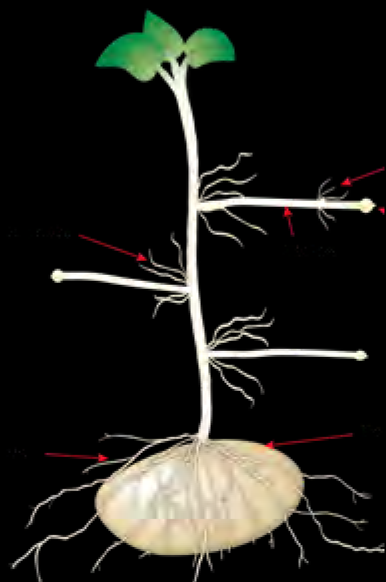

Potatoes, Water and Mineral Elements

Philip J. White

John Bradshaw, Tim George (SCRI)
John Hammond, Andrew Thompson (Warwick)

Improving International Potato Production, 2008

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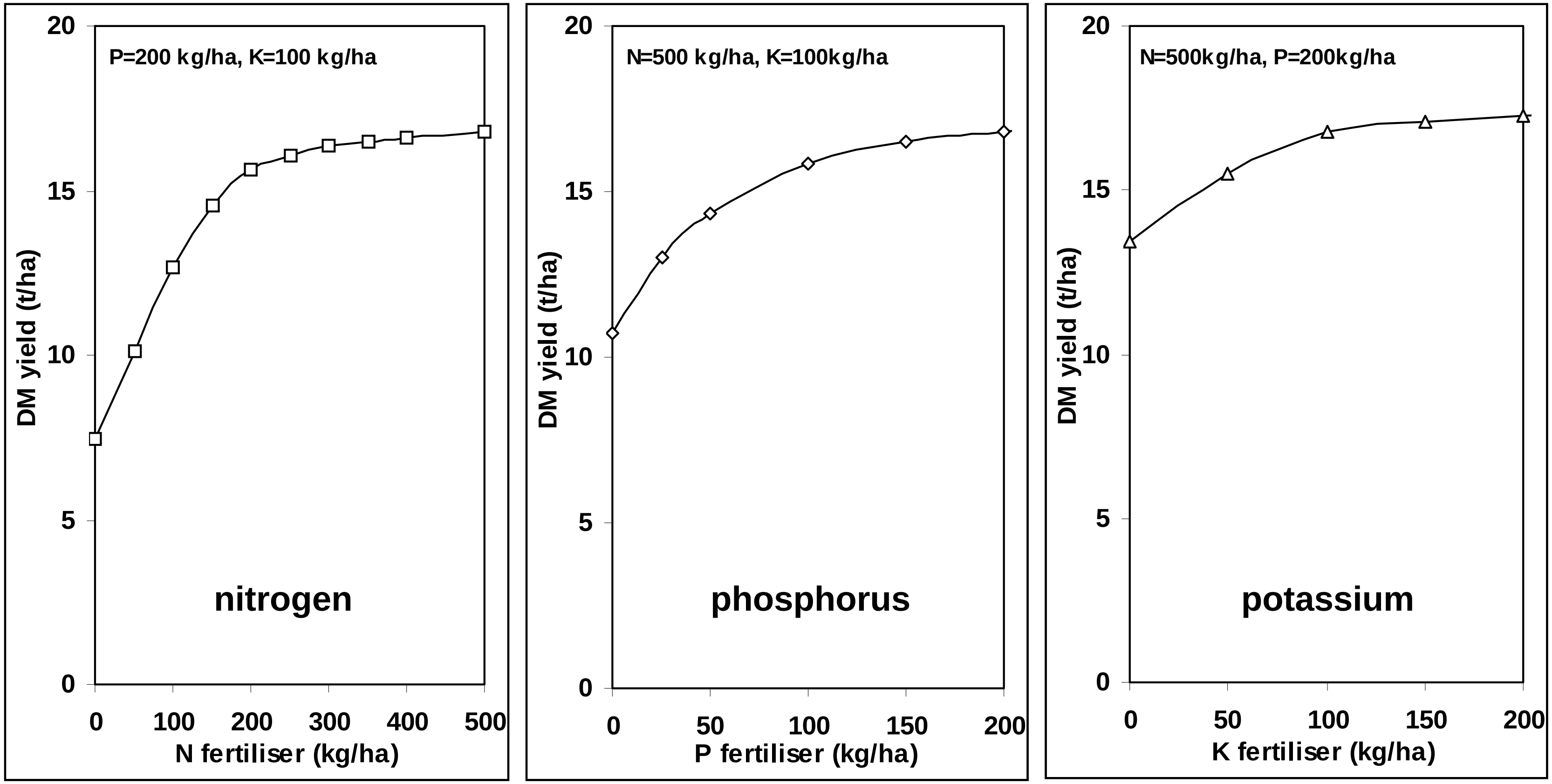
Clean Water and Essential Mineral Elements



Responses in potato yields to N, P and K fertilisation predicted by simulation models (http://www.qpais.co.uk/)

White et al. (2006) In: Potato Biology and Biotechnology, Advances and Perspectives, pp.739-752

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Potatoes Require High Phosphorus Fertilisation

In Great Britain in 2004:

Potato production occupied ~141,000 ha
(3.1 % of arable land)
P fertilisation of potatoes was ~17,600 tonnes
(9.4 % of inorganic P fertiliser)

Tuber production	**= 6.0 million tonnes**
Tuber P concentration	**= 0.37 kg t^{-1}**
Off take of P in tubers	**= 2,223 t**

Efficiency of P use	**= 13%**

White et al. (2006) In: Potato Biology and Biotechnology, Advances and Perspectives, pp.739-752

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Fertiliser Requirements of the Potato Crop

potato production occupied 3.1 % of arable land

Fertiliser	Fertiliser Consumption	Efficiency of use
Nitrogen	3.1 %	91 %
Phosphorus	9.4 %	13 %
Potassium	11.8 %	73 %

White et al. (2006) In: Potato Biology and Biotechnology, Advances and Perspectives, pp.739-752

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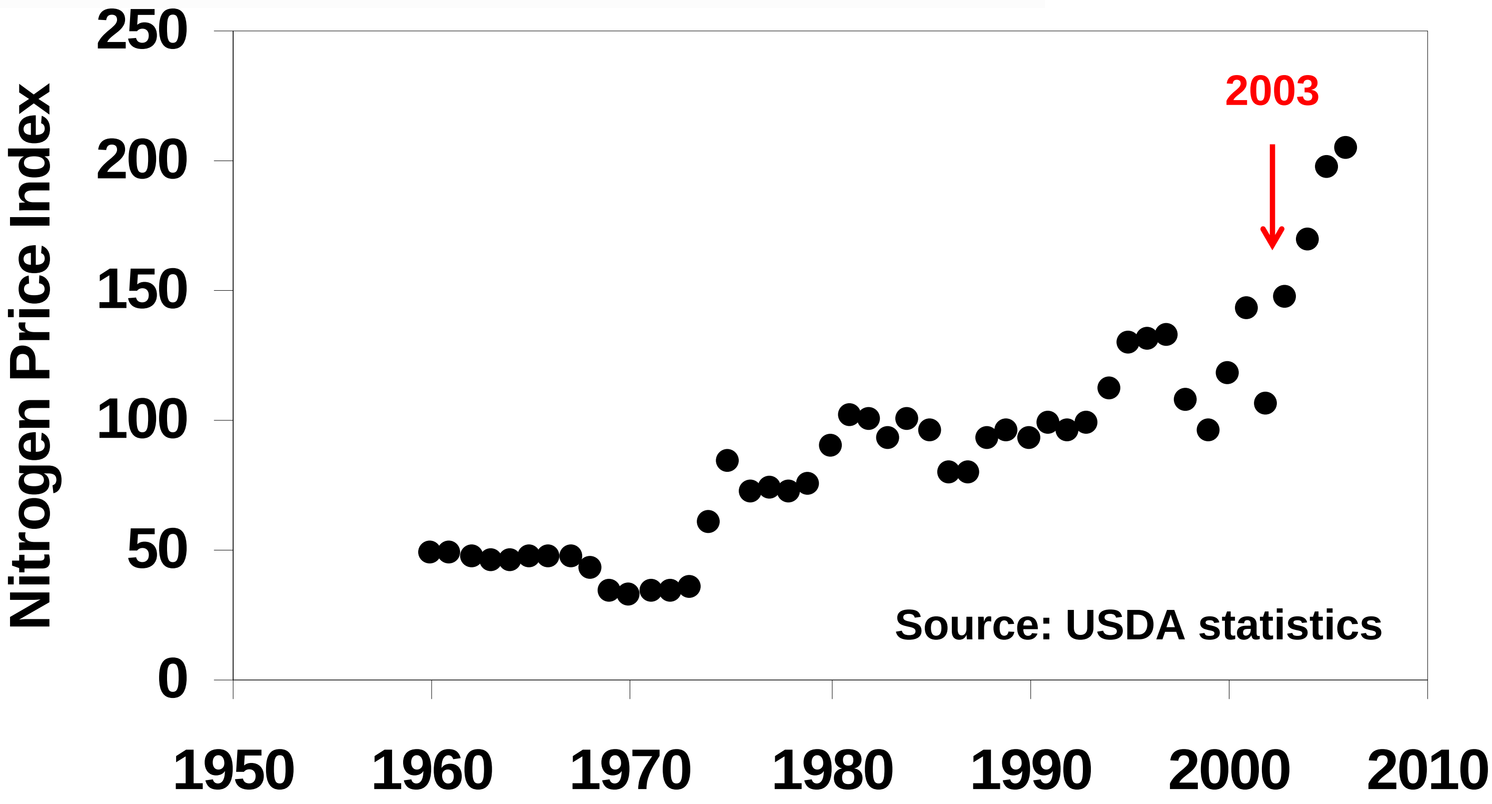
Concerns about Mineral Fertilisers

1. Financial Burden



The Price of Nitrogen Fertilisers (1960-2006)

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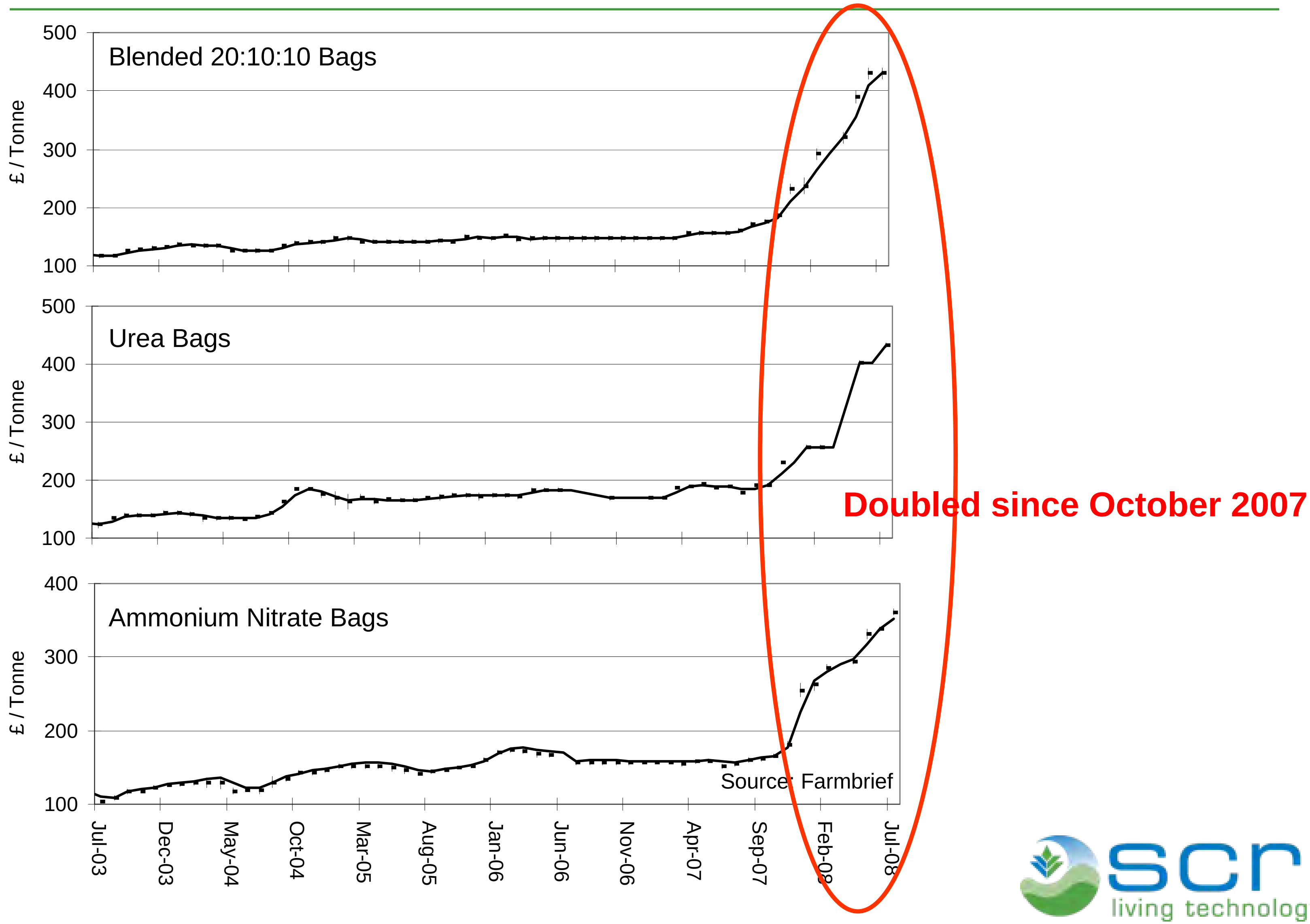
The Price of Nitrogen Fertilisers (2003-2008)



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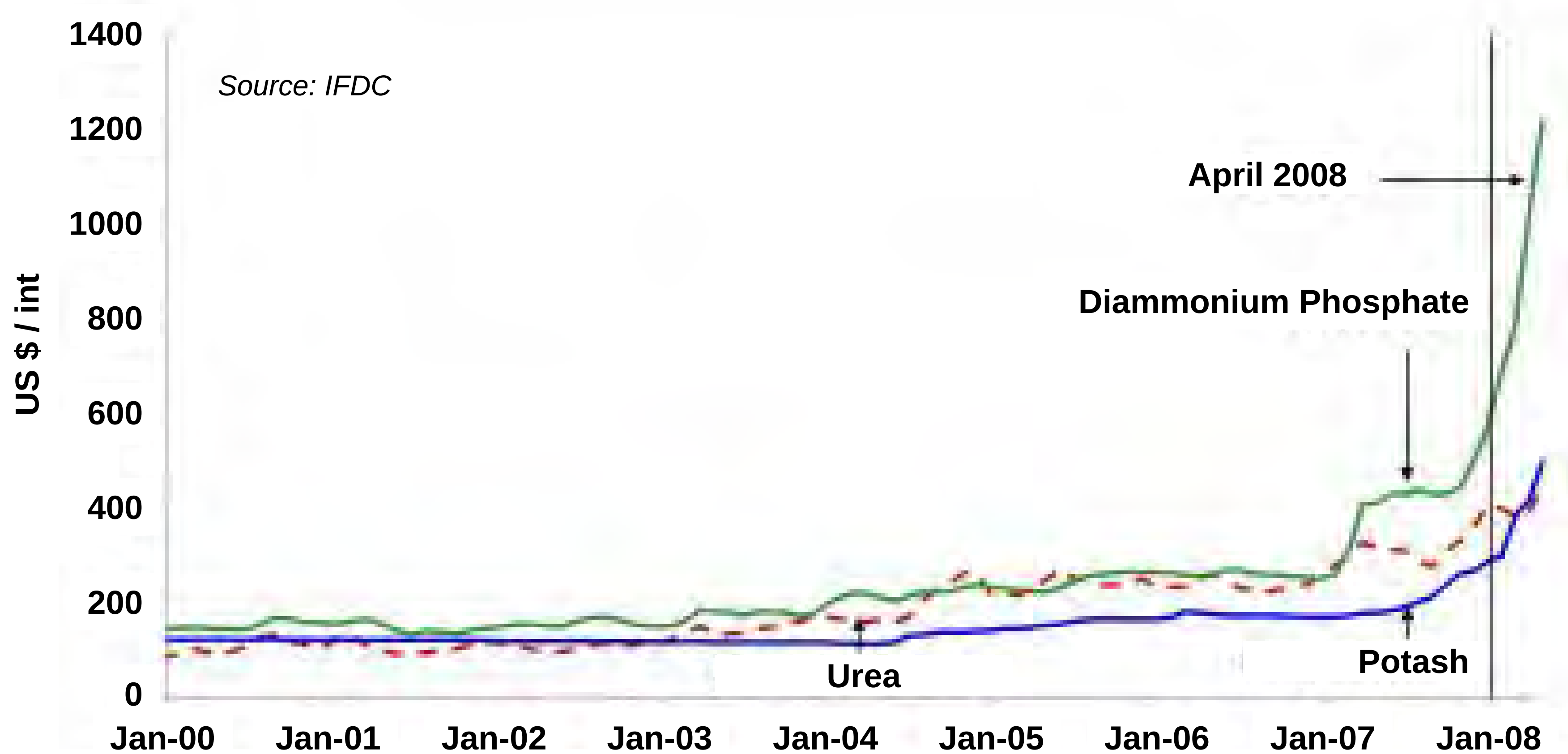
The Price of Fertilisers (2000-2008)



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Rocks are a Finite Resource

1. Financial Burden

2. Finite Resource (P, S, K)

time to exhaust reserve base at the current rate of consumption	
Phosphorus	50 - 100 years
Sulphur	10 - 25 years
Potassium	>100 years

SE Kesler (1994) Mineral resources, economics and the environment. Macmillan, New York

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Fertilisers and the Environment

1. Financial Burden
2. Finite Resource (P, S, K)
3. Environmental Pollution:
    a) CO_2 produced during manufacture (N)
    b) Toxic impurities
    c) Nitrates in produce and water
    d) Eutrophication (algal blooms)

Phosphate fertilisation is of particular concern

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Improving Fertiliser Use Efficiency

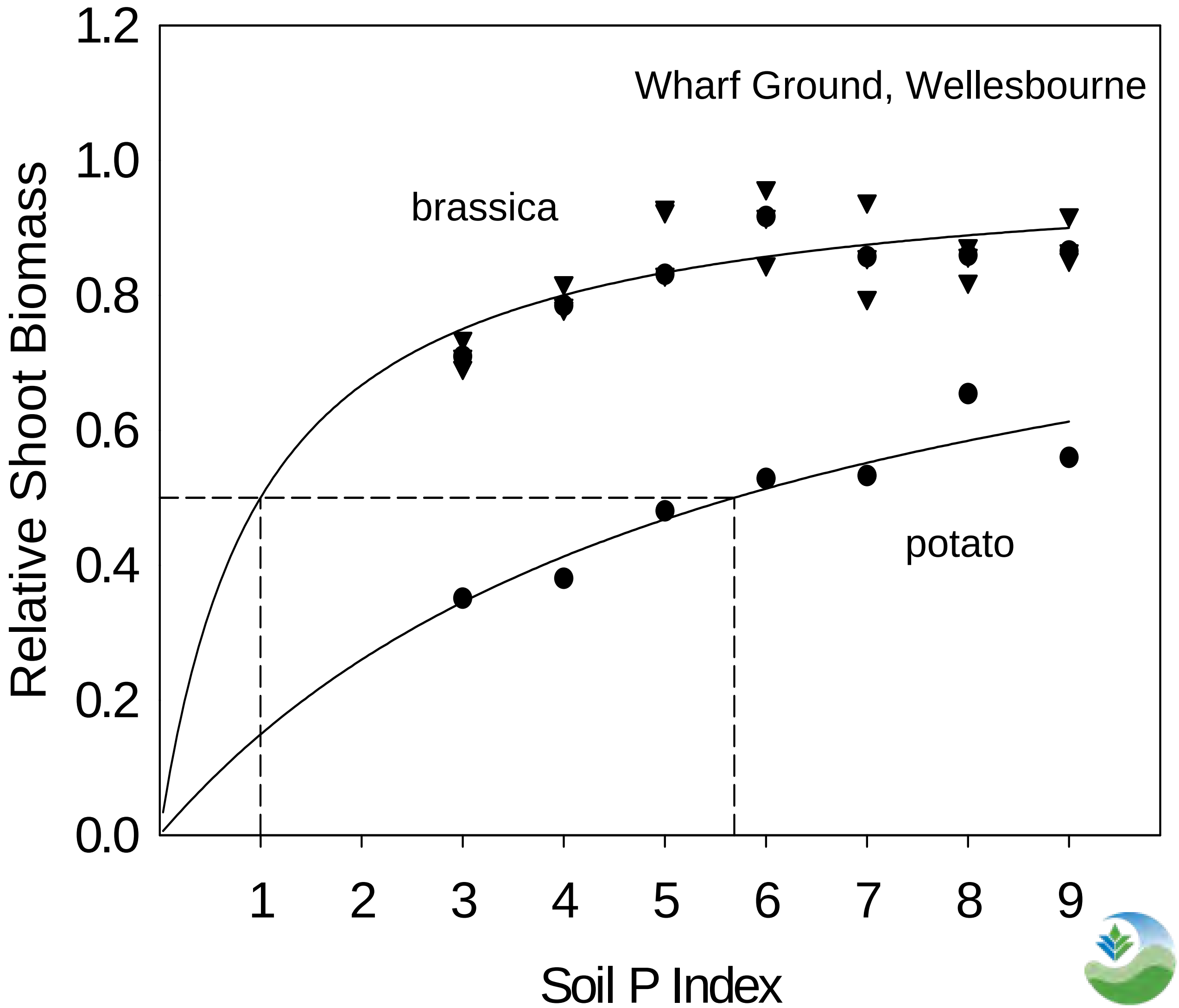
Through Agronomy

soil management, placement, scheduling, decision support

Through Genetics

select or breed varieties that require or consume less fertiliser

Potatoes Respond Poorly to P Fertilisation



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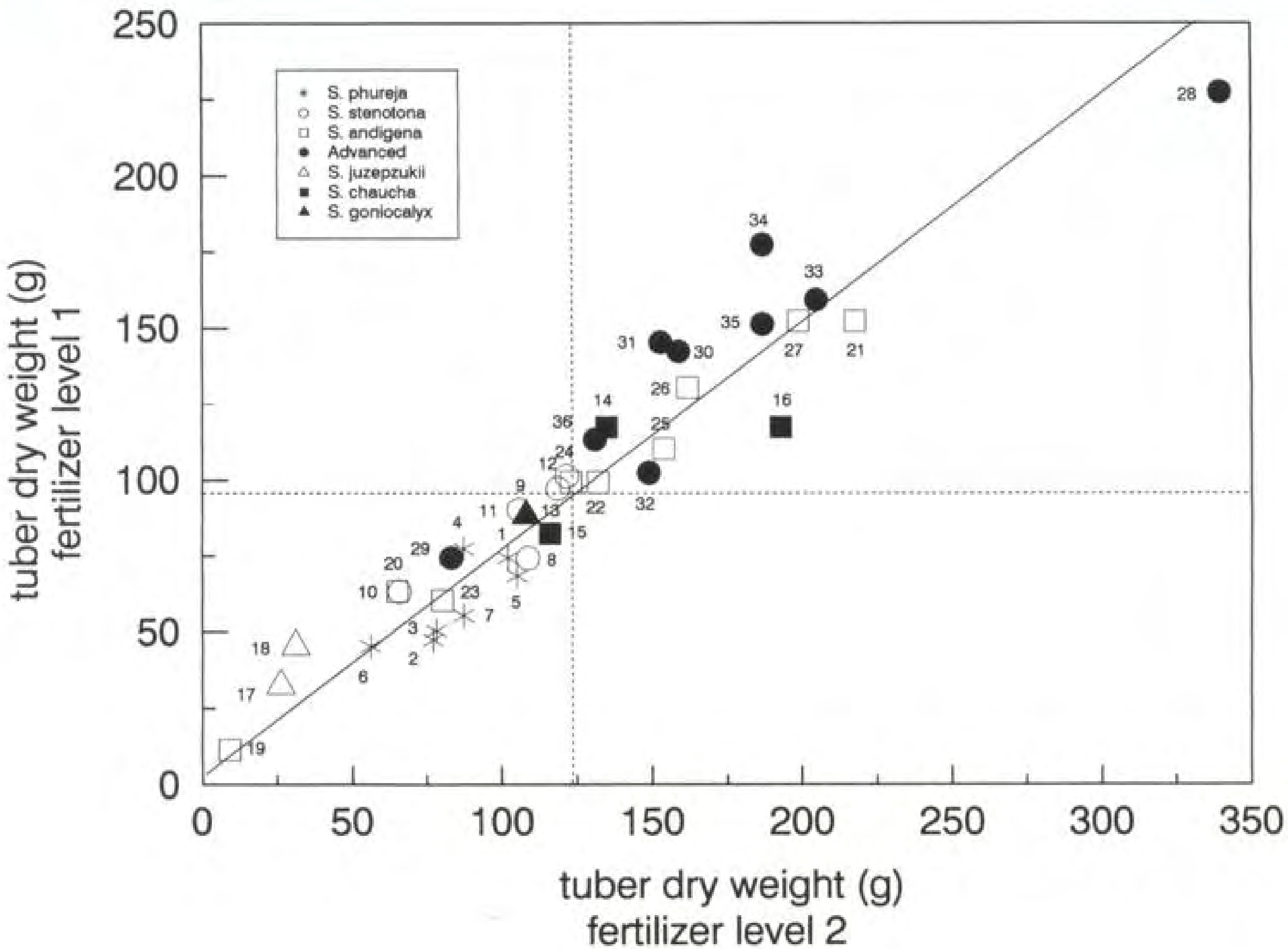
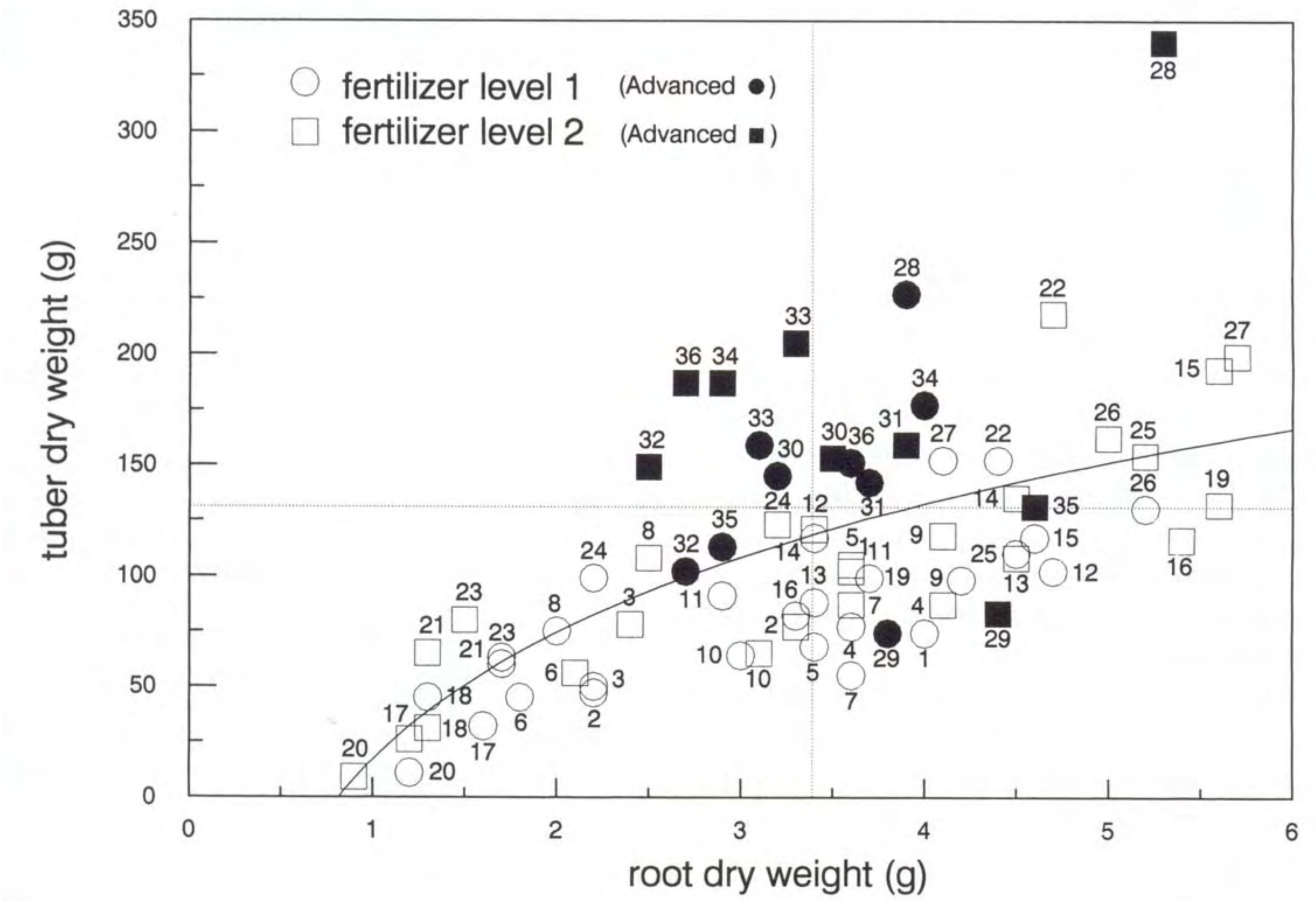
Solanum Species have Similar P Responses



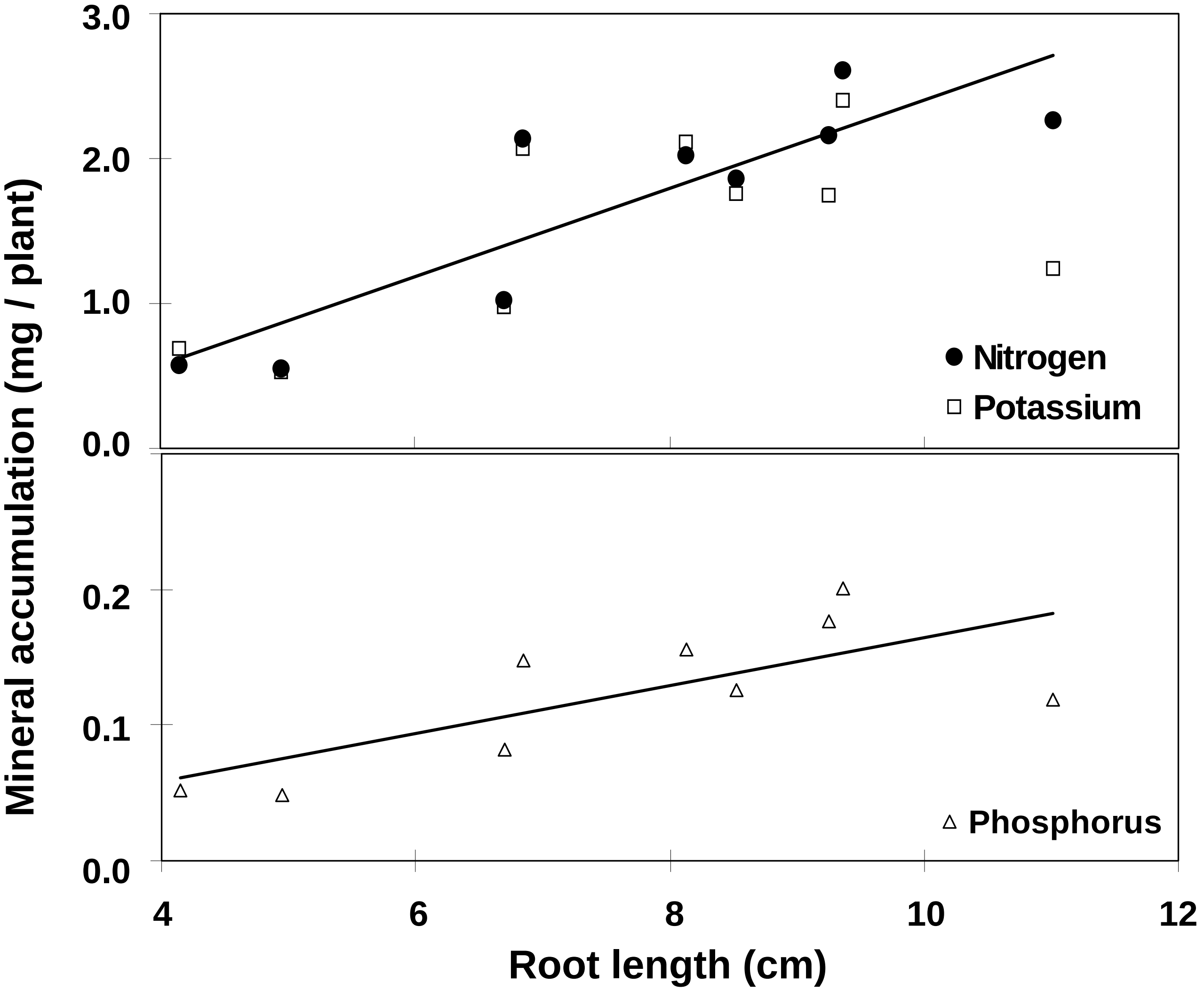
Sattelmacher et al. (1990) Plant & Soil 129, 227-233

Tuber Yield is Directly Related to Root Size

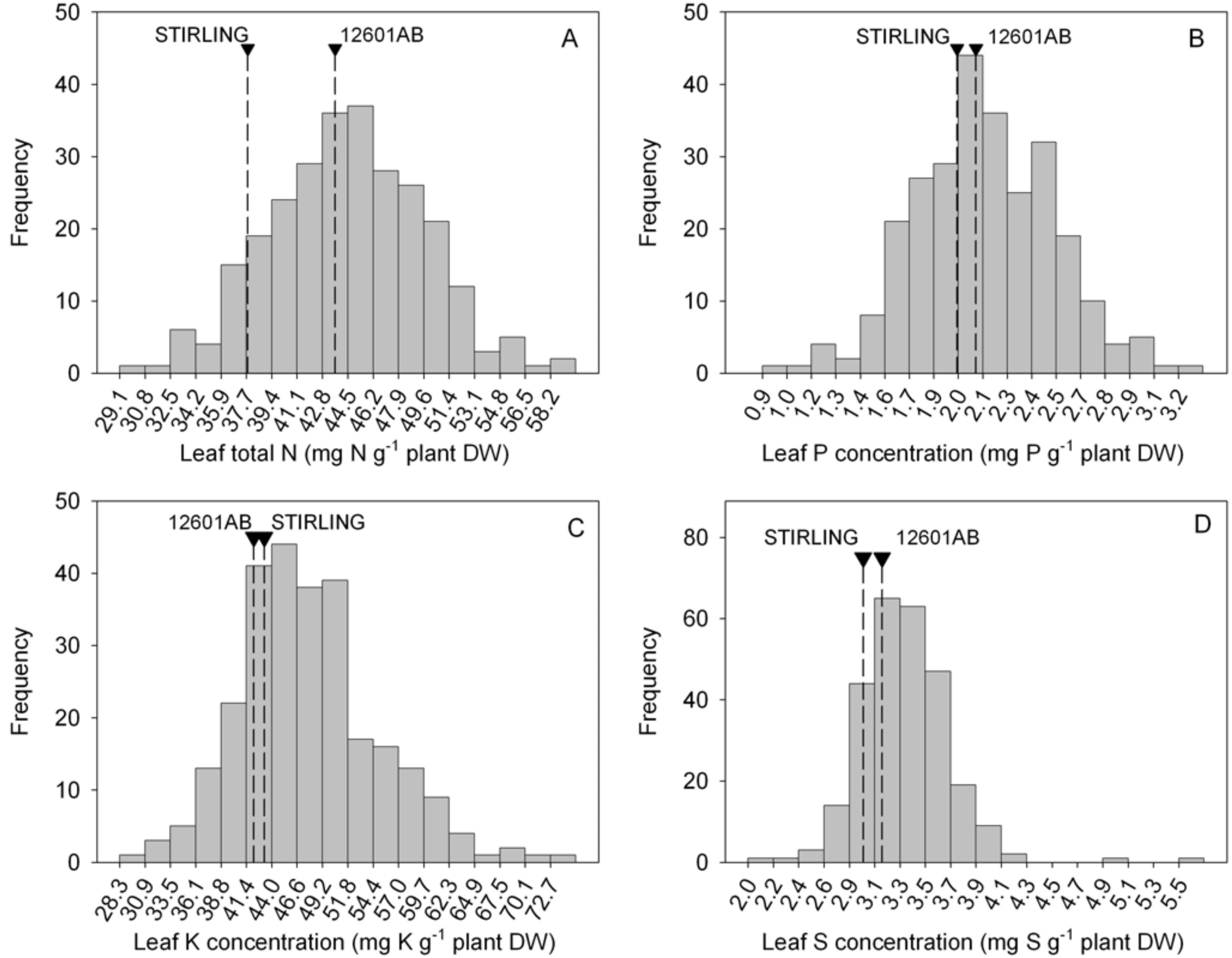


Sattelmacher et al. (1990) Plant & Soil 129, 227-233

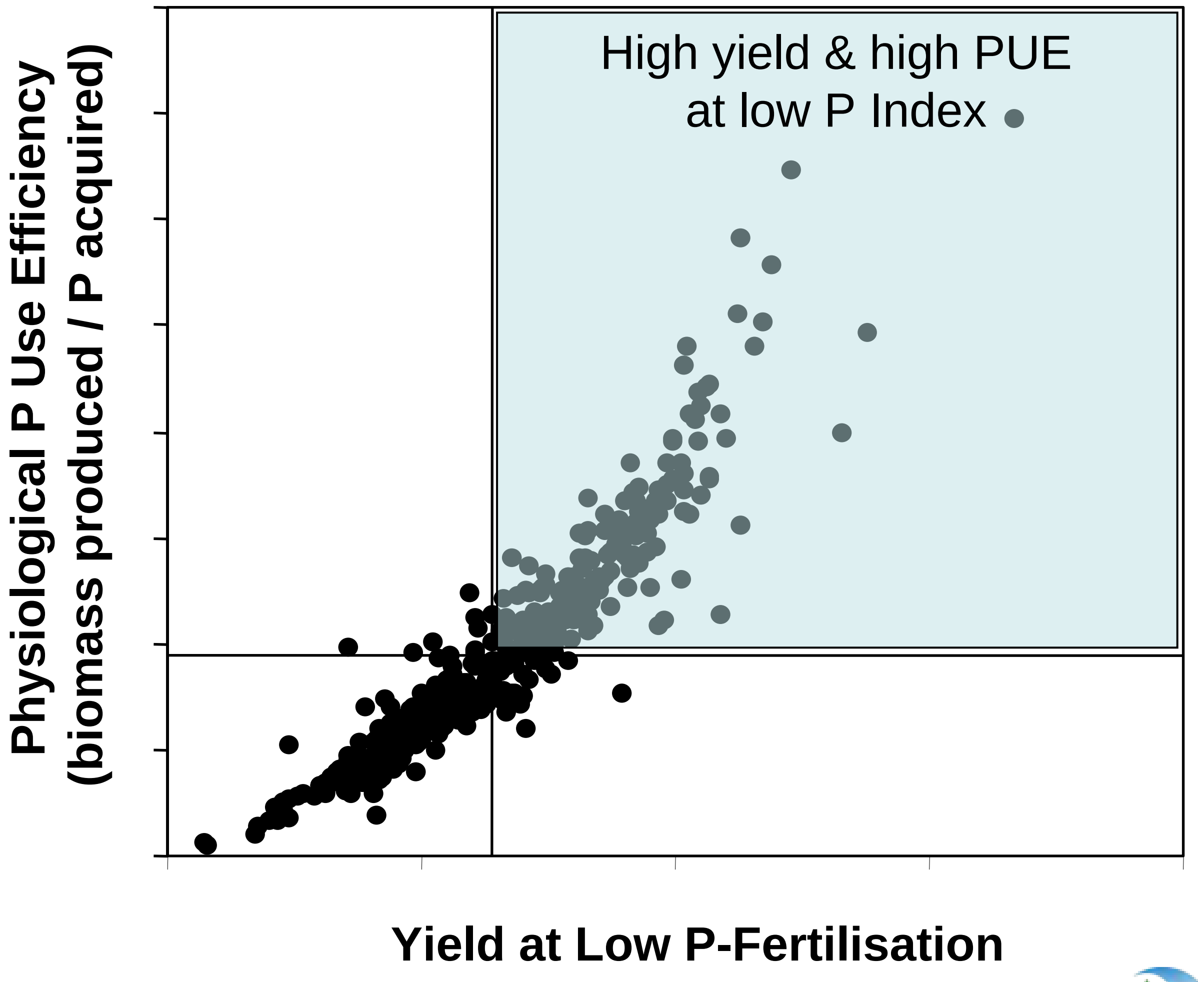
Mineral Acquisition is Related to Root Size



Genetic Variation in Tissue Mineral Concentrations



Select for Yield at Low P-Fertilisation and High Physiological P-Use Efficiency



Pressures on Water Use in UK Agriculture

- Climate Change: warmer, wetter winters and drier summers (in South and East, 1 in 10 summers will be “very dry” by 2020)
- Legislative: EU Water Framework Directive, Catchment Area Management Strategies, Water Bills (in England & Wales and Scotland), Groundwater Directive, and more…
- Competition between domestic, industrial and agricultural uses

Consequence: restrictions in abstraction and increased costs

Need to optimise our use of fresh water

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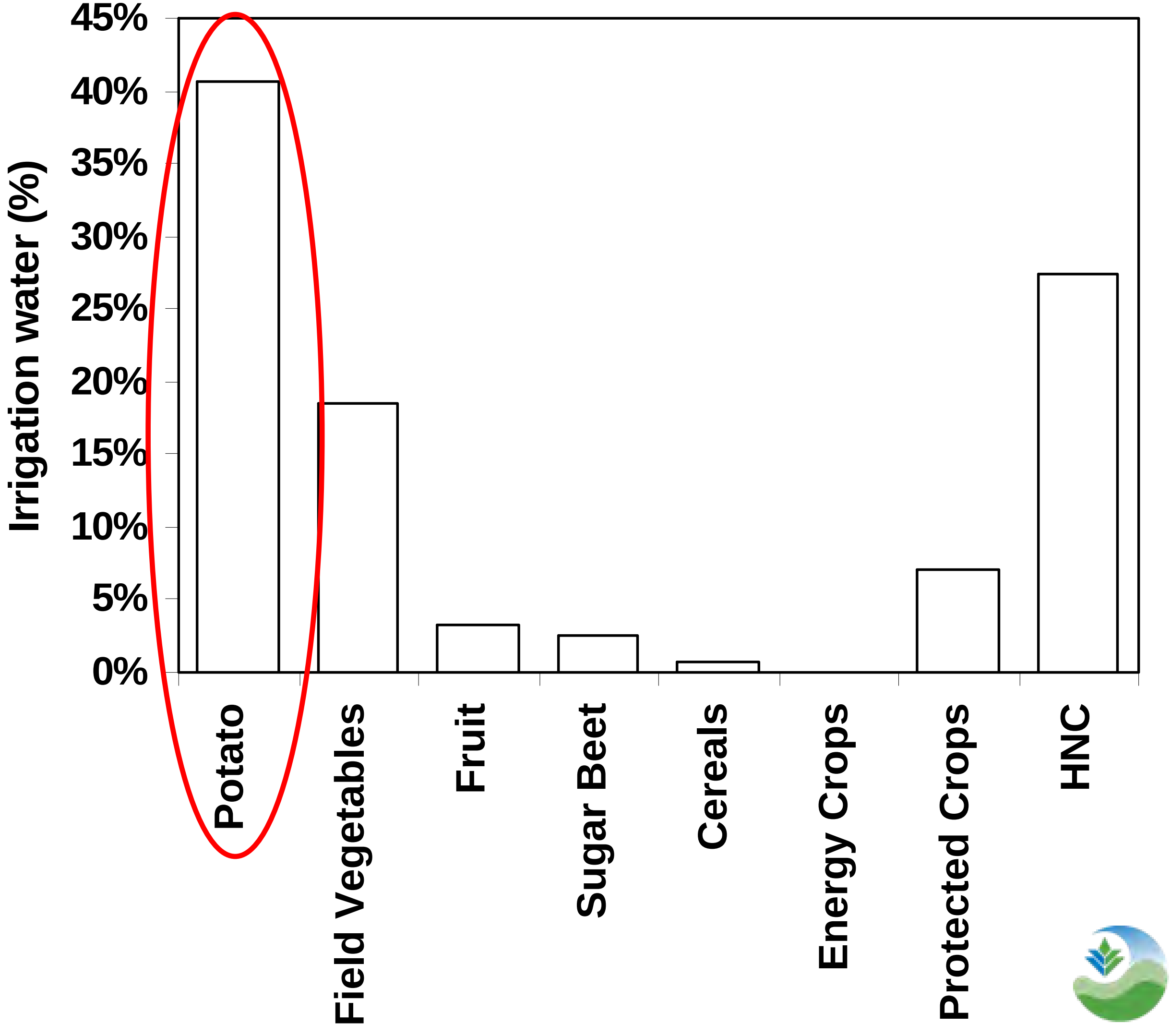
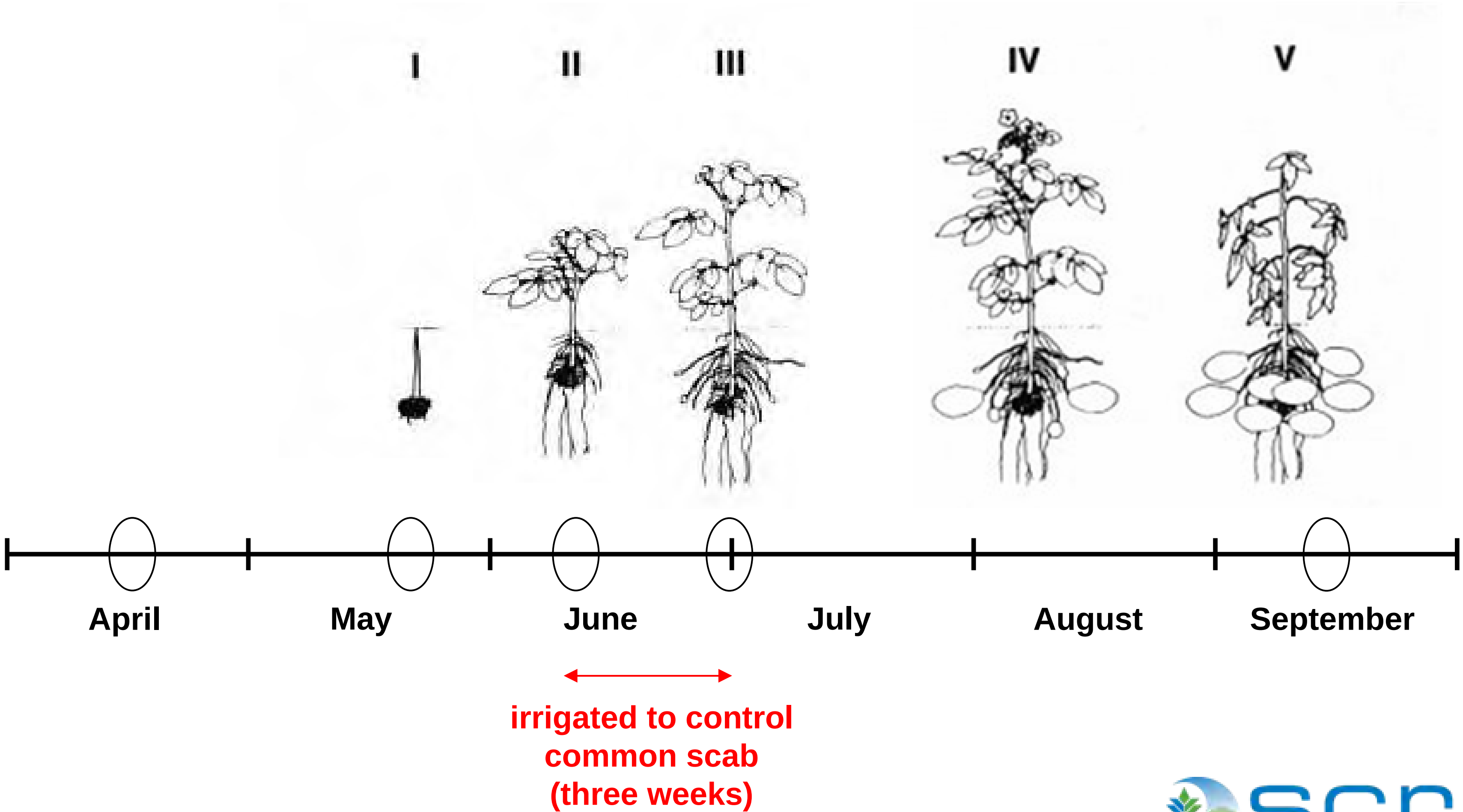
Water Used in UK Crop Production

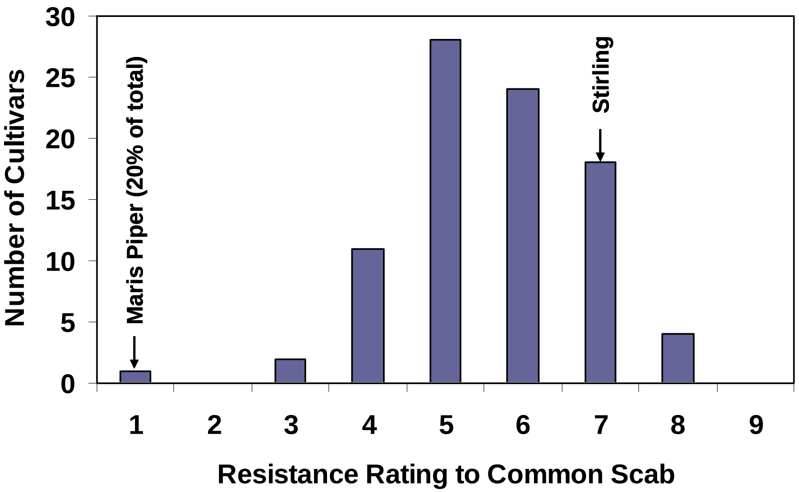


Irrigation of the UK Potato Crop



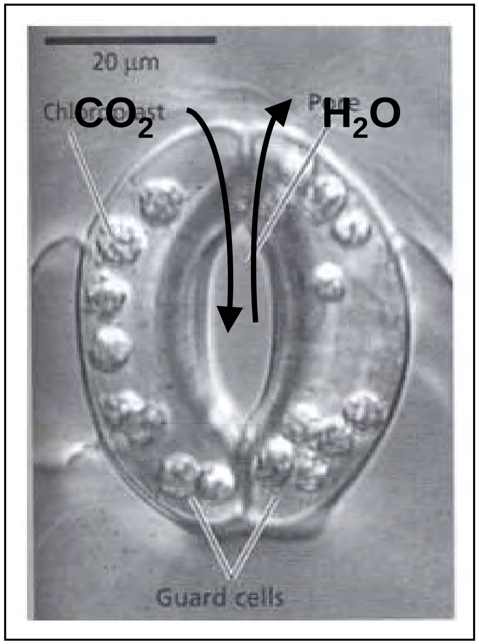
Non-Water Control of Potato Common Scab

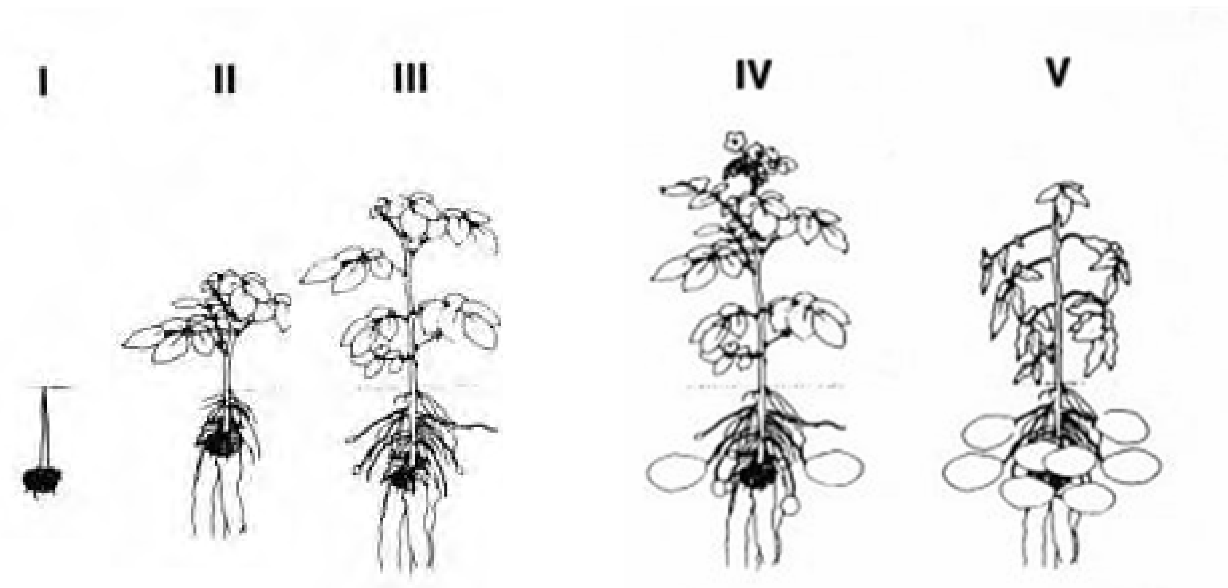
Stead & Wale (2004) BPC Research Review R248

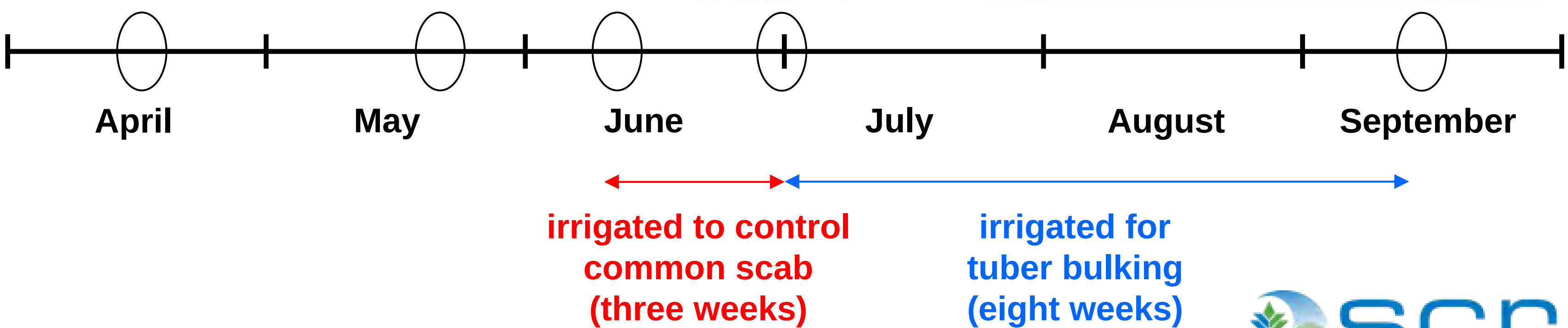


- 70% of UK crops irrigated to control common scab (*Streptomyces* spp.)
- Consumes 50% of irrigation water
- Non-water control would decrease water used in potato production
- Chemical control using disinfectants, sulphur, manganese and low soil pH
- Biocontrol agents available
- Diagnostics and decision support
- Cultivars vary in susceptibility and sources of resistance are available

Irrigation of the UK Potato Crop







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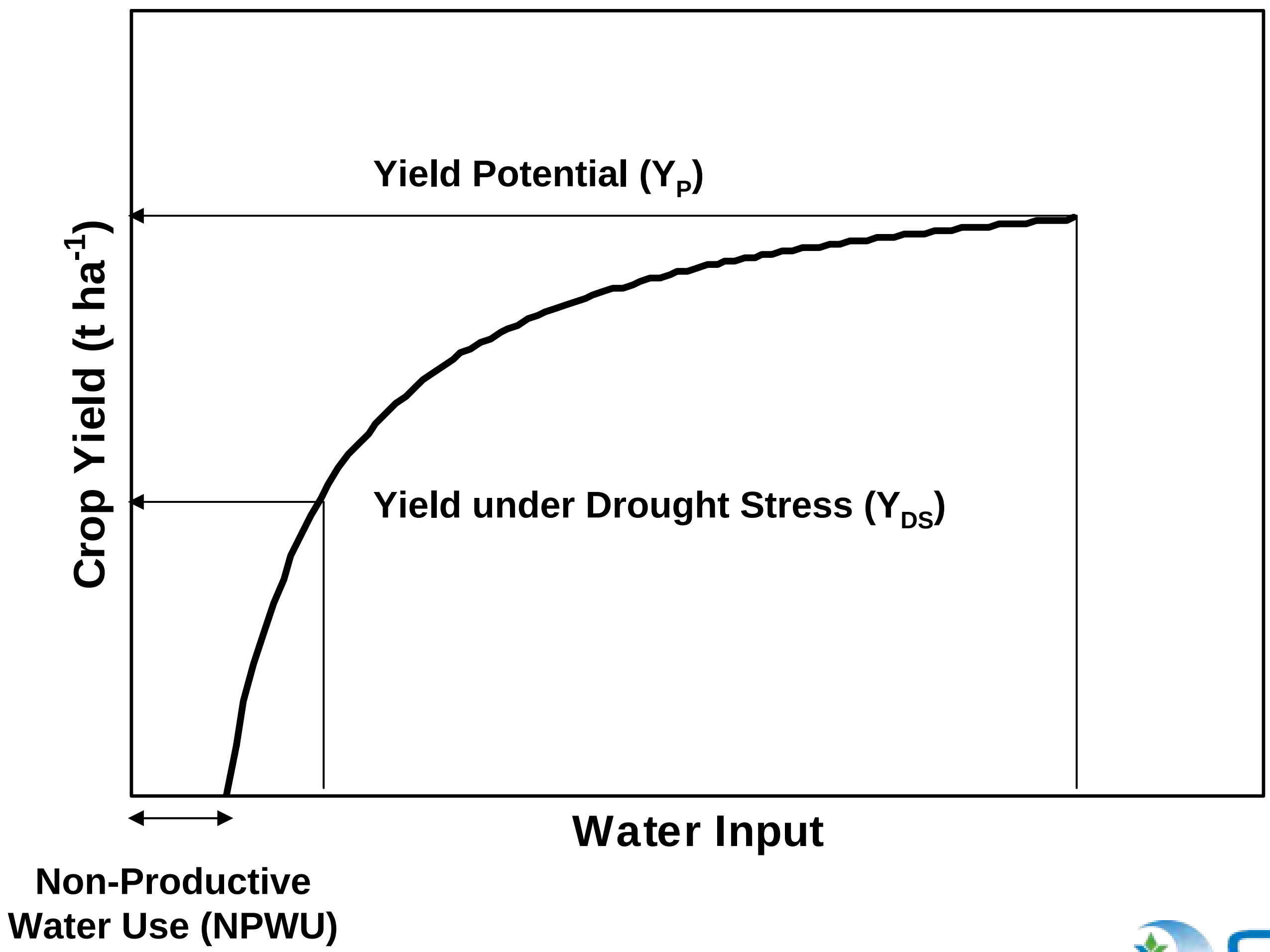
Water-Use Efficiency

(WUE = Yield / Water Input)



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Water-Use Efficiency

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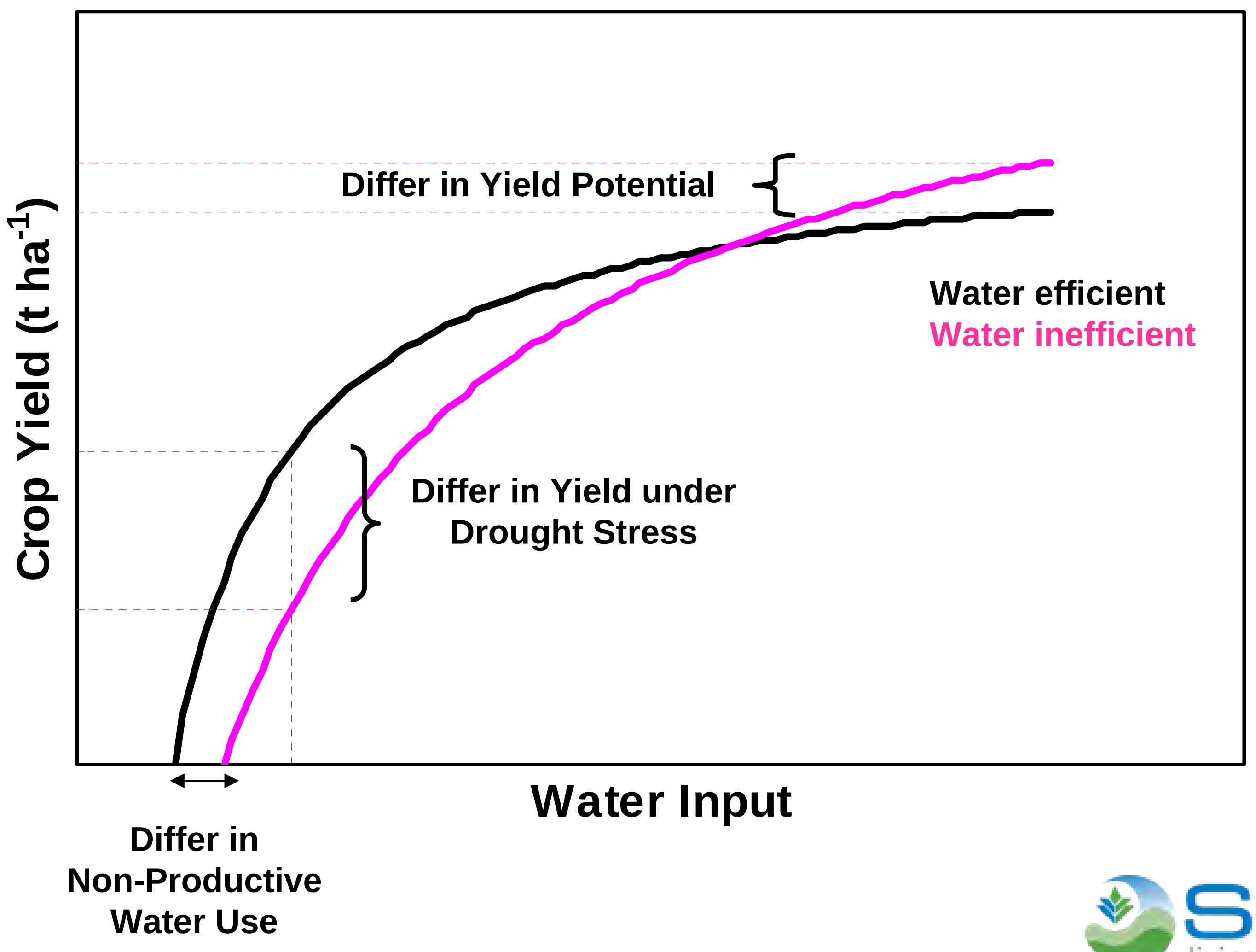

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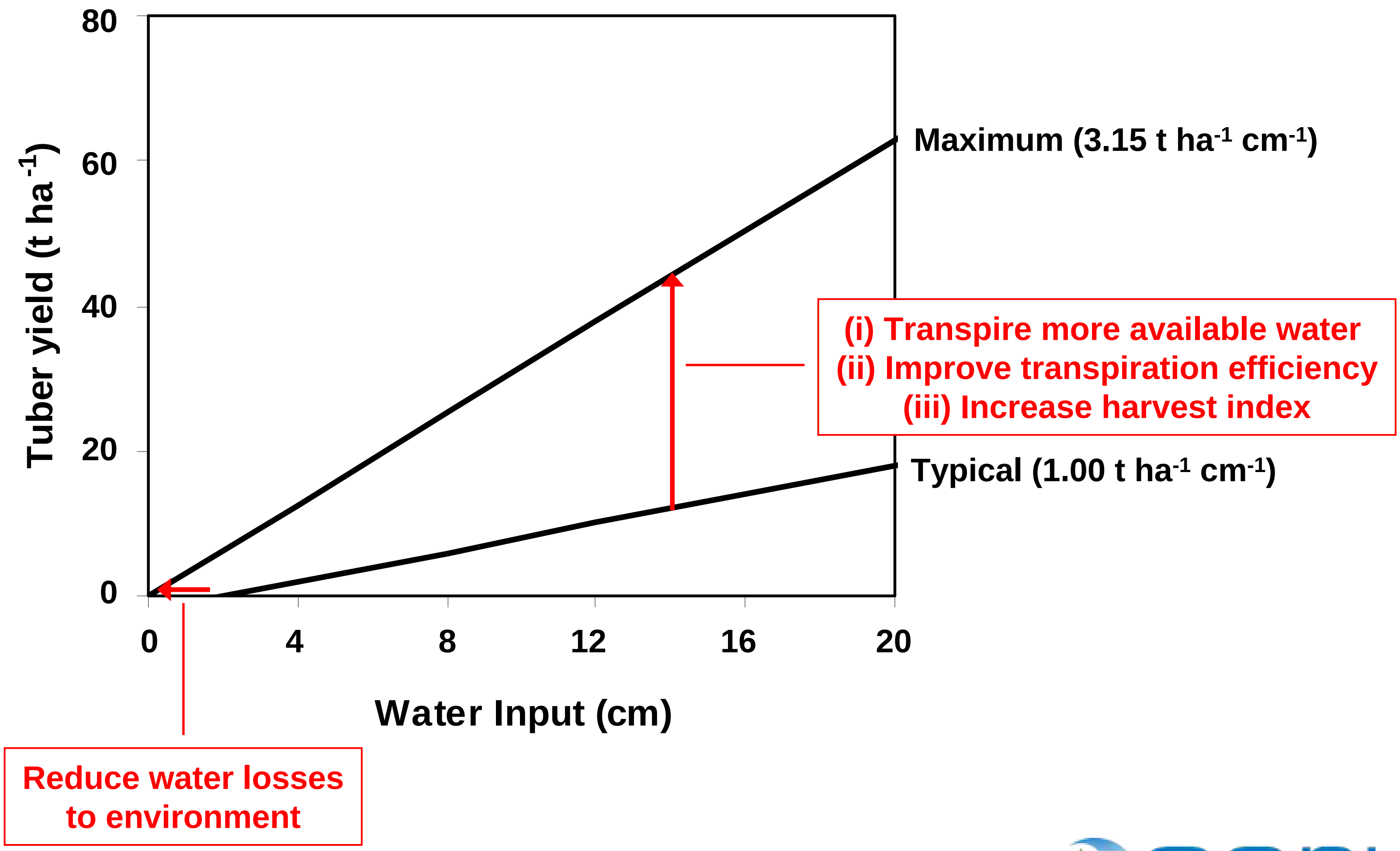
Water-Use Efficiency in Potato

(WUE = Tuber Yield / Water Input)



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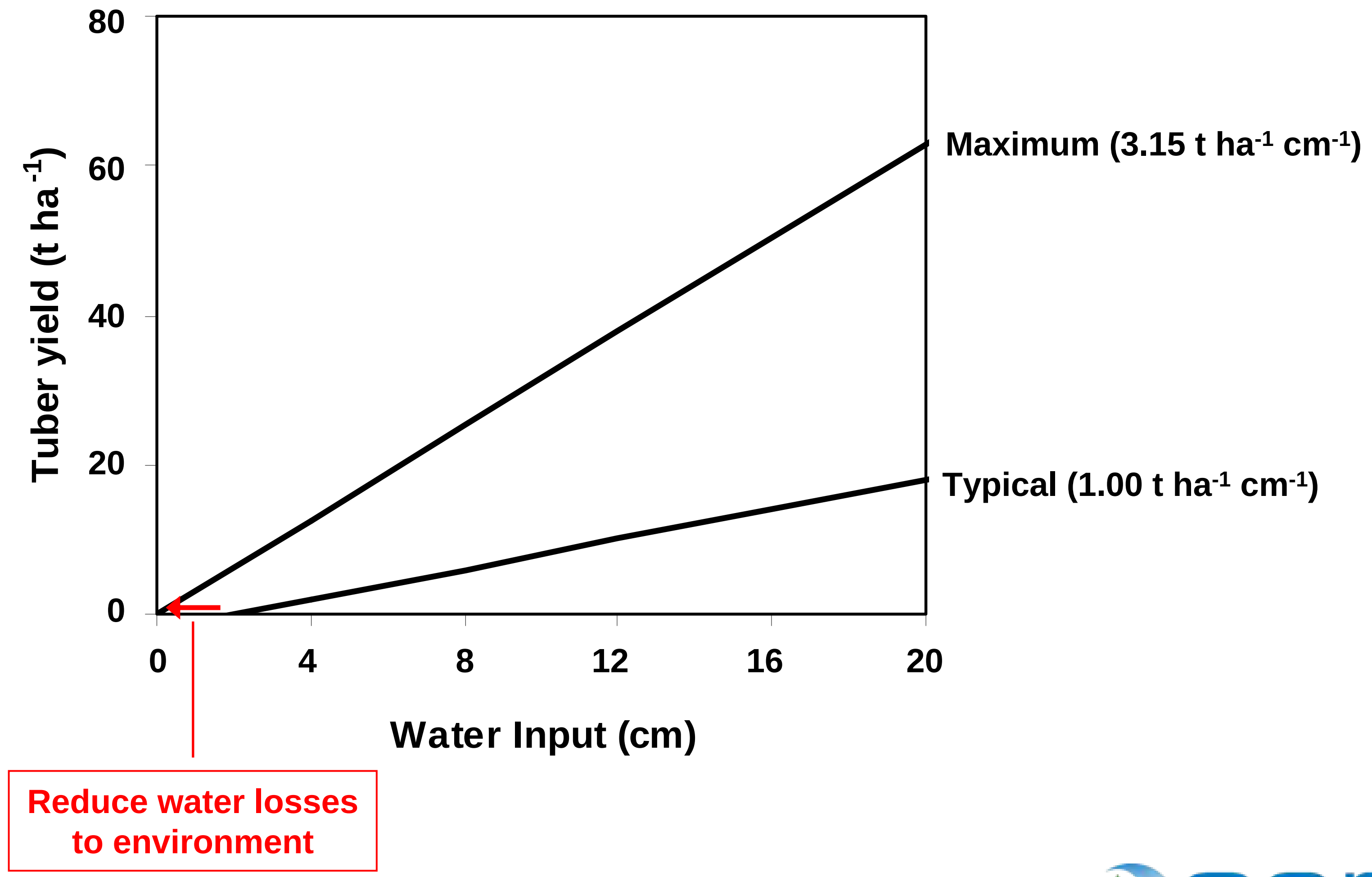
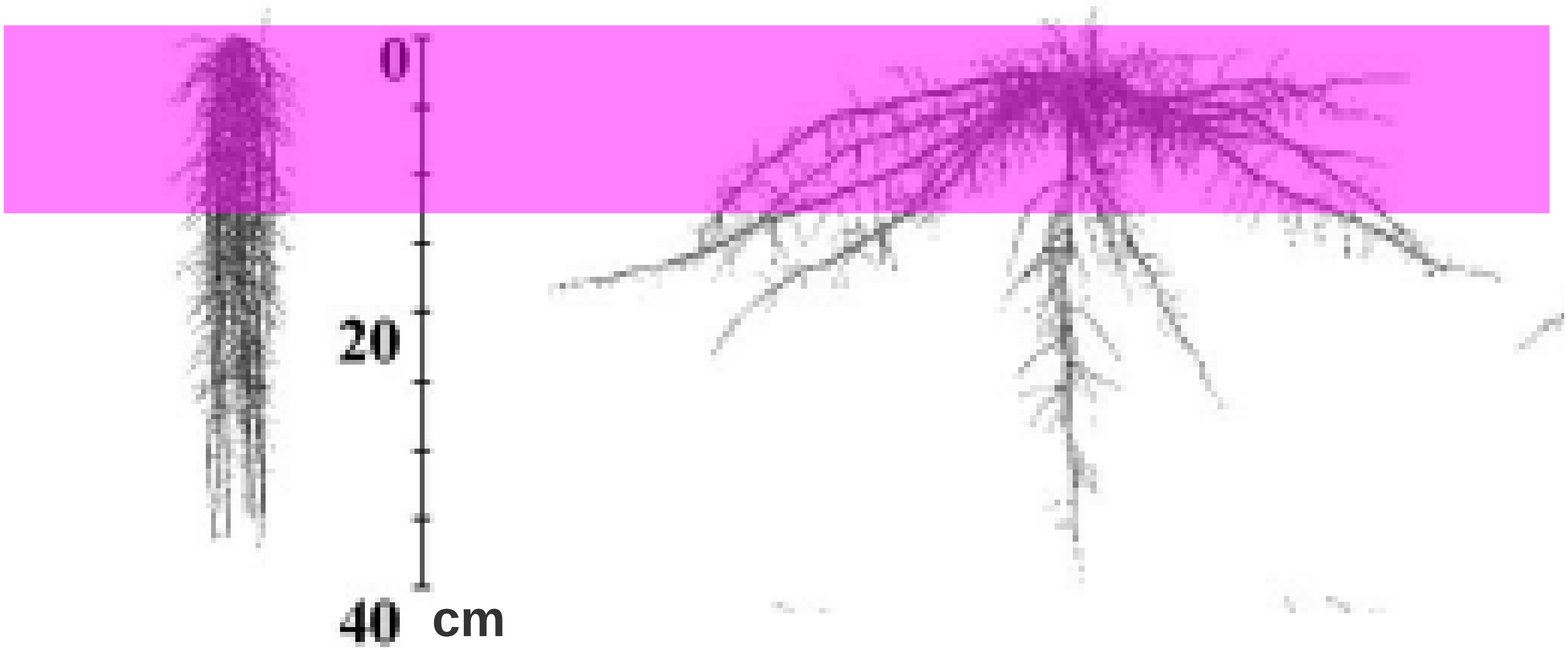


Reducing Water Losses to the Environment

(by developing a root system that captures water)

Root systems with varying basal root angle, but identical length and branching



Shallow-rooted phenotypes acquire water (and phosphate) from the topsoil, but deep rooted phenotypes acquire water (and nitrate) at depth

"long roots are like a long rope for a deep well"

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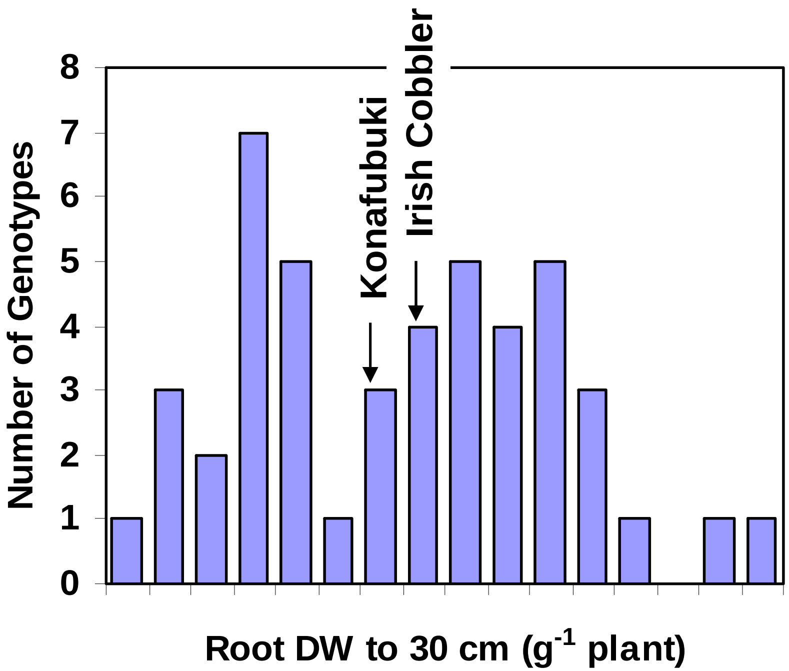
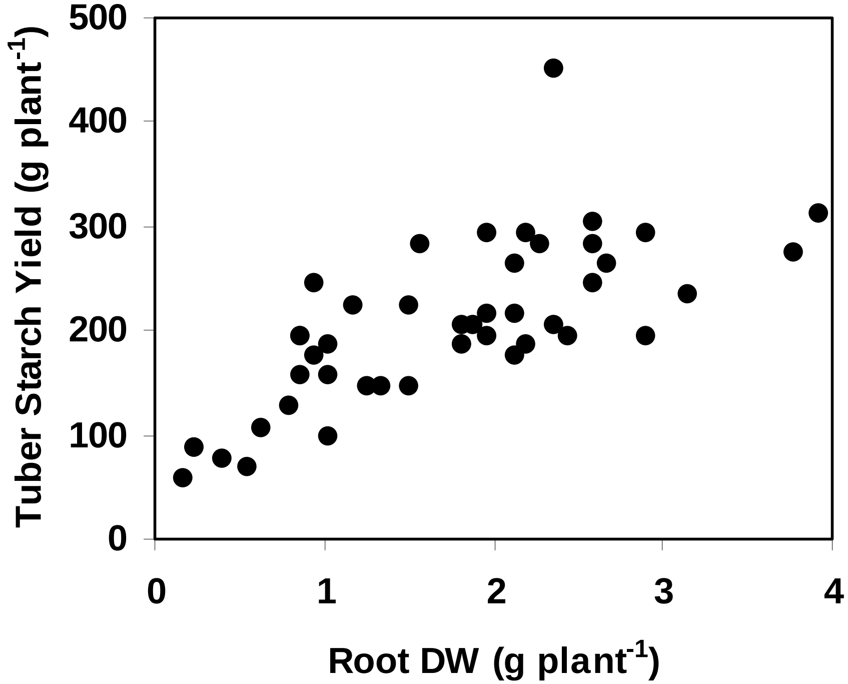
Root Biomass Varies Between Genotypes and Affects Sensitivity to Drought

Japanese bred new potato genotypes with high productivity and drought tolerance using root dry weight and starch yield as selection criteria





Iwama et al. (1999) Proc Int Symp "World Food Security", Kyoto, pp. 189-193

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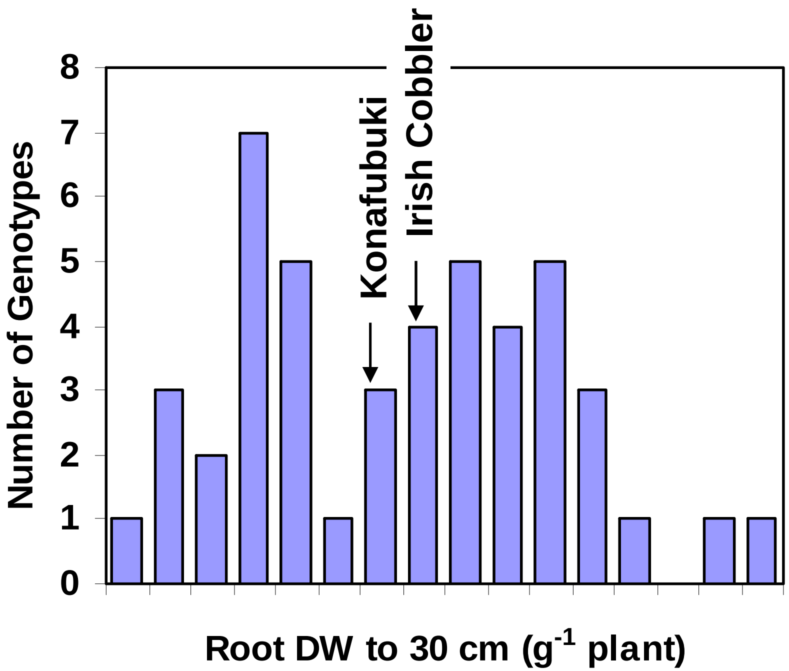

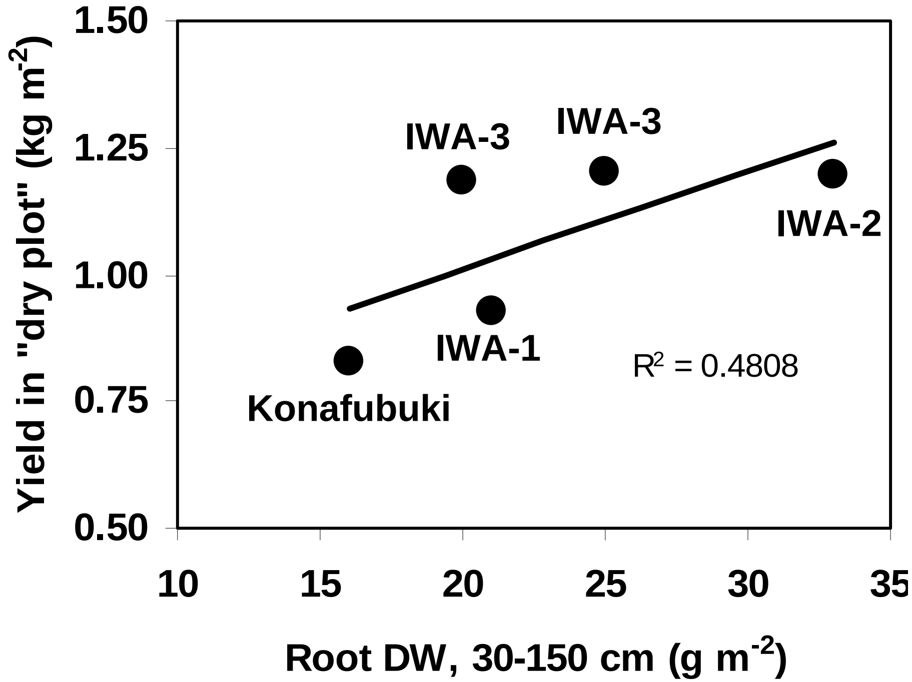

Iwama et al. (1999) Proc Int Symp “World Food Security”, Kyoto, pp. 189-193

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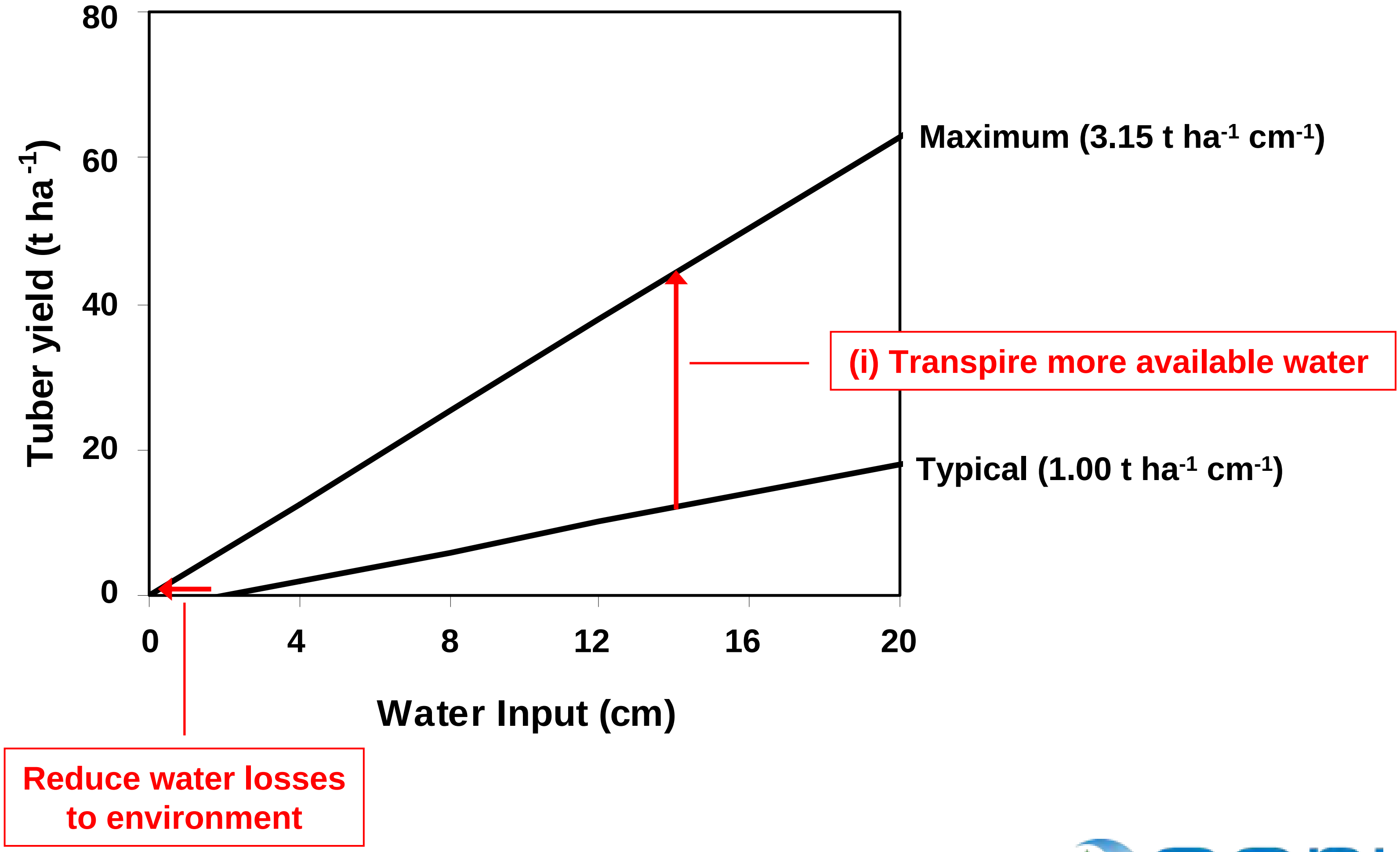
Water-Use Efficiency in Potato

(WUE = Tuber Yield / Water Input)



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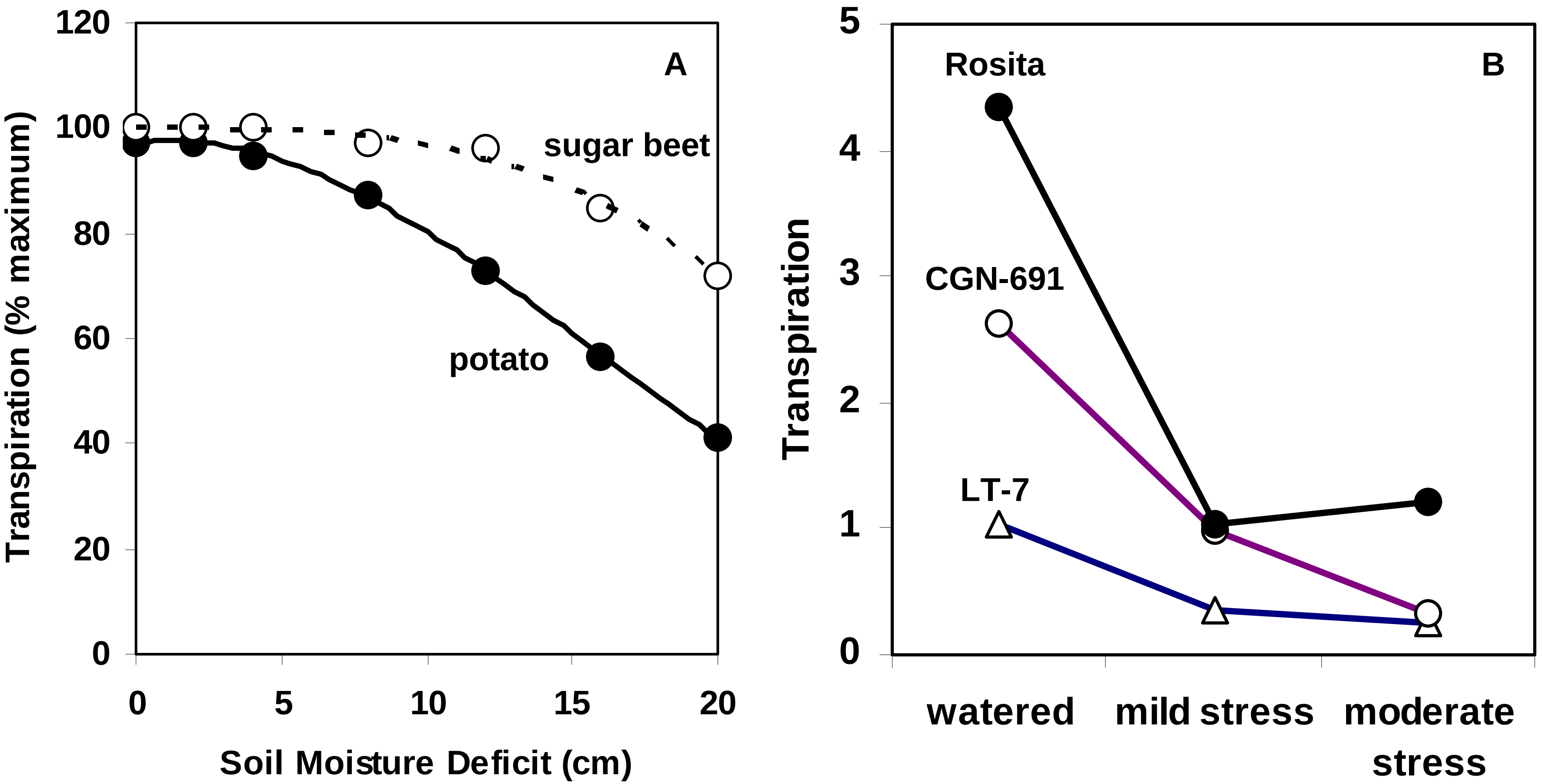
Soil Moisture Deficit, Stomata & Leaf Extension



(A) Burrows (1969) Agric Meteorol 6, 211-226
(B) Ekanayake & De Jong (1992) Ann Bot 70, 53-60

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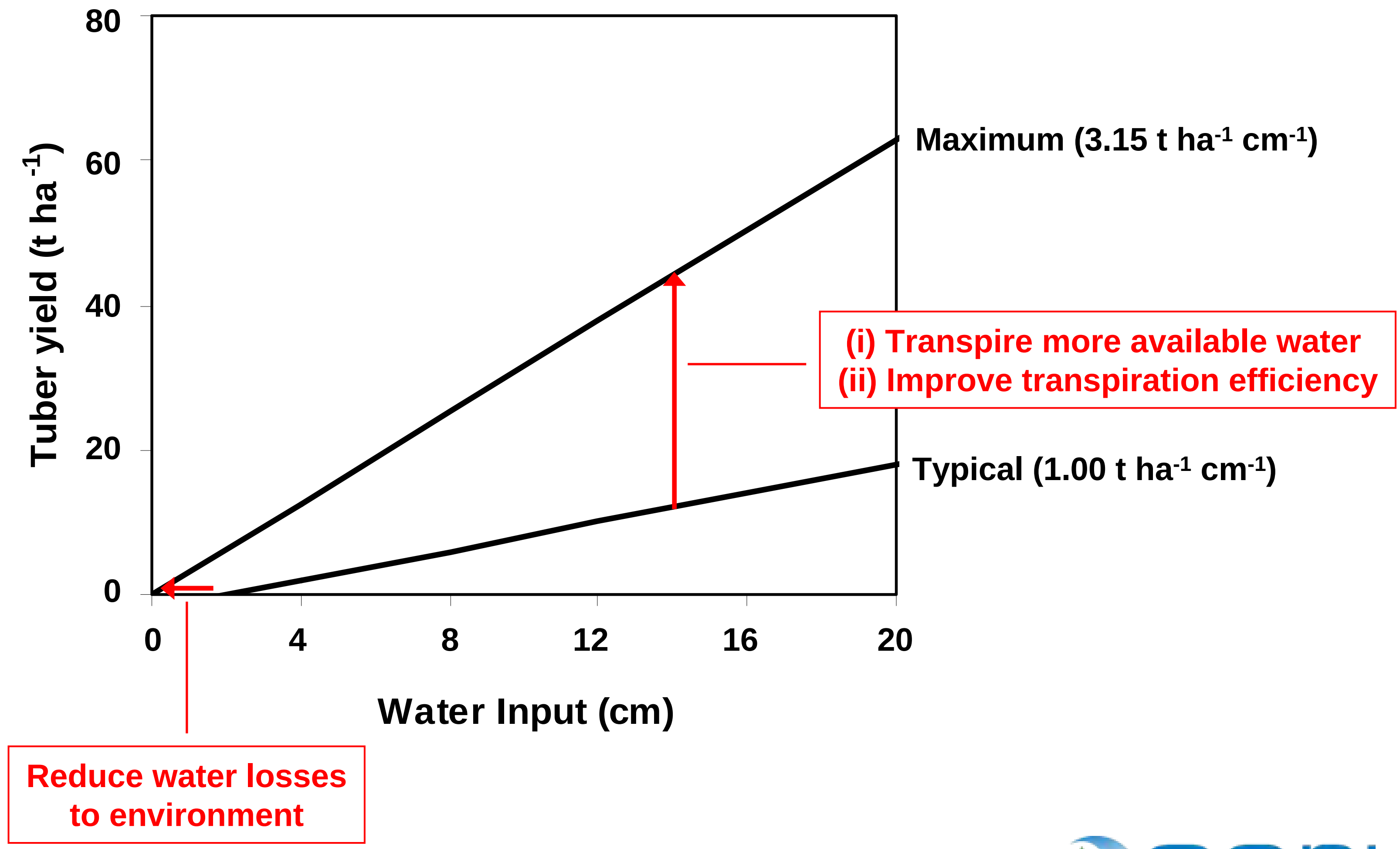
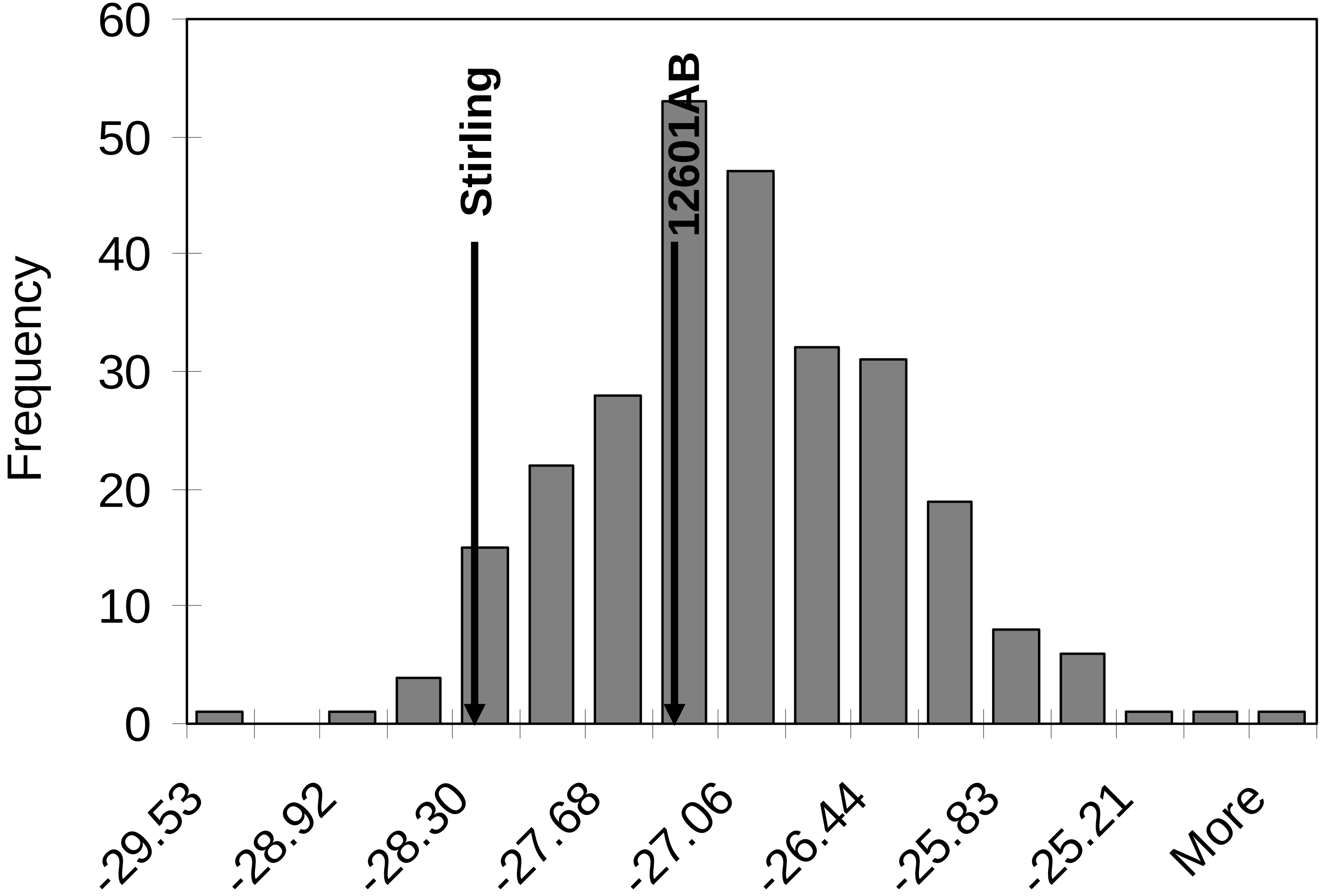
Water-Use Efficiency in Potato

(WUE = Tuber Yield / Water Input)



Transpiration Efficiency ($\delta^{13}C$) In an SCRI Genetic Mapping Population



PJ White, AJ Thompson & JE Bradshaw, unpublished data 2005

Water-Use Efficiency in Potato

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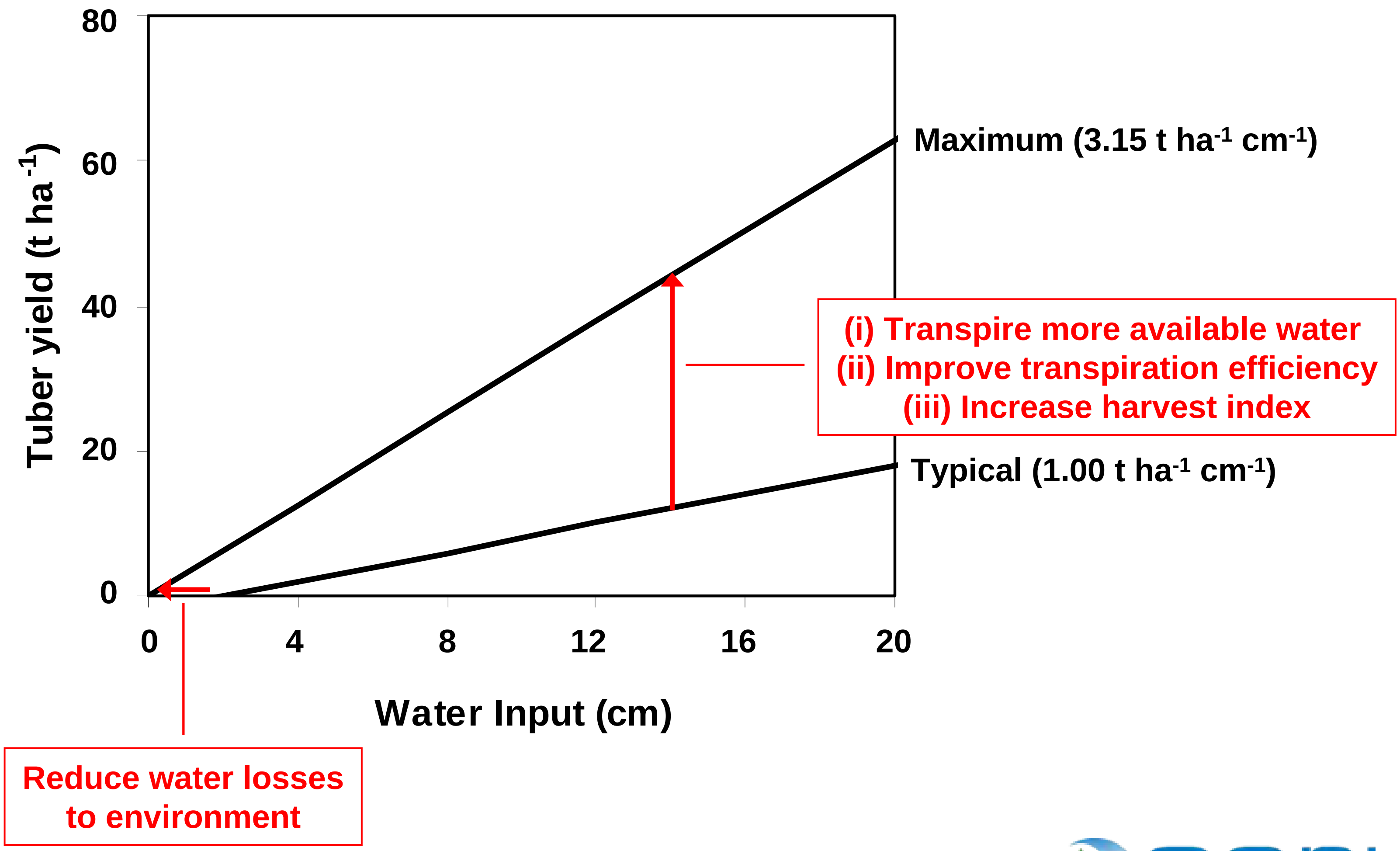
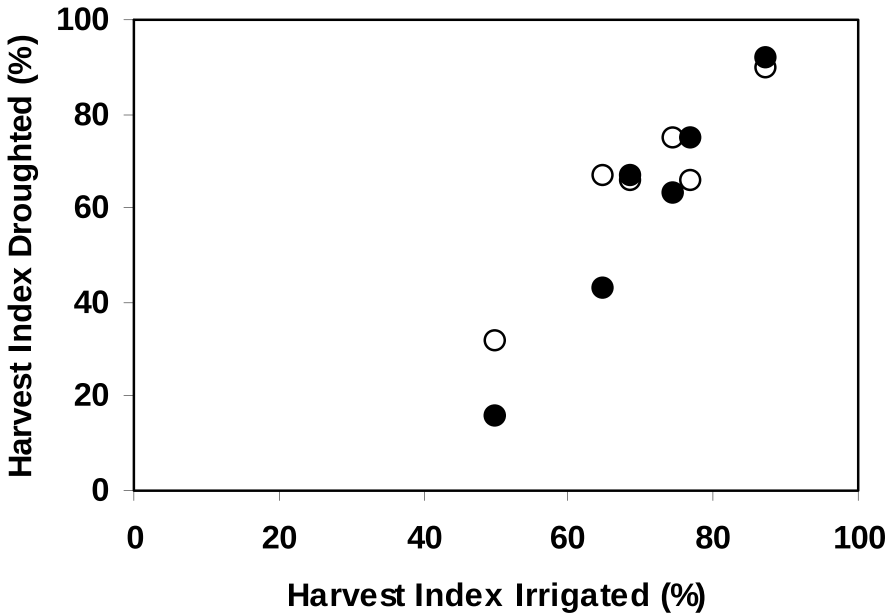


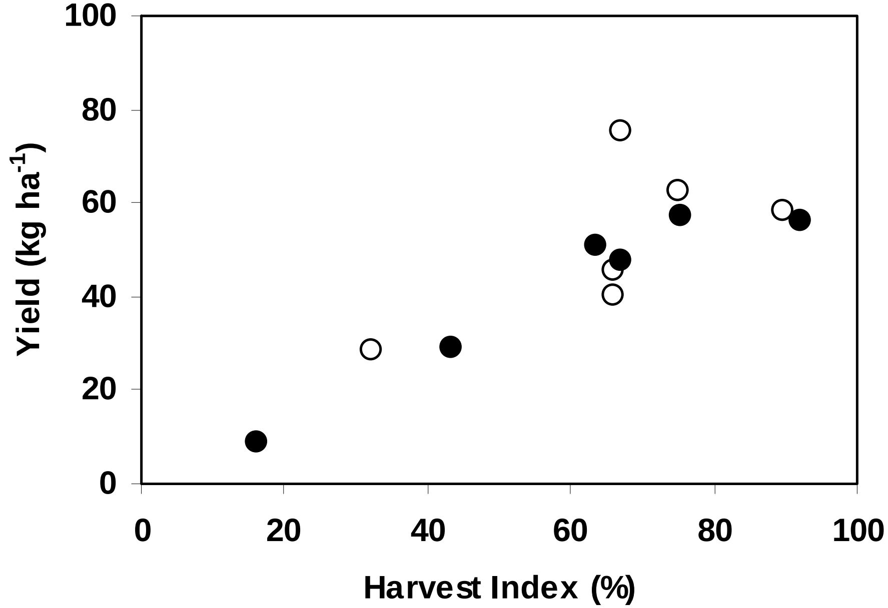
Importance of Maintaining Harvest Index under Drought Stress

Effects of water shortage on six potato genotypes in the highlands of Bolivia



Variation in Harvest Index

Correlates with Yield under Drought



Tourneux et al. (2003) Agronomie 23, 169-179

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Potatoes, Water and Mineral Elements

an appraisal of the situation

Potatoes
require high P and K fertilisation
and have a high demand for irrigation

Supplies of P and K rock depleting
Increasing demand for irrigation water

for economic, environmental and sustainability reasons
we must optimise fertiliser and water use

both agronomic and genetic strategies are available

I am optimistic for the future

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Potatoes, Water and Mineral Elements
an appraisal of targets for breeding

To reduce P use:

Genetic variation in yield at low P-fertilisation
Genetic variation in physiological P-use efficiency

To reduce water use:

Genetic variation in resistance to common scab
Genetic variation in water-use efficiency

There is considerable variation in root system morphology

Breeding for these should reduce fertiliser and water use
(and maintain yields)

I am optimistic for the future

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