Pulses: An integral component of mitigation and adaptation under climate change

Conference on Pulses for Sustainable Agriculture and Human Health

Shiv Kumar Agrawal

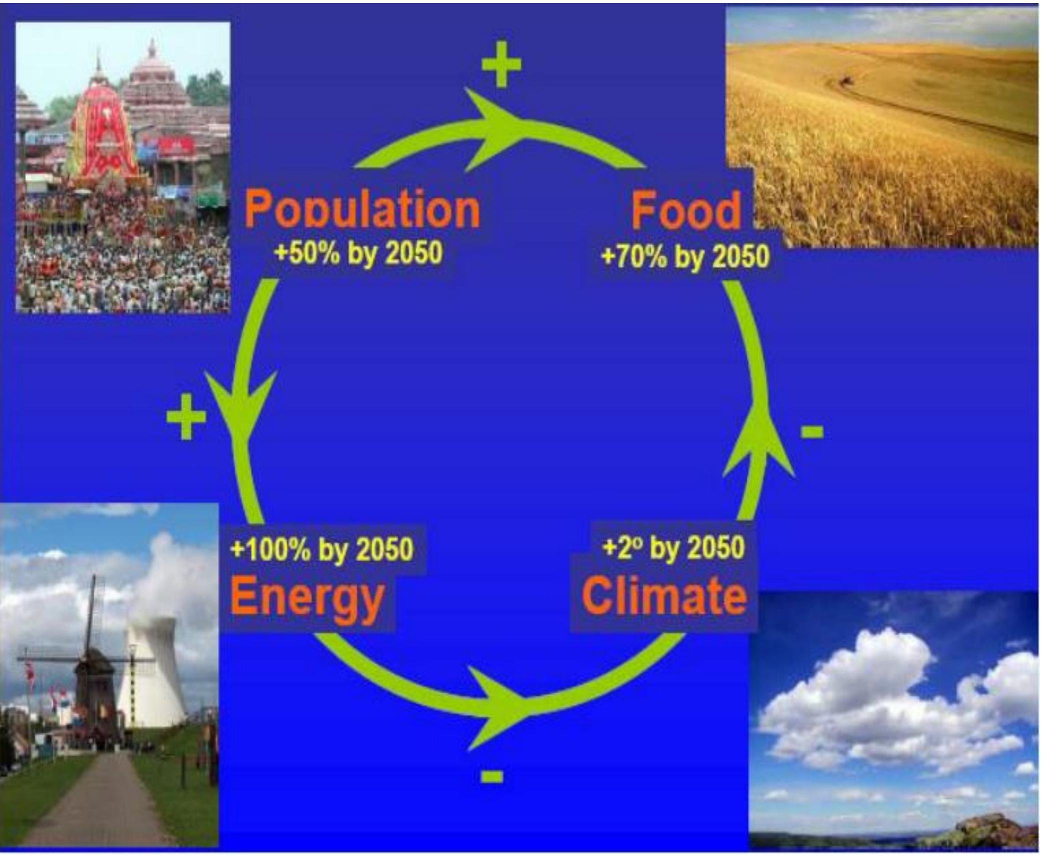
May 31, 2016

New Delhi, India

ICARDA

Science for Better Livelihoods in Dry Areas

Great Challenges of Agriculture

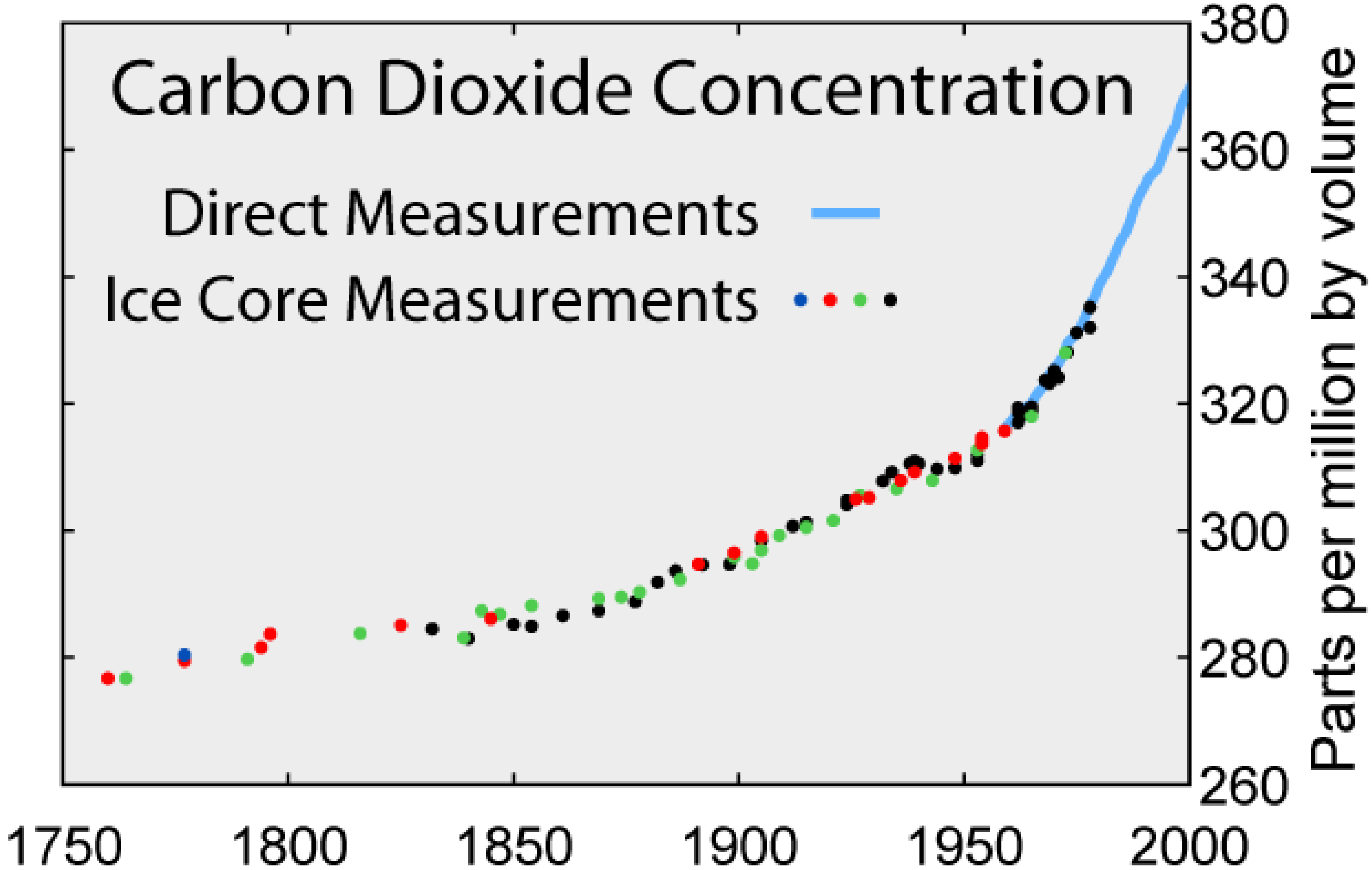


- Growing world population will cause a "perfect storm" of food, energy and water shortages by 2050
- Demand for food and energy will jump 70% and 100% and for fresh water by 30%, as the population tops 9 billion

How to expand agriculture output without further constraining natural resources under climate change is a challenge?

Today's Agriculture contributes to GHGs

- **Agriculture contributes 30-35% of global GHGs emissions**
- **Annual growth rate of atmospheric GHGs concentrations increased from 0.7 ppm a before the Green Revolution period to 1.6 ppm at present**



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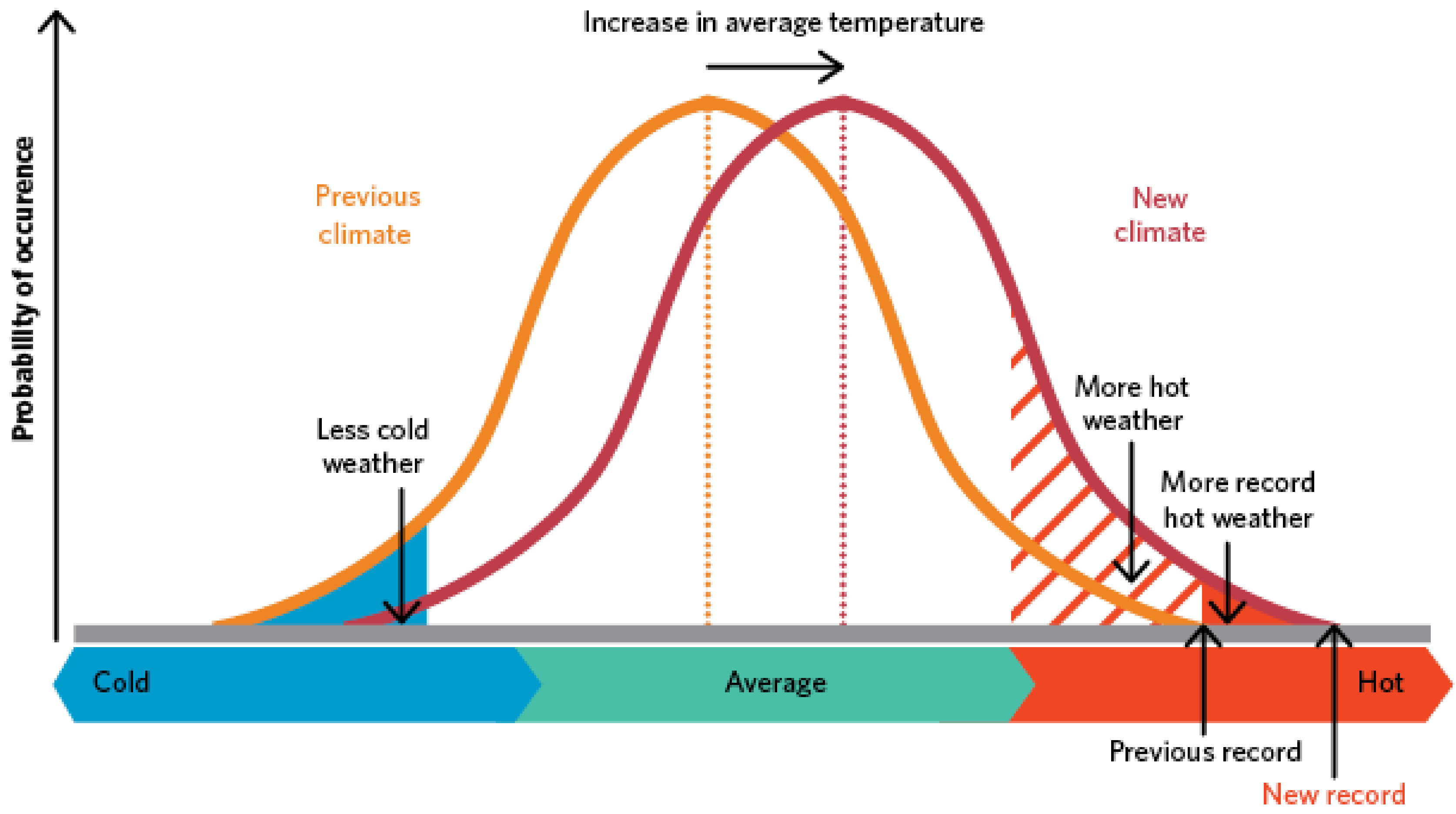
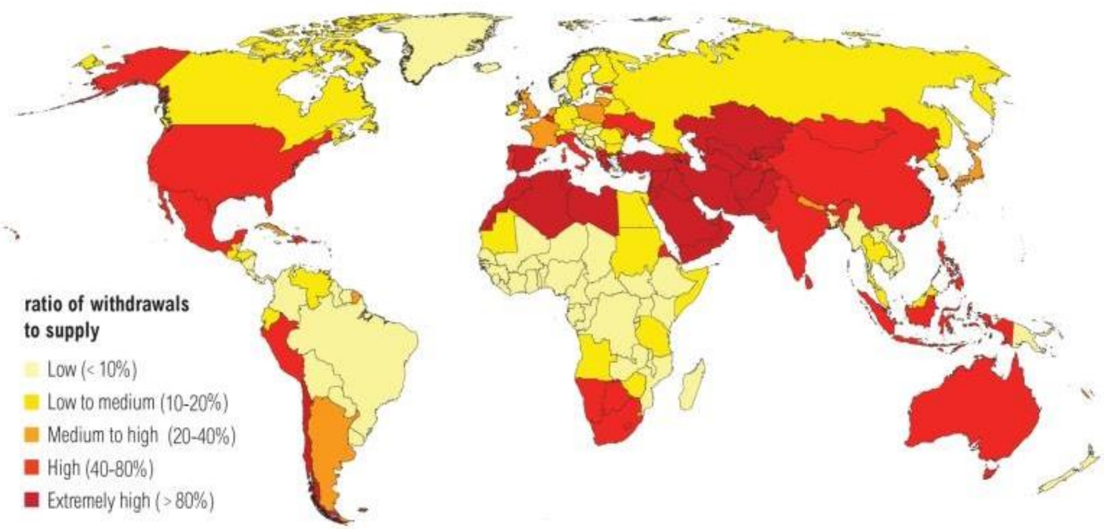
Climate Change: Temperature Stress



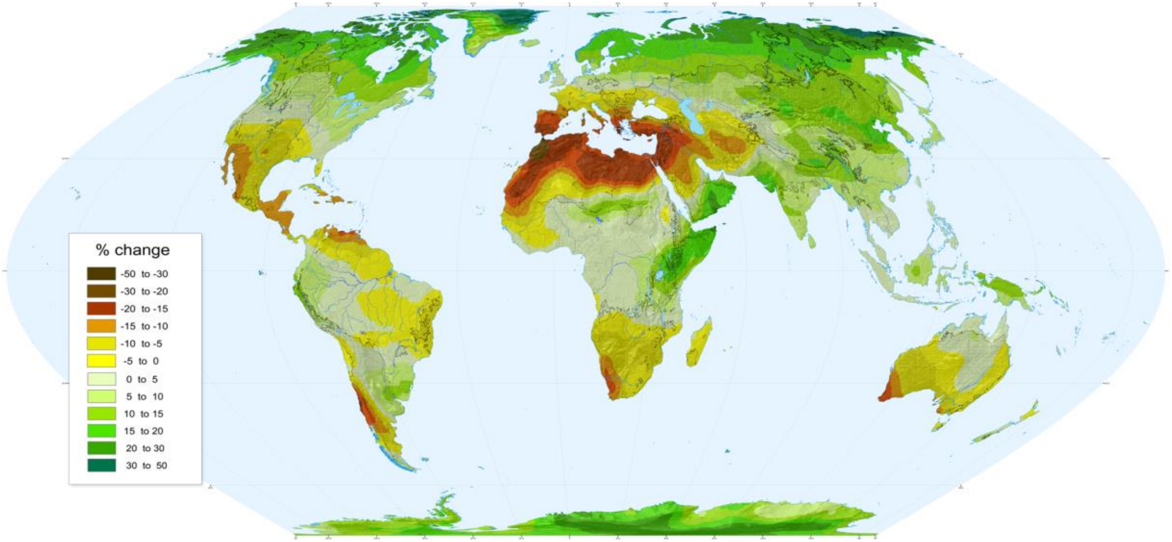
Annual temperature have changed more rapidly in recent years.
Frequency and intensity of temperature stress in future climates

Climate Change: Water Stress by 2040



- **70% of the global freshwater withdrawals are used for irrigation**
- **Ground water depletion (35 cm per year in north India)**
- **Rapid desertification and salinization**

Change in mean annual precipitation (1980s to 2080s; IPCC A1B)



- **Under climate change, dry lands will increase in area, and conditions for agriculture in dry lands will decline**
- **Major decreases of rainfall are expected in MENA and southern African dry lands, Australian, North America. Increases in rain are expected in the dry lands of East Asia dry lands.**
- **This is IPCC scenario A1B average of 21 GCMs**

Meeting Food Demand by 2050

The strategy is to produce more crops:

Produce more from less

- from less land,
- per drop of water,
- per unit input of fertilizers and pesticides,
- per unit of energy, and
- per unit of C emission.

Pulses in rotation can produce more from less

Wide Spectrum of Pulses for Crop Diversity

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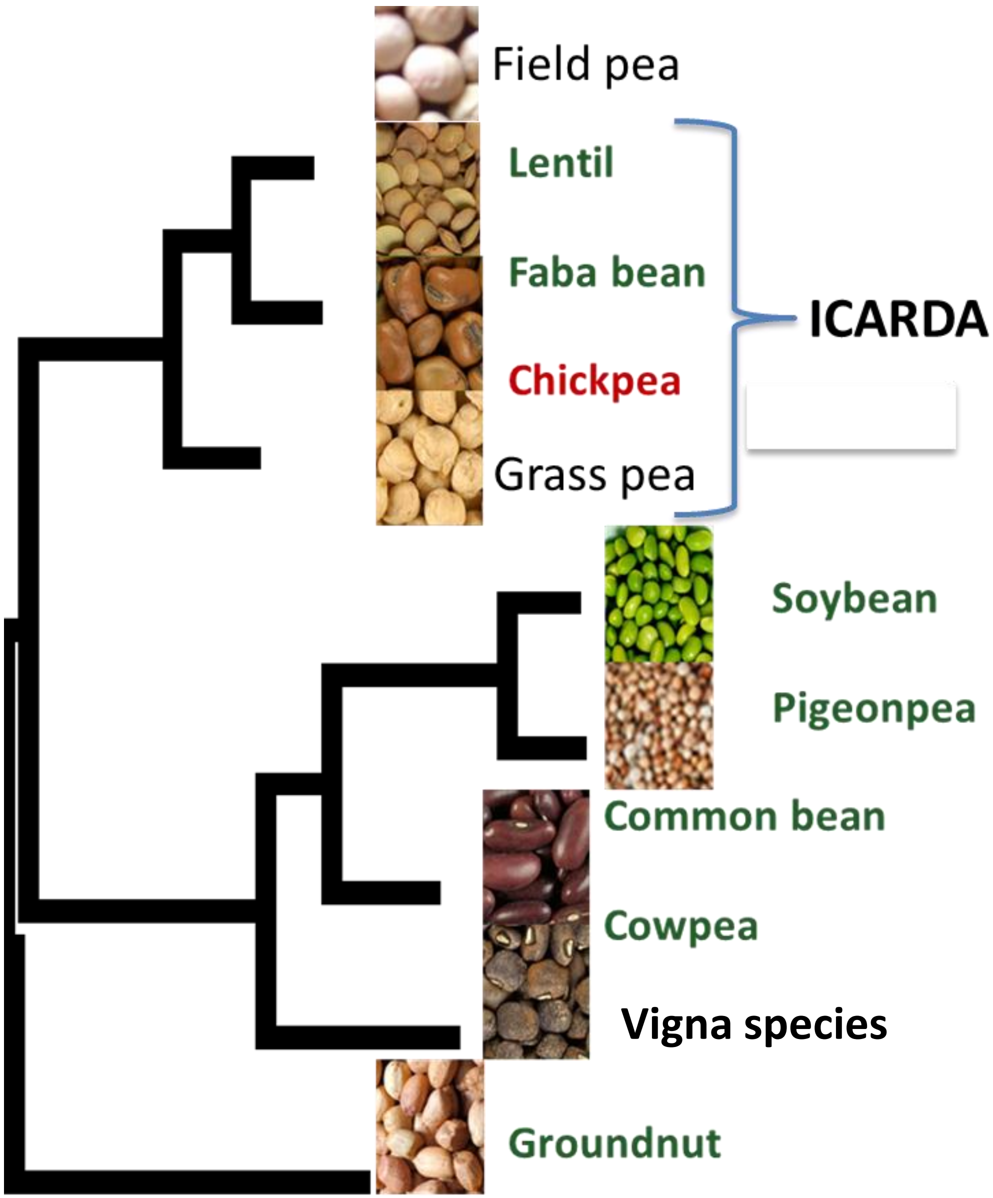

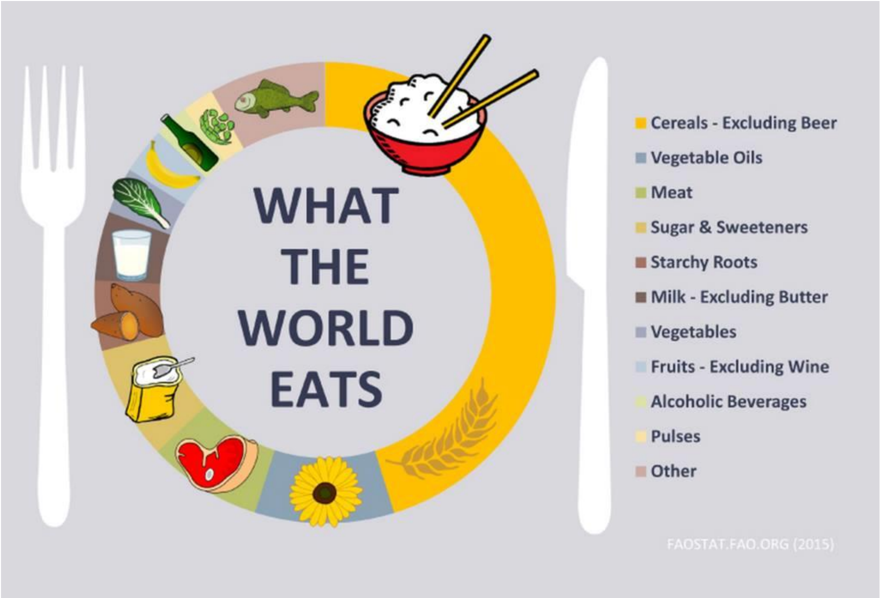

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Pulses have a very low water footprint

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Daal (1kg)
1250 liters

Chicken (1kg)
4325 liters

Mutton (1kg)
5520 liters

Beef (1kg)
13000 liters

- **Compared with plant-based protein sources like pulses, beef requires 10 times more water, 20 times more land, and creates 20 times more greenhouse gas emissions per unit of protein consumed.**
- **Global consumption of animal products to rise by 79% in 2050**
- **Animal-based foods accounts for 75% of our global agricultural land use and 66% of food-related greenhouse gas emissions.**

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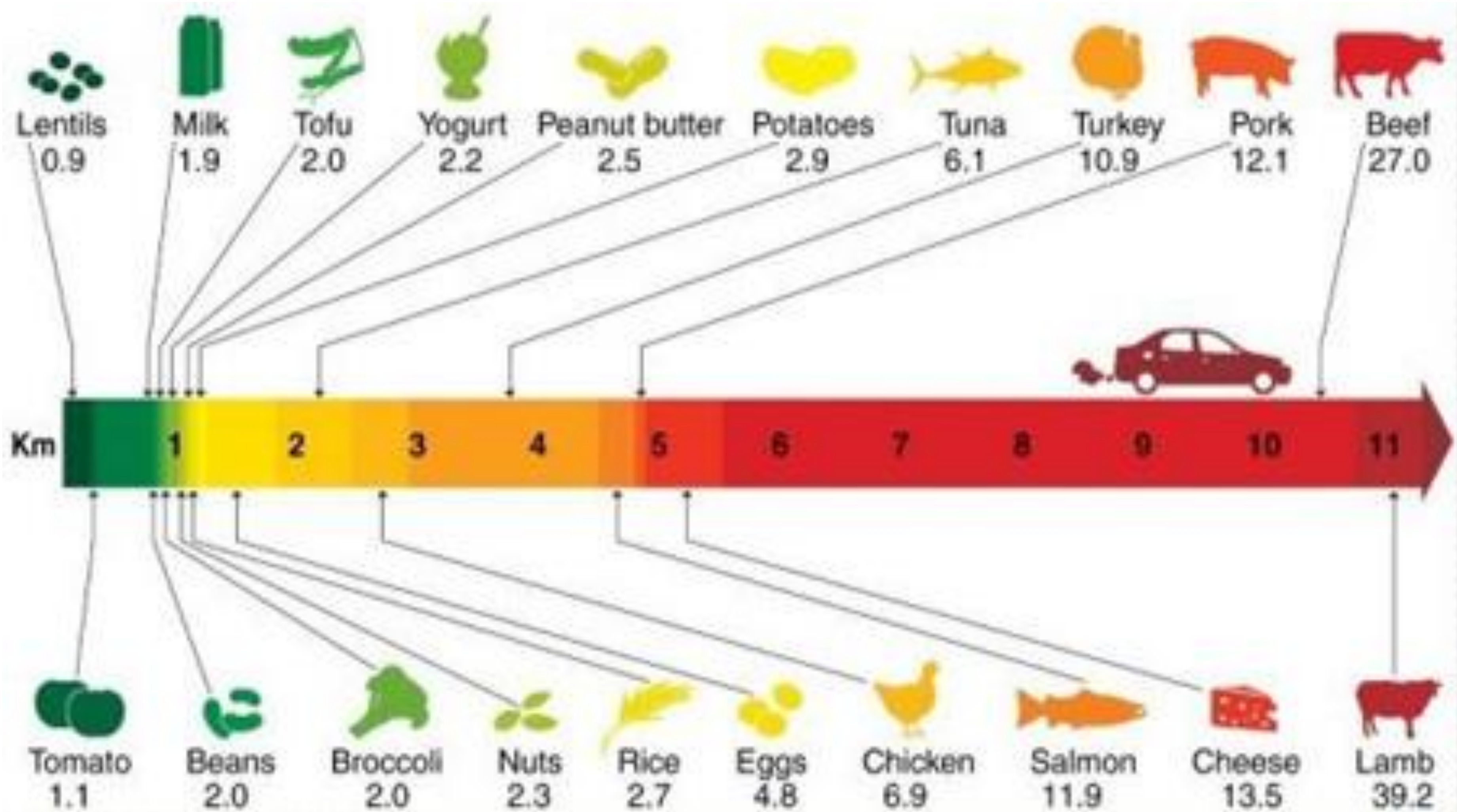
Full lifecycle CO_2 emissions from protein sources



- **Number shows kg of carbon dioxide equivalent produced per kg of food**

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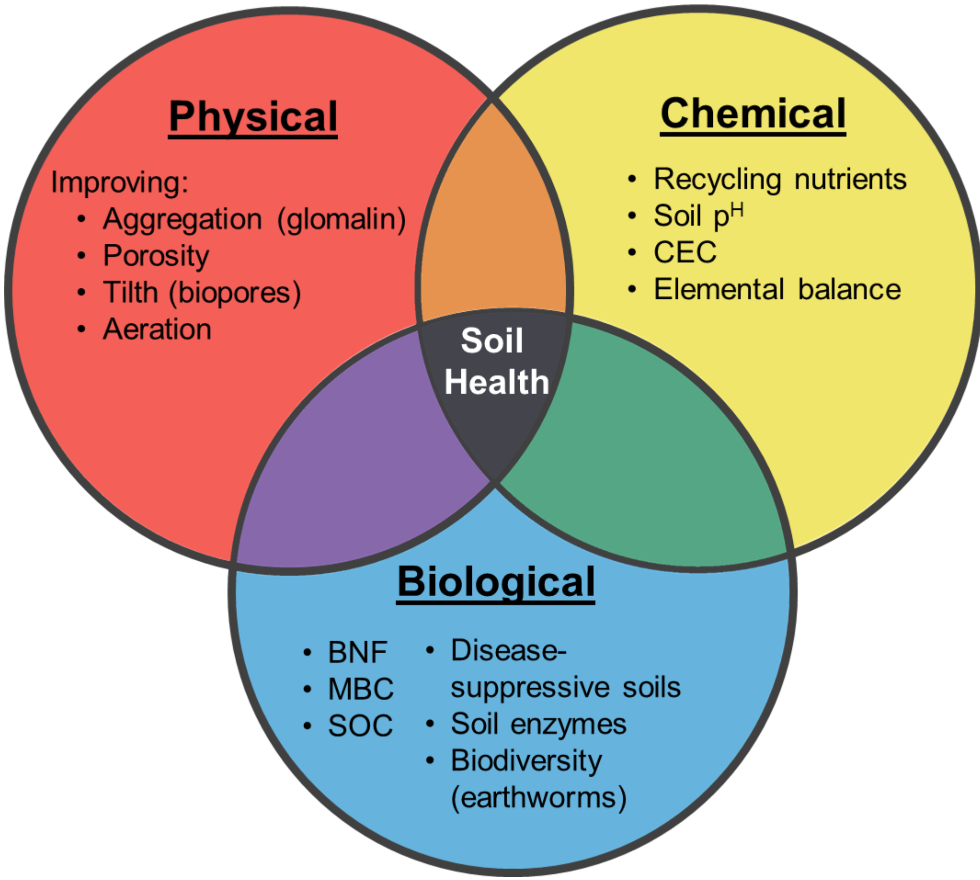
Pulses for Soil Health



- **BNF by crop legumes is estimated at 20-22 million metric ton N/year**
- **70-210 kg/ha N Fixed**

Pulse Crop	BNF (kg/ha)
Lentil	30-120
Chickpea	20-100
Dry Bean	5-70
Faba Bean	80-160

- **Residue of pulses has a lower C:N ratio (17) compared with 41 for oilseed and 32 for wheat.**
- **Negative carbon food print**
- **Thus, pulse in the rotation can impact soil health**

Pulses offer scope for diversification of cereal systems

- **Intensification of cereal based CS by inclusion of pulses as catch crop**
- **Diversification of cereal based CS by replacement**
- **Introduction in Rice-fallows in South Asia**
- **New niches such as winter planting**
- **Market opportunities for rural income**

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Carbon Footprint of various Cropping Systems

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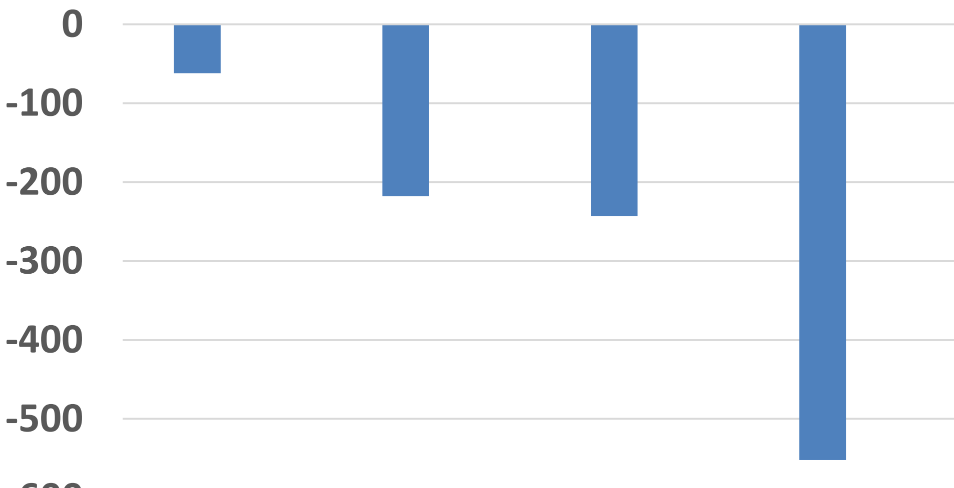
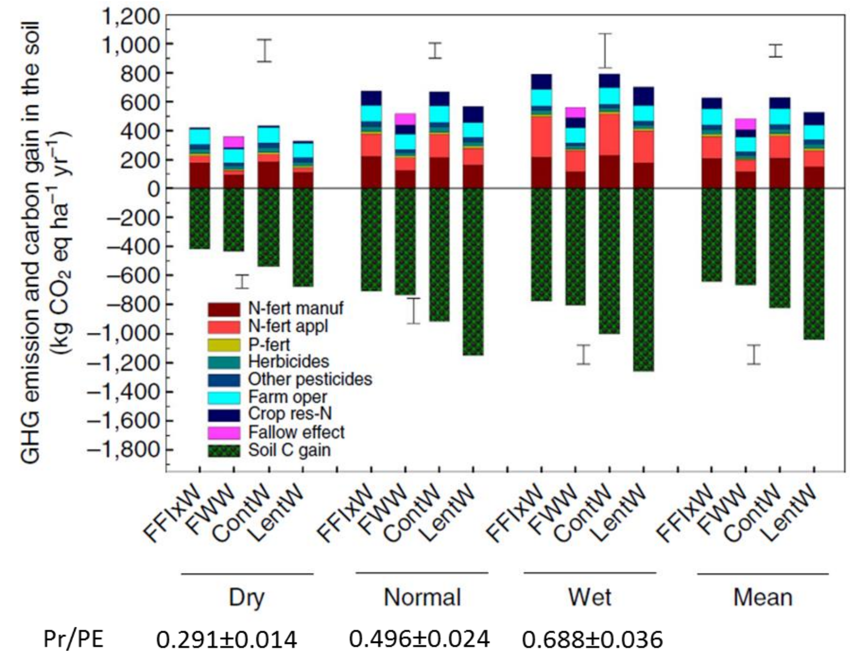
- The negative carbon footprints indicate that the production of a system sequesters more CO_2 from the atmosphere than is emitted (a net sink of CO_2).



	FFLxW	FWW	ContW	LentilW
Per ha	-62	-218	-243	-552
Per kg	-0.027	-0.164	-0.151	-0.377



Carbon emission (top) and sequestration (bottom) for alternative wheat cropping systems

Source: Gan et al., 2014

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Pulses in Cropping Systems – Soil Organic Carbon

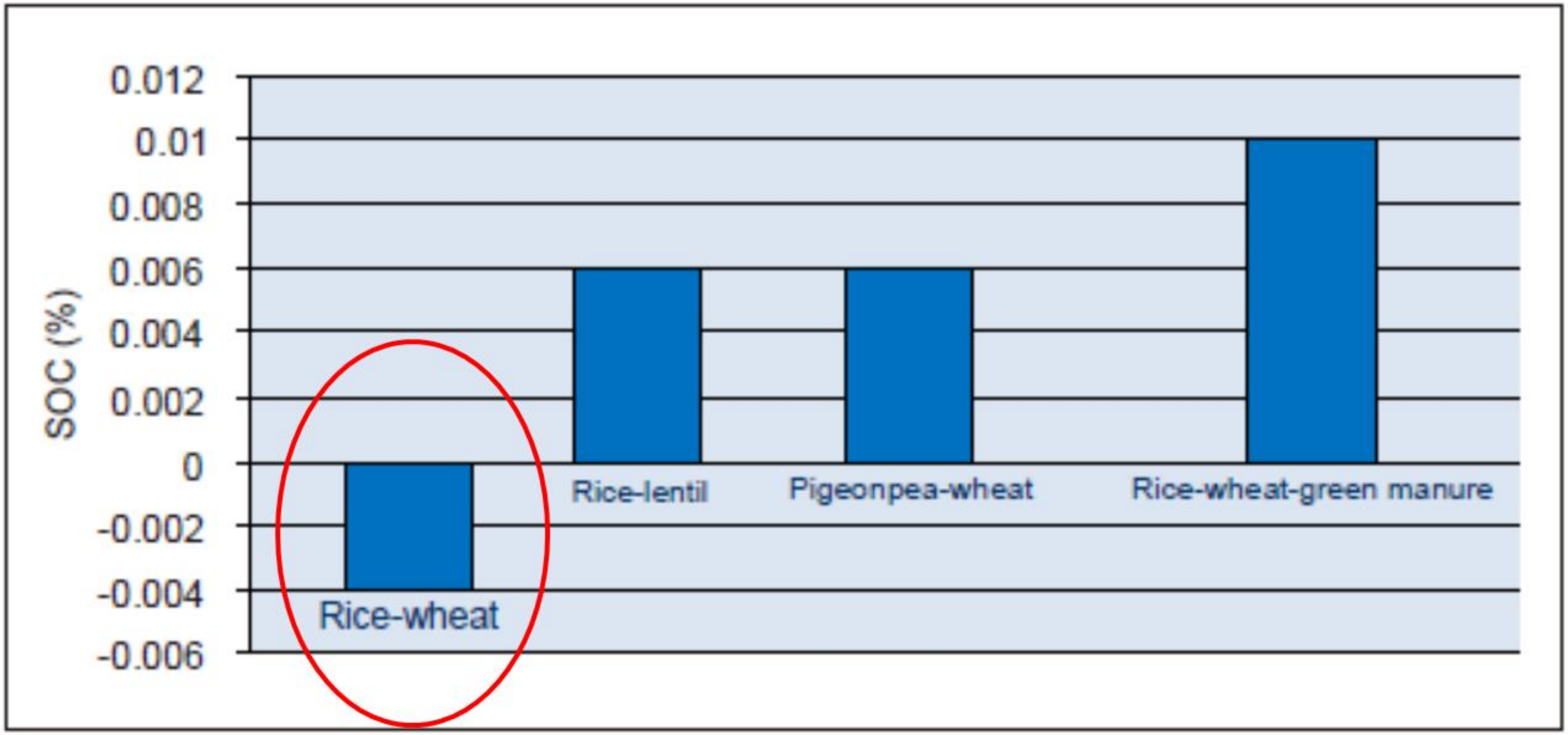

Fig.5 Changes in soil organic carbon (%) due to different pulse based cropping system
(Source: Singh *et al.*, 1996)

PULSES – Nitrogen economy in cereal-legume rotation

Preceding pulse crop	Following cereal	Fertilizer N- equivalent (kg N/ha)
Chickpea	Maize	60
Chickpea	Rice	40
Pigeonpea	Wheat	40
Mungbean	Rice	40
Urdbean/mungbean	Wheat	30
Lentil	Maize	30
Fieldpea	maize	25
Rajmash	Rice	10
Cowpea	Rice	40
Cowpea	Wheat	43

(Source: Subbarao, 1988)

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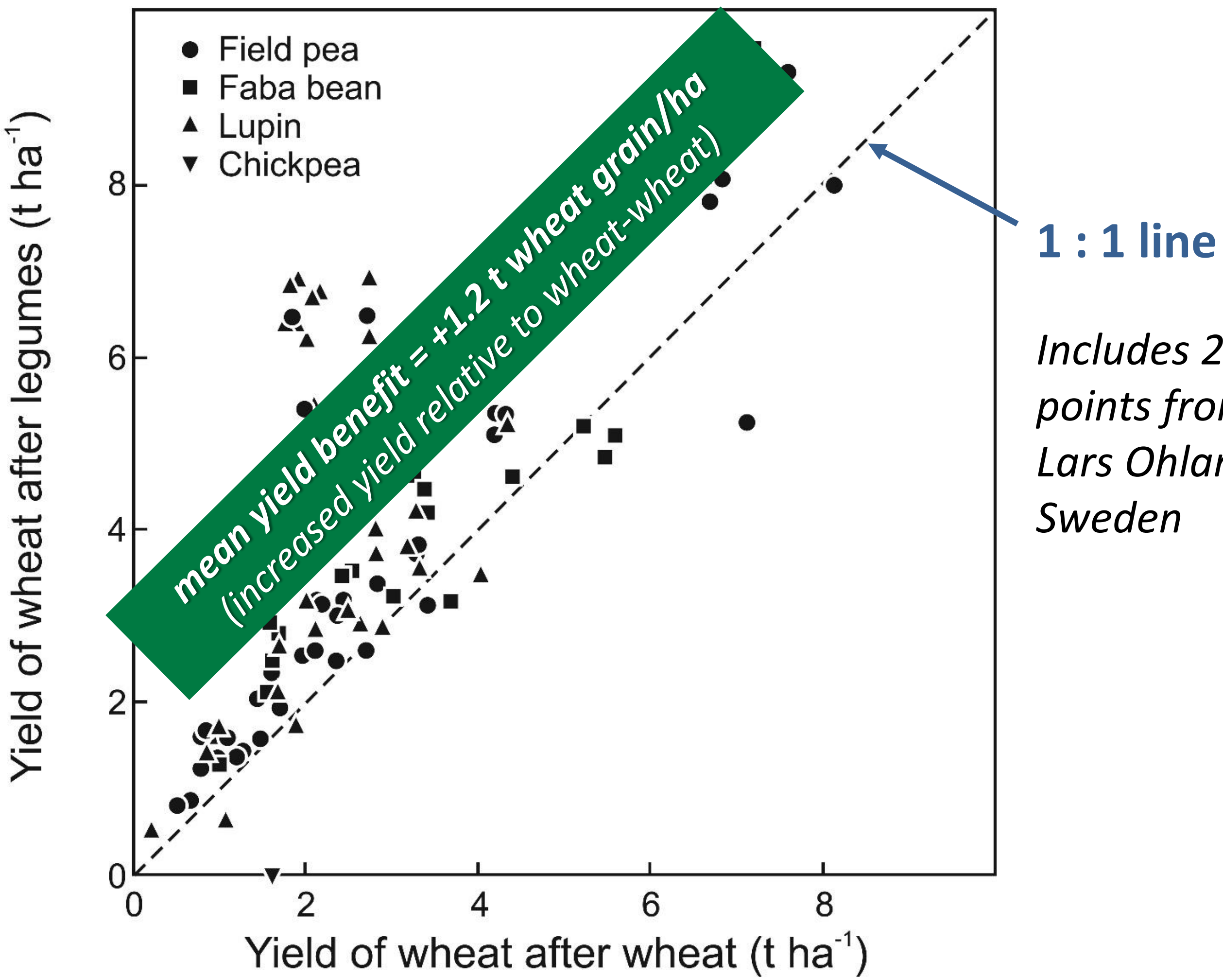
Rotational Benefits on Following Cereal Crops



Includes 20 data points from Lars Ohlander, SLU Sweden

Source: Angus *et al* (2008) Australian Agronomy Conf, Adelaide , Australia.
www.regional.org.au/au/asa/2008/concurrent/rotations/5786_angusjf.htm

Rotational Benefits on Following Cereal Crops

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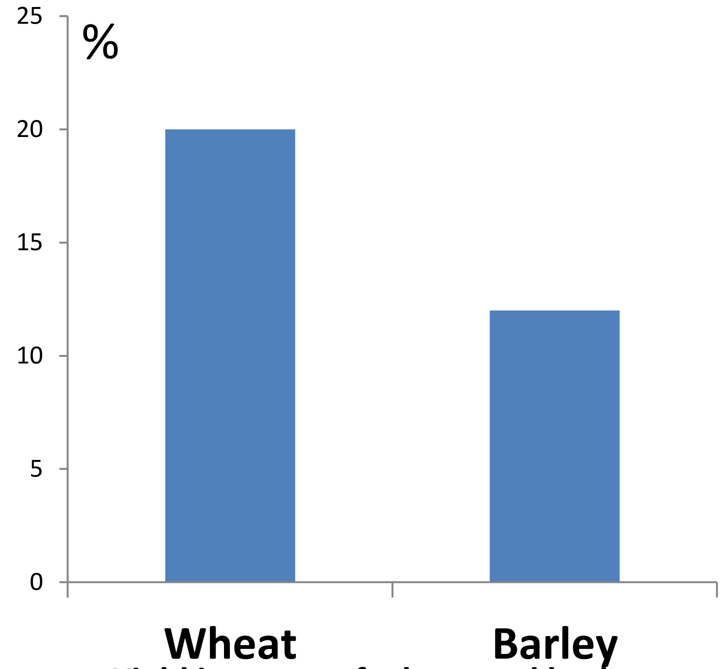
Impact of faba bean on N dynamics of following wheat crop

Parameter	Cropping sequence	
	Faba bean–Wheat	Barley–Wheat
Residue N from faba bean or barley (kg N ha^{-1})	96[b]	73[b]
Wheat N at maturity (kg N ha^{-1})	97	59
Wheat N benefit from legume (kg N ha^{-1})	38[c]	
Apparent recovery of faba bean N (%)	40[d]	
^{15}N-based estimated recovery of faba bean N (%)		
From shoot residues	3[e]	
From nodulated roots and rhizodeposition	8[e]	
Total	11[e]	



Yield increase of wheat and barley after faba bean

- **Wheat, barley or cotton crop grown after faba bean may recover between 11 and 17% of the plant N remaining after faba bean (NRAFB)**
- **NRAFB represent 2-19% of the total N requirement of those following crops**

Jensen et al. 2010

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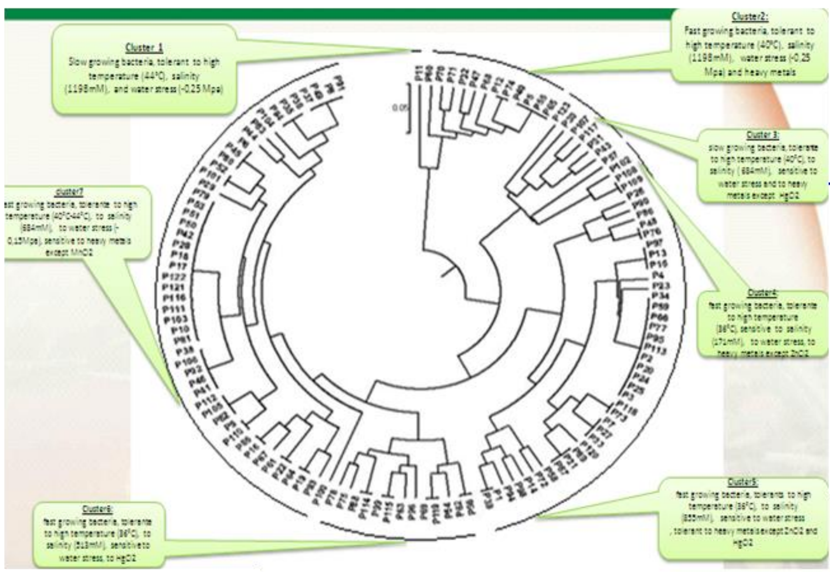
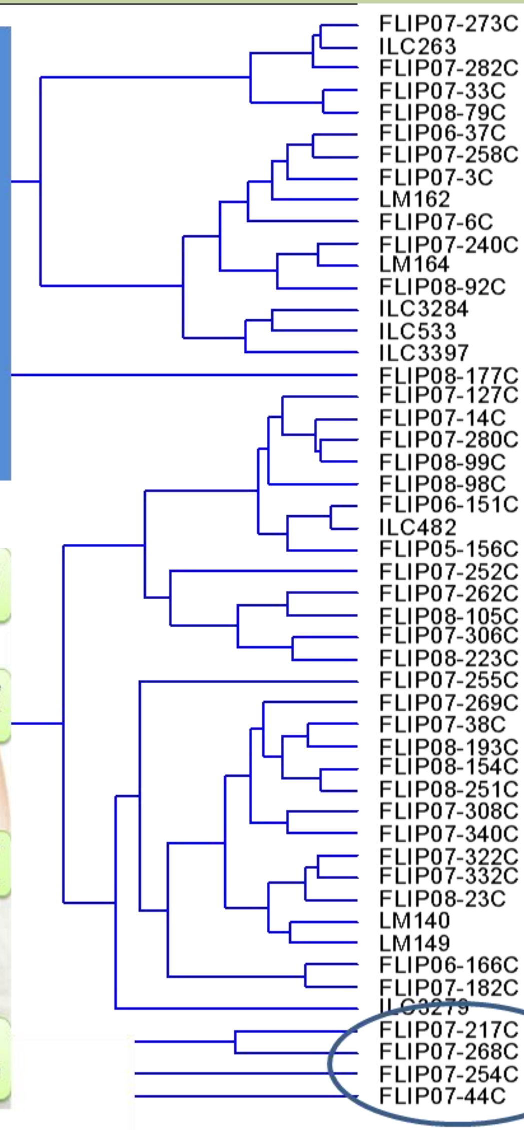
- ICARDA- Rhizobium repository
- Super nodulating lines identified
- Rhizobium tolerant to high temperature (40°C), salinity (1198mM), water stress (-0.25 Mpa) and heavy metals
- *N2 Africa project*

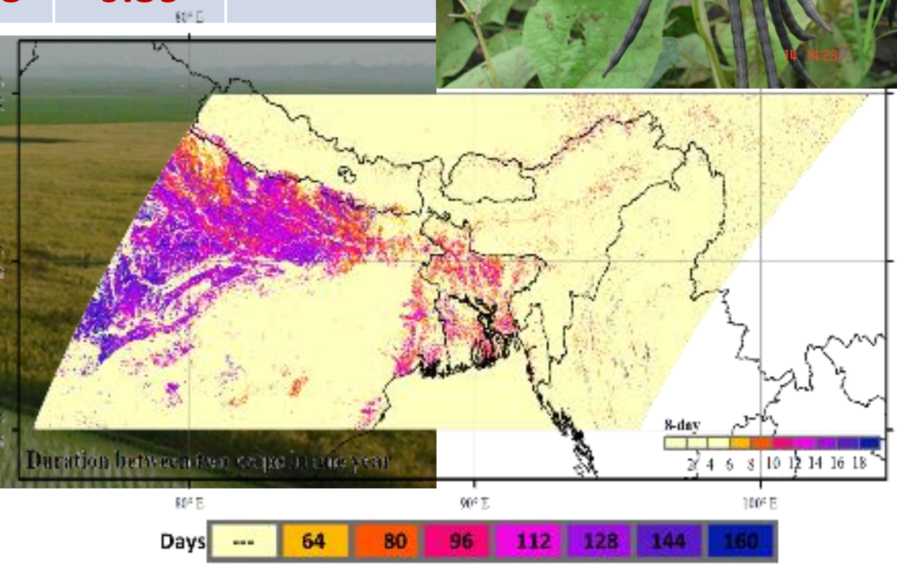




Rice based production systems in South Asia

	System	Bangladesh	India	Nepal	Pakistan
Irrigated	Rice-Rice	4.50	4.70	0.30	-
	Rice-Rice-Rice	0.30	0.04	-	-
	Rice-Wheat	0.40	10.30	0.57	2.20
	Rice-Vegetables		1.40		
Rainfed	Rice-Maize	0.35	0.53	0.43	-
	Rice- pulses	0.60	3.50	0.15	-
	Rice-fallow	2.11	11.65	0.39	-

- Nutrient deficiencies.
- Declining factor productivity
- Decline in ground water table
- Formation of hard pan in sub-soils



Source: Jat et al. 2011

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Performance of extra early lentils in Bangladesh

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Genotype	Duration (Days)	Grain yield (Kg/ha)
BLX-05008-15	77-82	1316
BLX-05008-05	77-84	1283
BLX-05008-22	84-89	1267
BLX-05008-02	77-81	1125
LRIL-22-70	92-110	2267
LRIL-21-68	93-103	1867
LRIL-22-133	90-102	1697
LRIL-22-61	88-101	1467
LRIL-22-205	93-100	1353

Monsoon Rice (July-Oct)

Super-early legumes Nov-Jan (<90 days window)

Boro Rice (Feb-June)

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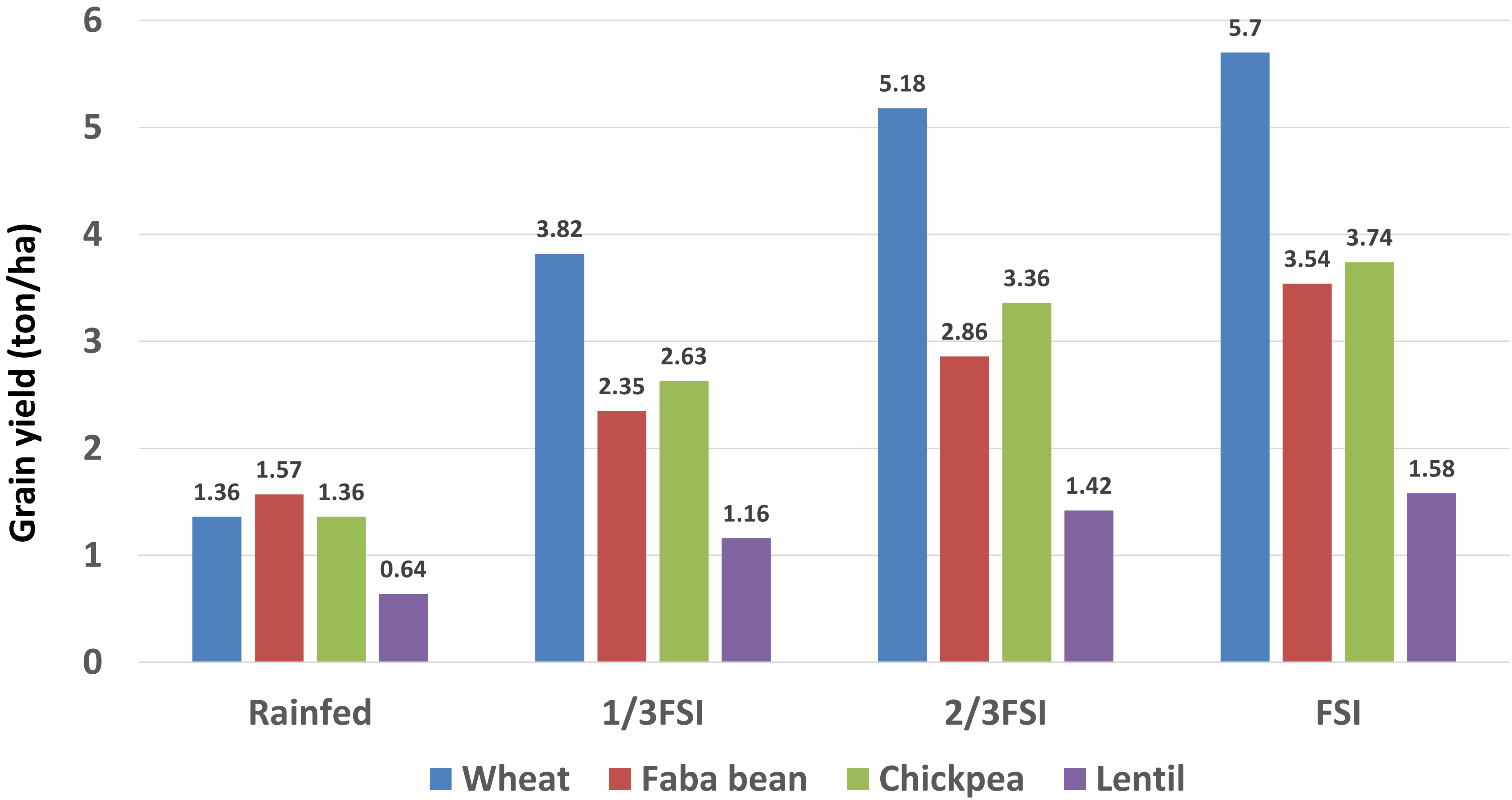
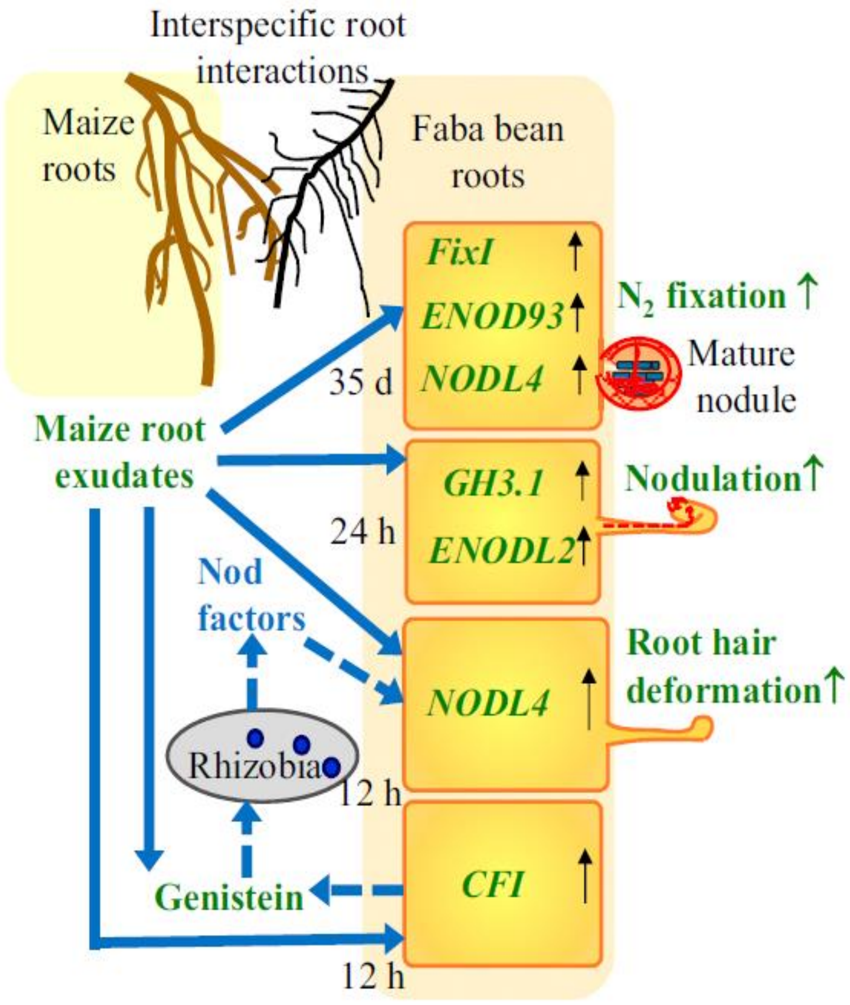
Substitution of cereals in rainfed areas

Grain yield of wheat and legumes under rainfed vs irrigation



Tel Hadya, 2007-2010

Benefits of Faba bean/maize intercropping



- **Enhanced productivity, nodulation and N2 fixation of faba bean through interspecific root interactions.**
- **Faba bean biomass and grain yield increased by 35% and 61%.**
- **Root exudates from maize increase**
  - **root hair deformation and nodulation in faba bean,**
  - **double exudation of flavonoids**
  - **up-regulate the expression of a chalcone–flavanone isomerase gene involved in flavonoid synthesis, and genes mediating nodulation and auxin response**

Source: Lee et al., 2016 (PNAS)

Adaptation: Drought Tolerant Varieties of Pulses

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Gokce is used on about 85% of the chickpea production areas (over 550,000 ha). With a yield advantage of 300 kg/ha over other varieties, and world prices over USD 1000/t, this represents an additional USD 165 million for Turkish farmers, in 2007 alone.

The Kabuli chickpea, 'Gokce', developed by ICARDA and Turkish national scientists, has withstood severe drought in Turkey and produced when most other crops failed in 2007.

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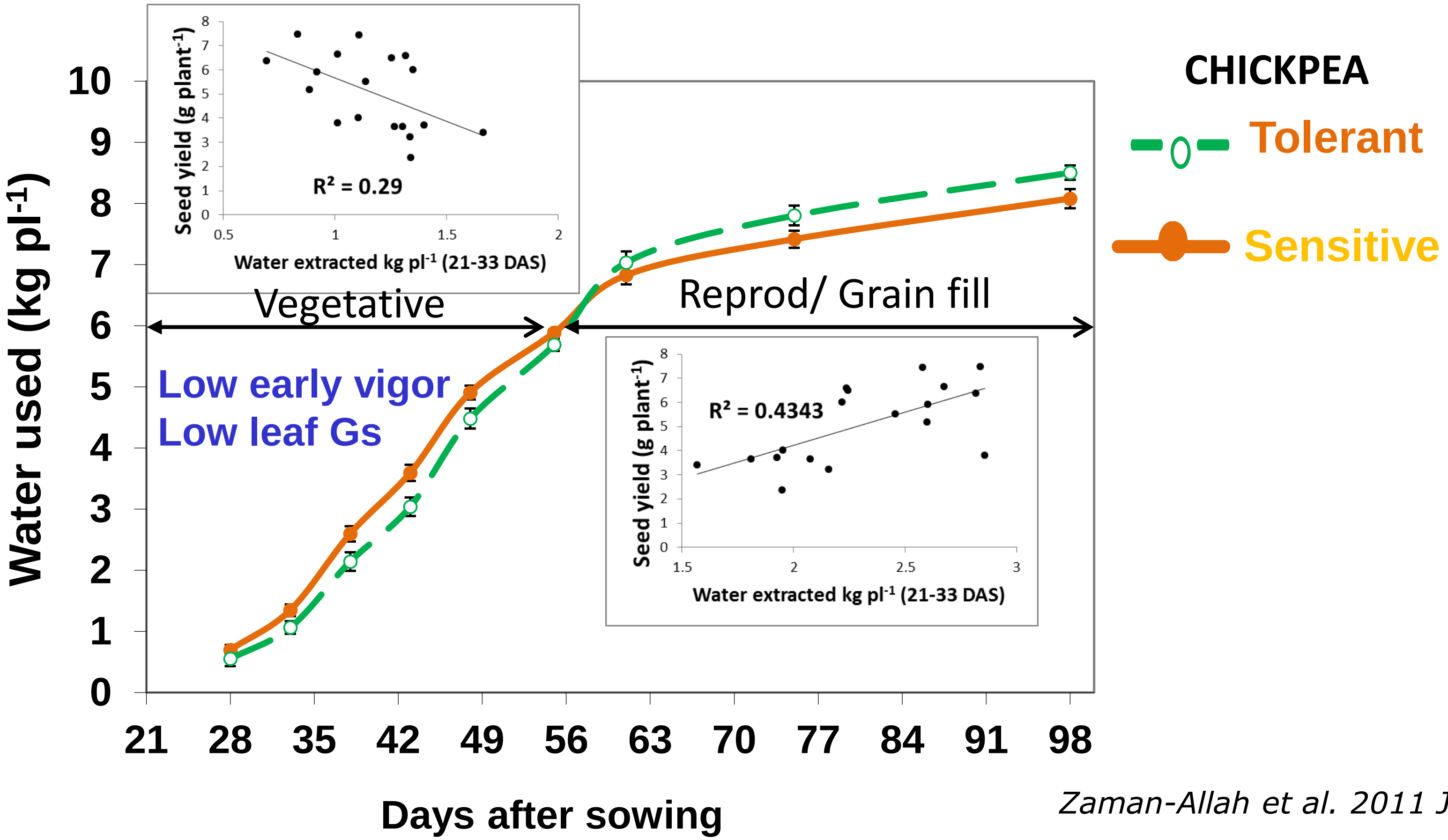
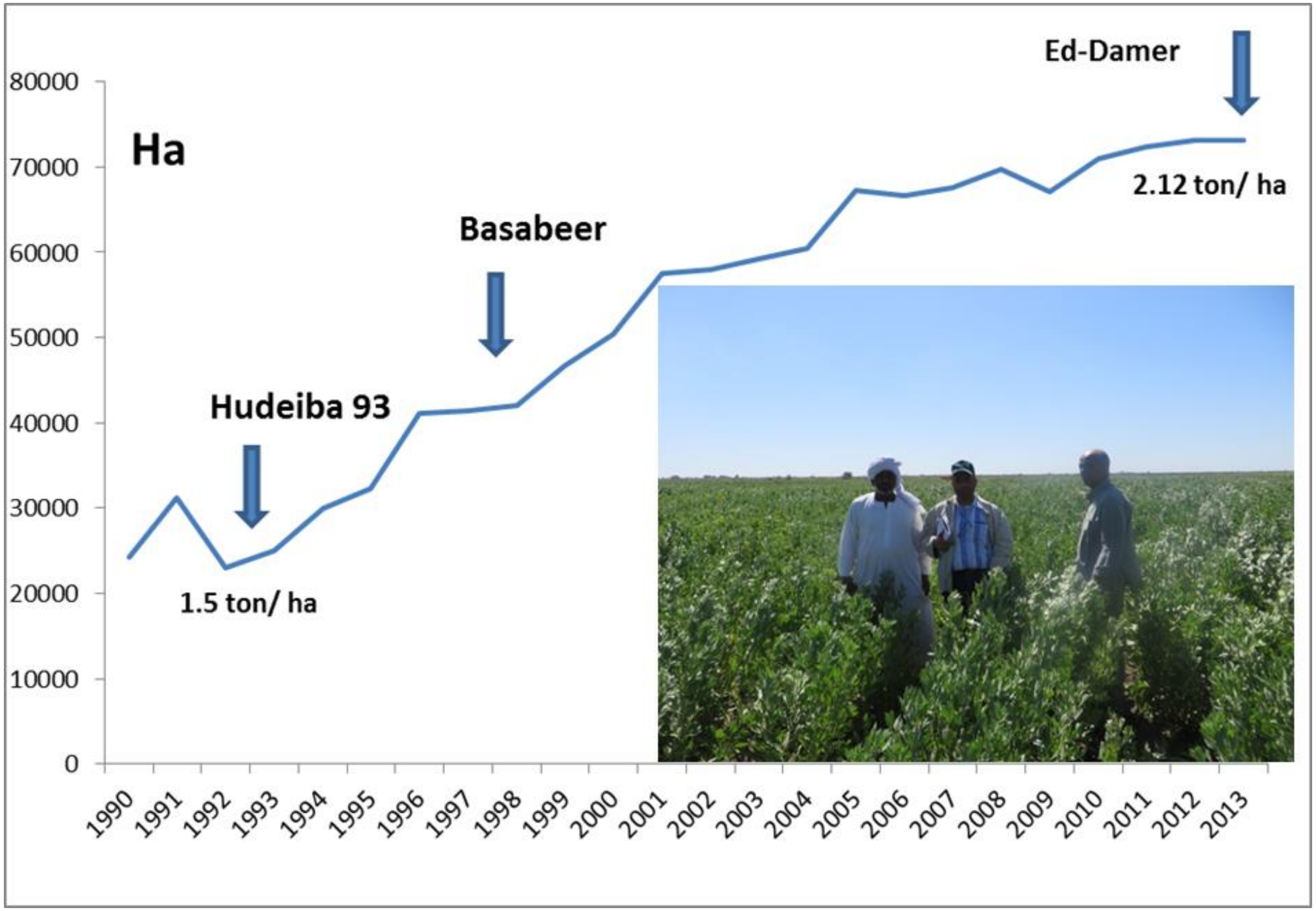
Adaptation to Drought: water use efficiency



Zaman-Allah et al. 2011 JXB

Tolerant: less WU at vegetative stage, more water left for reproduction and grain filling

Adaptation: Heat tolerant faba bean in Sudan



Production increased from ~40,000 t in nineties to 150,000 t at present.

- **Increase in area (~20000 ha in nineties to ~70000 ha)**
- **Productivity from 1500 to 2120 kg/ha**

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Pulses: A potential whole food solution

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Effect of lentil diet on anemic Sri Lankan Children after 60 Days

Indicator	0 days	60 days	% improvement
Hemoglobin (g/dL)	11.1	11.8	6.3
Serum Fe (µg/dL)	51.5	89.8	74.4
Total Fe binding capacity (µg/dL)	405.3	377.6	-6.8
Trans ferritin saturation (%)	12.8	24.3	89.8
Serum ferritin (ng/mL)	29.5	41.2	39.7

50g of pulses is a good source of Fe, Zn, and Se

Nutrient	Lentil	Field pea	Chickpea	Rice
Protein (%)	20 - 27[a]	20 - 23[d]	19-20	2.9
Se (µg kg^{-1})	425 – 672[a]	373-519[d]	450-850	93
Fe (mg kg^{-1})	73 – 90[b]	44-55	50-55	2.4
Zn (mg kg^{-1})	44 - 54[b]	20-30	20-32	3.7
Phytic acid (mg g^{-1})	1.8 - 4.4[c]	2.2 – 8.2	4.9 – 6.1	7.2-11.9

- Three times richer in protein as compared to rice
- Complementary Amino acid profile with cereals
- Micro-nutrient rich grains
- Rich in probiotic carbohydrates

Source; Pallemulle, Thavarajah, Thavarajah et al. unpublished data, 2013

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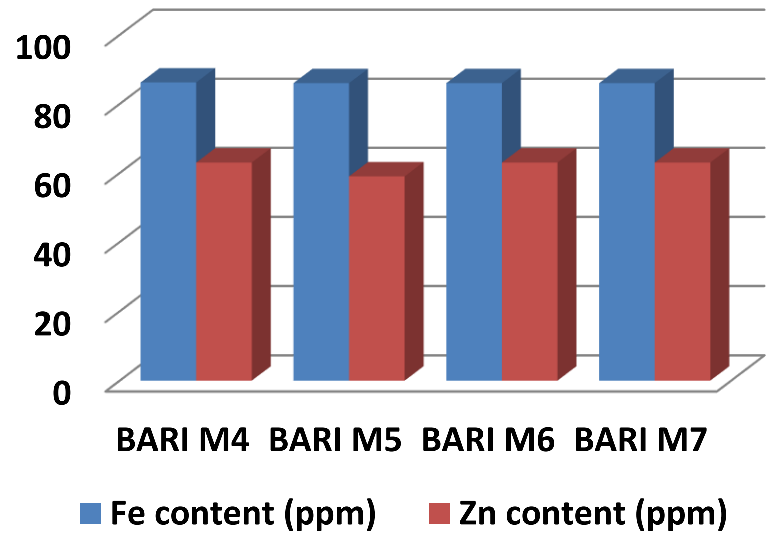
Impact on biofortified lentils in Bangladesh

- **Five bio-fortified varieties (BARI M4, M5, M6, M7 and M8) released and now cover ~90,000 ha area**
- **Average production 1.3 t/ha**
- **Producing 115,000 ton micronutrient dense lentil**

Fe and Zn contents of lentil varieties released in Bangladesh




New lentil variety BARI M7

Take Home Message

- Today's agriculture is expected to produce more than just food as we are heading fast towards a C-rich N-poor world which will result into a catastrophe.
- To slow down the pace, we need to include more pulses not only in our plates but also in the planet for the following ecosystem services:
    - Protection of soil, water and fossil resources
    - Crop rotation benefits
    - Enhanced farmland biodiversity.
    - Reduced greenhouse gas emissions.
    - Adaptation to climate change
    - Healthy and sustainable foods.

Thanking you