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Differential K efficiency in crops and genotypes

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Photo by I. Djalovic

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1) Justification for the breeding solution for low-nutrient soils

2) K efficiency

3) Differential K efficiency in crop germplasm

4) Mechanisms governing K efficiency

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Justify breeding as a solution for low-nutrient soils

- 1) Understand the nature of low nutrient availability in soil
 - total amount of a nutrient in soil is low
 - or
 - there is a large total amount, but plant availability is low due to unfavourable soil chemistry (pH, redox reactions, poor solubility, etc.)
- 2) Understand the nature of genetic background of increased efficiency and/or utilization of a nutrient of interest
 - germplasm variability
 - heritability
 - is genetic engineering an option?

Justify breeding as a solution for low-nutrient soils

3) What is a desirable outcome to be achieved?

- increased crop growth and yield
and / or
- increased nutrient content in edible crop parts

4) Consider:

- the type of agricultural management
- socio-economic situation
(availability and affordability of fertilizers)
- possible environmental (off-site) impacts of applying fertilizers, particularly in relatively large amounts
- time-frame desired for the management solution to become available and adopted

Example of K nutrition in Western Australian wheatbelt

Highly weathered, sandy soils predominate in the wheatbelt of Western Australia (~ 2/3 of area).

55% of virgin (non-agricultural) topsoils have <100 mg bicarbonate-extractable K/kg soil.

26% of 136 agricultural soils surveyed had <40 mg bicarbonate-extractable K/kg soil.

The critical concentration for yield response in cereals is about 40 mg bicarbonate-extractable K/kg soil.

+K

Field-grown wheat
at Varley, Western Australia

-K



Problems with addressing K deficiency by fertilization in W. Australian agriculture

Direct drilling of K fertilizer can cause seedling toxicity and limited yield response; broadcasting K is an additional operation farmers would prefer not to have.

Yield response to K fertilizer is short-lived.

Yield response is often patchy on a paddock scale.

Hence, a genetic solution (growing K-efficient genotypes) has to be **part** of addressing the problem of low K uptake by crops.

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K efficiency = the capacity of a genotype to grow and yield well in soils low in K availability

Efficiency in K acquisition

- greater total K uptake per plant

and / or

- greater specific K uptake rate per unit root length

Efficiency in K utilization:

- greater dry matter production per unit of K taken up

Heritability of K efficiency is high (eg. lucerne)

Selection for K utilization efficiency may be effective across variable field environments (eg. perennial ryegrass)

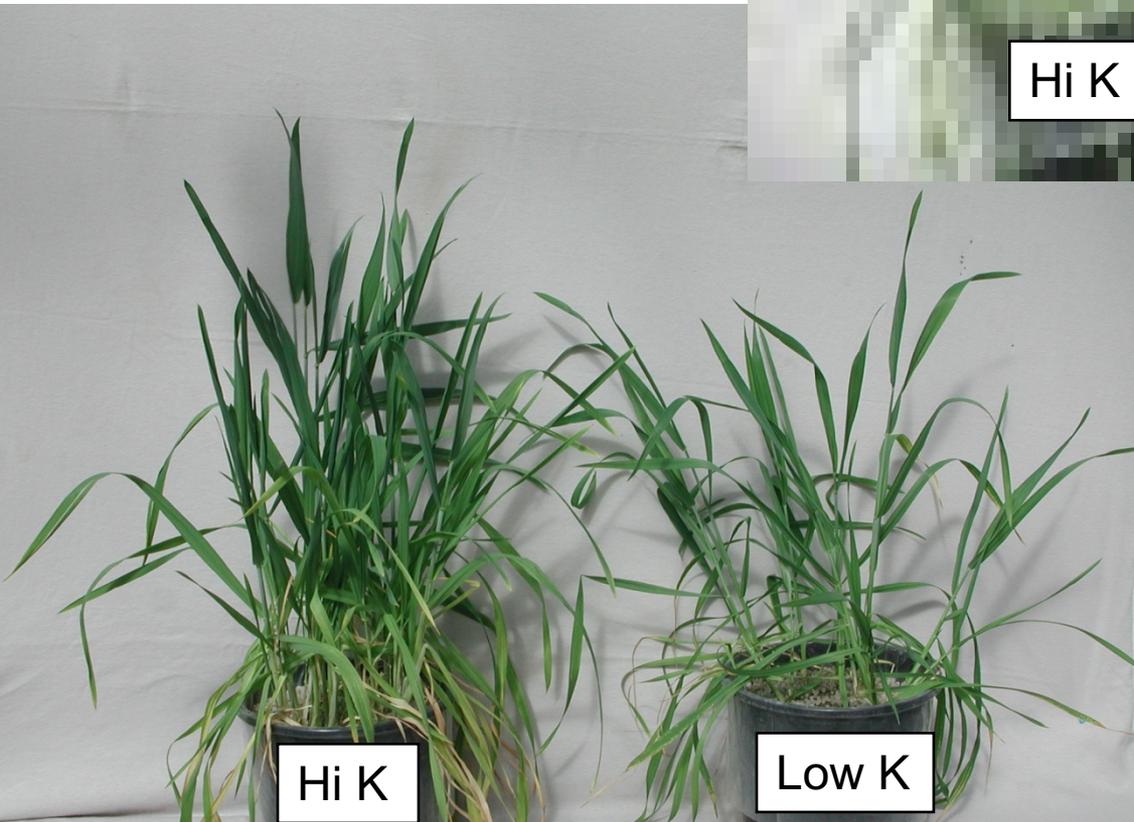
Steps for developing K-efficient genotypes:

- 1) Identify differences in K efficiency in the germplasm
- 2) Elucidate the principal efficiency mechanisms
- 3) Identify suitable molecular markers

Screening wheat germplasm at various rates of K application (Harrismith, Western Australia)



Nyabing wheat (K-efficient)



Cranbrook wheat (K-inefficient)

Nyabing wheat (K-efficient)

Cranbrook wheat (K-inefficient)



Hi K

Low K

Hi K

Low K



Barley cv Dash, K deficient



Barley cv Buloke, not K deficient

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I M E

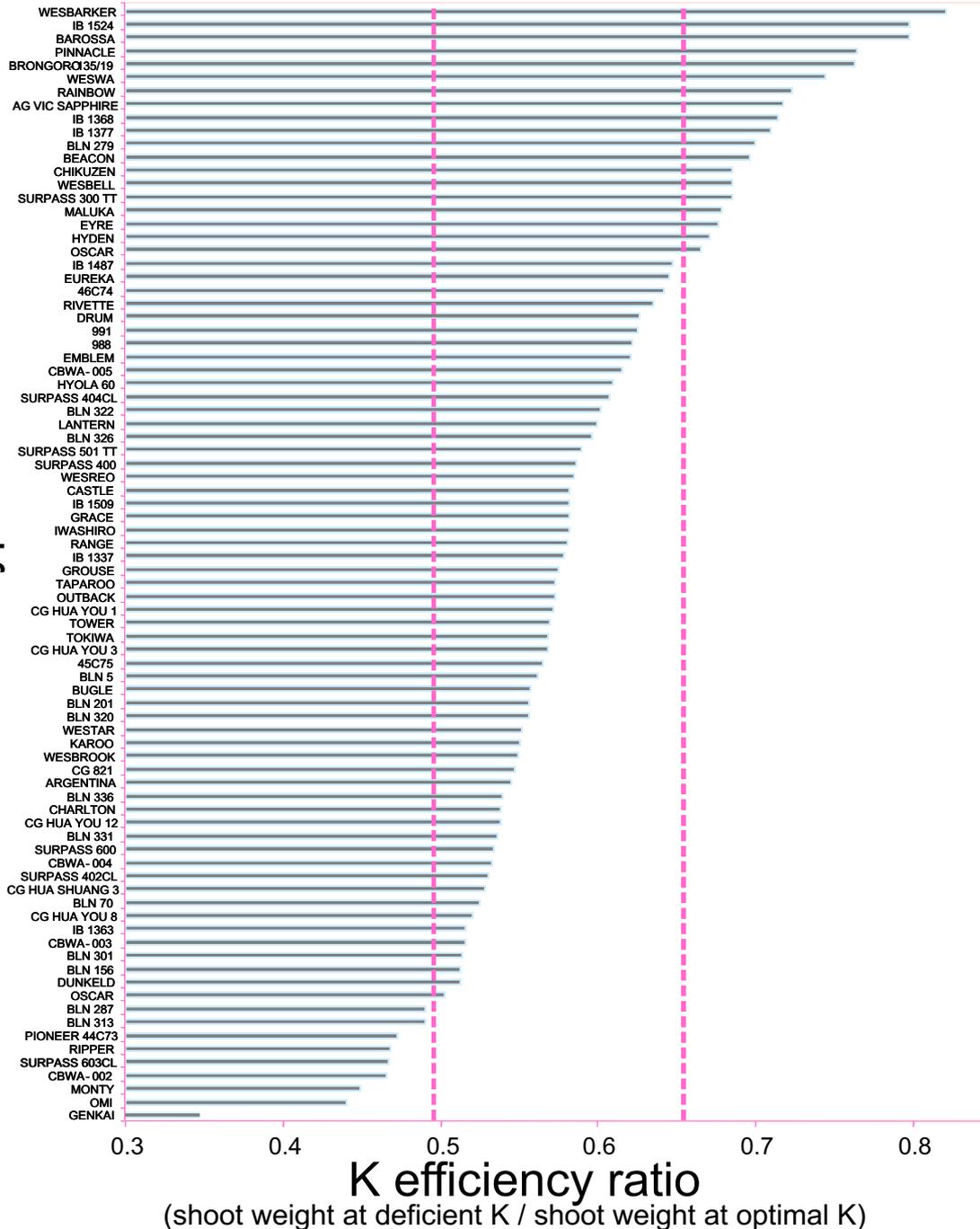
K efficiency ratios for 8 canola genotypes

grown for 37 days in sandy soil
(without or with 88 mg K/kg soil) in a
glasshouse

The vertical dashed lines separate the K
efficiency intervals at one standard error of the
genotype effect above and below the median.

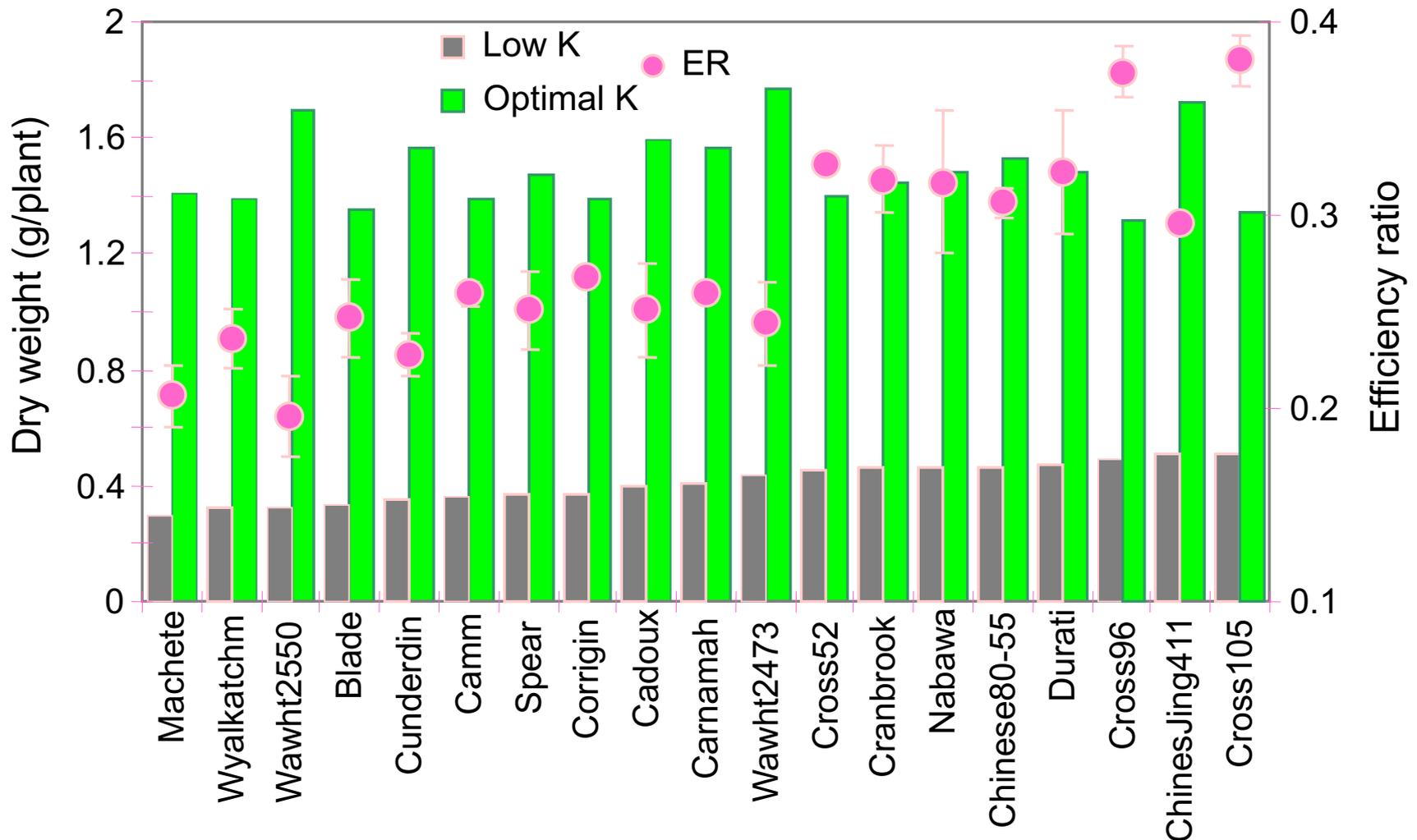
I = K-inefficient, M = medium, E = K-efficient

Genotypes



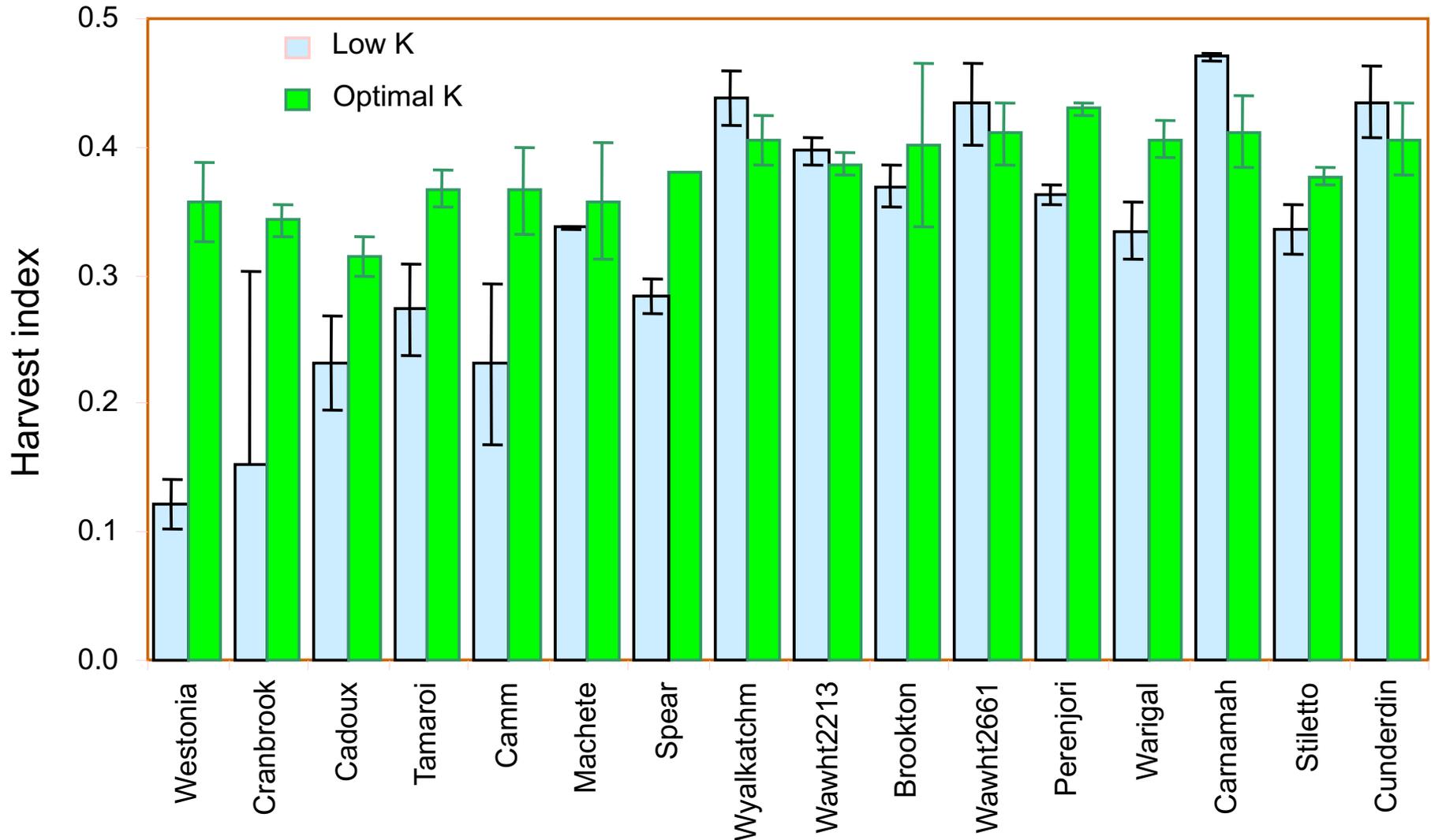
K efficiency ratios (shoot biomass at low K / high K) of selected **wheat** genotypes

154 wheat genotypes screened initially in a **glasshouse** in K-deficient soil (low K) amended with K (optimal K)



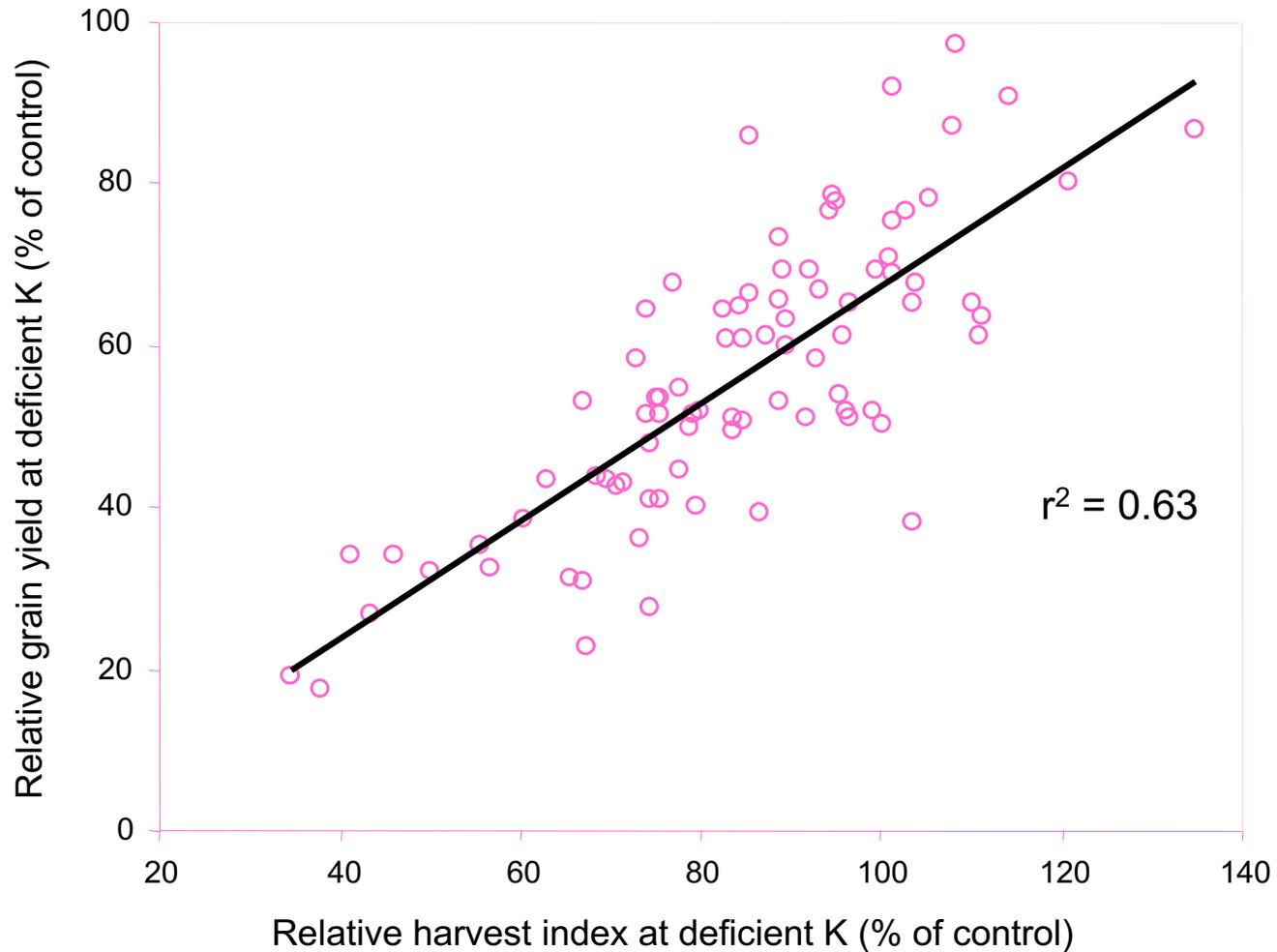
Harvest index of selected **wheat** genotypes at low and high soil K = grain weight / total above-ground weight

85 wheat genotypes screened in the **field** (Shenton Park) in K-deficient soil (low K) amended with K (optimal K)



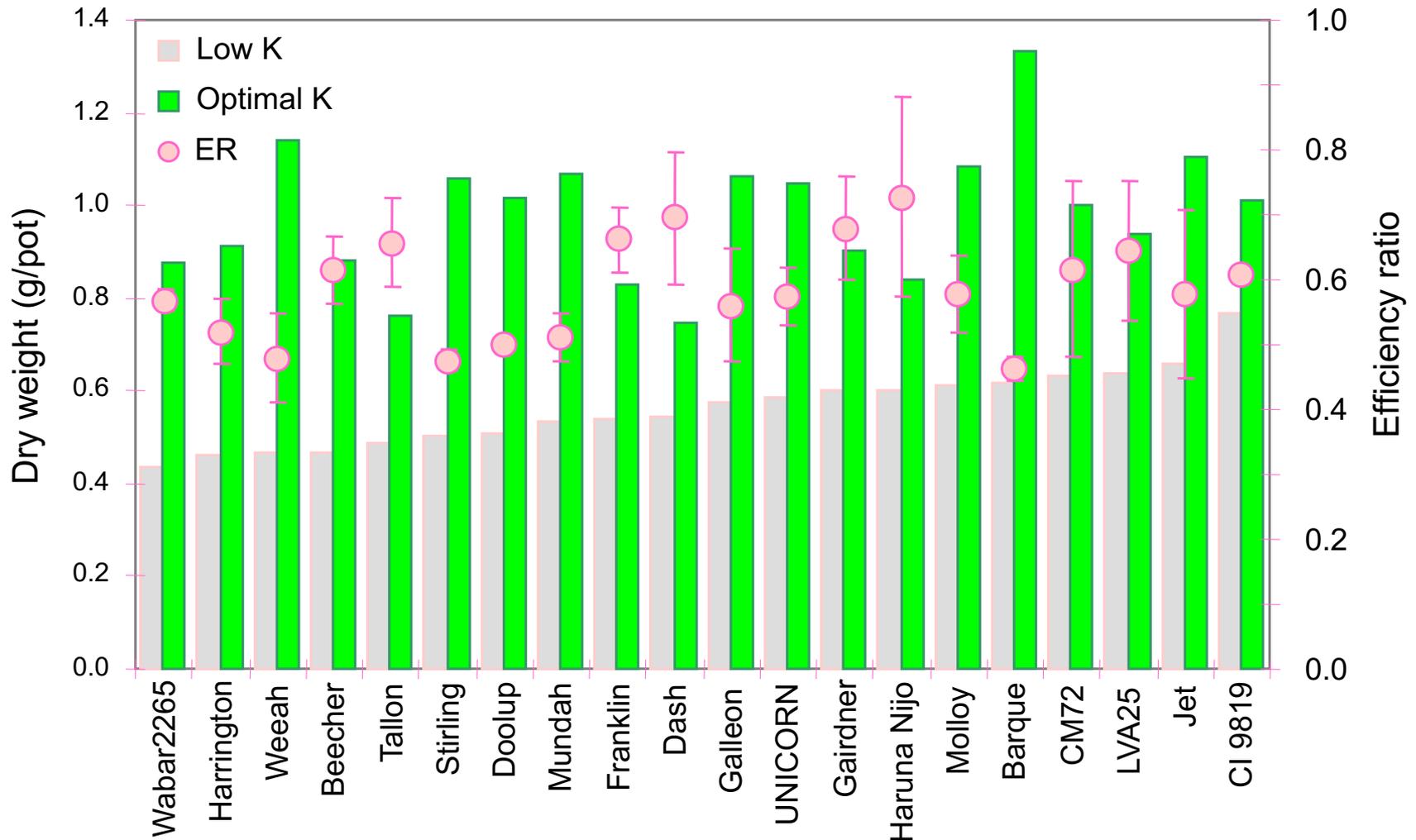
Harvest index and grain yield of **wheat** genotypes under K deficiency stress

85 wheat genotypes grown in the **field**



Shoot K efficiency ratios of selected **barley** genotypes = weight at suboptimal K / weight at adequate K

100 barley varieties screened initially in a **glasshouse** in K-deficient soil (low K) amended with K (optimal K)



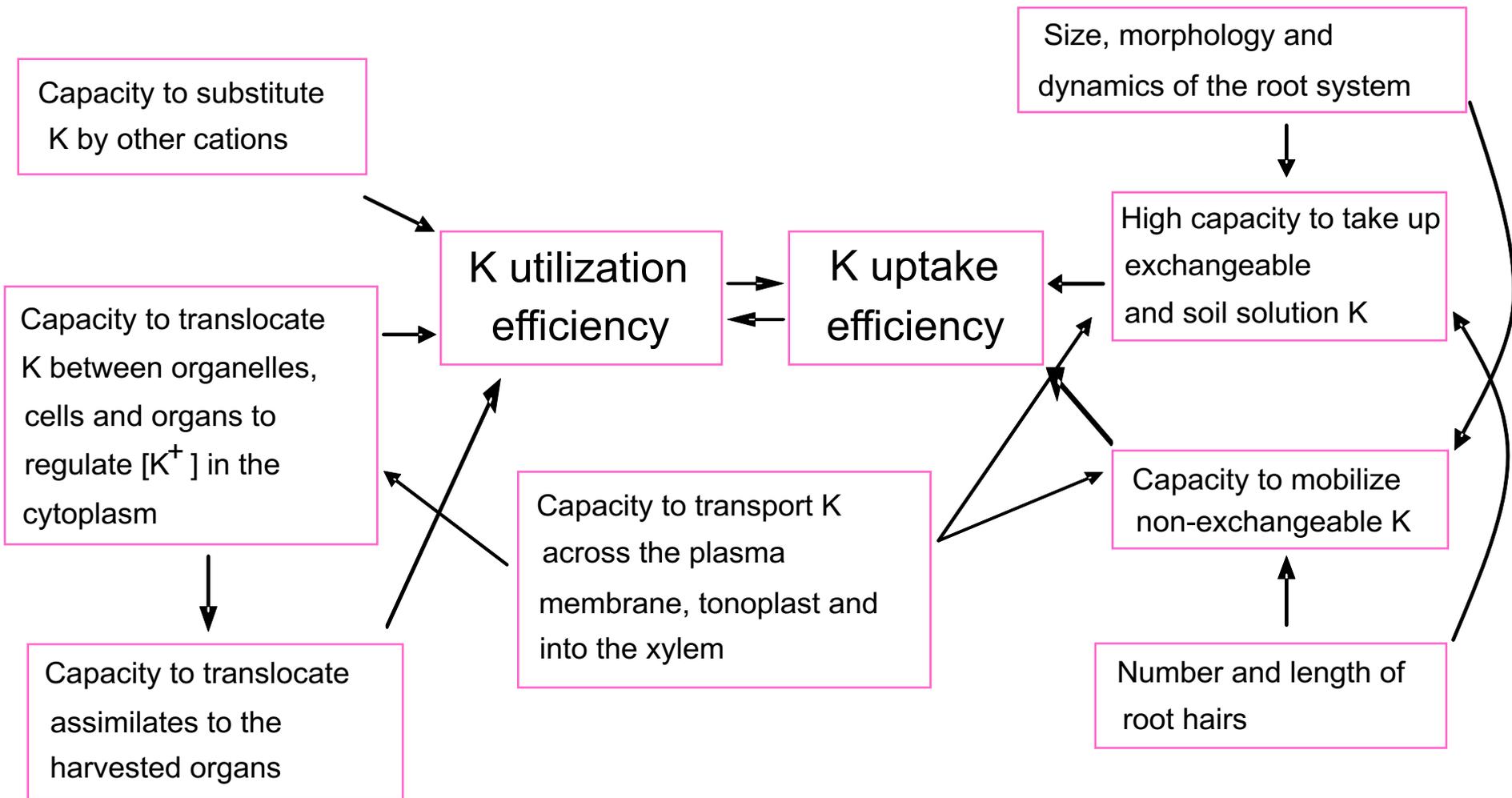
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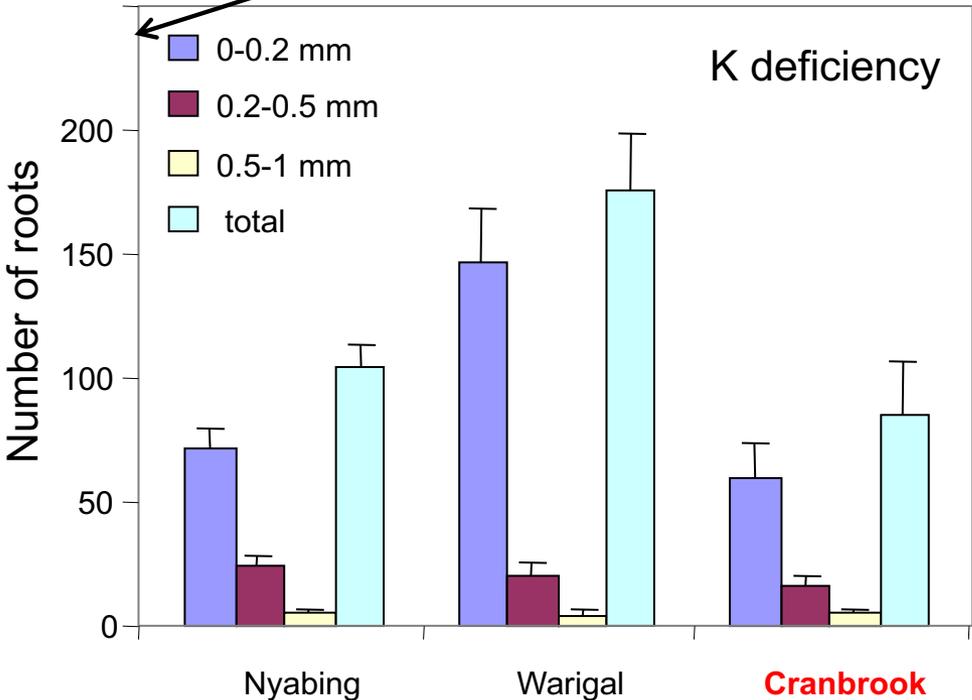
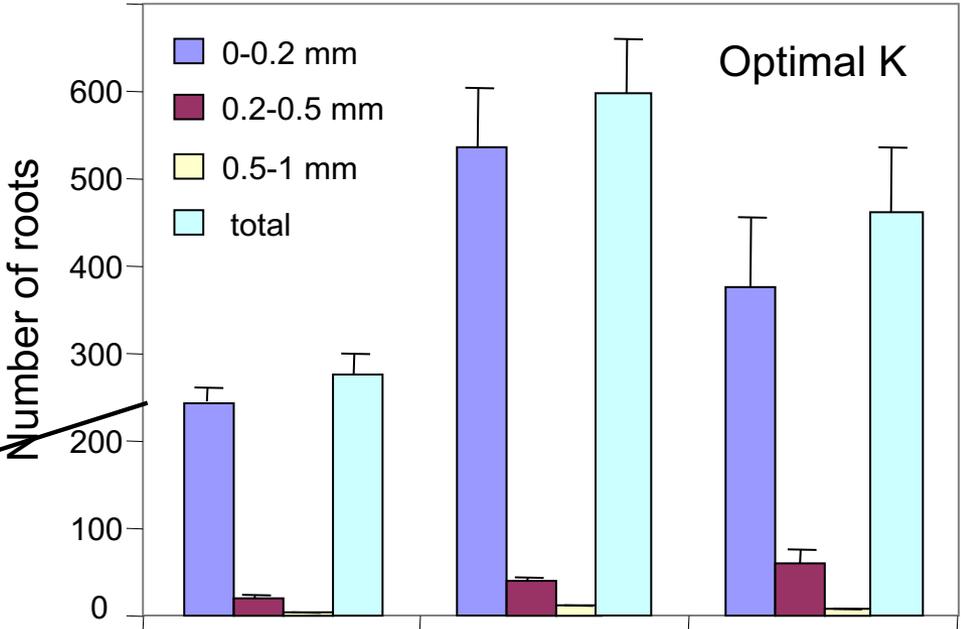
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Potential mechanisms of K uptake and utilization efficiency influencing K-efficient phenotype

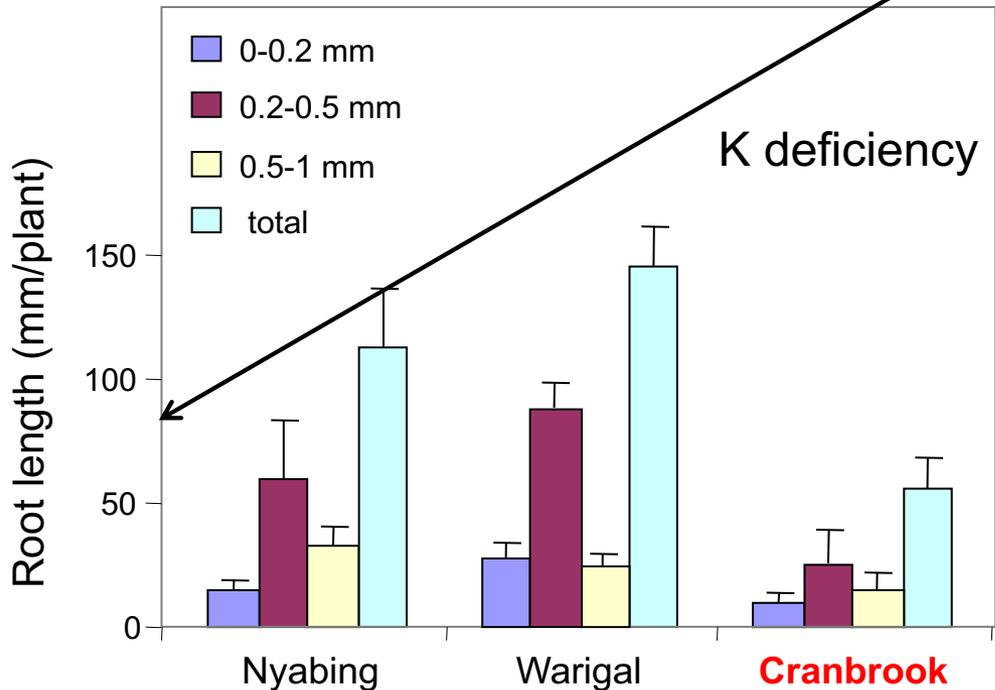
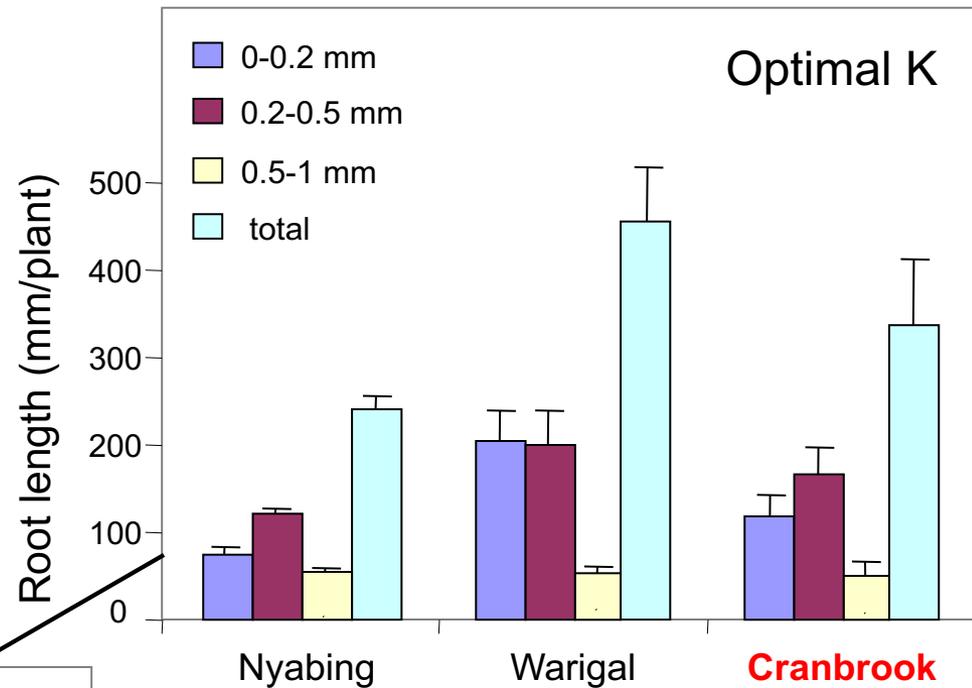


K deficiency decreases root branching in wheat, particularly in **K-inefficient genotype**

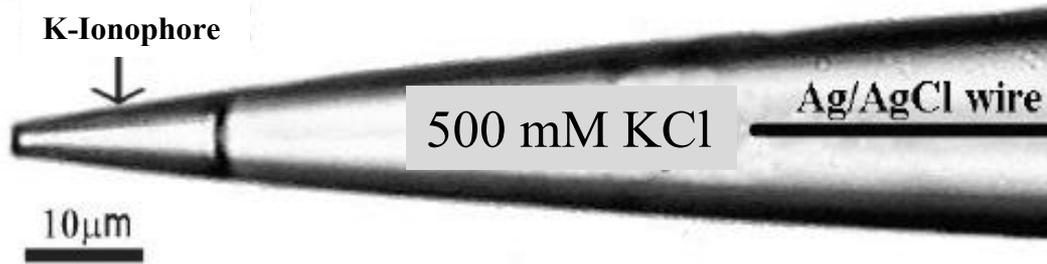


24-d-old plants grown in nutrient solution

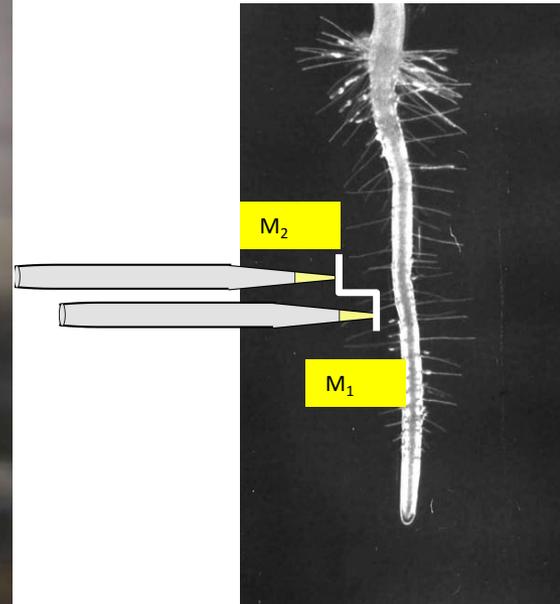
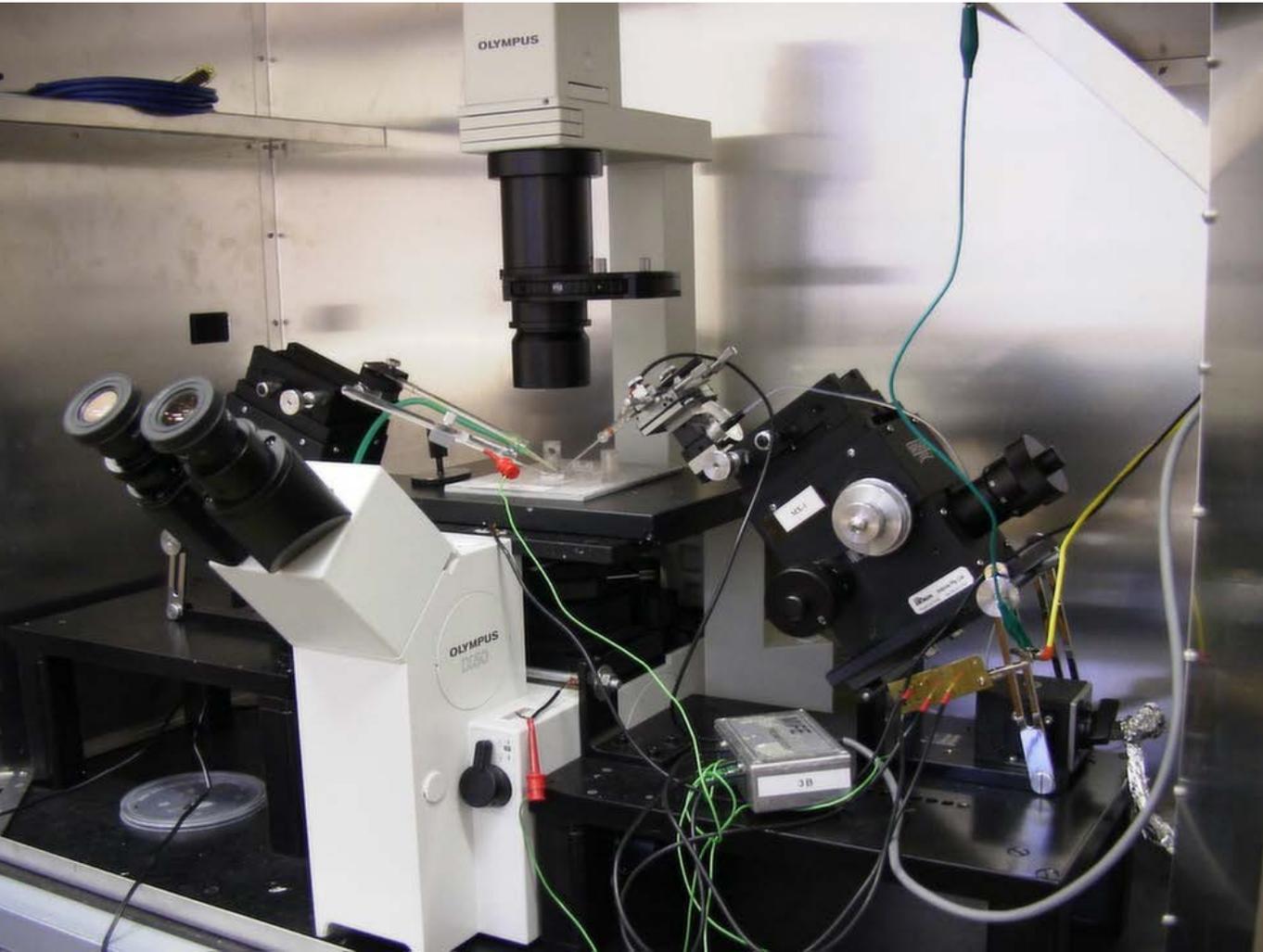
K deficiency decreases root elongation in wheat, particularly in **K-inefficient genotype**



24-d-old plants
grown in nutrient solution

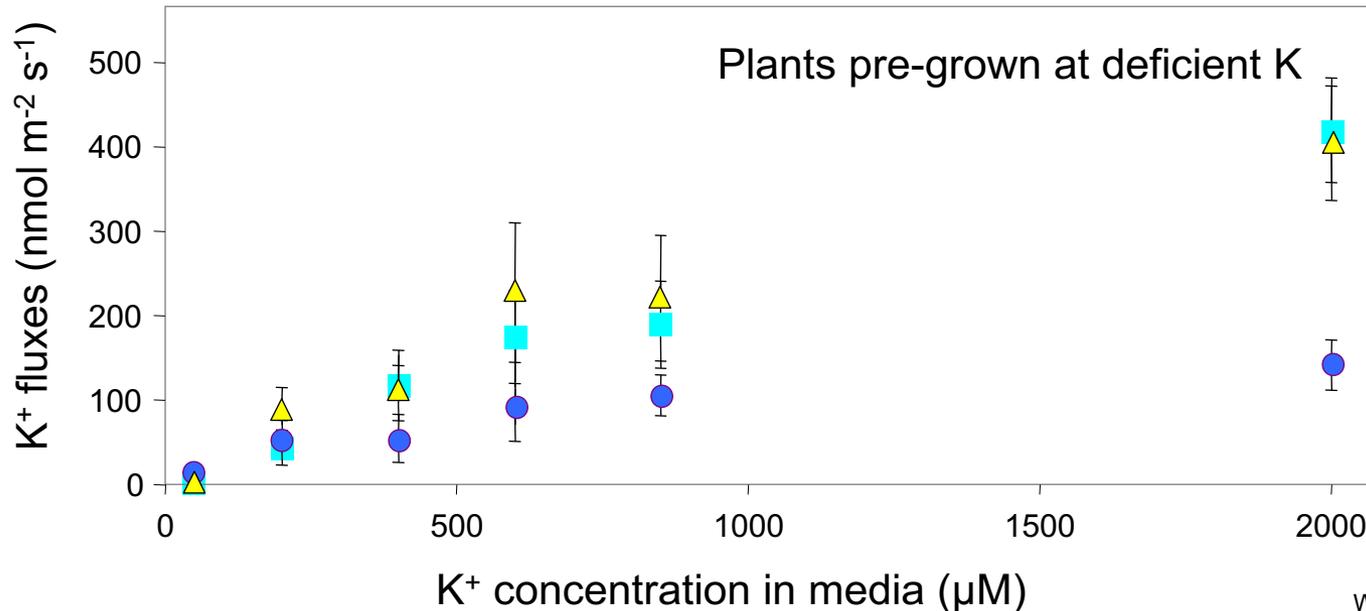
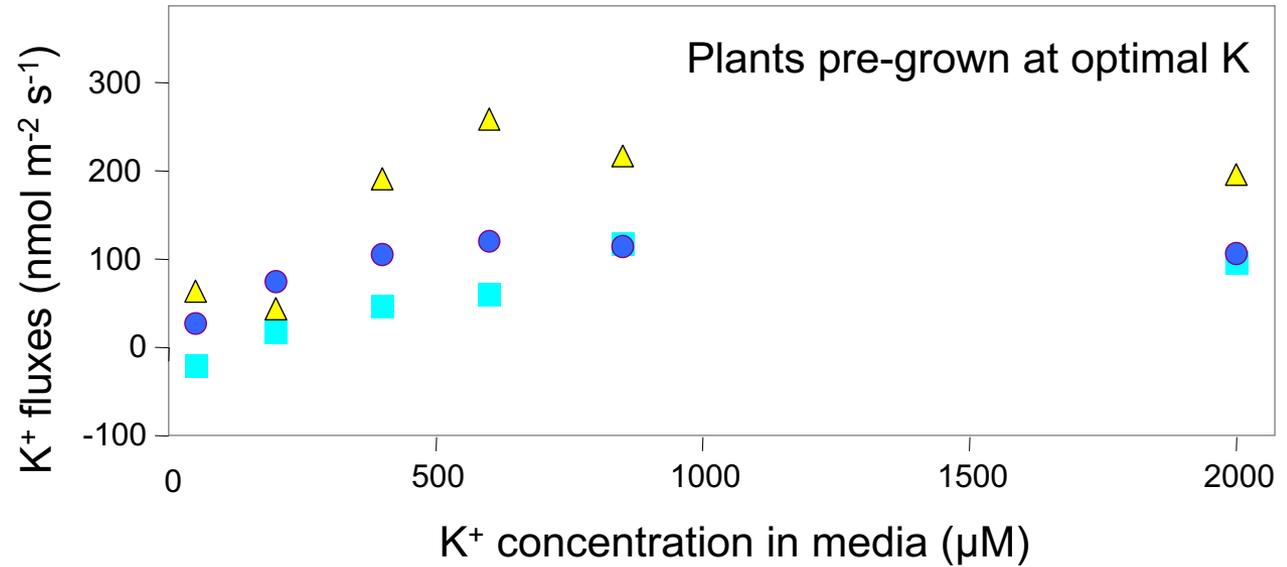


How do K-selective microelectrodes work?

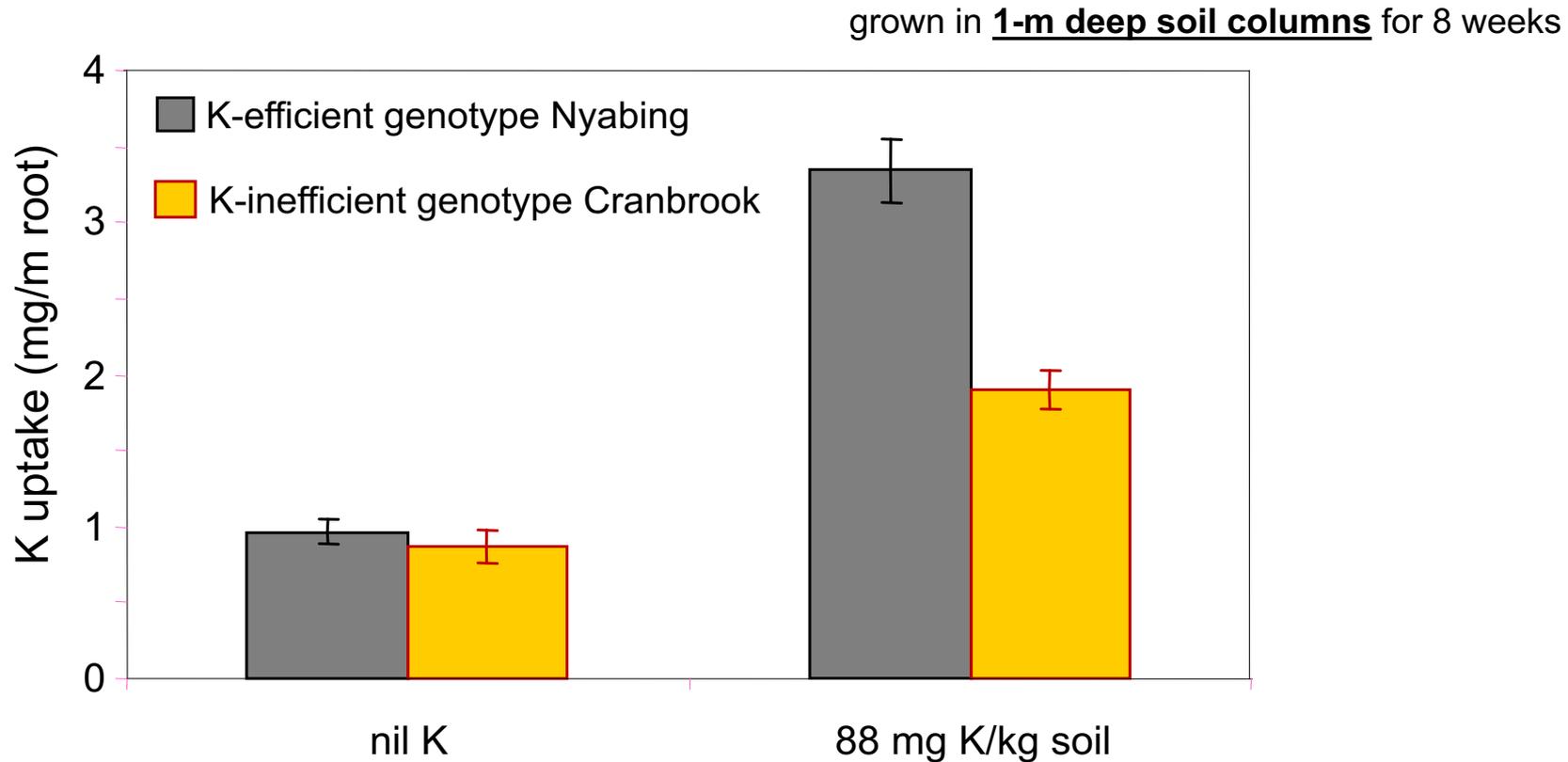


K deficiency increases K^+ influx, particularly in some K-efficient genotypes (Warigal)

- ▲ Nyabing
- Warigal
- Cranbrook

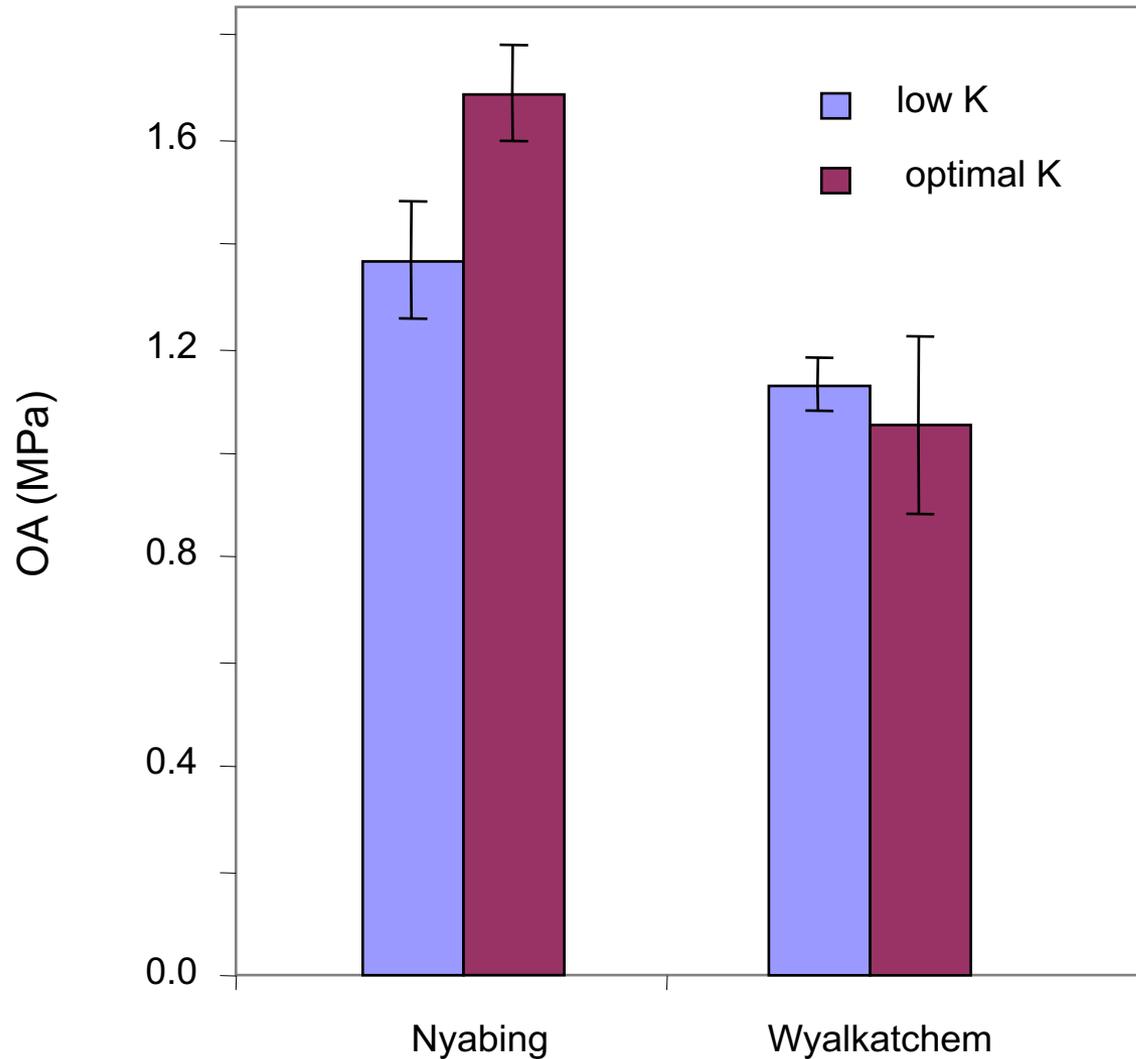


K uptake rate by wheat genotypes differing in K efficiency

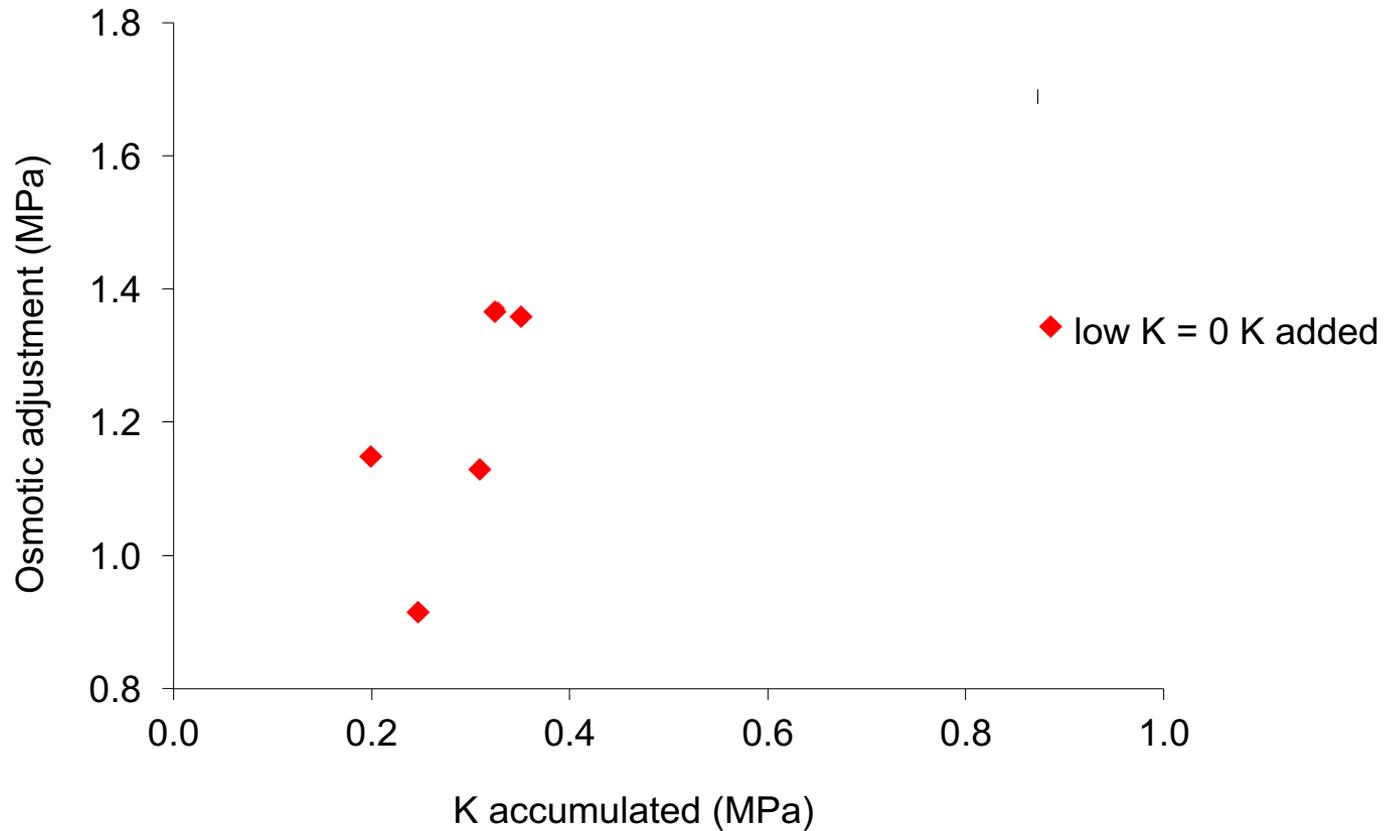


Potassium (K) is the principal mineral solute contributing to osmotic adjustment (OA) in many crop species, and the magnitude of OA under drought stress may be increased by application of K fertilizers.

Genotypes differ in response of OA to K availability



Correlation of osmotic adjustment under drought with leaf K^+ accumulation



Data for 5 genotypes presented

Conclusions

Genotypic variability in K efficiency exists in crop germplasm (examples shown: canola, barley and wheat).

K efficiency in wheat genotypes is based on maintenance of root growth (branching and elongation), increased rate of K uptake and maintenance of harvest index under K deficiency.

Under drought stress, K-efficient wheat genotypes have better K-based osmotic adjustment than K-inefficient ones, particularly when K fertilization is applied.