Water Use Efficiency in Potato

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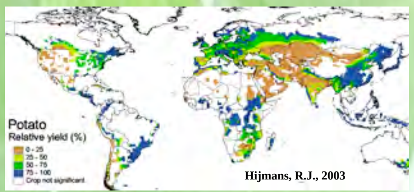
Abstract

Water is one of the key resources challenging the sustainability of modern agriculture. In developing countries, potato production is increasing because of its ability to provide nutritious food in a short season. However, the potato crop requires profuse irrigation. Yields of commercial potato varieties are often restricted by water availability. Their root systems are generally sparse and shallow, and they close their stomata, preventing photosynthetic carbon assimilation, whilst water is still available in the soil. To enable breeding of drought tolerant varieties, we are developing phenotypic screens that will allow us to explore the genetic basis of key traits for water use efficiency (WUE). From field trials of a genetic mapping population, ten genotypes with contrasting transpiration efficiencies based on leaf δ13C values were cultivated under controlled glasshouse conditions. After emergence, plants were grown for 30 days in soils watered to field capacity (30% volumetric content, -5 kPa water potential) before being divided into three groups irrigated to 30%, 20% (-300kPa, slight stress) and 12% (-1500kPa, wilting point) volumetric content. As WUE is a complex phenomenon, we evaluated a number of associated physiological and morphological traits. Tissue samples were also collected at different time points to examine differentially expressed genes at these moisture levels. Response to water stress not only includes closing stomata but also reducing the density of stomata during leaf development. Preliminary data from our experiments shows that transpiration-efficient genotypes, as indicated by low leaf δ13C values, have consistently lower stomatal conductance at 12% volumetric soil moisture than transpiration-inefficient genotypes. Thus transpiration-inefficient genotypes transpire more water at lower soil water content.

Introduction

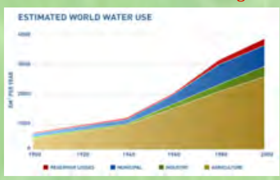
- Water is an inherent constituent of all metabolic processes for plant growth and development.
- Hydrological and cropping systems are affected by climate change.
- Increased intensity of weather events.
- Deforestation and Population pressure.
- Dependency on water has become a critical constraint to agriculture development and food security, the great challenge for coming decades is to increase food production with limited water.

Projected relative yield of Potato in 15-20 years



Hijmans, R.J., 2003

Proportion of water withdrawal for Agriculture



WUE:
- Transpiration Efficiency $^{13}\delta C$
- Photosynthetic capacity
- Specific leaf N

HI:
- Tuber harvest index
- Flowering
- CHO reserves
- Early Maturity

Water Conduction

WU:
- Root density
- Preserve soil moisture

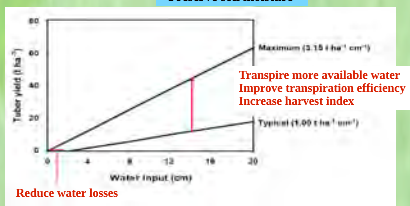
What is Water Use Efficiency (WUE)?

Crop Yield = Crop Water Use (WU) x Water Use Efficiency (WUE) x Harvest Index (HI)

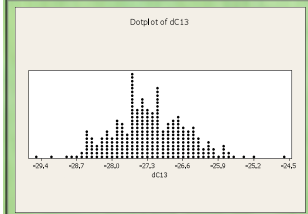
In simple terms, WUE is ratio of outputs to inputs   WUE = Outputs / Inputs

Outputs include: Biomass / Yield / Energy content / Saleable product / Financial return and others.

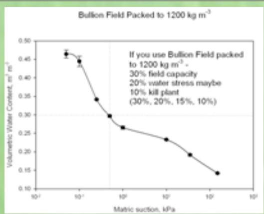
Inputs include: Rainfall / Irrigation / Transpired water / Evapotranspiration, etc.



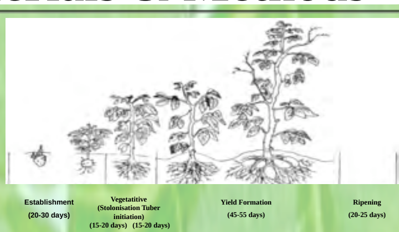
Materials & Methods



Ten genotypes with contrasting behavior for δ13C measurements from 12601 x Stirling population chosen from previous year's field trials.



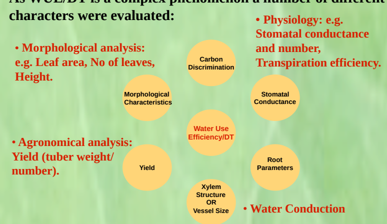
Genotypes were cultivated under controlled glasshouse conditions in 12" pots at three moisture levels. Figure represents the moisture levels of bullion field soil packed at 1200kg/m³.



Plants grown for 36 days at field capacity (30% volumetric content, -5 kPa water potential) and divided into three groups irrigated to: 1) 30%, 2) 20% (-300kPa, slight stress) and 3)12% (-1500kPa, wilting point) volumetric content. Measurements/samples collected on days 36 (control), day 56 and day 76.

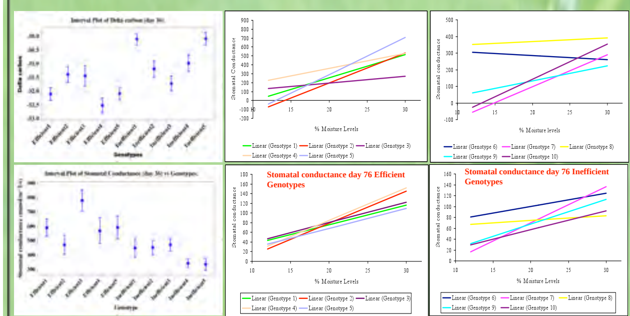
Phenotypic measures for WUE/Drought Tolerance (DT)

As WUE/DT is a complex phenomenon a number of different characters were evaluated:

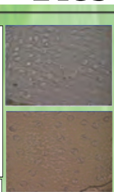


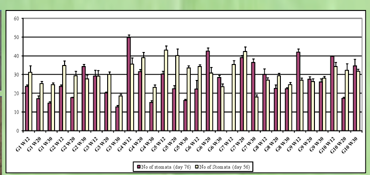
Differences between responses of susceptible and tolerant accessions and their interactions at different water stress levels at different phenological age.

Results

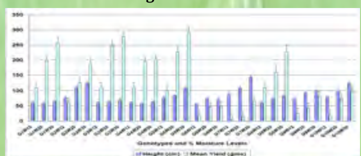


Figures showing the relationship between field Delta carbon values to the pot δ13C on day 36 after emergence. Preliminary data represented as graphical shows that transpiration-efficient genotypes, as indicated by low leaf δ13C values, have consistently lower stomatal conductance at 12% volumetric soil moisture than transpiration-inefficient genotypes. Thus transpiration-inefficient genotypes transpire more water at lower soil water content.

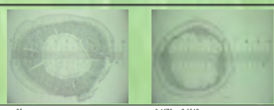


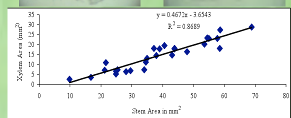


Stomatal conductance depends on stomatal density and size. Counting the stomatal density illustrates that stomatal number are significantly different between genotypes and histograms shows that stomatal density per unit area increases with decreasing moisture levels .

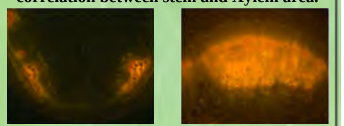


Height and yield data of transpiration efficient and inefficient genotypes are influenced by stomatal conductance and xylem cross sectional area.





Variation in stem diameter between different genotypes at different moisture levels and graph representing high correlation between stem and Xylem area.



A small experiment using Tracer dye (Eosin) demonstrated that only metaxylem was responsible for water conduction after tuberisation .

References:
Hijmans, R.J., 2003. American Journal of Potato Research 80: 271-280.
FAO, 2007