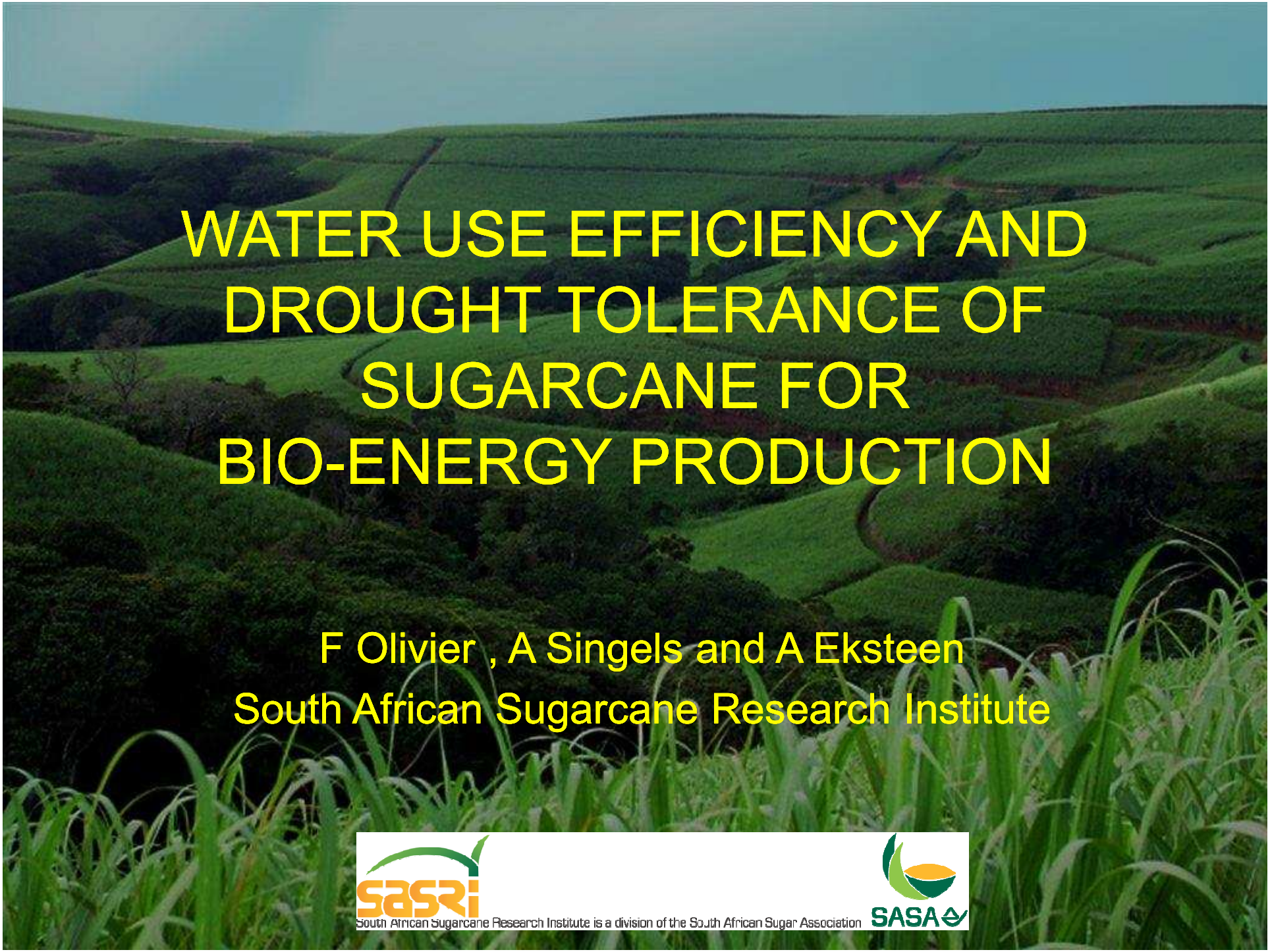

WATER USE EFFICIENCY AND DROUGHT TOLERANCE OF SUGARCANE FOR BIO-ENERGY PRODUCTION

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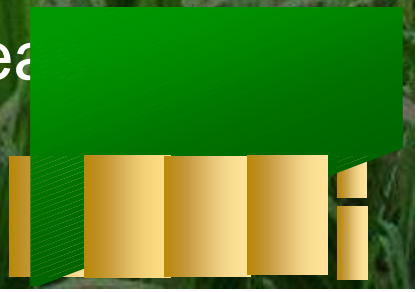
SASRI South African Sugarcane Research Institute is a division of the South African Sugar Association SASA

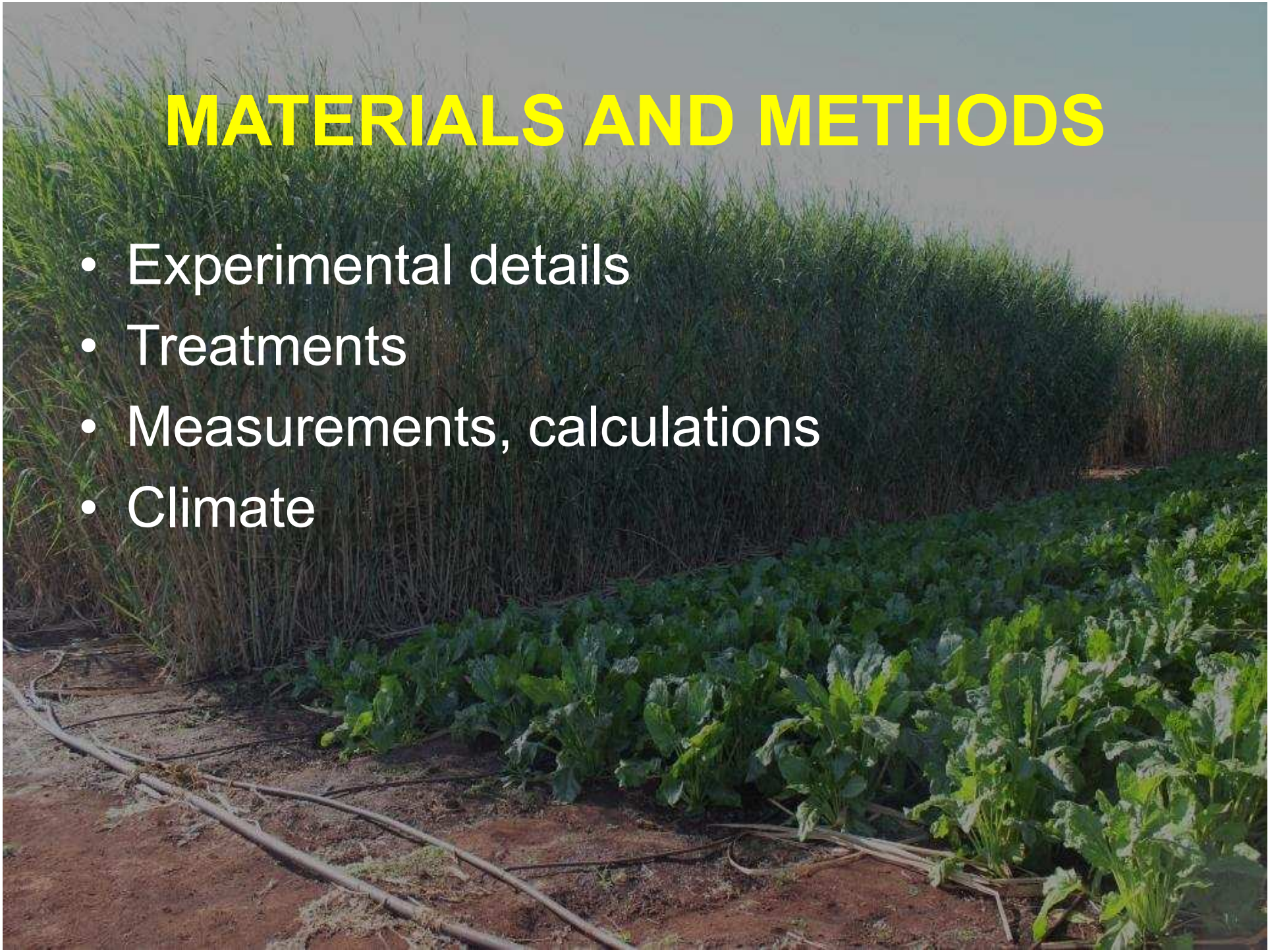
BACKGROUND

- The world is desperate for more CO_2-neutral energy
- Ethanol and electricity can be obtained from biomass crops
- Sugarcane is a candidate feedstock for bio-energy
  - High biomass yields (up to 250 t/ha)
  - Fermentable sugars (16%)
  - Fibre for cellulosic bio-fuel or electricity (15%)
  - Large existing production areas, surplus sugar
- Indications that high biomass genotypes use water more efficiently than sucrose genotypes
- Opportunity for expansion into marginal area



OBJECTIVES

- To gather quantitative information on
  - crop productivity (biomass and biofuel),
  - water use efficiency,
  - drought tolerance
- of different sugarcane genotypes
- Benchmark these against other potential bio-energy crops (Sorghum, Sugar beet and Napier grass)
- Assess practical aspects of cultivation



MATERIALS AND METHODS

- Experimental details
- Treatments
- Measurements, calculations
- Climate

Experimental details

- SASRI Mpumalanga Research Station near Komatipoort
- Completely randomised block design (6 genotypes X 2 water regimes X 4 reps)
- Surface drip irrigation system
- Water treatments
  - Well-watered: Replace extraction as measured with neutron water meter
  - Water stress: Irrigate 50% of well watered treatment

Treatments

Crop	Specie	Variety
Sugarcane (standard)	*Saccharum officinarum*	N19
Sugarcane (standard)	*Saccharum officinarum*	N31
Sugarcane (Type II)	*Saccharum spp.*	04G0073
Wild sugarcane (Type II)	*Erianthus arundinaceus*	IK76-63
Napier grass	*Pennisetum purpuream*	Landrace
Sorghum/Sudan grass	*Sorghum spp.*	Big Kahuna
Tropical sugar beet	*Beta vulgaris*	Phython

Measurements and calculations

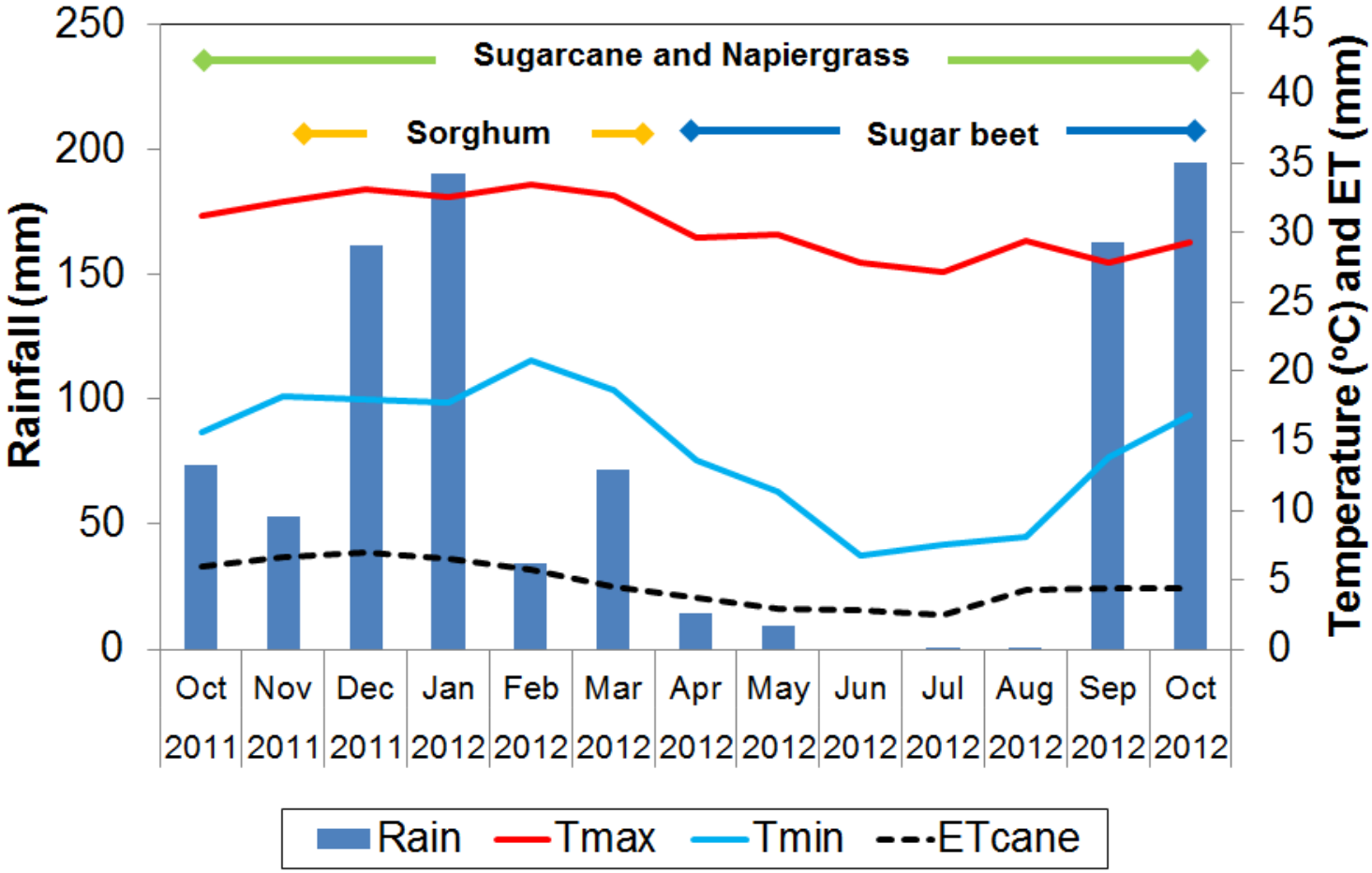
- Interception of photosynthetic active radiation
- Stalk population and height
- Dry mass of components - dead and green leaves, stem sugars and fibres) at 4, 8 and 12 months
- Theoretical ethanol yield from fibre and sugars

- Seasonal crop water use
  - $\sum ET = \Delta S + \sum I + \sum Reff - \sum DR$
  - Daily Reff = R – 5 (canopy interception)
  - Daily DR = $(ASWC + I + Reff - ET_{cane}) - ASWC_{capacity}$
- Water use efficiency
  - Aboveground biomass / $\sum ET$
  - Ethanol production / $\sum ET$
- Drought tolerance
  - $(Biomass_{stressed} / Biomass_{well\ watered}) \times 100$

Measurements and calculations

Biomass component	Ethanol yield (l/t)
Stem juice sucrose	537
Stem juice hexoses	510
Stem fibre: lignin	0
Stem fibre: cellulose and hemi-cellulose	340 - 385
Leaf fibre	250

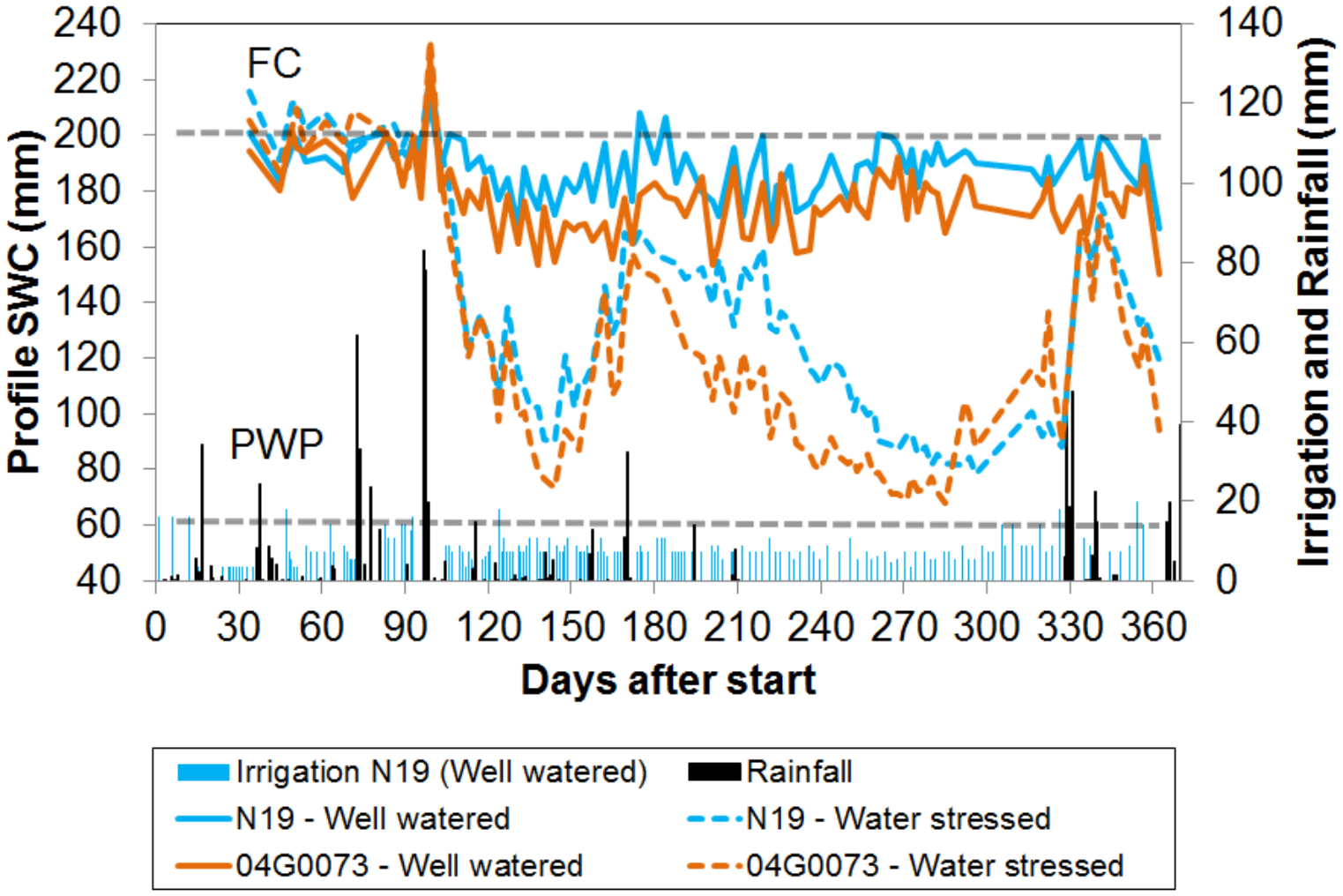
Climate


Sugarcane and Napiergrass
Sorghum
Sugar beet
Rainfall (mm)
Temperature (°C) and ET (mm)
250
200
150
100
50
0
45
40
35
30
25
20
15
10
5
0
Oct 2011
Nov 2011
Dec 2011
Jan 2012
Feb 2012
Mar 2012
Apr 2012
May 2012
Jun 2012
Jul 2012
Aug 2012
Sep 2012
Oct 2012
Rain
Tmax
Tmin
ETcane

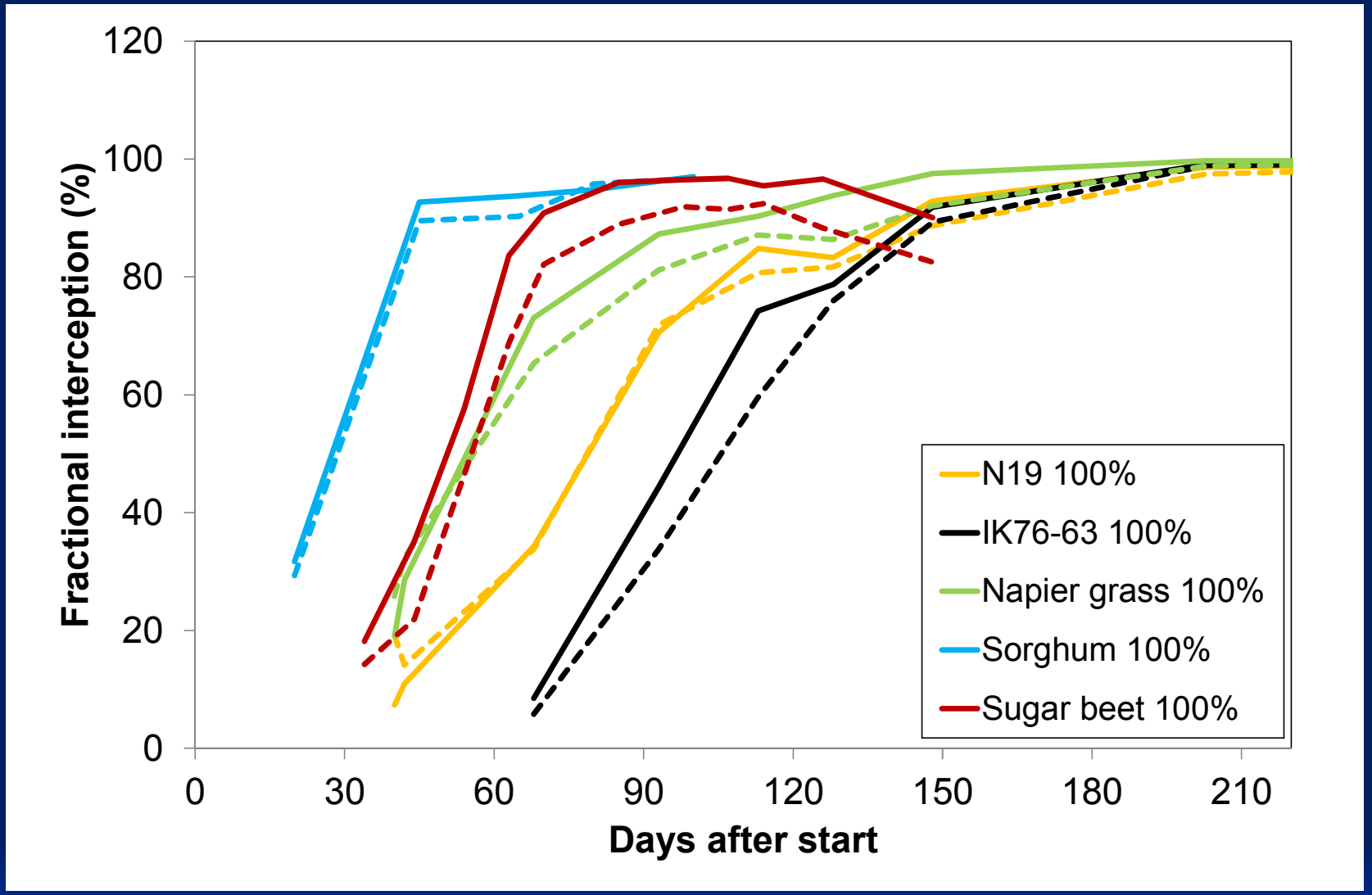
RESULTS

- Soil water status
- Fractional interception
- Water use
- Biomass
- Biofuel
- WUE
- Drought tolerance
- Agronomy

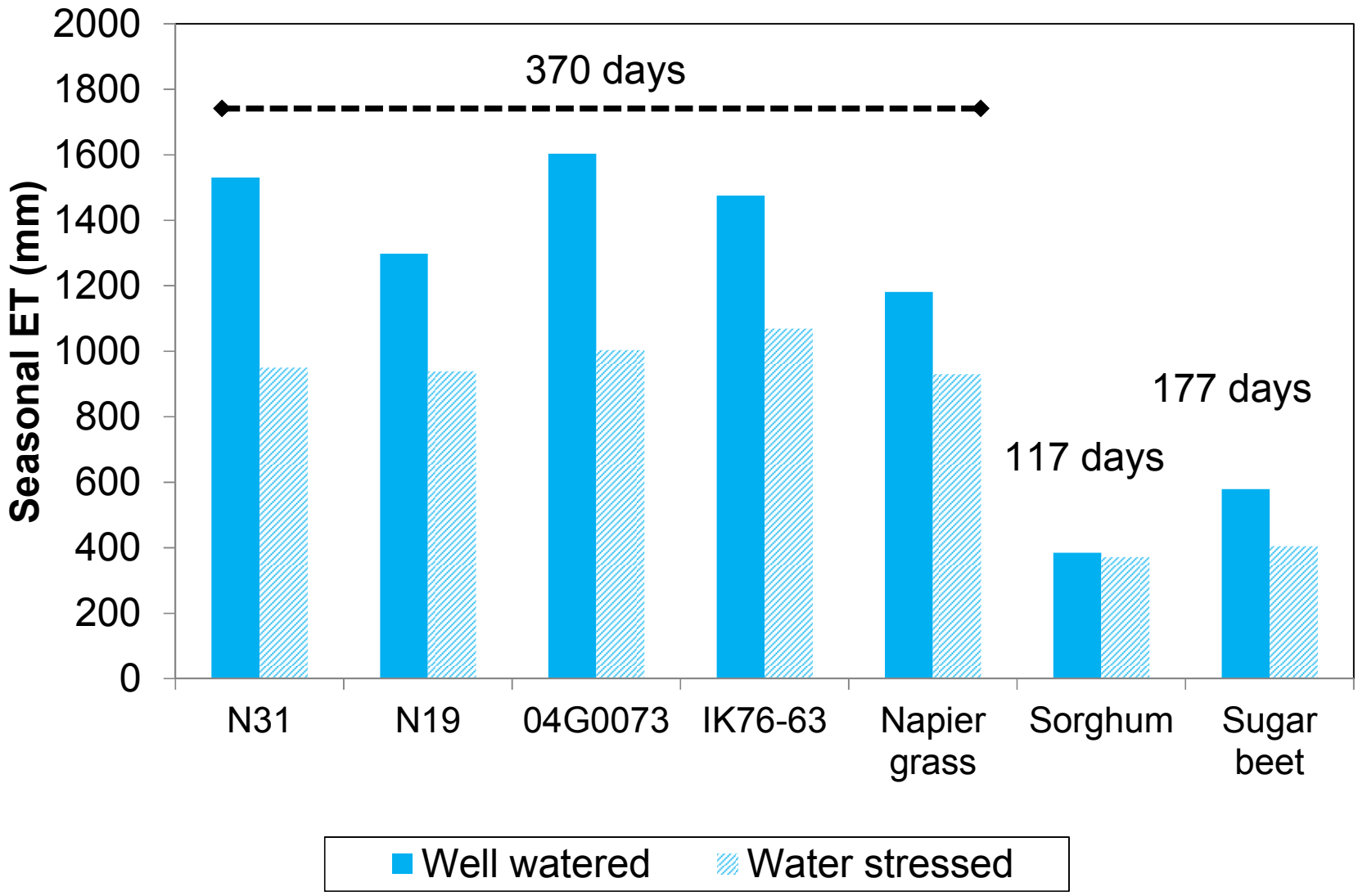
Soil Water Status



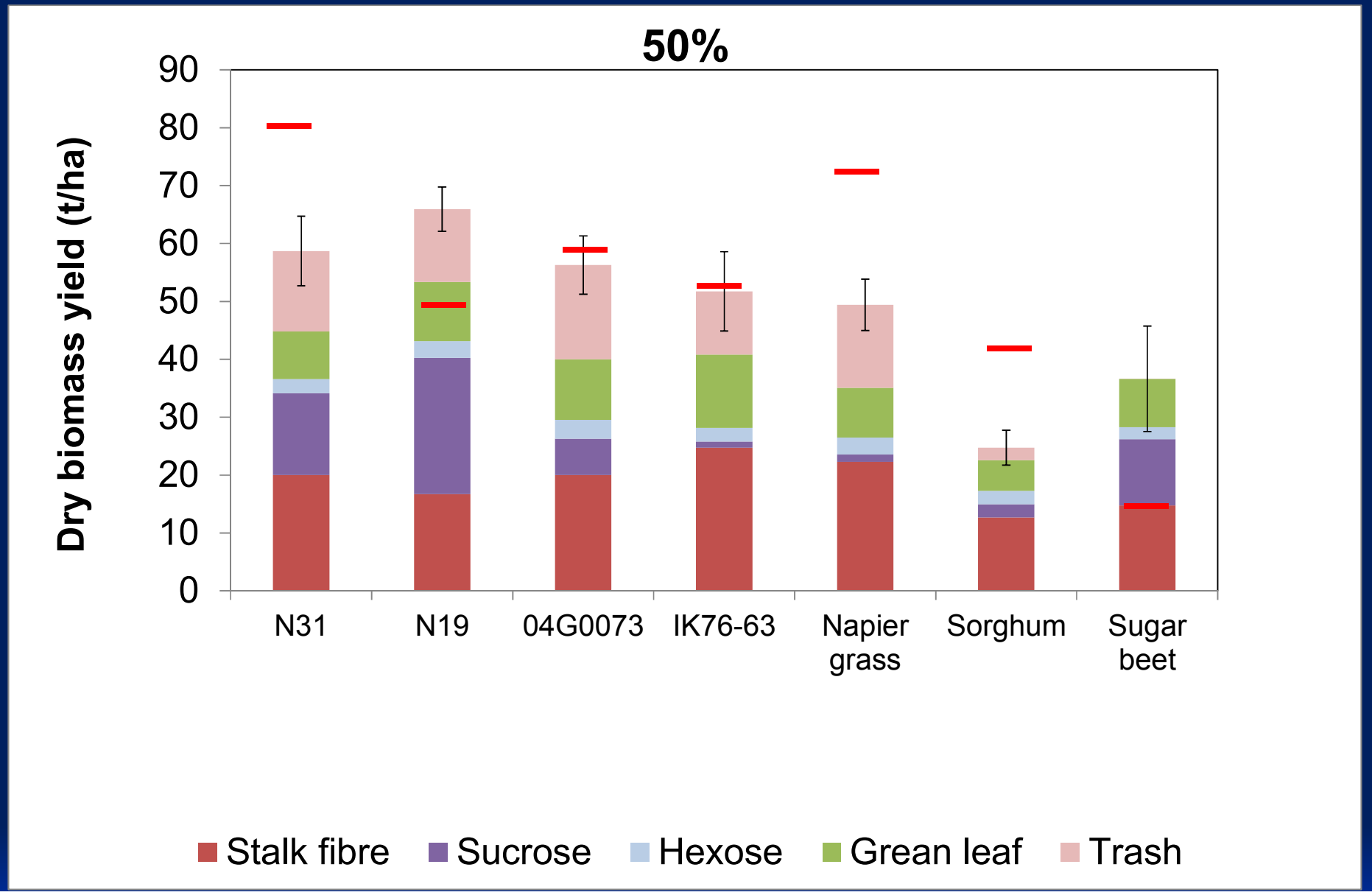
Canopy cover



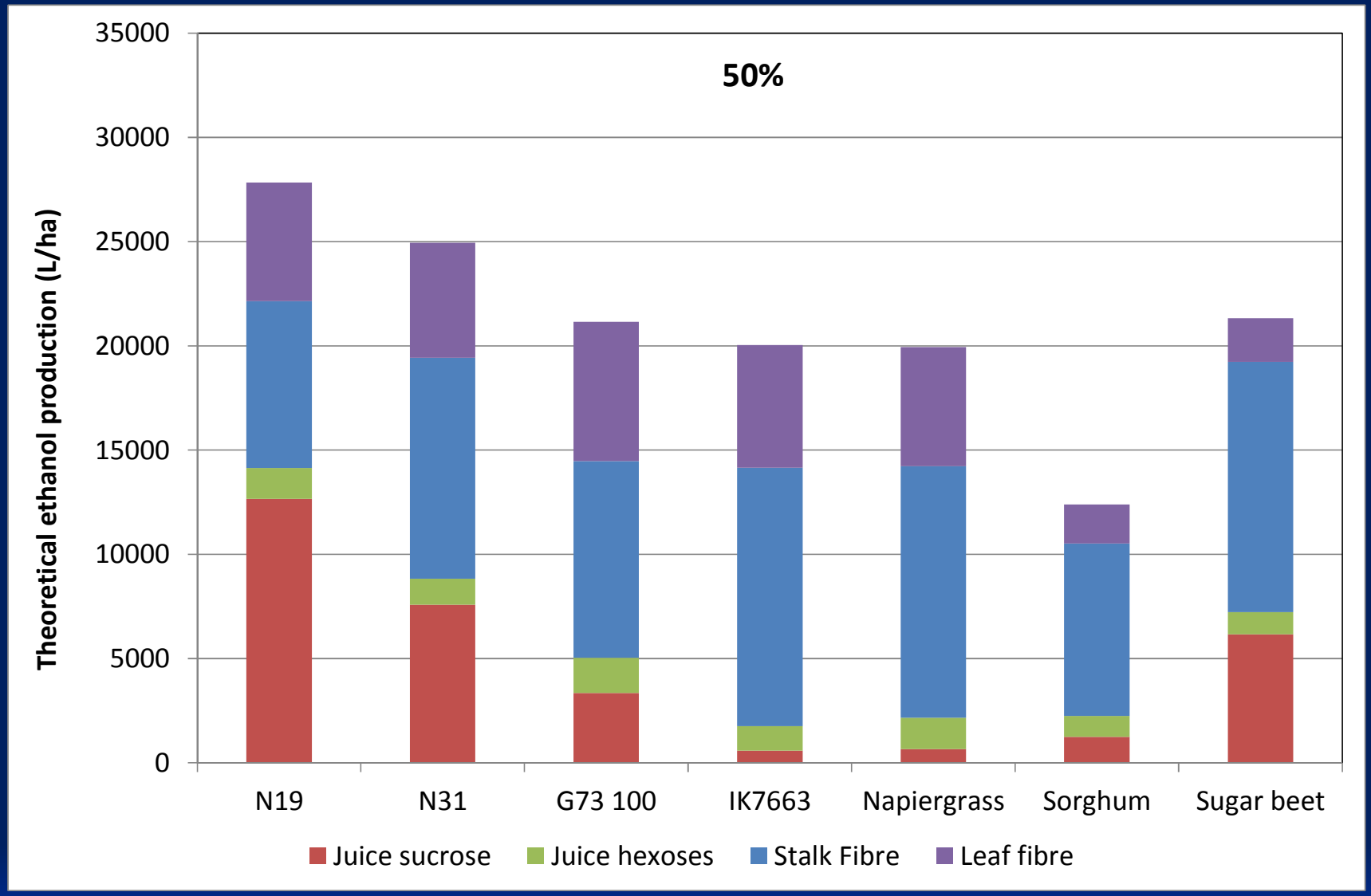
Crop water use



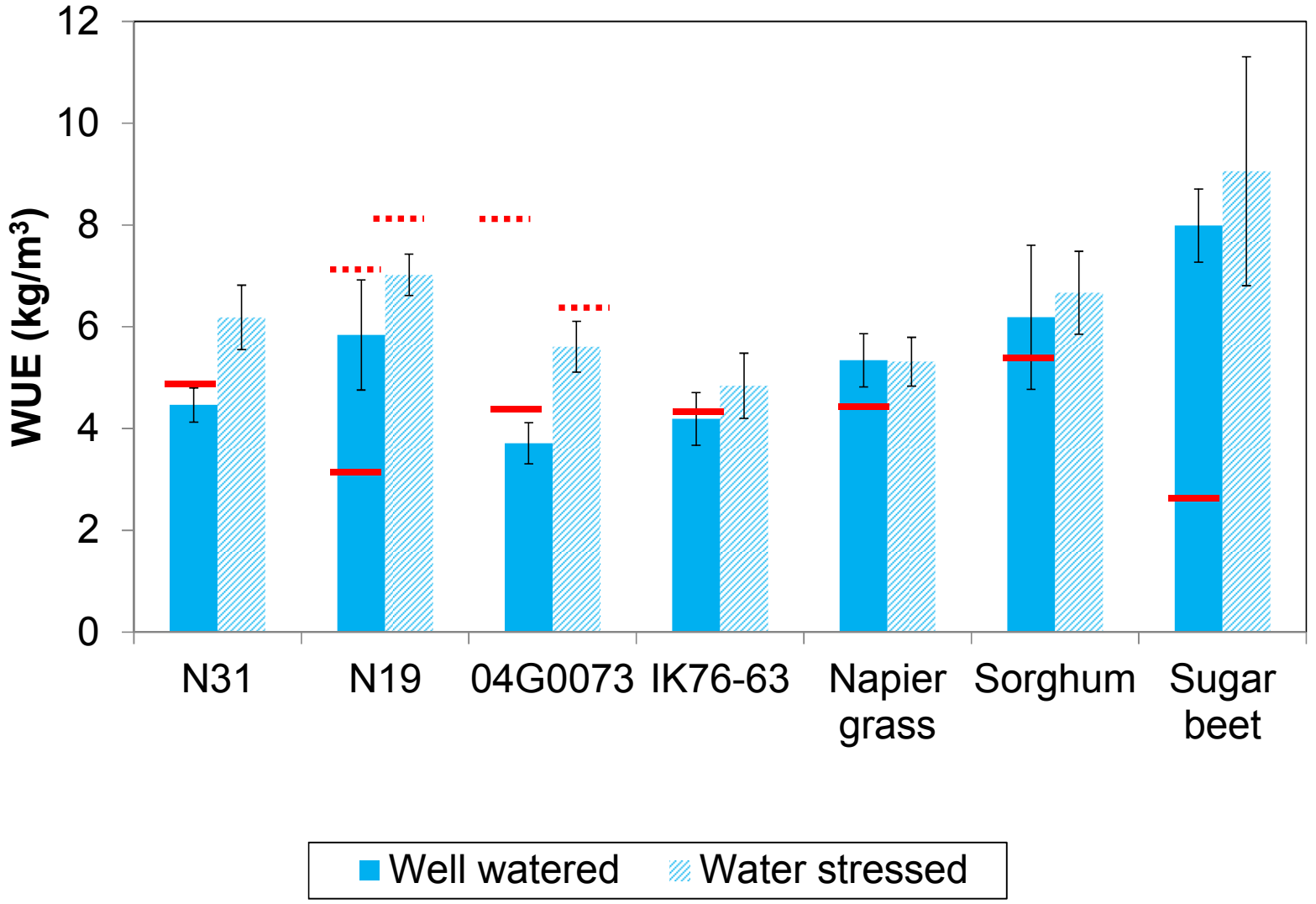
Dry biomass


50%
Dry biomass yield (t/ha)
90
80
70
60
50
40
30
20
10
0
N31
N19
04G0073
IK76-63
Napier grass
Sorghum
Sugar beet
Stalk fibre
Sucrose
Hexose
Grean leaf
Trash

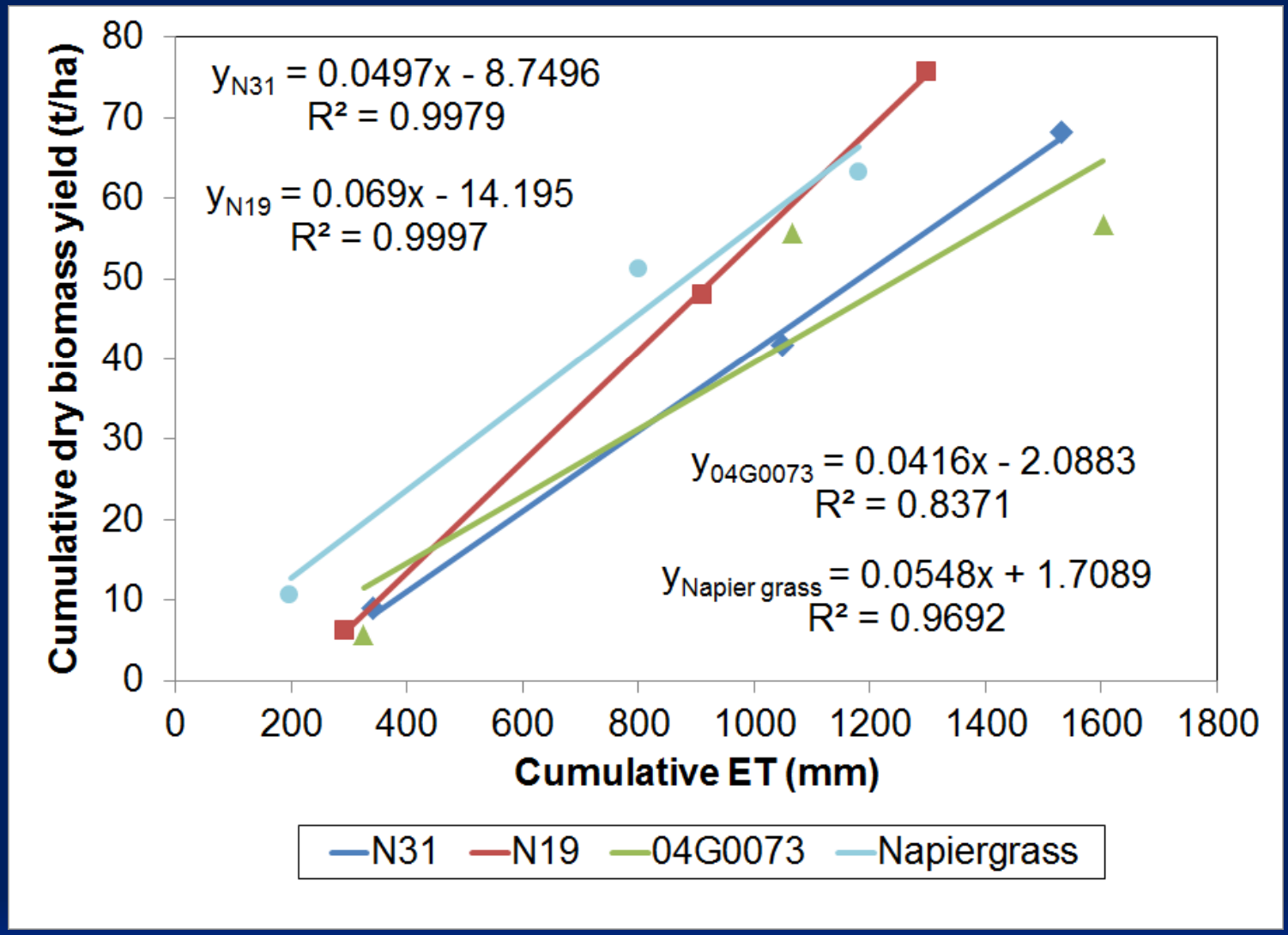
Biofuel


50%
Theoretical ethanol production (L/ha)
35000
30000
25000
20000
15000
10000
5000
0
N19
N31
G73 100
IK7663
Napiergrass
Sorghum
Sugar beet
Juice sucrose
Juice hexoses
Stalk Fibre
Leaf fibre

Biomass Water Use Efficiency



Biomass Water Use Efficiency

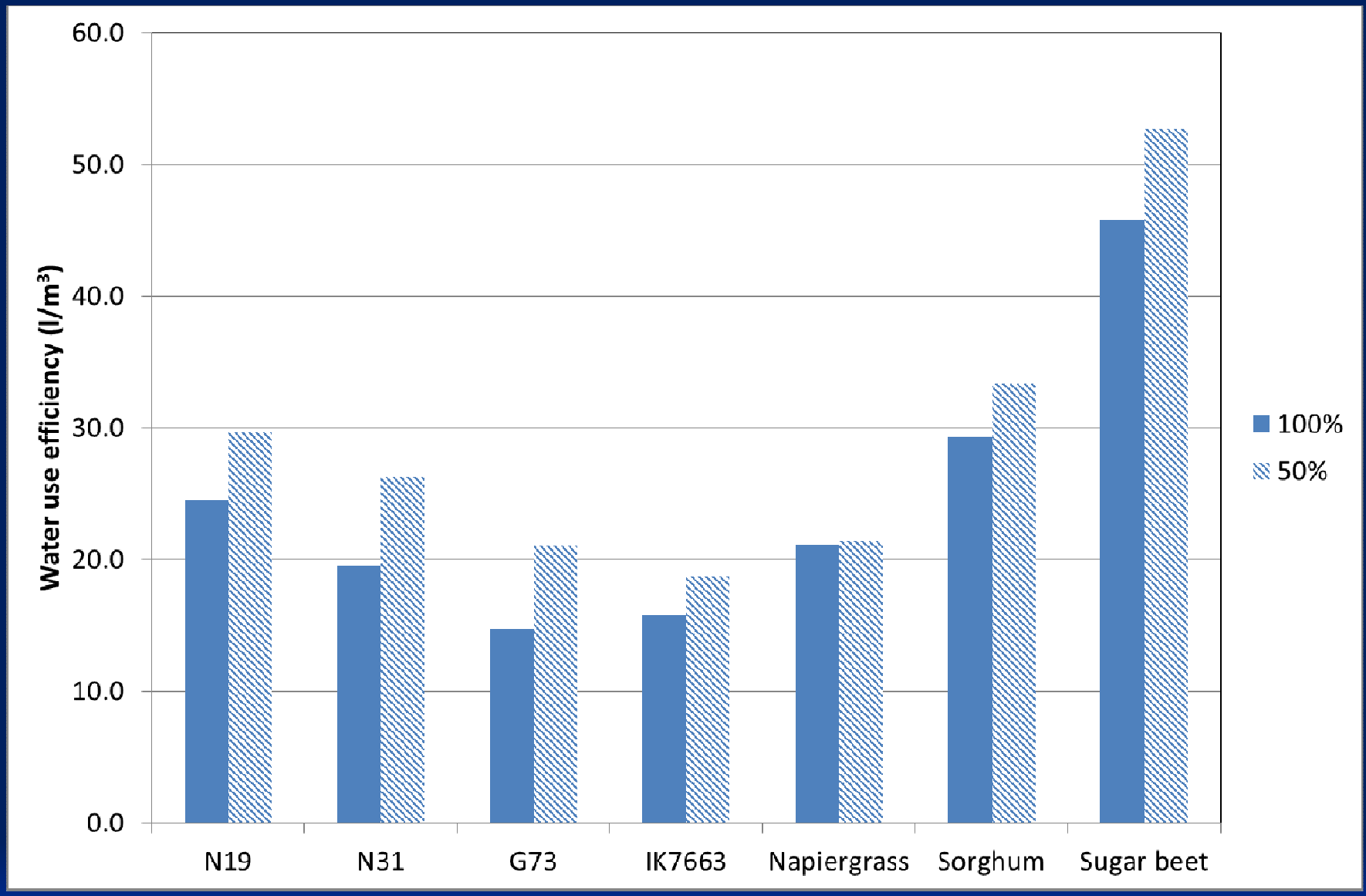


Biomass Water Use Efficiency (kg/m^3)

Genotype	100%	50%
N19	6.9	8.13
N31	4.97	7.01
G73	4.16	6.68
Napier grass	5.48	6.29

- Sugarcane literature: 2.5 – 5.0

Biofuel Water Use Efficiency



Sugarcane (IK76-63)

Sugarcane (N19)

Sugar beet

Sugarcane (IK76-63) & Napier grass

Napier grass

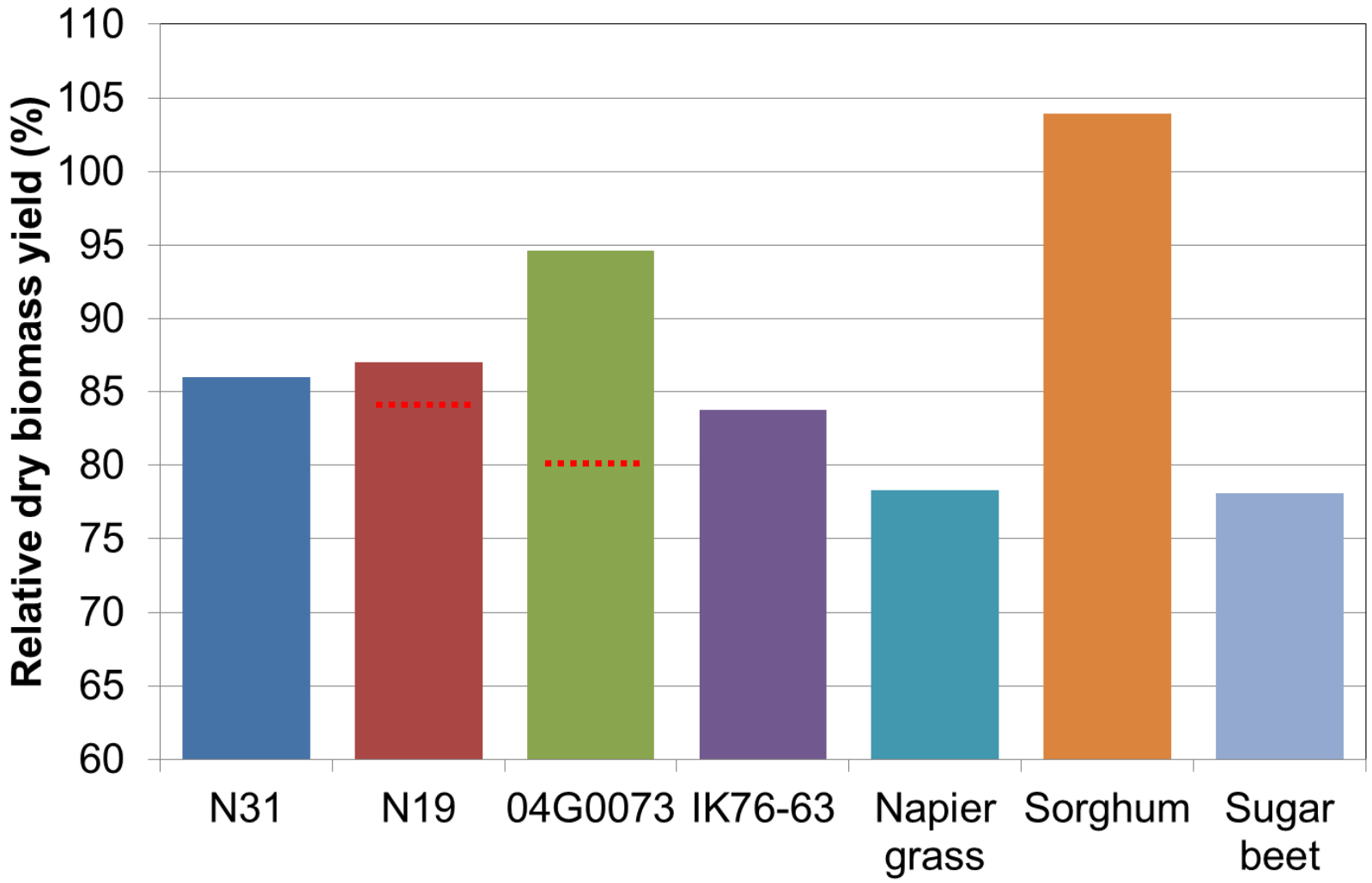
Sugarcane (04G0073)

Sugar beet

Sugarcane (04G0073 & N31)

Sugar beet

Drought Tolerance



Agronomic Issues

04G0073 – Early flowering

IK76-63 – Poor germination

Sugar beet – Healthy leaves

Napier grass – Self trashing

Sugar beet – Leaf diseases

Sorghum – Stalk borer

Napier grass – Self trashing

CONCLUSIONS

- Highest biomass and bio-fuel yield was achieved by N19 followed by N31, Napier grass, IK63 and G73
- Highest biomass and biofuel WUE achieved by sugar beet, followed by sorghum and N19, lowest by G73*.
- A combination of sorghum and sugar beet produced most biomass in one year and had highest WUE (by far)
- Drought tolerance: High biomass sugarcane G73 and sorghum seems more drought tolerant than standard sugarcane and other crops*
- Productivity affected by flowering, trashing, pest and diseases.
- Quantitative data on resource capture, resource conversion efficiency and drought tolerance will aid spatial modelling of crop productivity and water use

TAKE HOME MESSAGES

Suitability for biofuels

- Sugar beet/sorghum combination most productive and water use efficient option
- Conventional sugarcane cultivars can compete with biomass crops for ethanol production due to ease of cultivation and processing versatility

Way forward

- Test more biomass cultivars
- Refine crop models and spatially estimate biomass and energy productivity and water use for existing and new sugarcane production areas
- Quantify nitrogen requirements
- Determine economics of production

ACKNOWLEDGEMENTS

- SASRI technicians
- Former Ph.D. student Yuri Tsupko
- Sugarcane Industry funding

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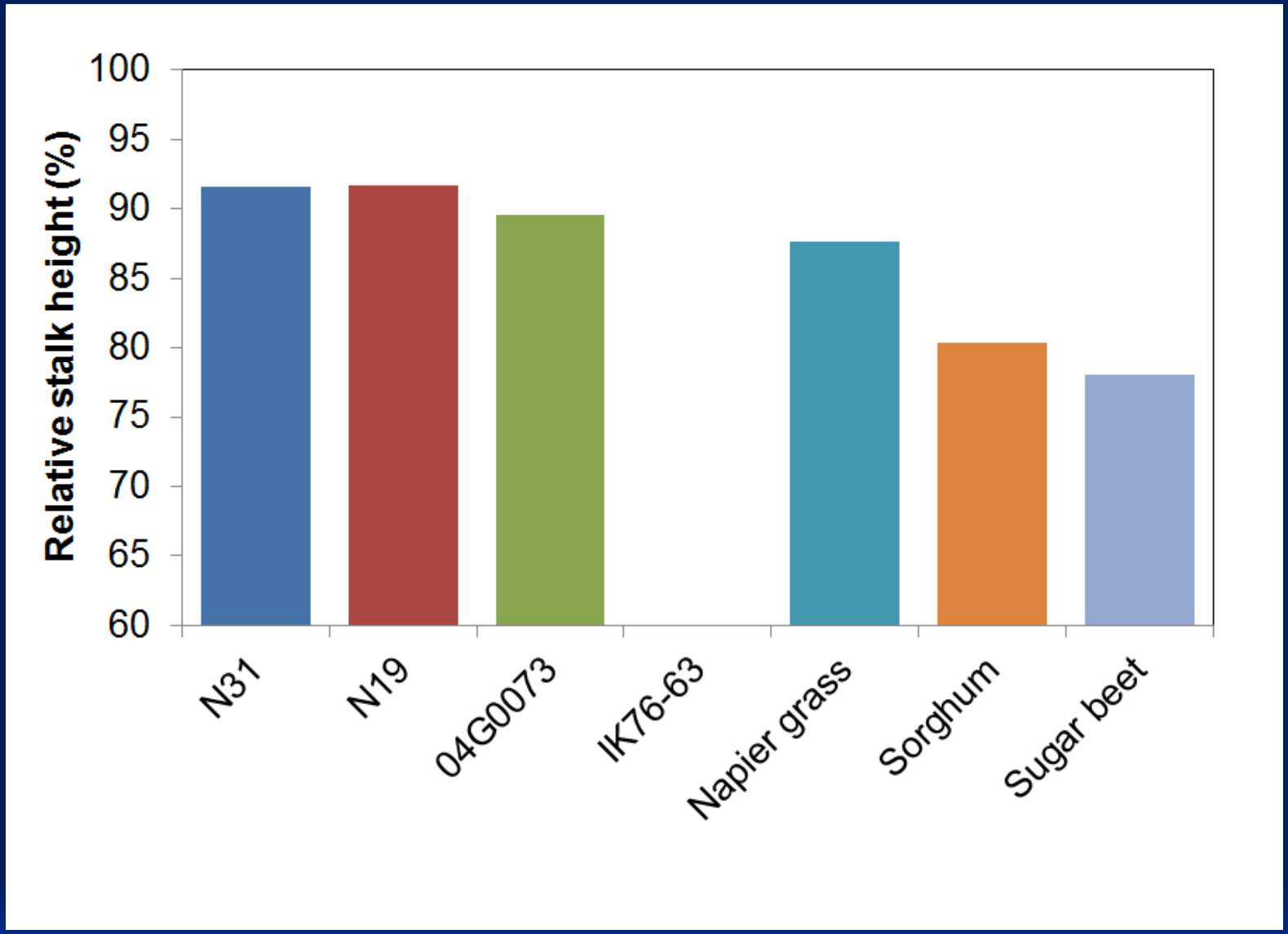
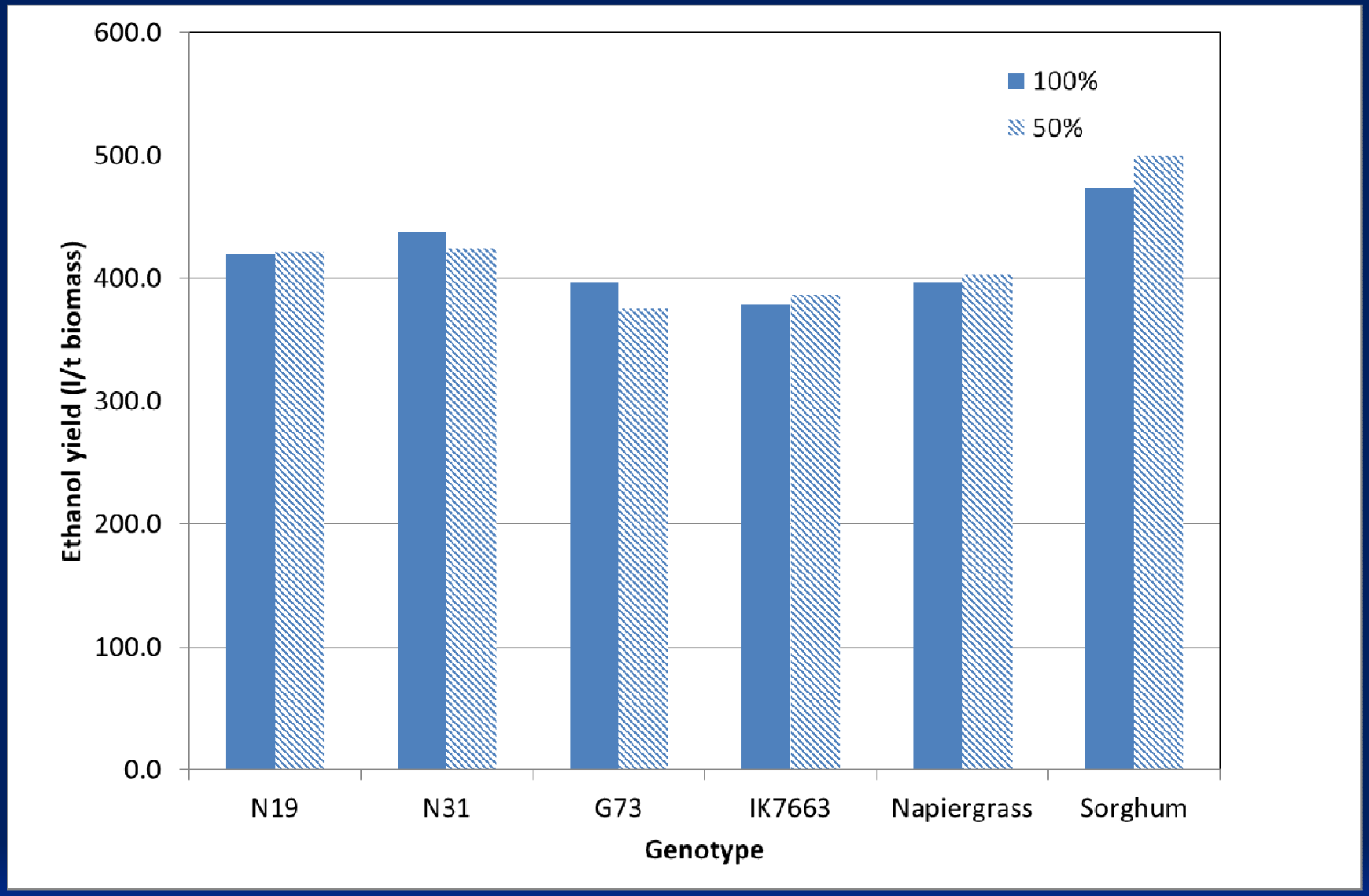
Drought Tolerance



Biofuel yield



Agronomic Issues

Genotype	Comments
N19 and N31	Lodged in September
04G0073	Flowered in June, lodged in September
IK76-63	Poor and slow germination
Napier grass	Self trashing
Sorghum	Poor germination, stalk borer and aphids required regular control
Sugar beet	Poor germination required gap re-planting, diseases required control

- TitleResource use efficiency and environmental performance of biofuel cropping systems.AuthorsVries, S. C. deAuthor AffiliationWageningen University, Wageningen, Netherlands.Thesis Resource use efficiency and environmental performance of biofuel cropping systems 2012 pp. 212 pp.
- alues of WUE ranging from 3.3 to 4.6 g·kg−1 for the perennial C4 grasses in the present study were comparable to median values of 4.2 reported for grain sorghum (Sorghum bicolor L.), 3.9 for pearl millet, and 4.8 g kg−1 for maize [31]. Agriculture 2012, 2, 325-338; doi:10.3390/agriculture2040325
- agriculture
- ISSN 2077-0472 www.mdpi.com/journal/agriculture Article
- Water Use and Water-Use Efficiency of Three Perennial Bioenergy Grass Crops in Florida
- John E. Erickson 1,*, Arkorn Soikaew 2, Lynn E. Sollenberger 1 and Jerry M. Bennett 1
- 1 Agronomy Department, University of Florida, Gainesville, FL 32611, USA;
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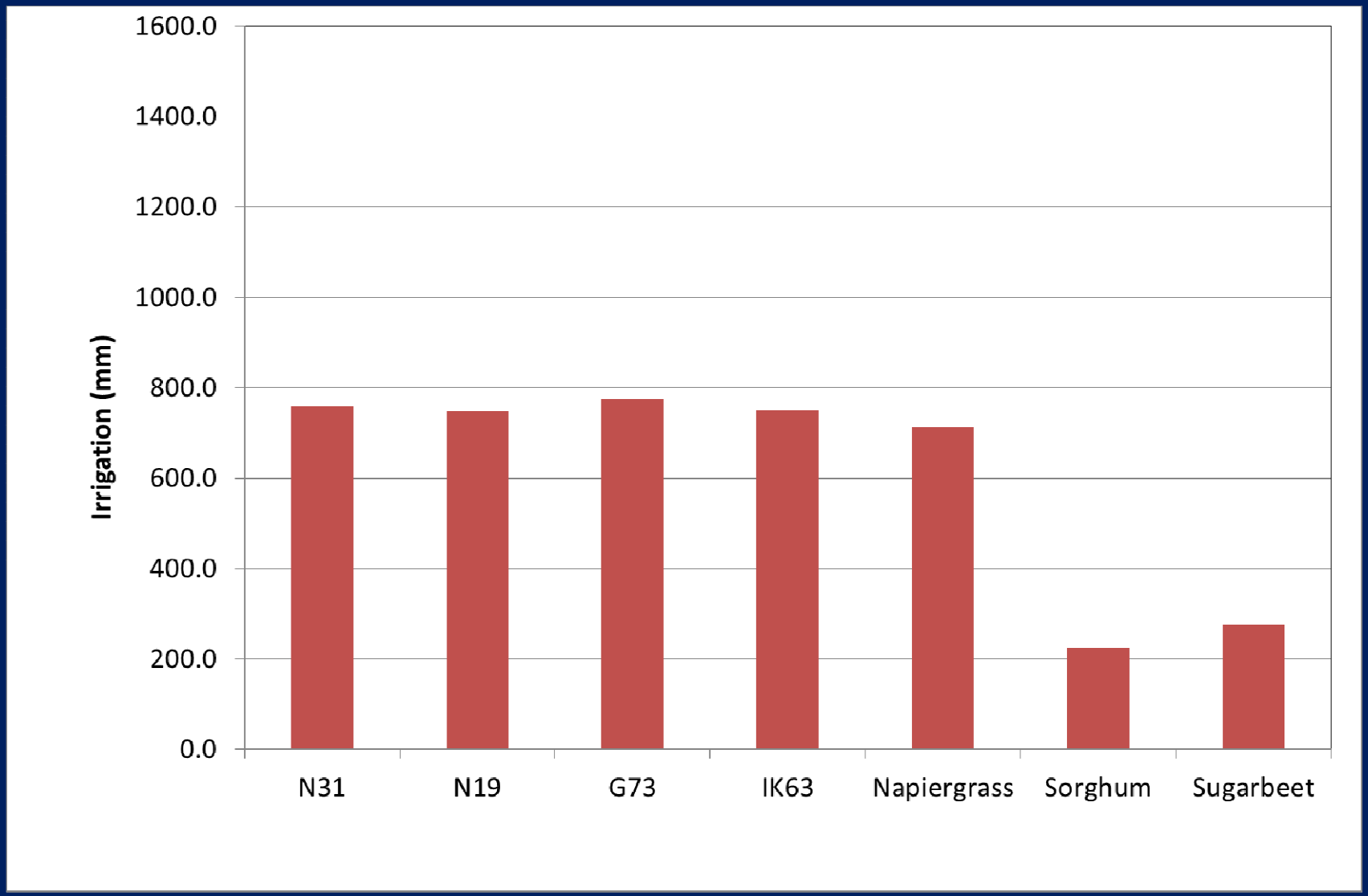
1600.0
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
Irrigation (mm)
N31
N19
G73
IK63
Napiergrass
Sorghum
Sugarbeet