Leibniz Universität Hannover

Institute of Biological Production Systems
Vegetable Systems Modelling Section

Effect of grafting on yield and quality of grafted tomato under drought stress

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Introduction

Water use has been growing at more than twice the rate of population increase in the last century.

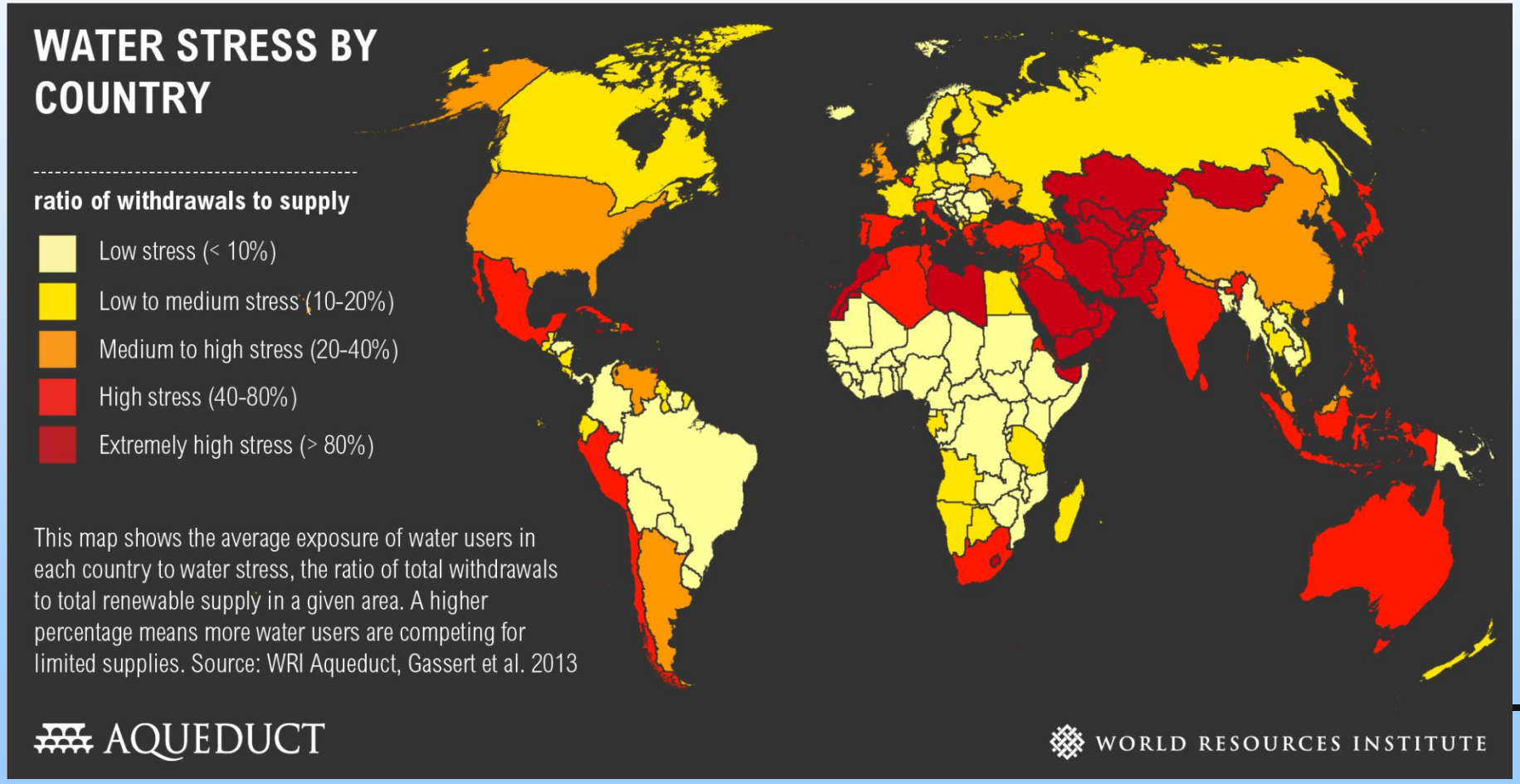
In many countries, as a consequence of global climate changes water use for agriculture production was considerably reduced.

By 2025, 1800 million people will be living in countries or regions with absolute water scarcity, and two- thirds of the world population could be under stress conditions.

Introduction- Water Deficit

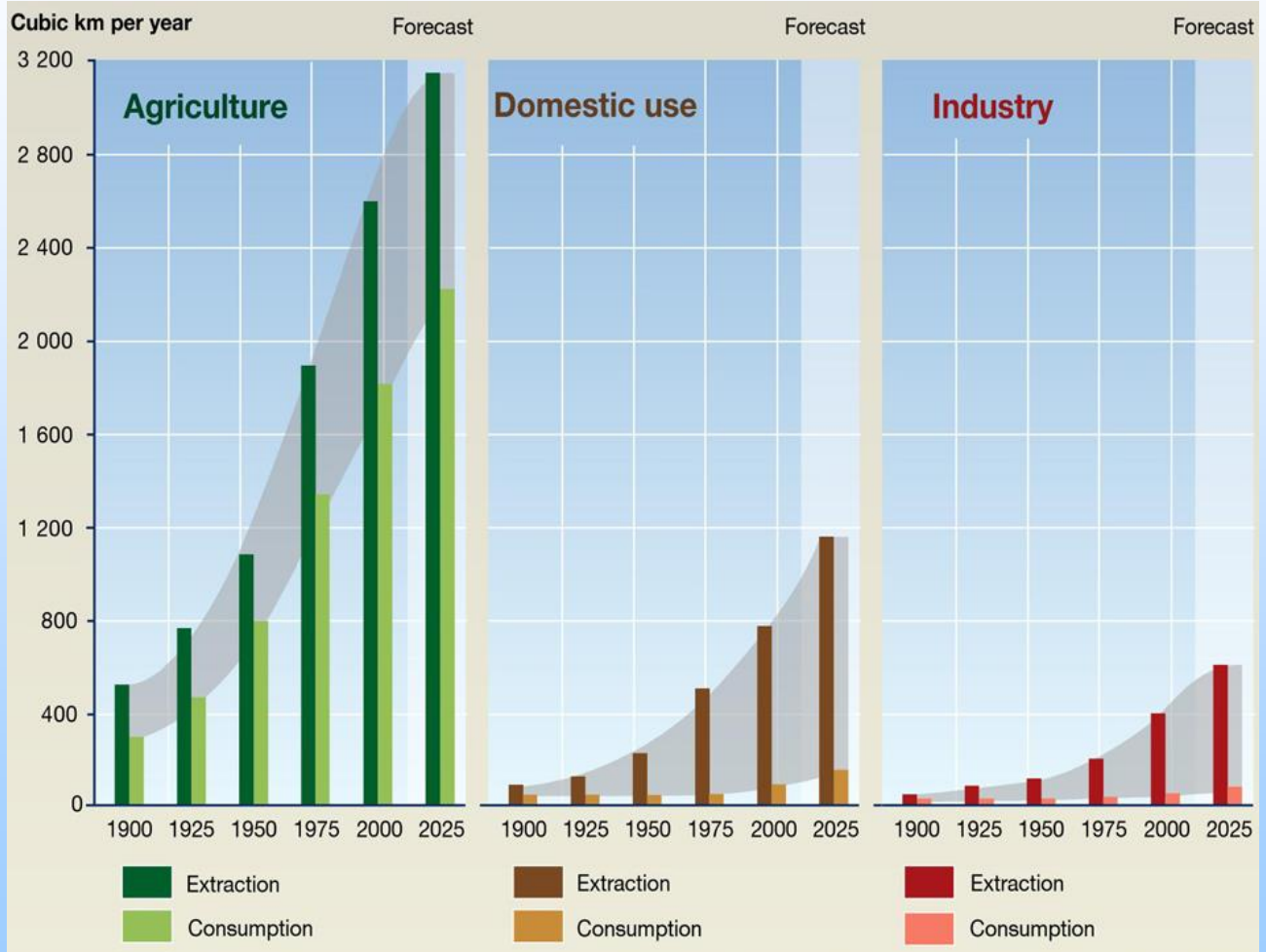
- **Water is an increasingly scarce resource worldwide due to increased consumption, mismanagement and pollution.**

- **One-third of the earth's surface is classified as arid or semiarid because it is subjected to permanent drought.**



Introduction- Water Deficit

Water deficits and insufficient water are the main limiting factors affecting worldwide crop production.



The grey band represents the difference between the amount of water extracted and that actually consumed. Water may be extracted, used, recycled (or returned to rivers or aquifers) and reused several times over. Consumption is final use of water, after which it can no longer be reused. That extractions have increased at a much faster rate is an indication of how much more intensively we can now exploit water. Only a fraction of water extracted is lost through evaporation.

Irrigated agriculture is a major consumer of water and accounts for about two thirds of the total fresh water diverted to human uses.

- In water management, appropriate policies and strategies can be helpful for the sustainability of agricultural and economic activities.

- As a water management tool; regulated deficit irrigation can reduce production costs, conserve water and minimize leaching of nutrients and pesticides into ground water.

- Whether permanent or temporary, drought limits the growth and distribution of natural vegetation and yield of cultivated plants more than any other environmental factor.

- Drought stress affects the anatomy, morphology, physiology and biochemistry of crop plants.

Lean and Hinrichsen (1994); Nuruddin et al. (2003)

Introduction- Drought Stress

How does drought stress affect crop plants?

Morphological response

- **During shoot and root growth**
  - (-) stem diameter and elongation
  - (-) leaf area
  - (+) root length and root hairs
- **During fruit development and ripening**
  - (-) yield
  - (-) fruit quality (small diameter)
  - (+) soluble solids

Physiological & Biochemical response

- (-) cell expansion
- (-) protein synthesis
- (-) stomatal opening
- (-) CO_2 assimilation
- (+) sugar level
- (+) Abscisic acid (ABA)

Aloni and Pressman (1981); Gallardo *et al*., (2004)

Introduction- Tomato (*Lycopersicon esculentum* L.)

- One of the most important horticultural crops in the world.
- Known in Europe since 1498.
- Cultivated as vegetable since 1820.
- Total tomato production in the world around 150.0 Mio t (FAO, 2013).
- Around 15% (18.23 Mio t) of the total production from EU (27+) countries.
- The production in Turkey:
  - 11 Mio t (FAO, 2013).

Introduction- Tomato (*Lycopersicon esculentum* L.)

- Production is very concentrated in semi-arid region.
- Sensitive to drought stress.
- A controlled supply of water period.

SOLUTION???

High-yielding genotypes would be to graft them onto rootstocks

(Garcı´a-Sa´nchez et al., 2007; Satisha et al., 2007; Doorenbos and Kassam, 1979)

History of grafting

First grafting in 1920s in Japan and Korea on watermelone (Oda, 1995)

Important technique in Asia and Europe, due to intensive and continuous cropping (Lee, 1994)

In Spain, 154 million grafted plants 40% of them tomatoes (Leonardi and Romano, 2004)

Advantages of grafting caused by rootstocks

Improvement of water use efficiency (Cohen and Naor, 2002)

Enhancement of drought tolerance (Estan *et al.*, 1995)

Higher leaf water potential and leaf stomatal conductance (Weng, 2000)

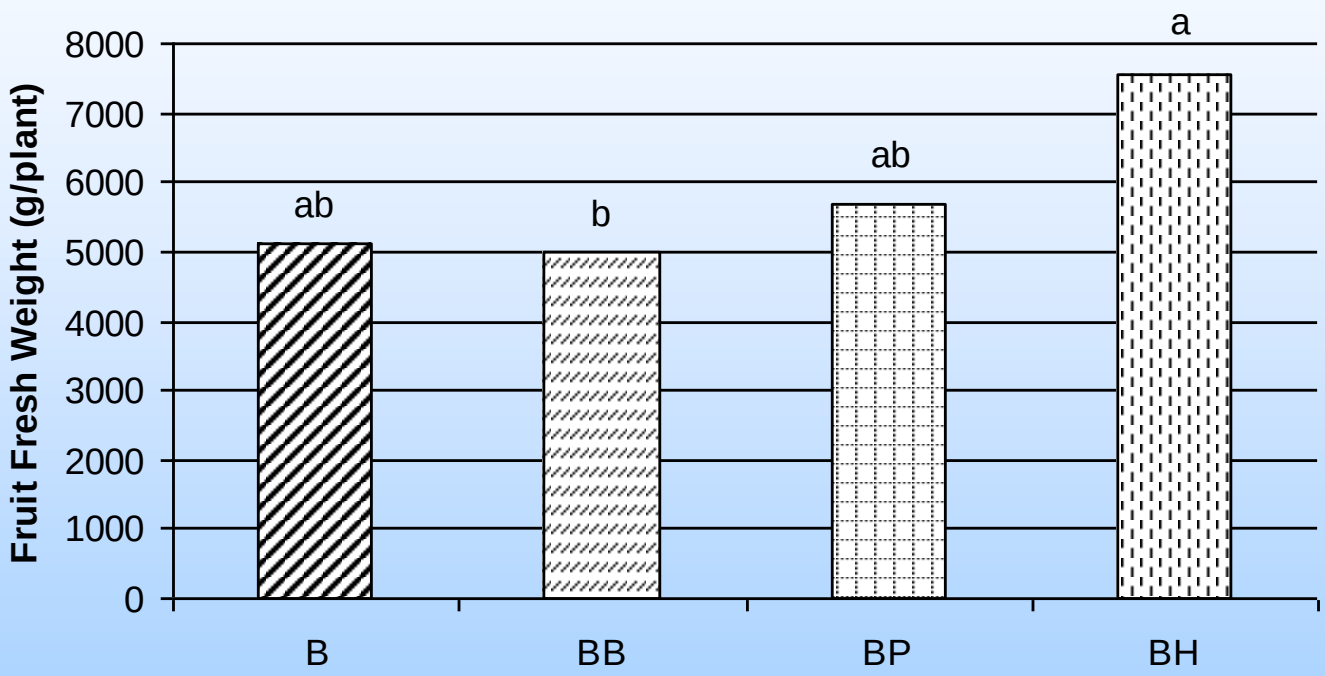
Increase in yield and fruit development (Lee, 1994)

Increase in water and mineral uptake (Bersi, 2002)

Strong, vigorous root system (Leoni *et al.*, 1990)

Higher root length and root hairs (White, 1963)

Effect of grafting on fruit fresh weight of tomato scion-rootstock combinations



Big Red: Scion variety

Heman: Rootstock variety

Primevera: Rootstock variety

B: Non-grafted

BB: Big Red-Big Red

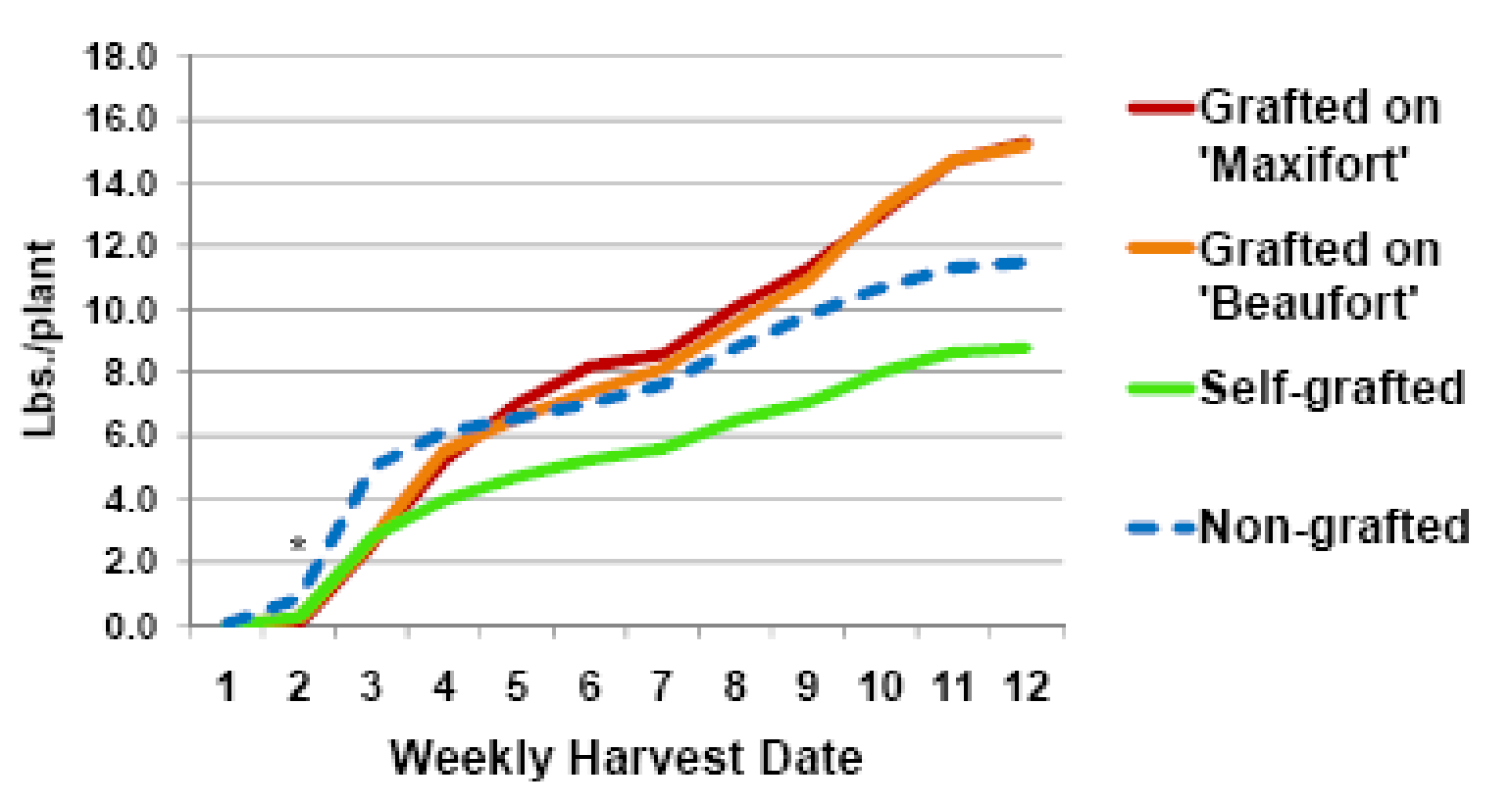
BH: Big Red-Heman

BP: Big Red-Primavera

Fruit fresh weight of non-grafted and 3 grafted tomato scion-rootstock combinations (Khah *et al.*, 2006)

The tomato rootstock variety of Heman has an efficient root system as comparing to rootstock variety of Primevera (Khah *et al.*, 2006).

Effect of different rootstocks grafting on cumulative yield of Cherokee Purple Tomato



Cumulative yield of non-grafted and 3 grafted tomato rootstock varieties (Hitt *et al*., 2009)

Research Objectives

- **To determine the reciprocal grafting and its interactions between tomato rootstock and scion varieties regarding growth, development and yield under different water supply levels.**

- **To identify the morphological and physiological plant traits related to drought tolerance of tomato rootstock and scion varieties.**

Research Hypotheses

- Growth and yield of tomato scion varieties are affected negatively under drought stress conditions due to inefficient morphological and physiological root characteristics.

- Vegetative growth of tomato rootstock varieties are not influenced negatively under drought stress conditions due to efficient morphological and physiological root characteristics.

- The growth and yield of the tomato scion-rootstock combinations increase under well water conditions and maintain an acceptable yield formation under drought stress conditions due to both efficient root and shoot system.

Materials and Methods

- Automatically controlled greenhouse at the Institute of Biological Production Systems, Gottfried Wilhelm Leibniz University Hannover, Germany.

- No drought stress (DS) and DS treatments for growth and fruit yield with three replications
  - 2 tomato scion (S) varieties [Pannovy (Pan) and Treasury (Treas)]
  - 2 tomato rootstock (R) varieties [Brigeor (Brig) and Maxifort (Max)]

- Design ⇨ Randomized Complete Block Design (RCBD)

- Grafting ⇨ homografting on
  - S-S,
  - R-R,
  - S-R combinations

- As a control treatment, the scion and rootstock varieties were grafted on themselves.

Materials and Methods

- Soil water holding capacity was maintained at a value of 85% WHC for well watered plants and 45% WHC for drought stress plants

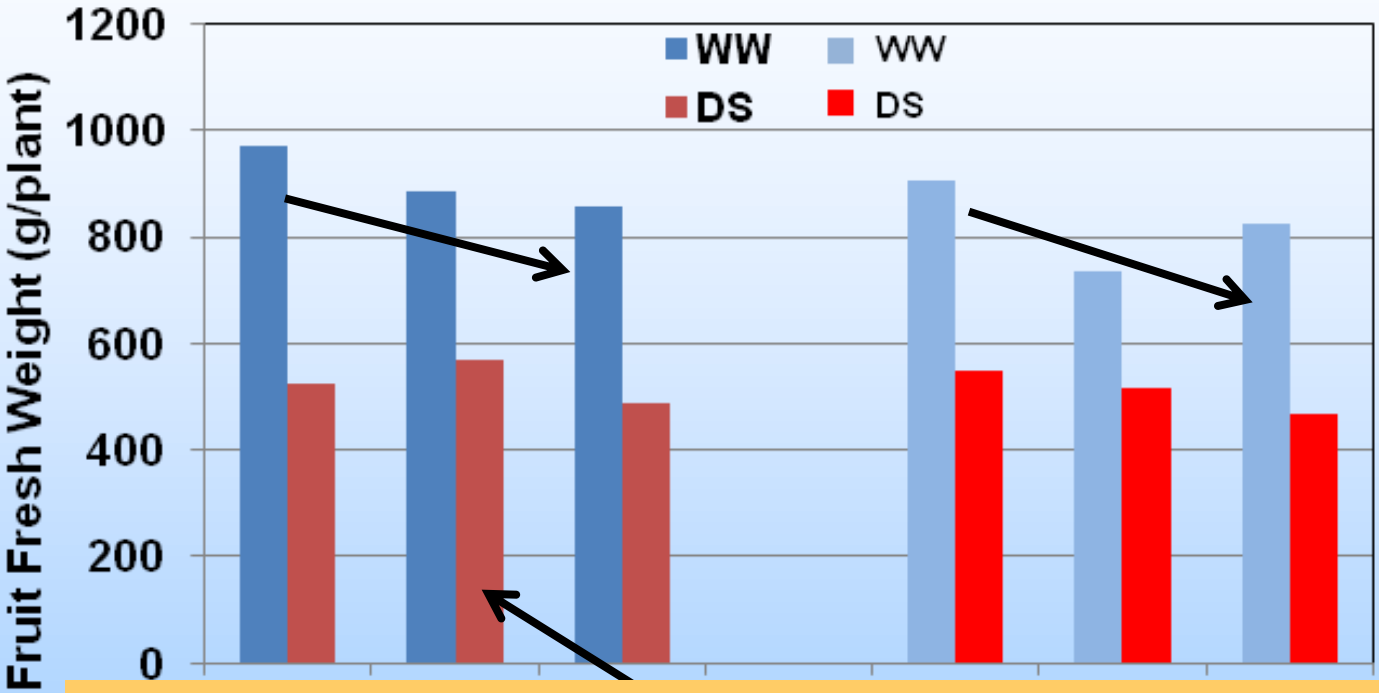
- Top soil covered with gravel to avoid the evaporation

- **Irrigation:** The pots were weighed daily in the morning to irrigate to the target value for 85% WHC for well watered plants and 45% WHC for drought stress plants

- To give the plants of the drought stress treatments time to adopt, in the beginning only 50% of the transpired water of the previous day was replaced in order to increase the stress level.

Results

Fruit fresh weight of tomato S-R combinations at final harvest



Significances of interactions

Stress ***

ScionxRootstock n.s.

Rootstockx Stress ***

ScionxStress n.s.

Significances of treatments:

WW>DS

Significances of S and R varieties grafted as R:

RPannovy > RBrigeor

RPannovy > RMaxifort

RTreasury> RBrigeor

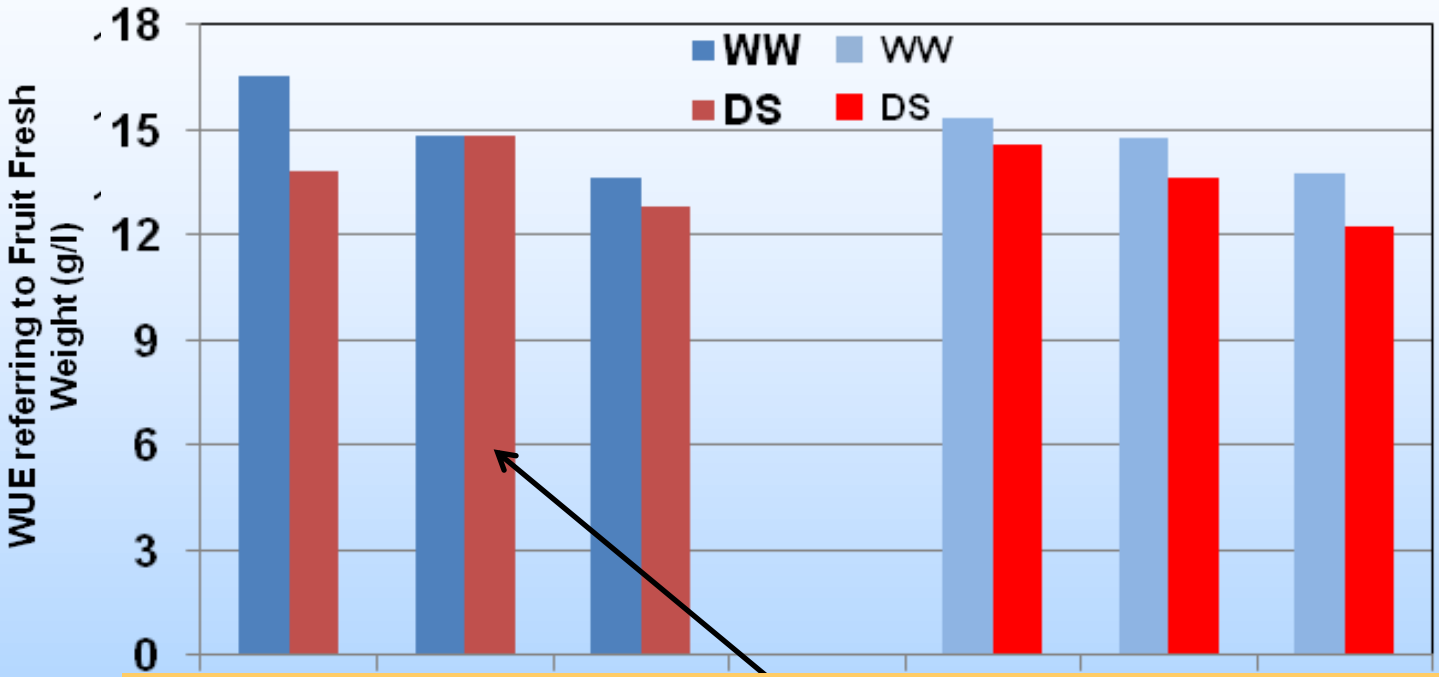
RTreasury> RMaxifort

Increase in fruit fresh weight under DS condition in S-R combinations can be explained by the contributory morphological and physiological plant traits like optimal root/shoot partitioning, higher leaf conductance and efficiency in water use.

WW: Well watered DS: Drought stress

Results

WUE referring to fruit fresh weight of tomato S-R combinations at final harvest



Significances of interactions

Stress *

ScionxRootstock n.s.

Rootstock x Stress n.s.

ScionxStress n.s.

Significances of treatments:

WW>DS

Significances of S and R varieties grafted as R:

RPannovy > RBrigeor

RPannovy > RMaxifort

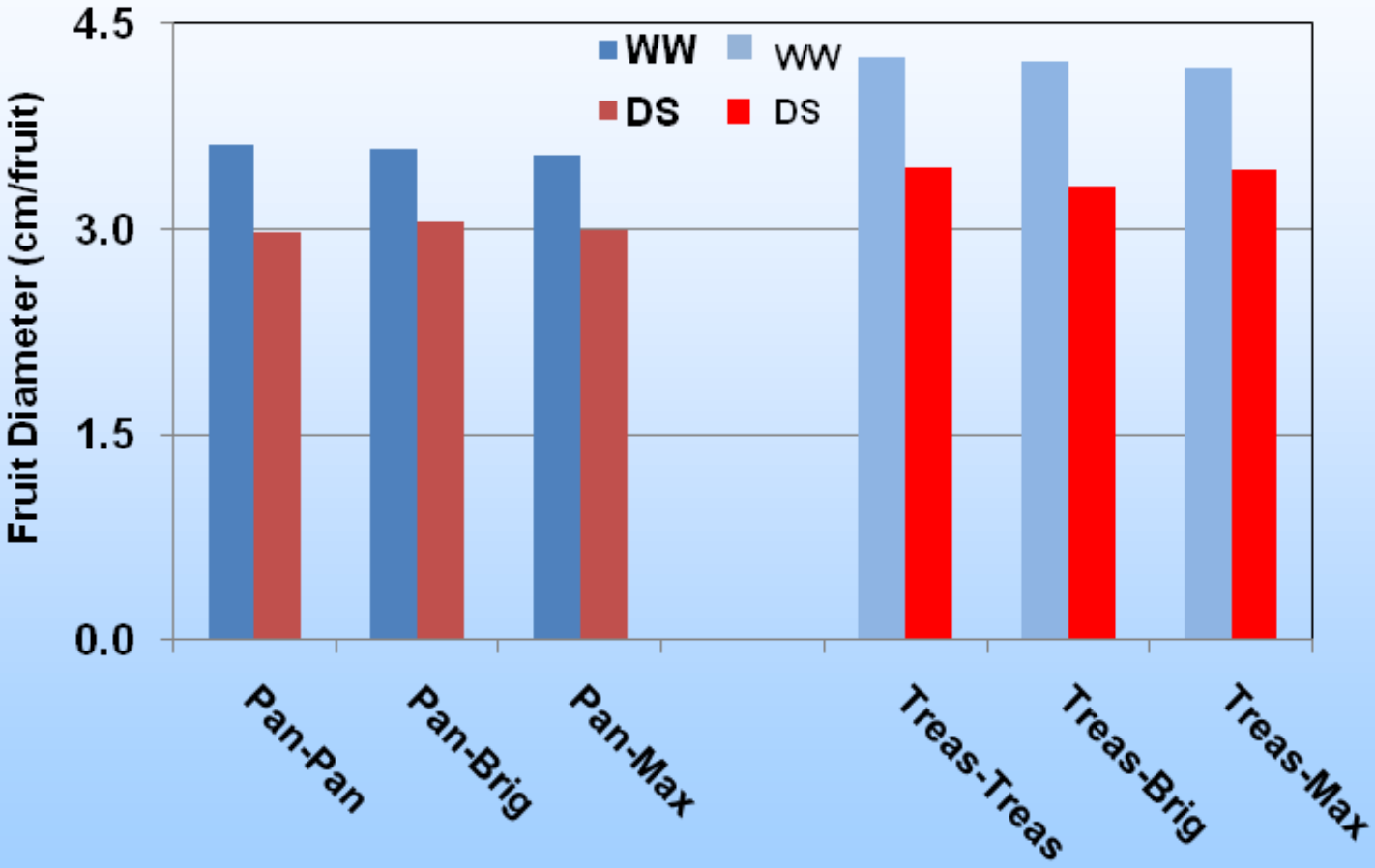
RTreasury > RBrigeor

RTreasury > RMaxifort

Increase in WUE referring to early fruit fresh weight under DS condition in Pan- Brig combination may be the result of less water consumption that related with decline in water transpiration (Jefferies, 1992).

WW: Well watered DS: Drought stress

Fruit diameter of tomato S-R combinations at final harvest



Significances of interactions

Stress ***

ScionxRootstock n.s.

Rootstock x Stress n.s.

ScionxStress *

Significances of treatments:

WW>DS

Significances of S and R varieties grafted as S:

STreasury > SPannovy

Significances of S and R varieties grafted as R:

RTreasury > RPannovy

RTreasury > RBrigeor

RTreasury > RMaxifort

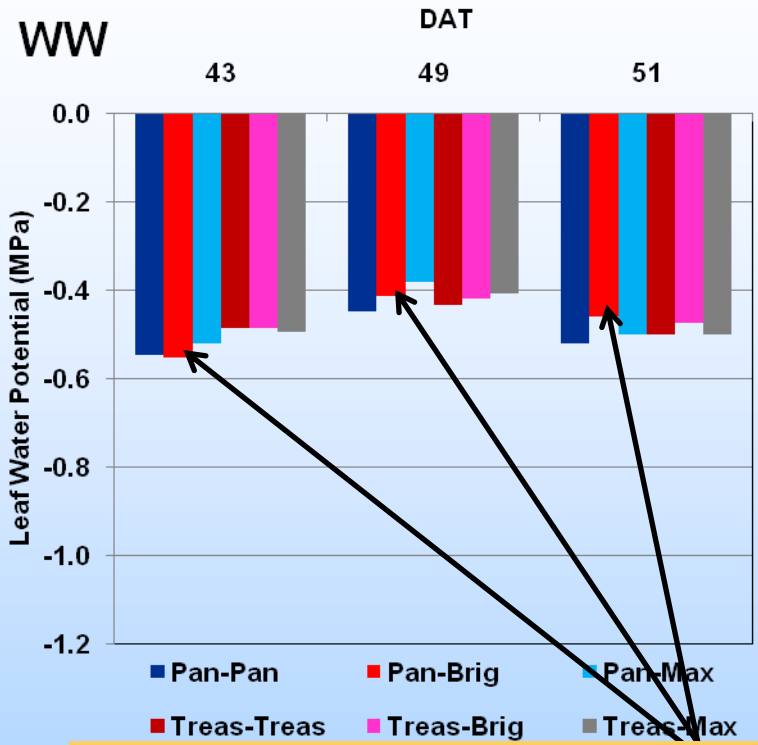
RPannovy > RBrigeor

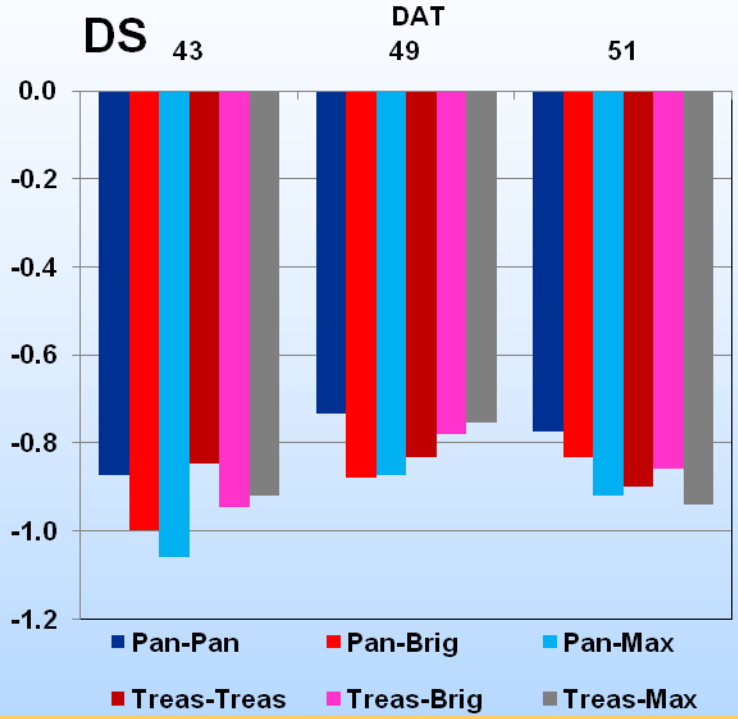
RPannovy > RMaxifort

WW: Well watered DS: Drought stress

Results

Leaf water potential of tomato S-R combinations at different growth stages





Lower leaf water potential of S-R combinations under DS condition might be the result of water loss through transpiration as compared to self-grafted control plants (Weng, 2000).

ScionxStress n.s.

ScionxStress n.s.

ScionxStress *

Significances of treatments:

WW > DS

Significances of treatments:

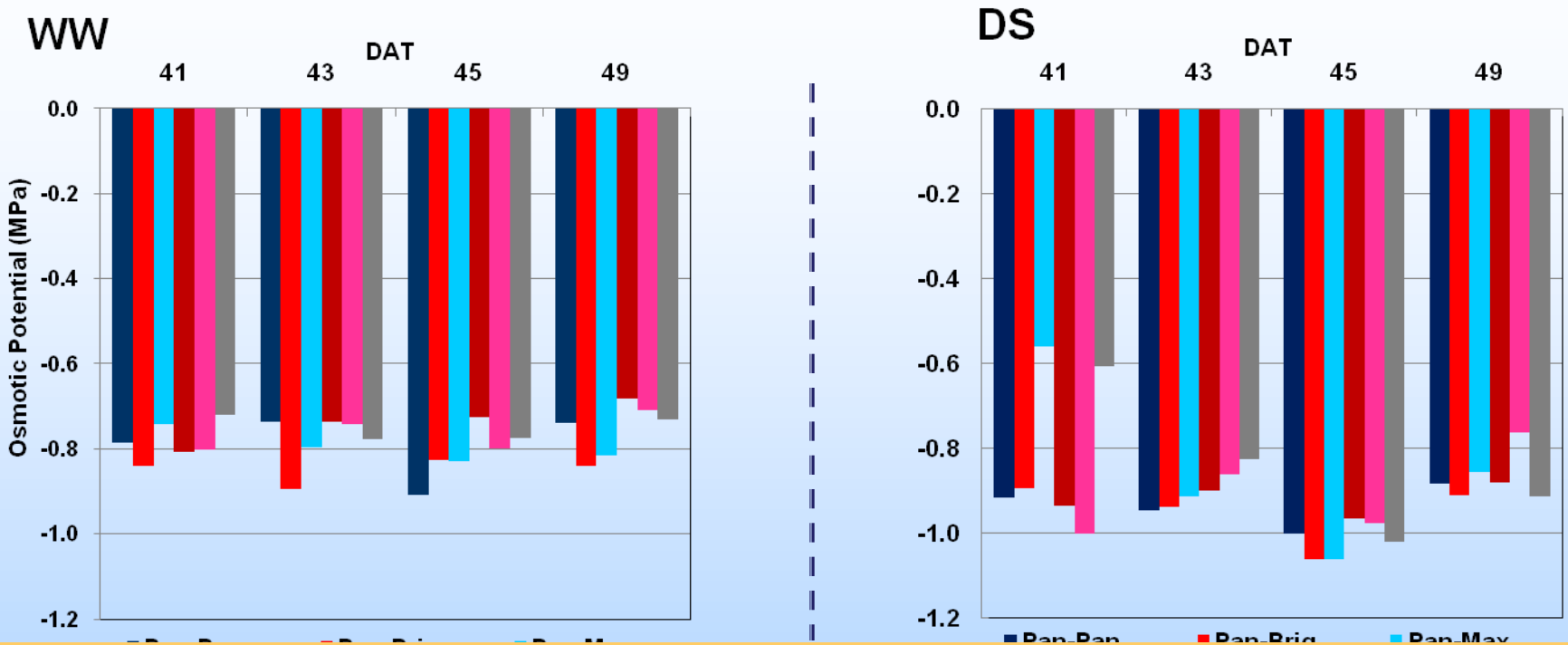
WW > DS

Significances of treatments:

WW > DS

Results

Leaf osmotic potential of tomato S-R combinations at different growth stages



Significantly lower osmotic potential under DS condition at four different measurements might be due to increase drought tolerance of plants by osmotic adjustment to maintain turgor and turgor-dependent processes to a significantly lower water potential (Turner and Jones, 1980; Rains et al., 1980).

Sig. of treatments:

WW >DS

Sig. of treatments:

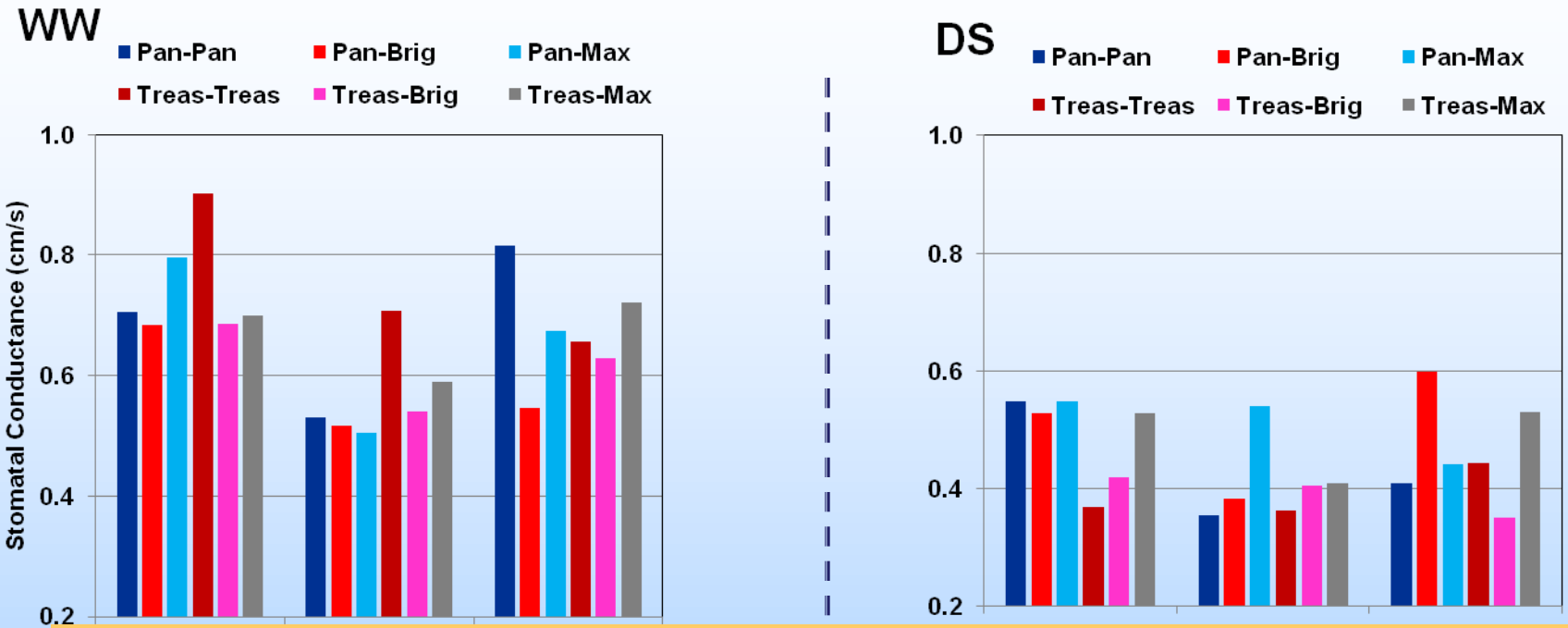
WW > DS

Sig. of treatments:

WW > DS

Results

Stomatal conductance of tomato S-R combinations at different growth stages



Lower stomatal conductance under DS condition might be the result of hydraulic effects or the production of chemical signals such as ABA produced in root tips of rootstocks (Jefferies, 1992; Tardieu *et al.*, 1992).

Significances of treatments:

WW>DS

Significances of treatments:

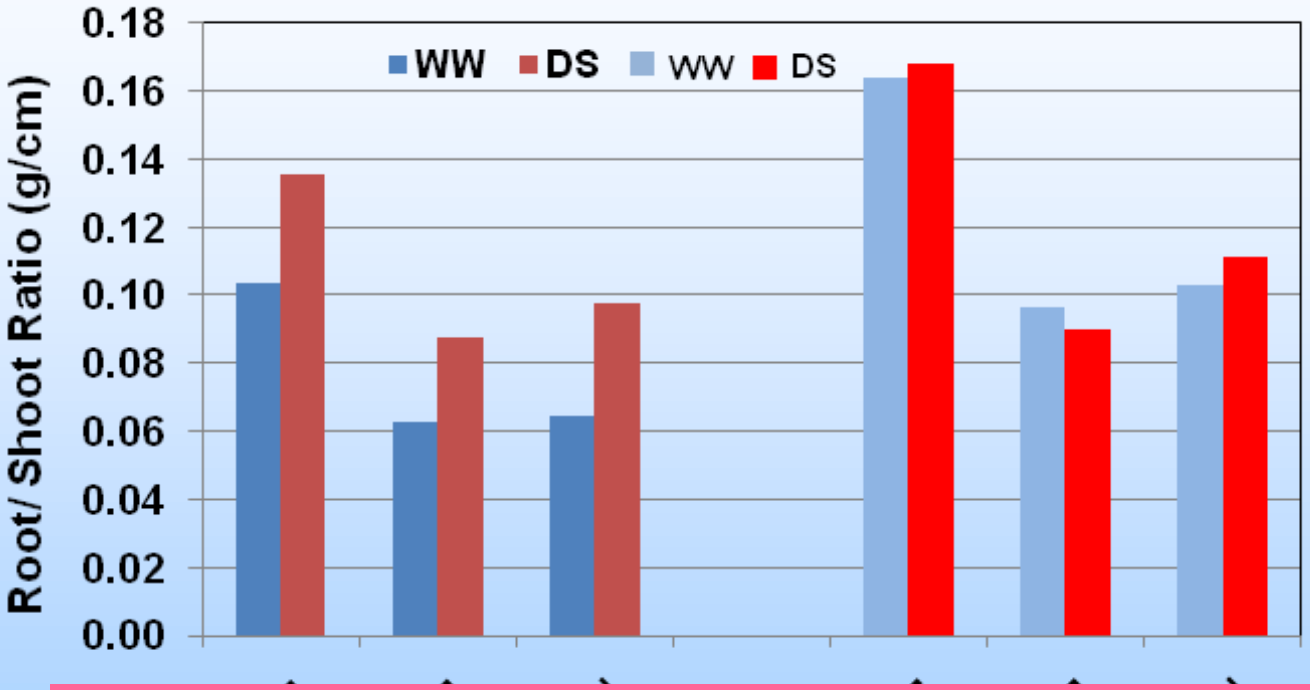
WW>DS

Significances of treatments:

WW>DS

Results

Root/Shoot ratio of tomato S-R combinations at final harvest



Significances of interactions

Stress **

ScionxRootstock n.s.

Rootstockx Stress n.s.

ScionxStress n.s.

Significances of S and R varieties grafted as R:

RMaxifort > RBrigeor

Significances of S and R varieties grafted as S:

SMaxifort > SBrigeor

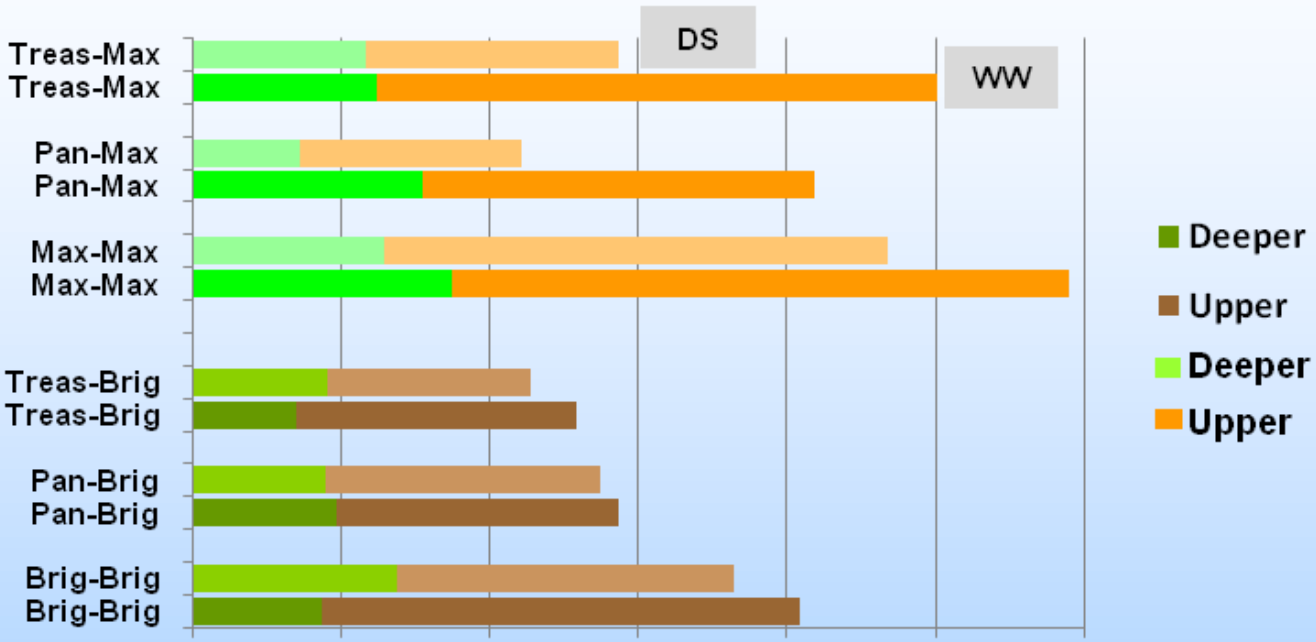
SMaxifort > STreasury

Under DS condition, growth of the roots is less affected by water storage than aerial plant parts and thus an increase in root/shoot ratio occur (Sharp *et al.*, 1988).

WW: Well watered DS: Drought stress

Results

Root length density of tomato S-R combinations at final harvest



Sig. of interactions for upper layer
Stress **
ScionxRootstock n.s.
Rootstockx Stress n.s.
ScionxStress n.s.
WW > DS

Sig. of interactions for deeper layer
Stress n.s.
ScionxRootstock n.s.
Rootstockx Stress n.s.
ScionxStress n.s.

Significances of S and R varieties grafted as S for upper layer:
SMaxifort > STreasury
SMaxifort > SPannovy

Significances of S and R varieties grafted as R for deeper layer:
RMaxifort > RBrigeor

Slightly reduction in root length density of both S varieties under DS condition with Brigeor might be the result of the differences in root xylem diameter that increased water absorption from soil by the hydraulic conductivity (Jefferies, 1992).

WW: Well watered DS: Drought stress

Conclusions

- Fruit fresh weight significantly decreased under DS compared to WW condition.
- Compared to self-grafted S varieties, the fruit fresh weight reduced in S-R combinations under WW condition.
- Under DS condition both S varieties (Pannovy and Treasury) increased the fruit fresh weight with R variety of Brigeor.
- Compared to WW condition, the fruit diameter was lower under DS condition.
- Leaf water potential, leaf osmotic potential and leaf conductance were significantly higher under WW condition than under DS condition.

Conclusions

- **Higher stomatal conductance under DS condition was shown by Pan-Brig, Pan-Max and Treas-Max combinations.**

- **Root/shoot ratio was significantly higher under DS than WW conditions.**

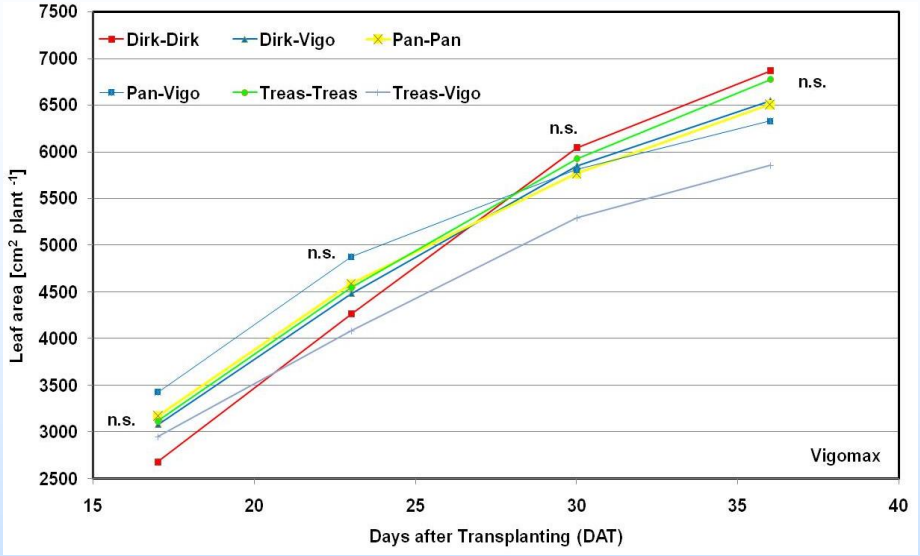
- **Root length density was significantly higher under WW condition compare to DS condition.**

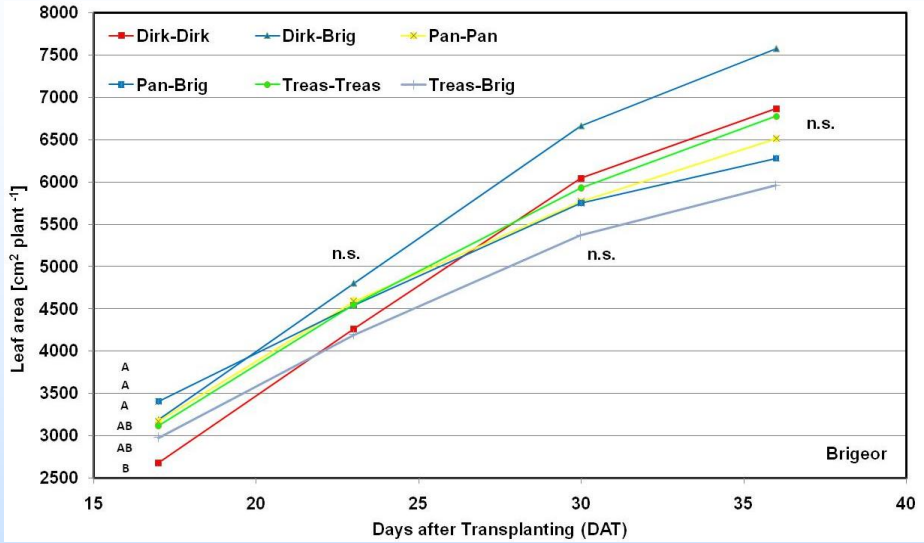
- **Root length density of both S varieties decreased with Brigeor, but increased with Maxifort under both conditions.**

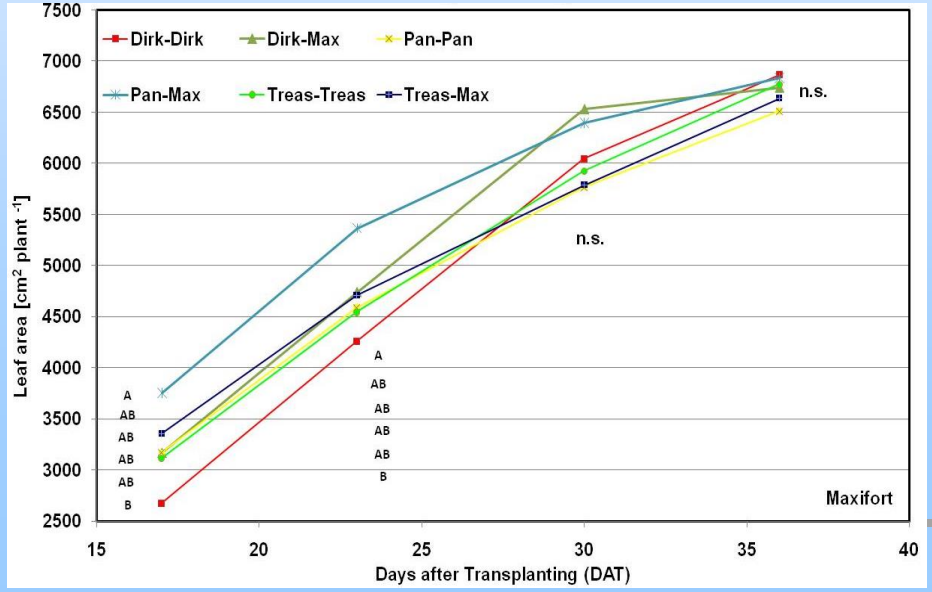
Thank you for your attention!...

Results - Experiment I

Leaf area of tomato scion-rootstock combinations at different growth stages







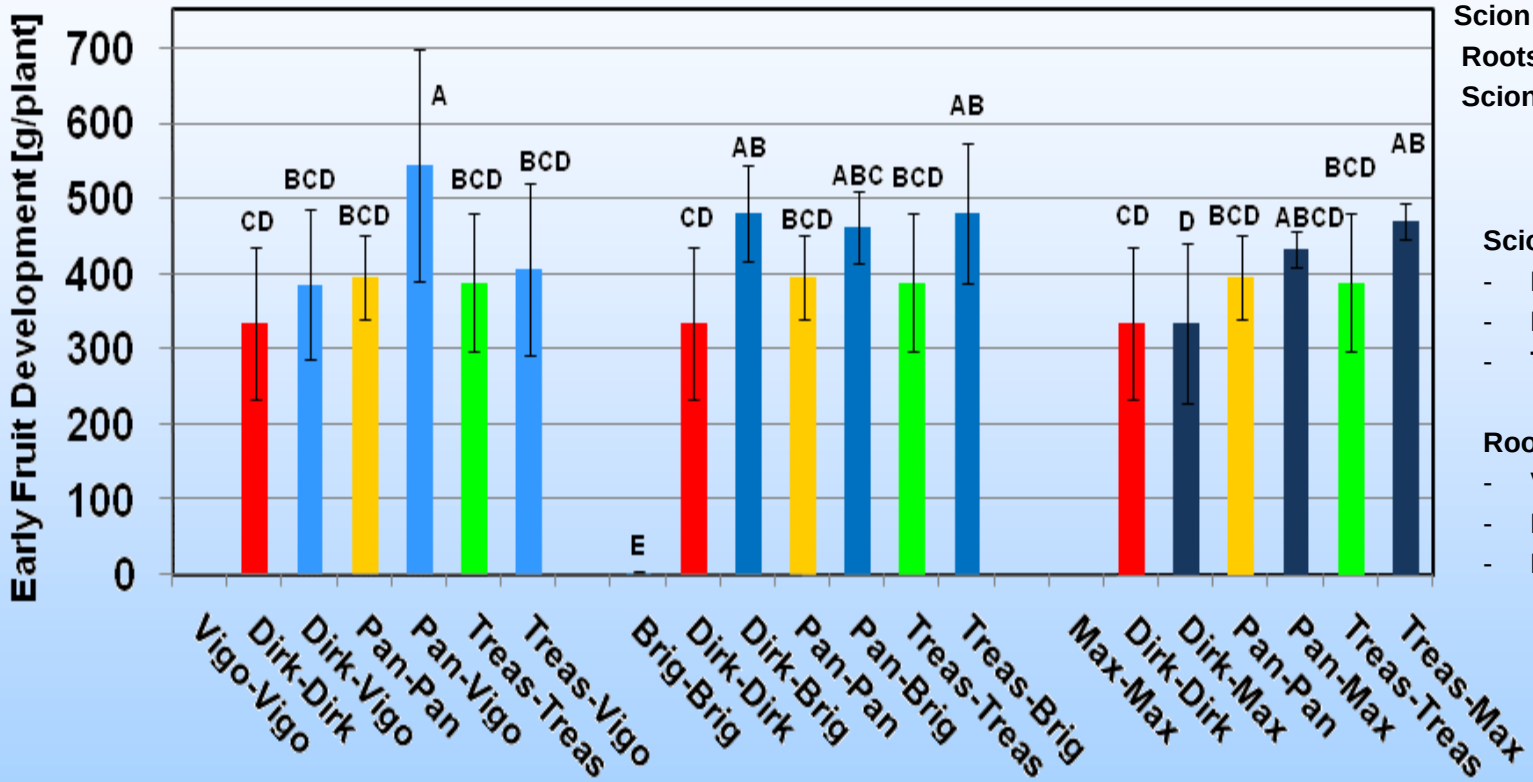
Scion Varieties:
- Dirk
- Pannovy
- Treasury

Rootstock Varieties:
- Vigomax
- Brigeor
- Maxifort

The higher leaf area of Dirk is probably a result of the vigorous root system of the Brigeor which may enhanced water and mineral uptake of grafted plants (Lee, 1994).

Results - Experiment I

Fruit fresh weight of tomato scion-rootstock varieties at final harvest



Scion ***
Rootstock n.s.
ScionxRootstock n.s.

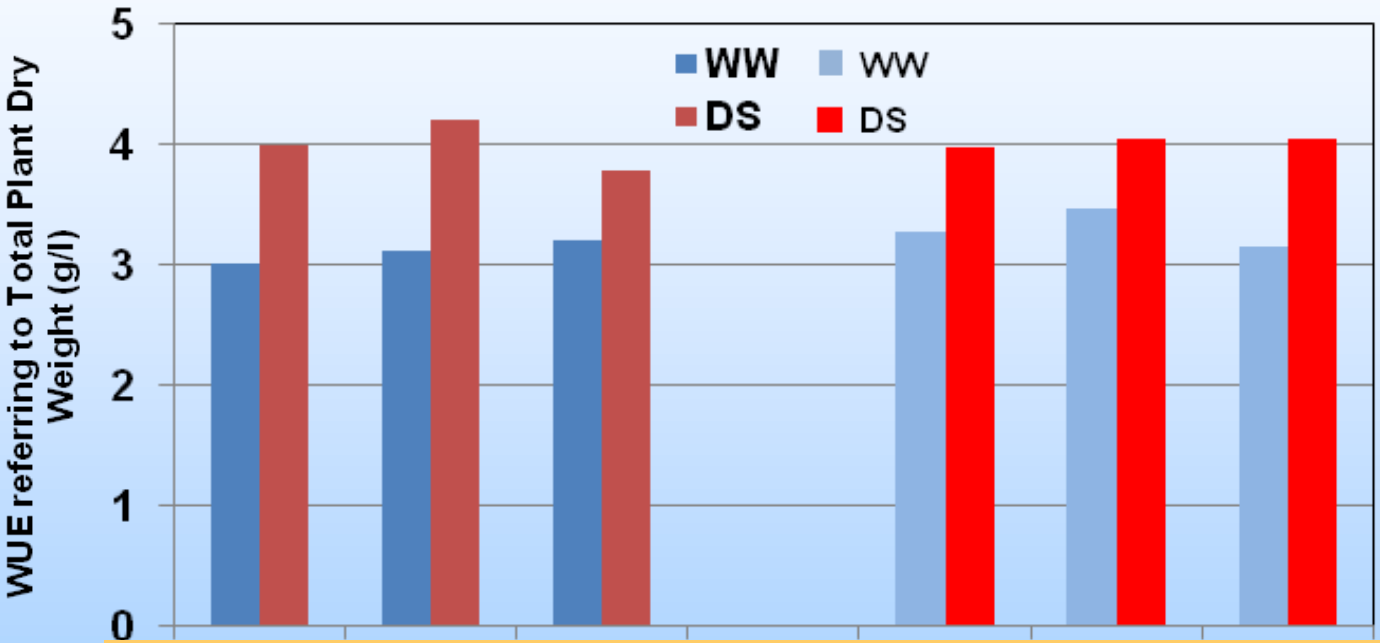
Scion Varieties:
- Dirk
- Pannovy
- Treasury

Rootstock Varieties:
- Vigomax
- Brigeor
- Maxifort

The higher early fruit development of Pannovy is probably a result of the enhanced water and nutrient uptake by the vigorous root system of Vigomax and thus higher leaf area duration during the reproductive growth stage (Abdelmageed *et al.*, 2004).

Results

WUE referring to total plant dry weight of tomato S-R combinations at final harvest



Significances of interactions

Stress ***

ScionxRootstock n.s.

Rootstock x Stress n.s.

ScionxStress n.s.

Significances of treatments:

DS > WW

Significances of S and R varieties grafted as R:

RBrigeor > RPannovy

Higher WUE referring to total plant dry weight of tomato S-R combinations under DS condition is the result of higher leaf and stem dry weight.

WW: Well watered DS: Drought stress