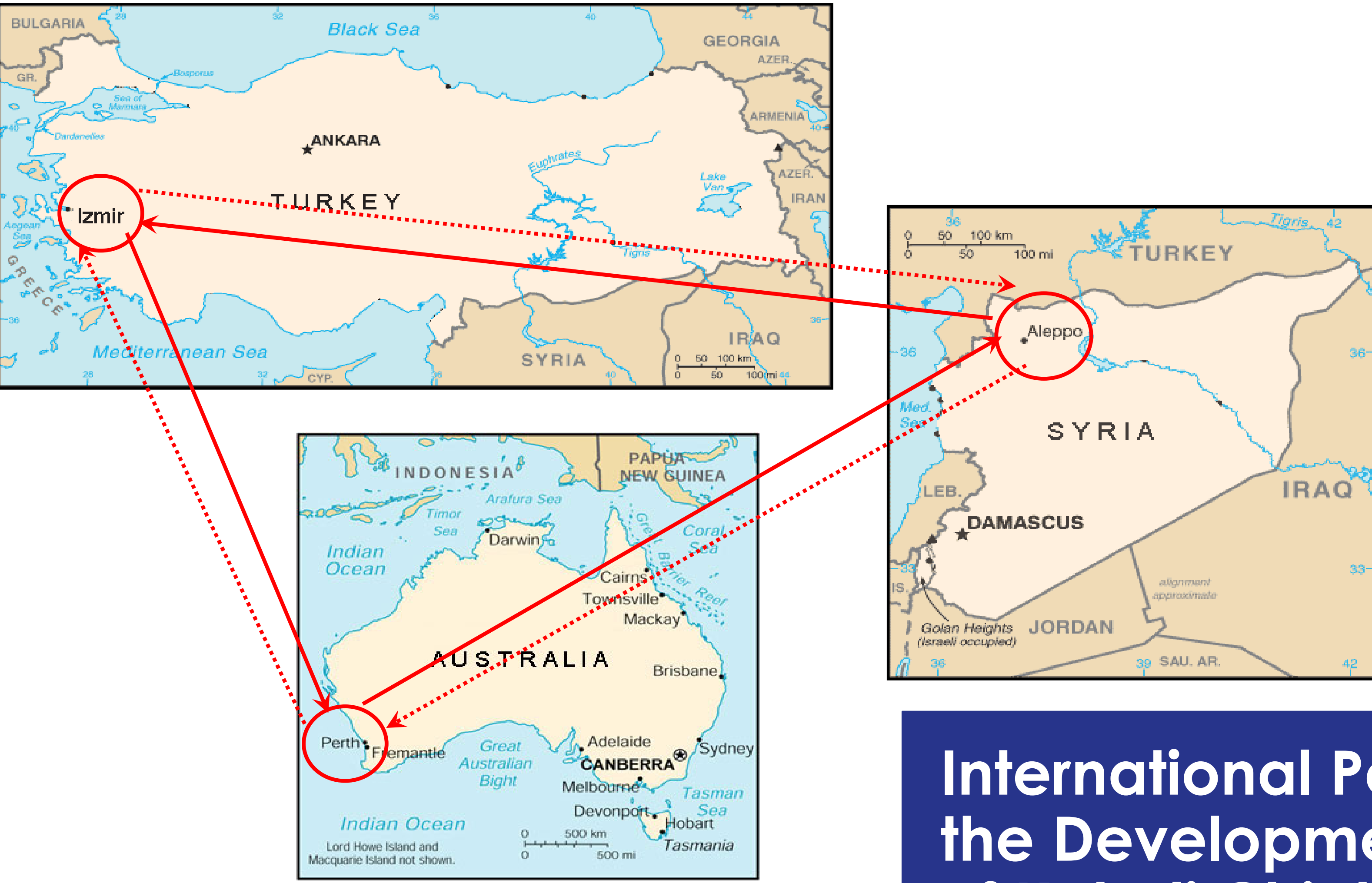
- Further improvement in adaptation and grain yield of grain legume species in these environments requires increased early growth for rapid ground cover and improved tolerance to low temperatures during flowering and podding and development and transfer of robust agronomic packages

THE UNIVERSITY OF WESTERN AUSTRALIA

Grain Legume Varieties Developed and Commercially Released in Australia



Rapid adoption of desi chickpea by farmers as a cash crop in the mid 1990's



THE UNIVERSITY OF WESTERN AUSTRALIA

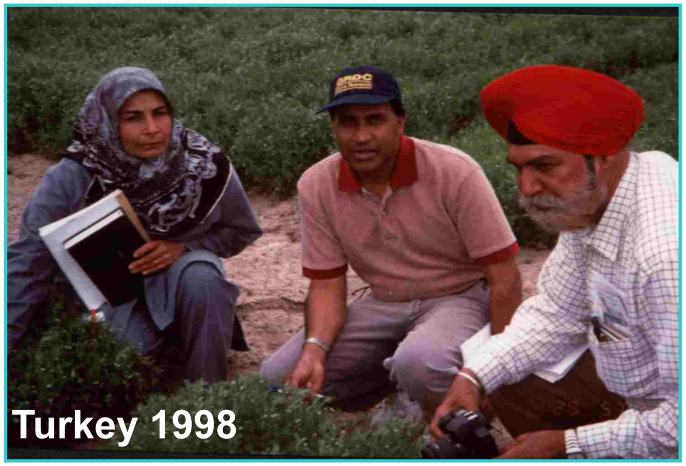
International Partnership in the Development of Kabuli Chickpeas

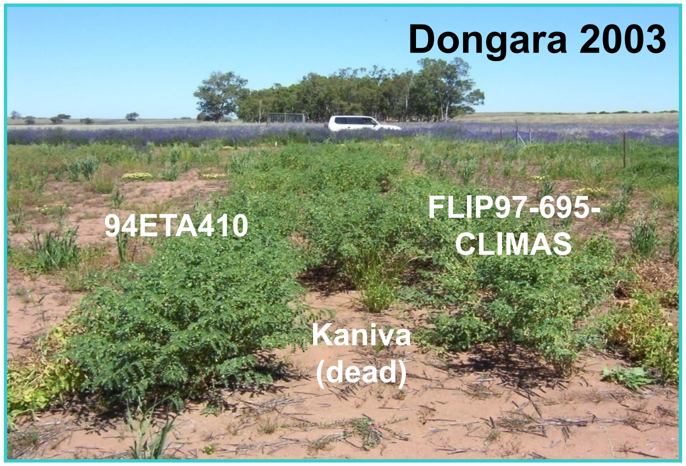
Offshore screening program in Turkey

- Approx. 2,000 ICARDA and AARI breeding lines screened in Turkey. 335 superior lines were selected and introduced to Australia between 1998

Australian kabuli chickpea varieties

Ascochyta resistant kabuli chickpea lines- ICARDA





Disease nurseries

Kabuli chickpea germplasm evaluation Dongara September 2004

THE UNIVERSITY OF WESTERN AUSTRALIA

Commercial release in August 2005

Kimberley Large Chickpea- for Ord River

PULSE VMP
Pulse Variety Management Package

AMBAR ⌽

Desi Chickpea

VMP 200? #0?

THE UNIVERSITY OF WESTERN AUSTRALIA

KEY FEATURES

- Desi chickpea variety that combines early flowering, competitive yield and ascochyta blight resistance.
- Ascochyta blight resistance is rated as (R) Resistant
- It is the earliest flowering and earliest maturing of all current varieties making it particularly well suited to short season environments.
- Bushy growth habit and profuse branching helps to utilize good growing conditions.

PULSE VMP
Pulse Variety Management Package

NEELAM ⌽

Desi Chickpea

VMP 200? #0?

KEY FEATURES

- Highest yielding variety in 2010 NVT
- Ascochyta blight resistance is rated as (R) Resistant
- Mid flowering and mid maturity, adapted to most growing regions of southern Australia
- Medium/tall plant height, taller than PBA Slasher⌽
- Seed size is 17g/100g, marginally larger than GenesisTM 836

CLIMA

Ceora ⓟ

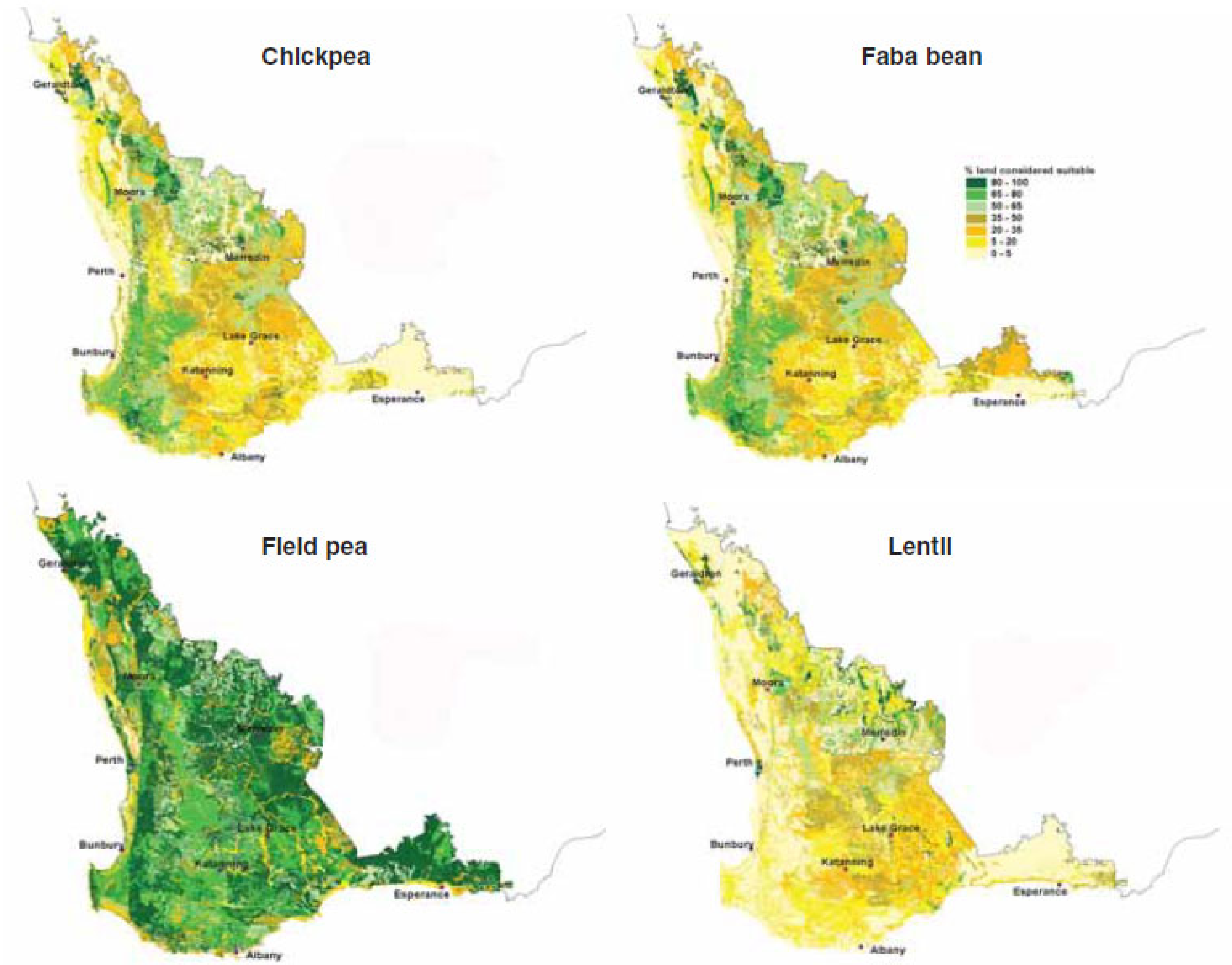
Australia's first grass pea (*Lathyrus sativus*) cultivar

(Tested as Lathyrus 20B)

SUMMARY

- A hardy annual legume with a growth habit similar to the field pea, Ceora ⓟ is intended to fulfil a multi-purpose role as a low-cost, low-input grain legume, green forage species, hay or green manure crop.
- Ceora ⓟ is reputed for its hardy nature with superior tolerance to waterlogging and infertile soils compared to most other legume species. It is relatively drought tolerant and disease resistant.
- Ceora ⓟ is best adapted to medium to heavy textured soils where the annual rainfall ranges between 300-650 mm.
- Ceora ⓟ produces similar seed yields to those of field pea and *Lathyrus cicera* variety Chalus. It has very low toxin content when compared with overseas varieties.

Ceora: Australia's First low ODAP Grass pea



Percentage land area suitable for at least one pulse crop (field pea, chickpea, faba bean and lentil) in the agricultural area of Western Australia

Source: Soil and environmental factors affecting pulse adaptation in WA Bob French & Peter White

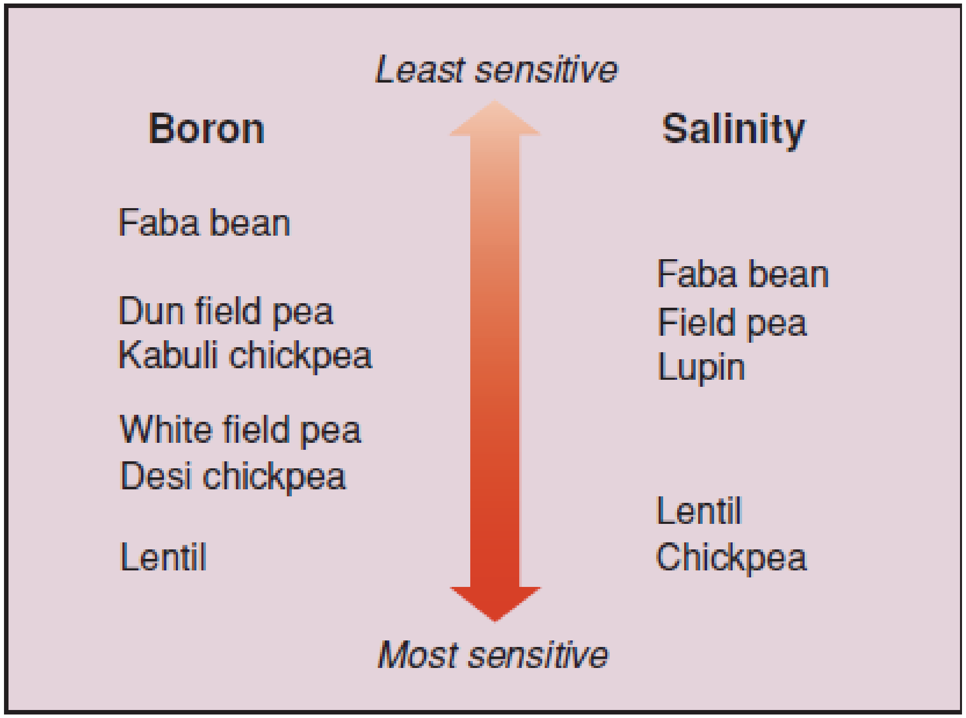
Table 1. Summary of determinants of pulse crop adaptation in Western Australia

	Field pea	Chickpea	Faba bean	Lentil	Narbon bean	Common vetch
Soil pH requirement	5.0 – 9.0	5.5 – 9.0	6.0 – 9.0	6.5 – 9.0	5.0 – 9.0	5.0 – 9.0
Texture	Loamy sand - clay	Sandy loam - clay	Loam - clay	Loam - clay	Sandy loam - clay	Loamy sand - clay
Average yield potential	High	Medium	High	Low	High	High
Yield stability	Good	Average	Poor	Average	Average	Poor
Drought adaptation strategies	Drought escape and tolerance	Drought avoidance and tolerance	Drought escape	Drought escape and tolerance	Drought escape	Drought escape
Waterlogging	Sensitive	Very sensitive	Moderately tolerant	Very sensitive	Moderately sensitive	Sensitive
Boron toxicity/ sodicity	Moderately tolerant	Very sensitive	Moderately tolerant	Very sensitive	Moderately tolerant	Moderately tolerant
Salinity	Moderately sensitive	Very sensitive	Moderately sensitive	Moderately sensitive	Sensitive	Moderately sensitive
Surface crusting	Moderately sensitive	Moderately sensitive	Moderately sensitive	Sensitive	Moderately sensitive	Sensitive
Other considerations	Adapted to late sowing	Adapted to mid–late sowing	Requires early sowing or high yield potential environment	Good yield potential on suitable soils		

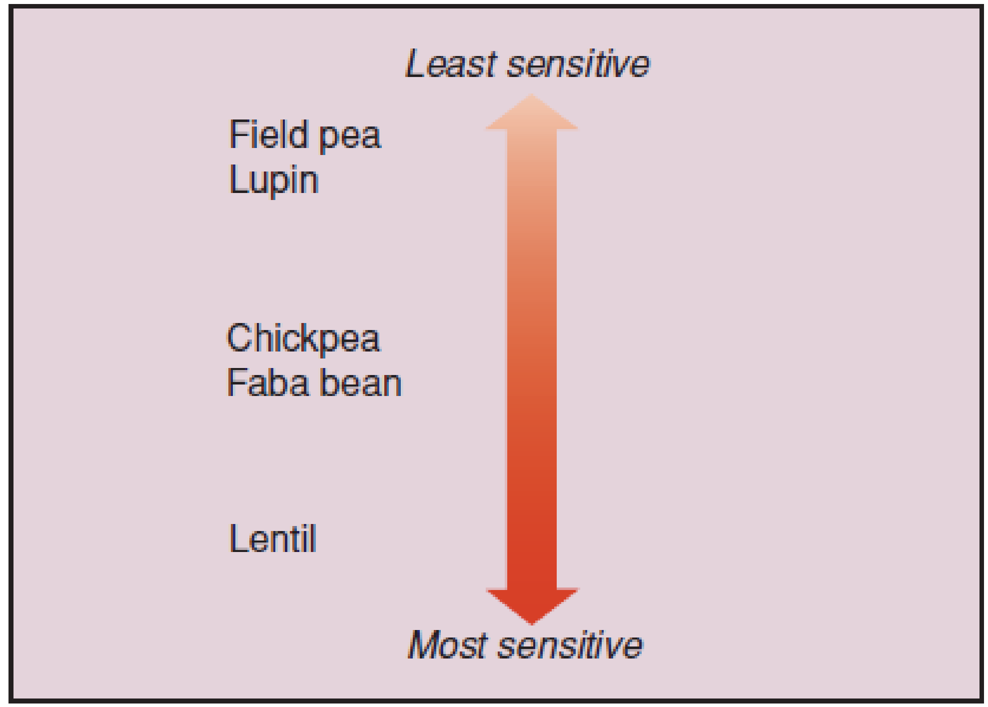
THE UNIVERSITY OF WESTERN AUSTRALIA

Sc

THE UNIVERSITY OF WESTERN AUSTRALIA



Relative sensitivities of grain legume species to boron toxicity and salinity

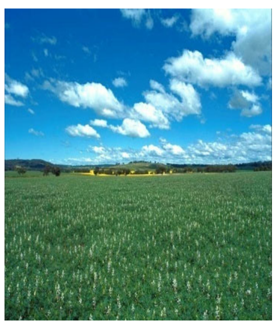


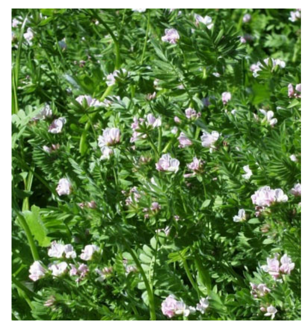
Sensitivity of different grain legume species to sulfonylur
residues

Source: Soil and environmental factors affecting pulse adaptation in WA Bob French & Peter White

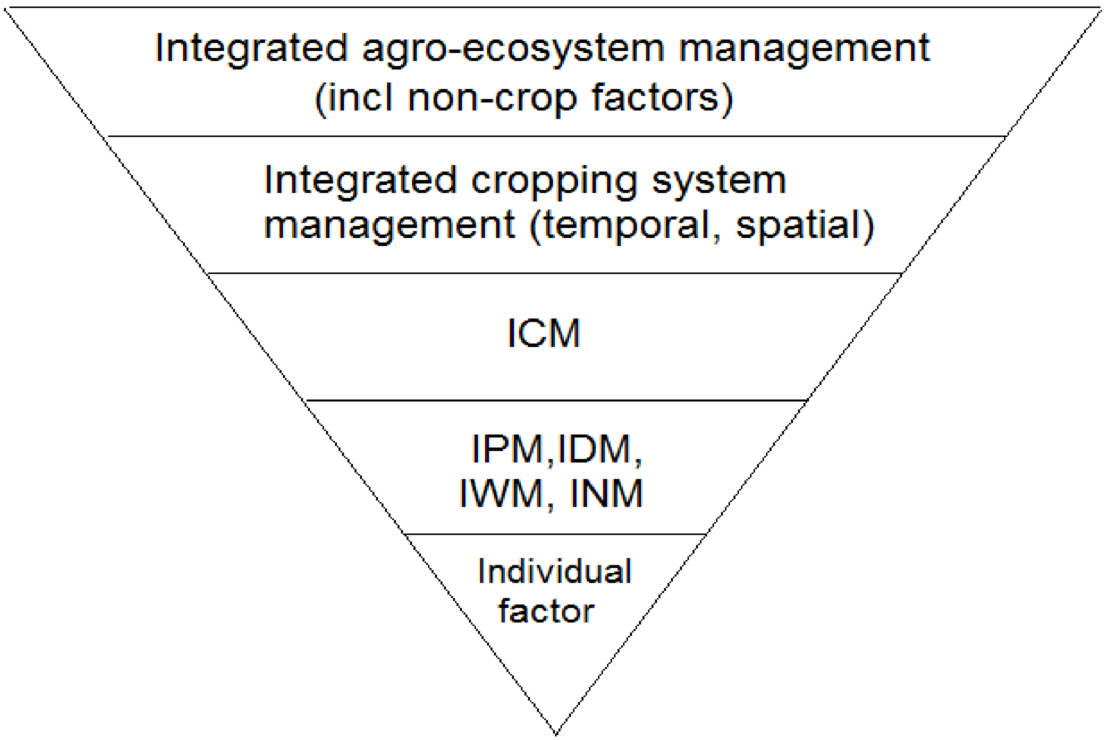
Phase rotation

Wheat **Lupin** **Canola** **Wheat** **Legumes**


No-till pulse crop (sown on cereal stubble)
with shielded sprayer to control
inter-row weeds with a broad-spectrum herbicide

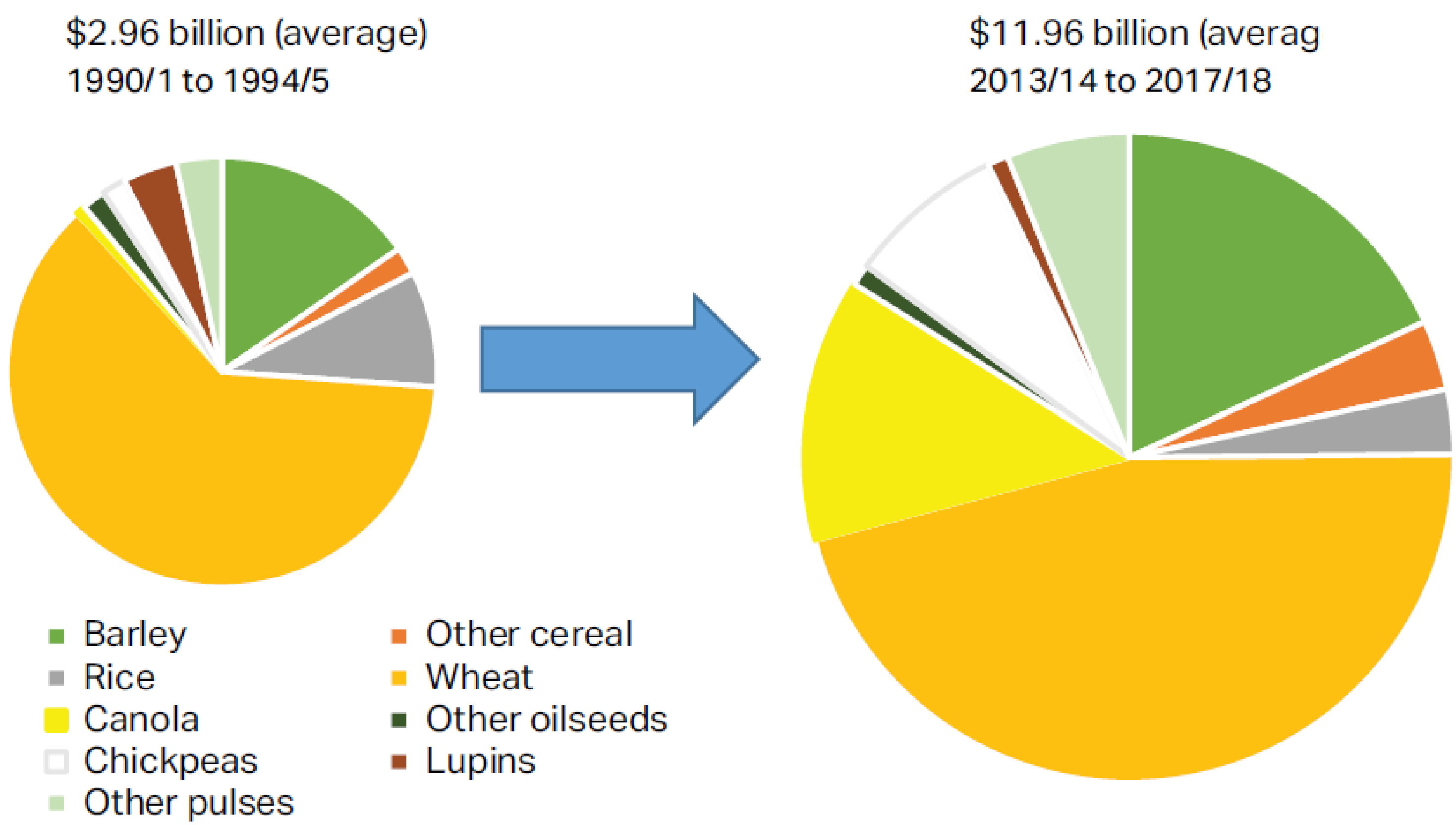


Integration hierarchy in increasing complexity in moving from individual factor responses to integrated agro-ecosystem management

Siddique et al 2012

Crop shares of Australian grain exports
1990/1 to 1994/5 vs 2013/14 to 2017/18

THE UNIVERSITY OF WESTERN AUSTRALIA



Source: Farm Policy Journal Vol 16 No.1 Autumn Quarter 2019

Opportunity and Necessity Drive Innovation

THE UNIVERSITY OF WESTERN AUSTRALIA

Research on Pulses needed to:

- Increase productivity
- Improve climate resilience
- Understand the health and nutritional benefits
- Add value through ingredients and food processing

Global investment in pulse R,D&E is too low compared with cereal crops:
(US $ 175 million per annum in 13 pulse crops)

THE UNIVERSITY OF WESTERN AUSTRALIA

nature plants

PERSPECTIVE

PUBLISHED: 2 AUGUST 2016 | ARTICLE NUMBER: 16112 | DOI: 10.1038/NPLANTS.2016.112

Neglecting legumes has compromised human health and sustainable food production

Christine H. Foyer[1,2*], Hon-Ming Lam[3], Henry T. Nguyen[4], Kadambot H. M. Siddique[5], Rajeev Varshney[6], Timothy D. Colmer[2,5], Wallace Cowling[5], Helen Bramley[7], Trevor A. Mori[8], Jonathan M. Hodgson[8], James W. Cooper[1], Anthony J. Miller[9], Karl Kunert[10], Juan Vorster[10], Christopher Cullis[11], Jocelyn A. Ozga[12], Mark L. Wahlqvist[13,14], Yan Liang[15], Huixia Shou[16], Kai Shi[17], Jingquan Yu[17], Nandor Fodor[1], Brent N. Kaiser[18], Fuk-Ling Wong[3], Babu Valliyodan[5] and Michael J. Considine[2,5,19]

Article

A chickpea genetic variation map based on the sequencing of 3,366 genomes

https://doi.org/10.1038/s41586-021-04066-1

Received: 15 October 2020

Accepted: 28 September 2021

Published online: 10 November 2021

Open access

Rajeev K. Varshney[1,2,✉], Manish Roorkiwal[1], Shuai Sun[3,4,5], Prasad Bajaj[1], Annapurna Chitikineni[1], Mahendar Thudi[1,6], Narendra P. Singh[7], Xiao Du[3,4], Hari D. Upadhyaya[8,9], Aamir W. Khan[1], Yue Wang[3,4], Vanika Garg[1], Guangyi Fan[3,4,10,11], Wallace A. Cowling[12], José Crossa[13], Laurent Gentzbittel[14], Kai Peter Voss-Fels[15], Vinod Kumar Valluri[1], Pallavi Sinha[1,16], Vikas K. Singh[1,16], Cécile Ben[14,17], Abhishek Rathore[1], Ramu Punna[18], Muneendra K. Singh[1], Bunyamin Tar'an[19], Chellapilla Bharadwaj[20], Mohammad Yasin[21], Motisagar S. Pithia[22], Servejeet Singh[23], Khela Ram Soren[7], Himabindu Kudapa[1], Diego Jarquín[24], Philippe Cubry[25], Lee T. Hickey[15], Girish Prasad Dixit[7], Anne-Céline Thuillet[25], Aladdin Hamwieh[26], Shiv Kumar[27], Amit A. Deokar[19], Sushil K. Chaturvedi[28], Aleena Francis[29], Réka Howard[30], Debasis Chattopadhyay[29], David Edwards[12], Eric Lyons[31], Yves Vigouroux[25], Ben J. Hayes[15], Eric von Wettberg[32], Swapan K. Datta[33], Huanming Yang[10,11,34,35], Henry T. Nguyen[36], Jian Wang[11,35], Kadambot H. M. Siddique[12], Trilochan Mohapatra[37], Jeffrey L. Bennetzen[38], Xun Xu[10,39] & Xin Liu[10,11,40,41,✉]

Zero hunger and good health could be realized by 2030 through effective conservation, characterization and utilization of germplasm resources[1]. So far, few chickpea (*Cicer arietinum*) germplasm accessions have been characterized at the genome sequence level[2]. Here we present a detailed map of variation in 3,171 cultivated and 195 wild accessions to provide publicly available resources for chickpea genomics research and breeding. We constructed a chickpea pan-genome to describe genomic diversity across cultivated chickpea and its wild progenitor accessions. A divergence tree using genes present in around 80% of individuals in one species allowed us to estimate the divergence of *Cicer* over the last 21 million years. Our analysis found chromosomal segments and genes that show signatures of selection during domestication, migration and improvement. The chromosomal locations of deleterious mutations responsible for limited genetic diversity and decreased fitness were identified in elite germplasm. We identified superior haplotypes for improvement-related traits in landraces that can be introgressed into elite breeding lines through haplotype-based breeding, and found targets for purging deleterious alleles through genomics-assisted breeding and/or gene editing. Finally, we propose three crop breeding strategies based on genomic prediction to enhance crop productivity for 16 traits while avoiding the erosion of genetic diversity through optimal contribution selection (OCS)-based pre-breeding. The predicted performance for 100-seed weight, an important yield-related trait, increased by up to 23% and 12% with OCS- and haplotype-based genomic approaches, respectively.

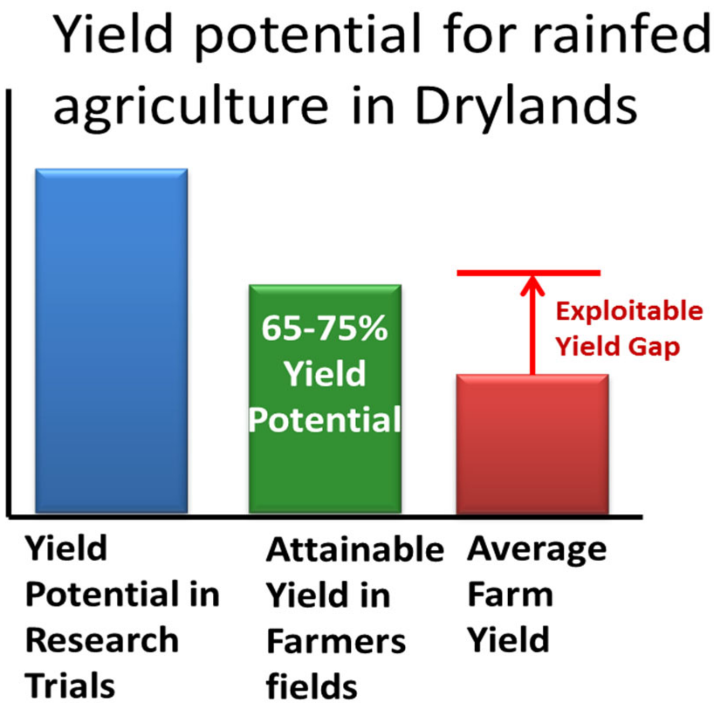
Area under pulses in Western Australia ('000s ha)

Crop	1999-2004	2021*	2025?
Field pea	99 (2004)	26.4	125
Chickpea	72 (1999)	6.9	100
Faba beans	38 (1997)	18.4	50
Lentils	10 (1998)	4.9	15

*GIWA Report https://www.giwa.org.au/wa-crop-reports/2021-season/giwa-crop-report-february-2022/

Strategies for Enhancing Pulse Production

- Vertical increase in productivity through sustainable intensification of production systems
- Closing the yield gaps
- Crop genetic improvement and new genetic gains for improved varieties
- Horizontal expansion
- Reduced post-harvest losses



- **25-60% yield gaps in pulses**
- **Reasons are many…**
- **Closing the yield gaps can alone supply 60% of pulses deficit**
- **Farmers participatory research**

Conclusions and way forward

- IYP2016 was timely because pulses are important for food & nutritional security, environmental benefits, and mitigation of climate change
- Demand for pulses is growing but supply constraints will lead to rise in prices and increase trade
- Pulses production and trade scenario in changing
  - New countries producing pulses and exporting to deficit countries
- Global level
  - Increase funding for pulse R, D & E
  - Incentives for improved technologies to public and private sector
  - Effective trade

- National level
  - Bridge yield gaps to increase domestic production
  - Improve pulse value chains to benefit producers and consumers
  - Attract private sector in pulses production, processing and marketing
  - Promote innovative institutions for scale