Physiological responses of Bambara groundnut (*Vigna subterranea*) to drought stress

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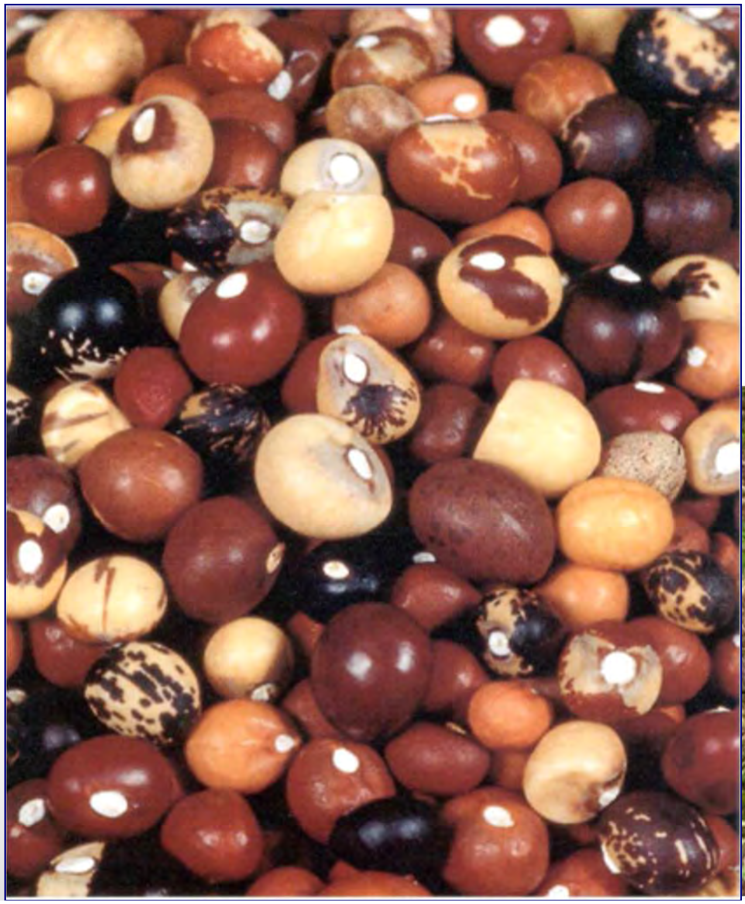
on behalf of **Chai Hui Hui**

Bambara groundnut (*Vigna subterranea* (L.) Verdc)

Underutilised sub-Saharan African legume: human and soil health



Also grown in South East Asia – Thailand, Indonesia

Bambara groundnut (*Vigna subterranea* (L.) Verdc)

Grown primarily by subsistence farmers

It is perceived as a ‘woman’s crop’

Seeds are a reasonably balanced, nutritious food - represents an important source of protein

The crop is drought resistant, reasonably free of diseases and pest and adapted to poor soils

No improved varieties, only landraces

Yields are variable

Bambara groundnut – a climate resilient crop?

South East Asia – high rainfall

Sub Saharan Africa – low rainfall

What are key mechanisms?

Physiological attributes associated with yield under semi-arid conditions – drought resistance in Bambara groundnut

- Collinson *et al.,* 1996; 1997; 2000
- Mwale *et al*., 2007a, b
- Berchie *et al*.,
- Jørgensen *et al.,*

- Change in leaf orientation-paraheliotropism (Stadler, 2009).

- Stomatal regulation of water loss, osmotic adjustments and reduced leaf area (Collinson *et al.*, 1997).

- Early maturing (Mabhaudhi *et al.,* 2013).

Bambara groundnut – a climate resilient crop?

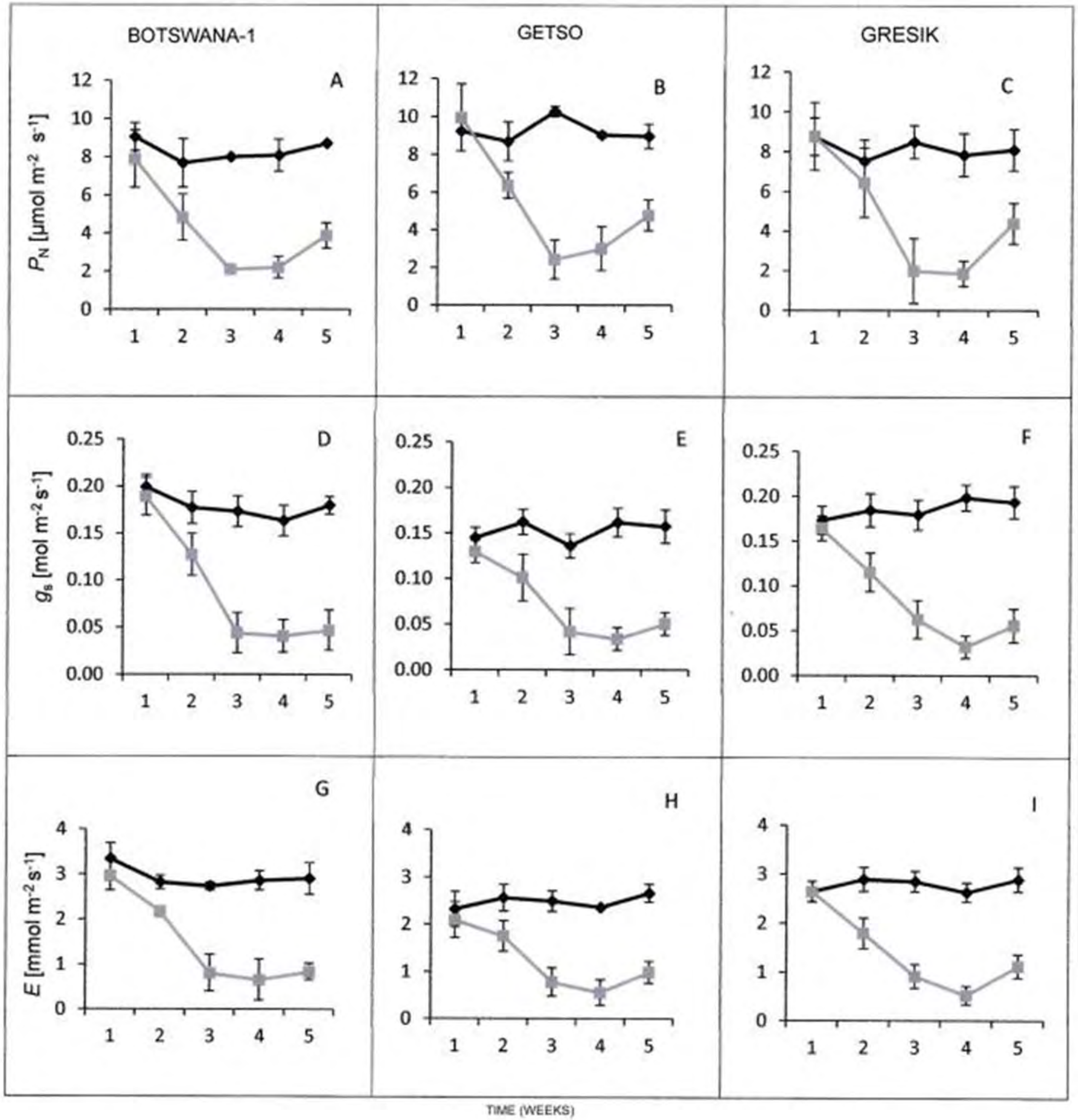
The crop is known to adjust its phenology depending on the prevailing environmental conditions

This plasticity has enabled the crop to perform well under water stressed and watered conditions

What are the underlying mechanisms? – physiological, biochemical and molecular

Metabolic and physiological traits associated with Bambara groundnut adaptation to drought stress conditions.

Initial comparative studies – other know drought resistance crop plants e.g. cowpea.
Segregating population derived from a narrow cross (DipC x Tiga Niguru) - **adaptive/agronomic traits**



Changes in:

Net assimilation rates (P_N),

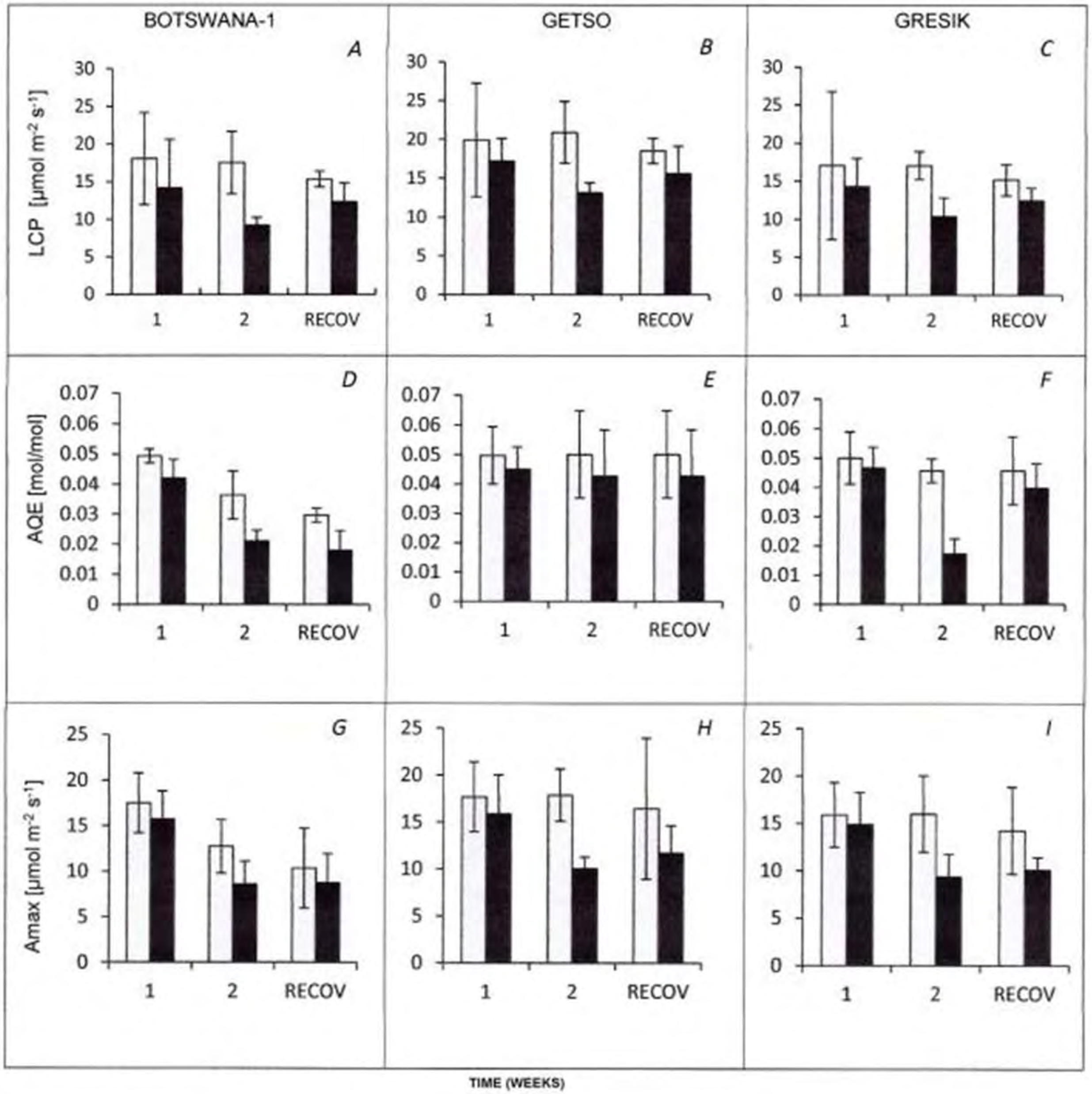
Stomatal conductance (g_s)

Transpiration rates (E)

(♦) Control

(■) Stressed

Water loss and water uptake

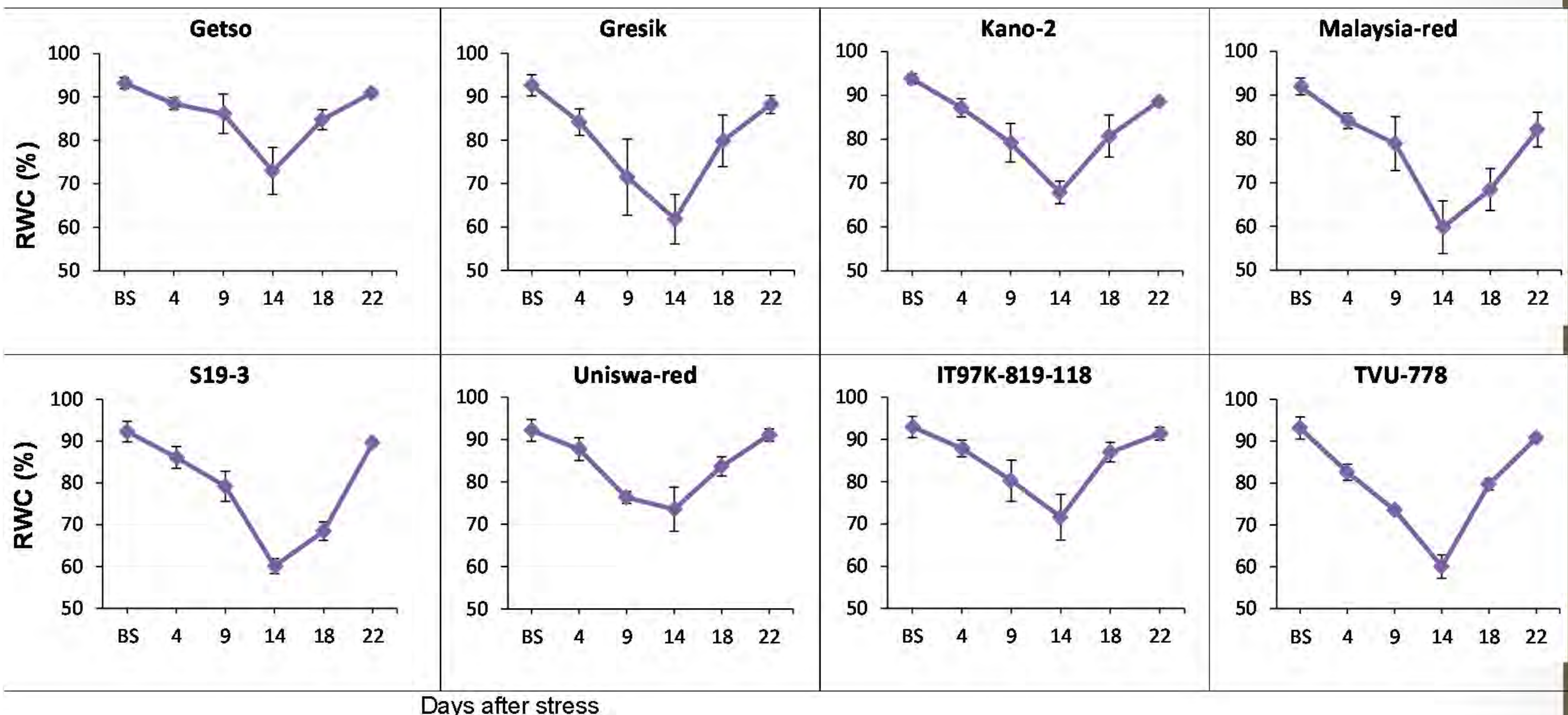


Light Compensation Point (LCP)

Assimilation quantum efficiency (AQE)

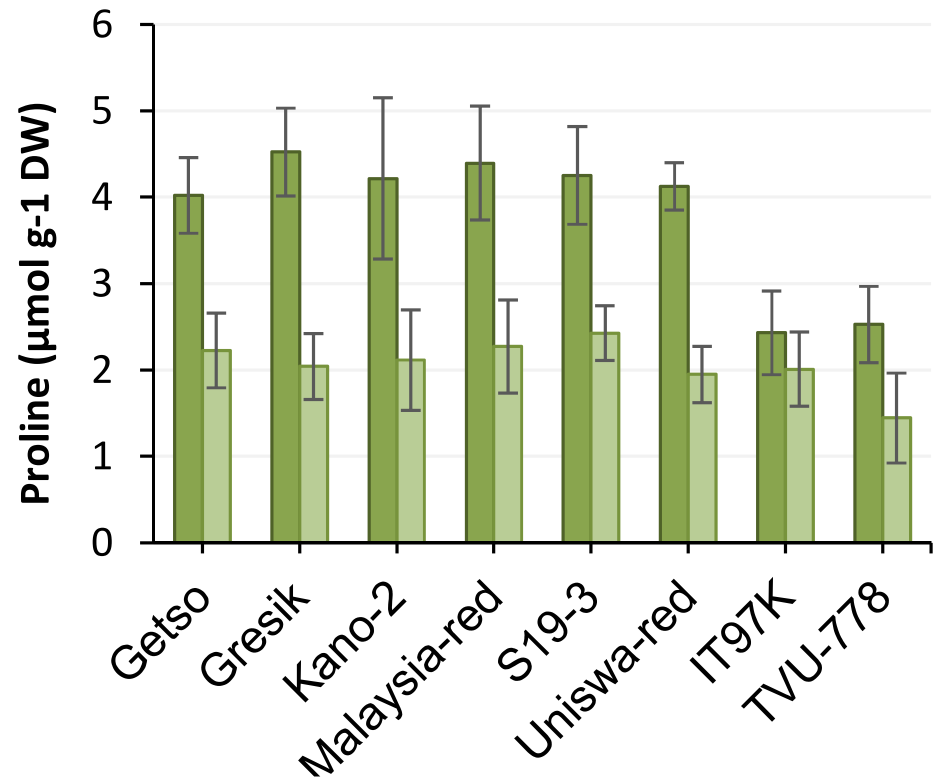
Maximum photosynthetic capacity (Amax)

Relative water content (RWC) in water stressed Bambara groundnut and cowpea genotypes.



At 15 days stress, the RWC in the drought tolerant cowpea line IT97K was comparable to that in the Bambara groundnut landraces Uniswa-red and Getso, which was significantly higher than that in the other landraces and the drought susceptible cowpea, TVU-778.

Biochemical - Proline



The concentration of free proline was significantly (P<0.001) higher in stressed plants.

Proline - osmoprotectant in plants during osmotic stresses e.g. drought

osmotic adjustment is an important drought resistant mechanism in plants

Study Objective

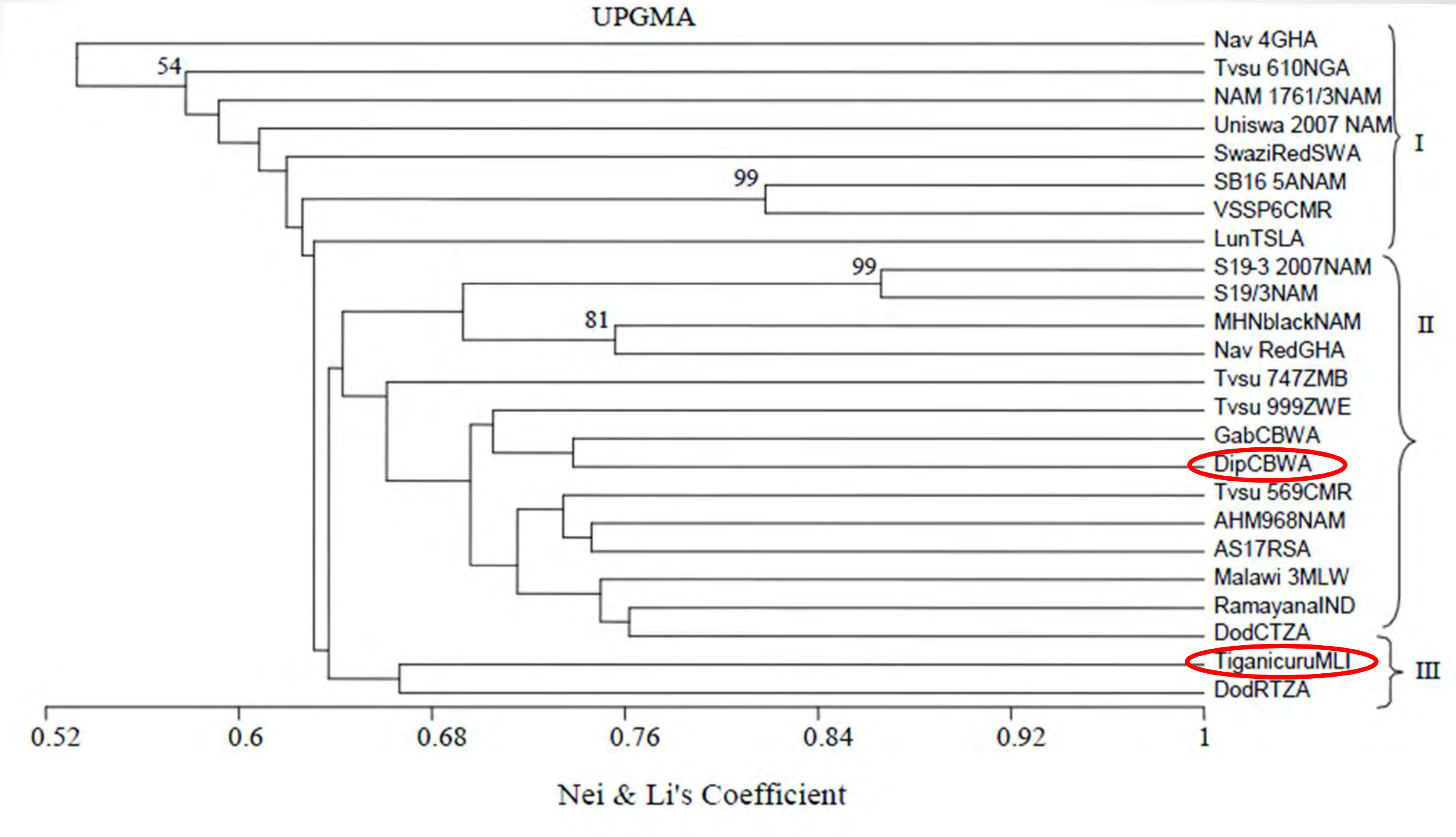
To examine the effects of mild drought on morpho-physiological traits – F_5 population

Materials and methods

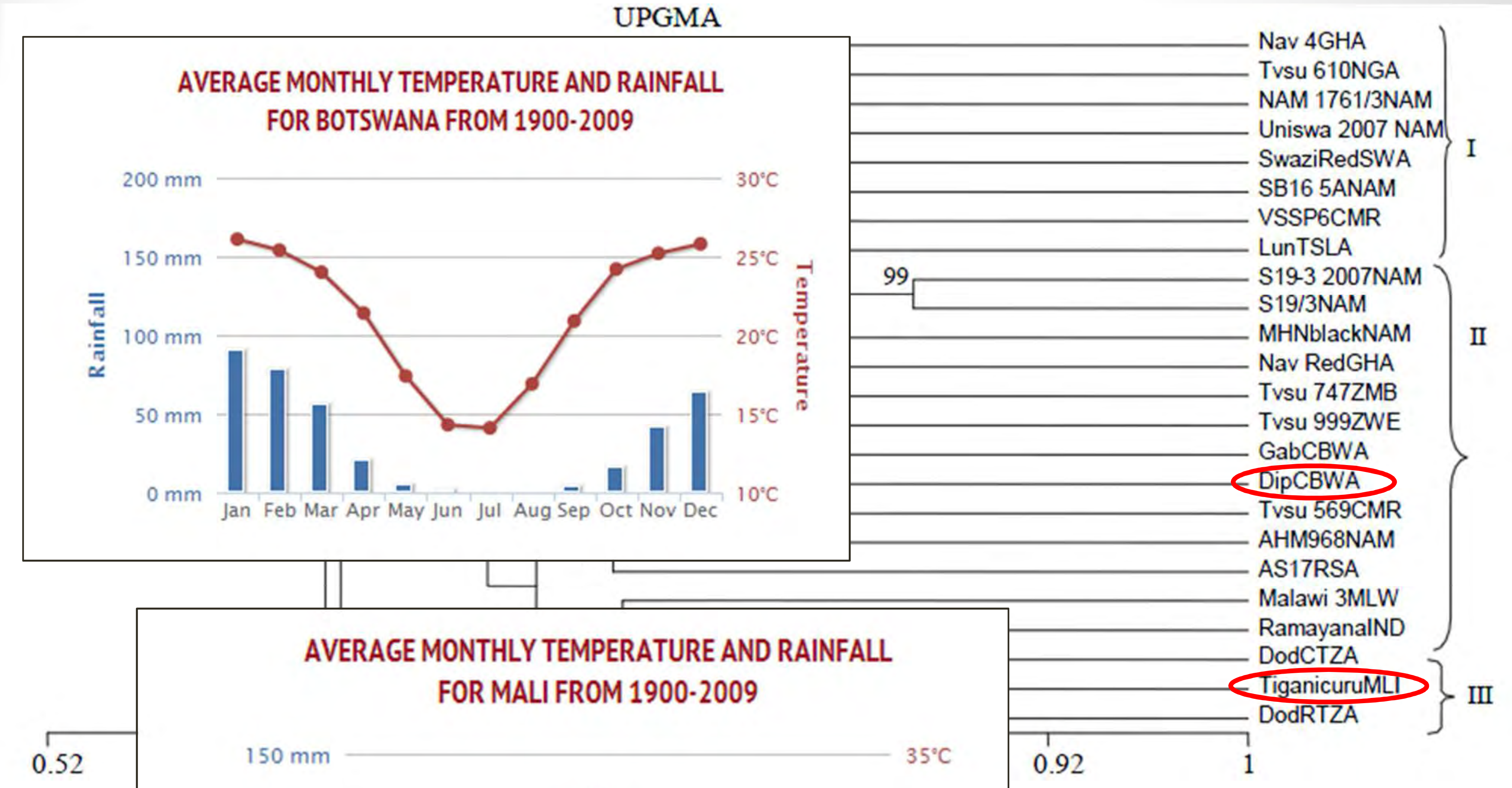
- **Plant material** - F_5 segregating population derived from a cross between single genotypes derived from DipC (maternal) and Tiga Nicuru landraces
- **Treatment**- mild drought stress at flowering stage

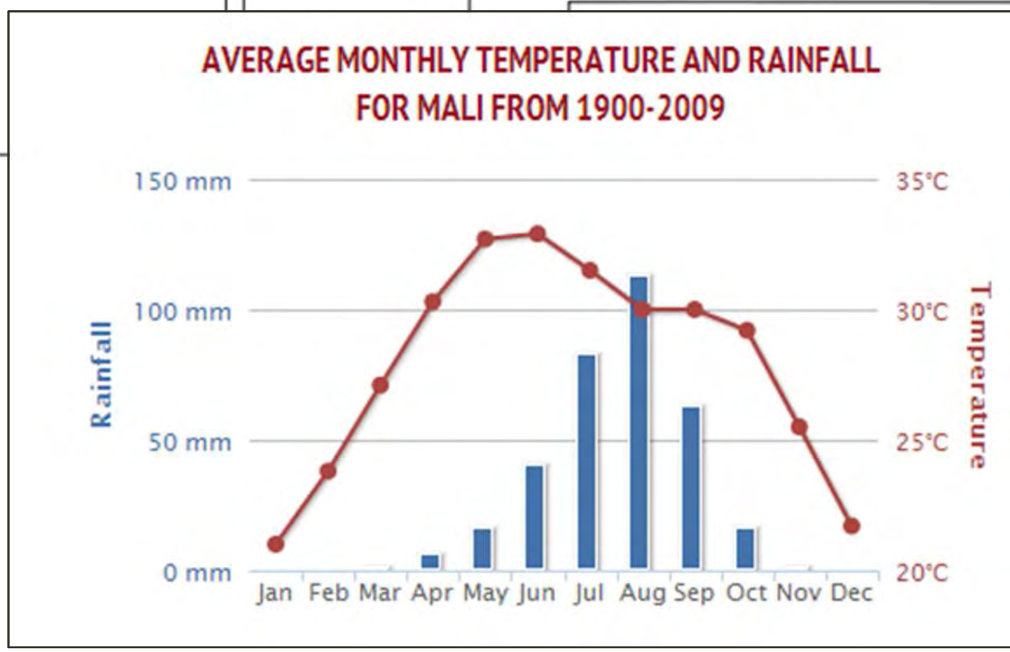
  -> 50 DAS until 92 DAS
- Three replicates and arranged in randomised block design (RBD)

Future Crop Glasshouse, University of Nottingham, UK



DipC from Botswana and Tiga Nicuru from Mali – DArT markers in a genetic diversity analysis of Bambara groundnut (Molosiwa, 2012) .





Traits of importance: maturity, seed size, canopy spread, yield

Drought resistance?

X

DipC

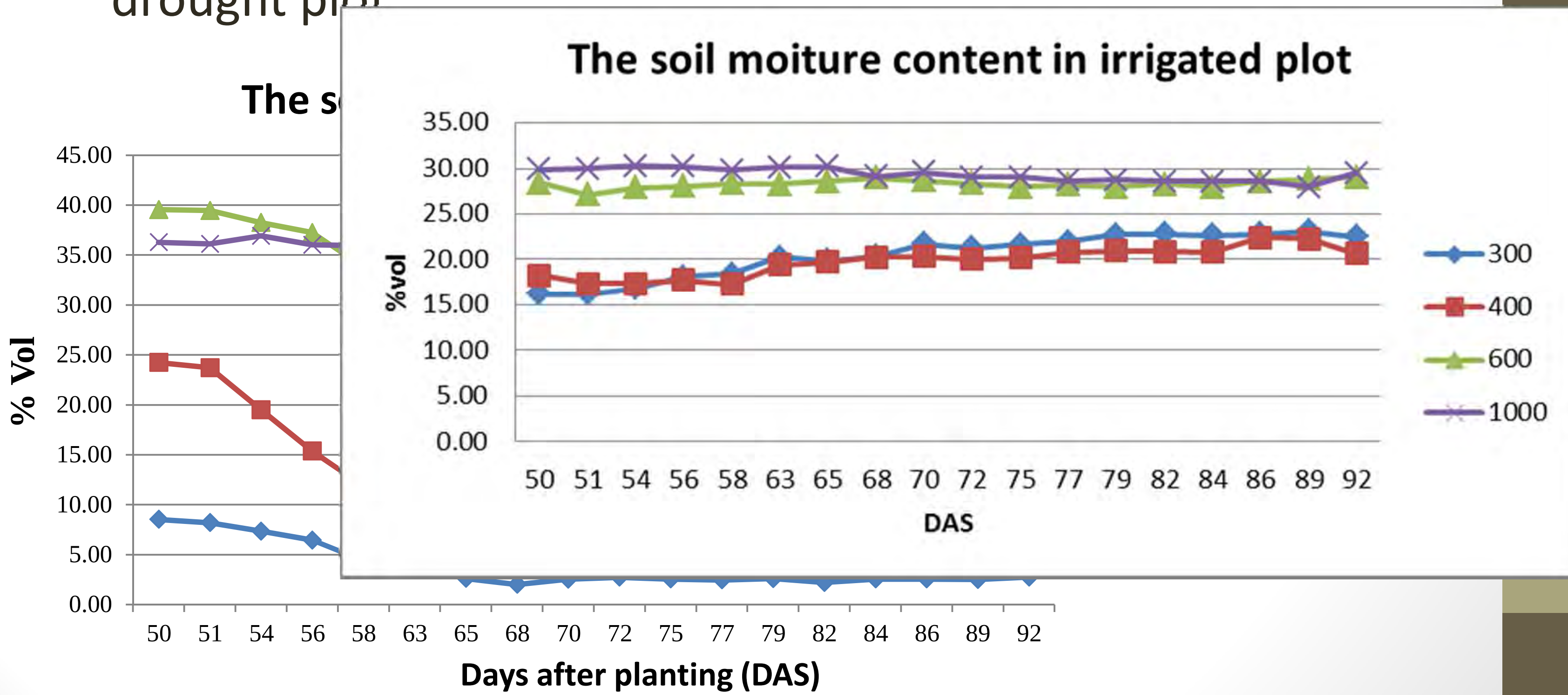
Tiga Nicuru

Segregating population derived from a cross between single genotype DipC (maternal) x Tiga Nicuru landraces

Results

Soil moisture content

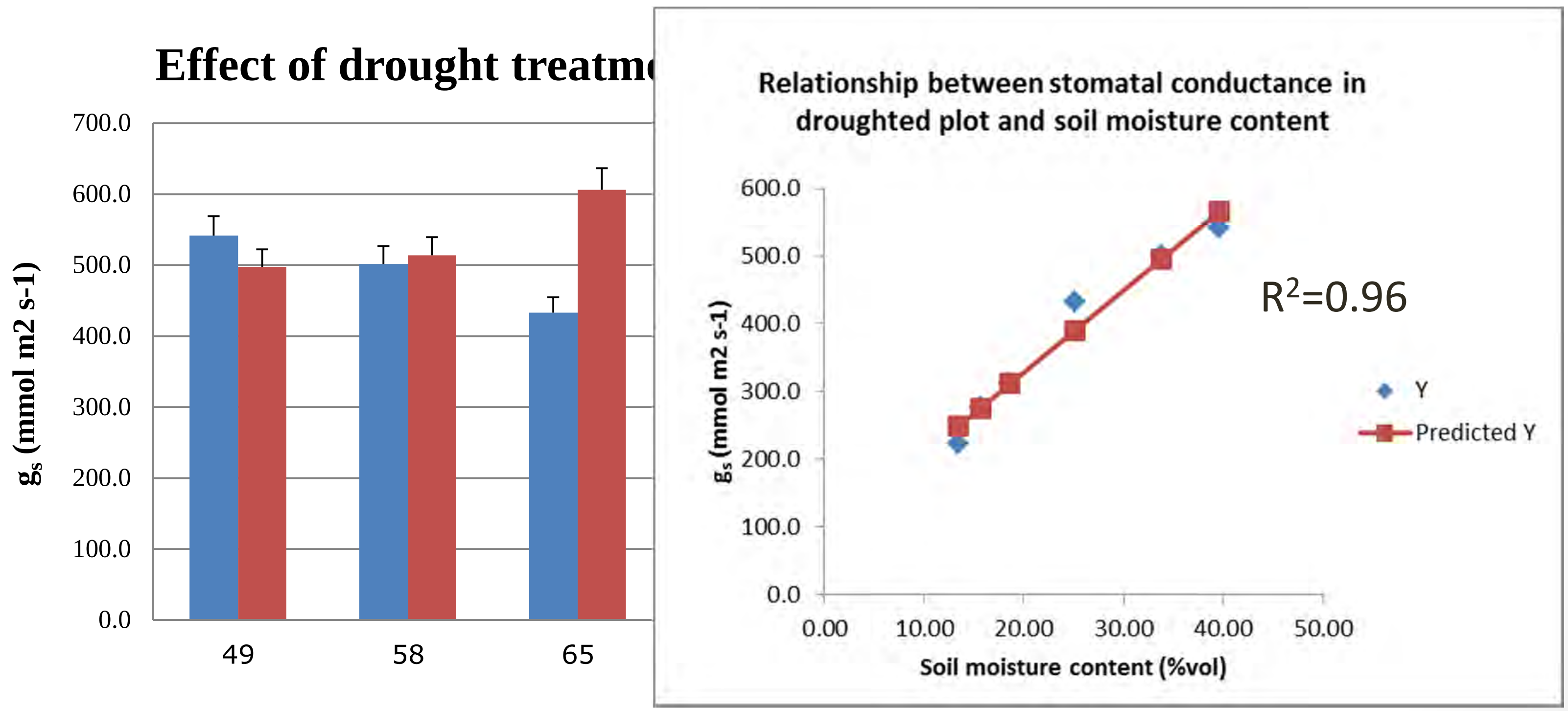
- based on the PR2 reading (% vol) in the drought plot throughout the treatment from 50 DAS to 92 DAS
    - 52.7% reduction in soil moisture was achieved in the drought plot



Stomatal conductance

- Stomatal conductance (g_s) declined gradually as a result of a mild drought: 540mmol m^2 s^{-1} to 220mmol m^2 s^{-1}

Data points represent mean value ± standard error, n=65. Arrow: re-watering of plants at 92 DAS.

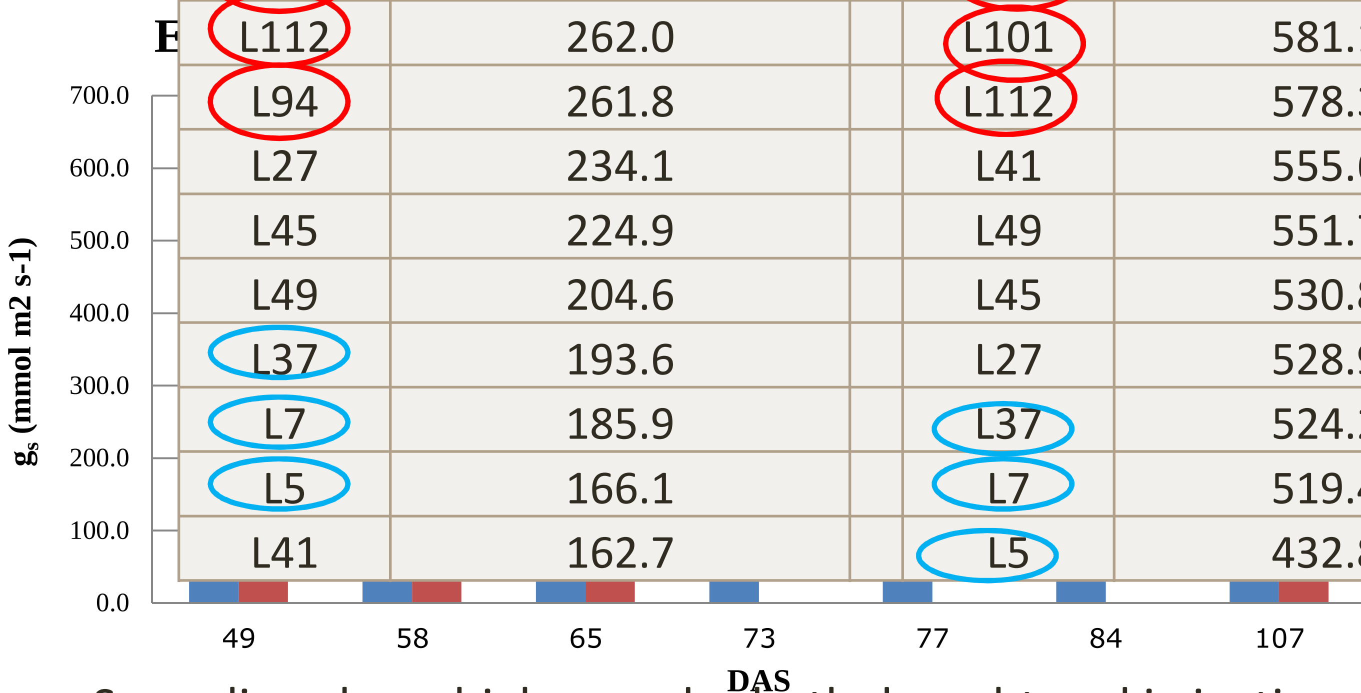


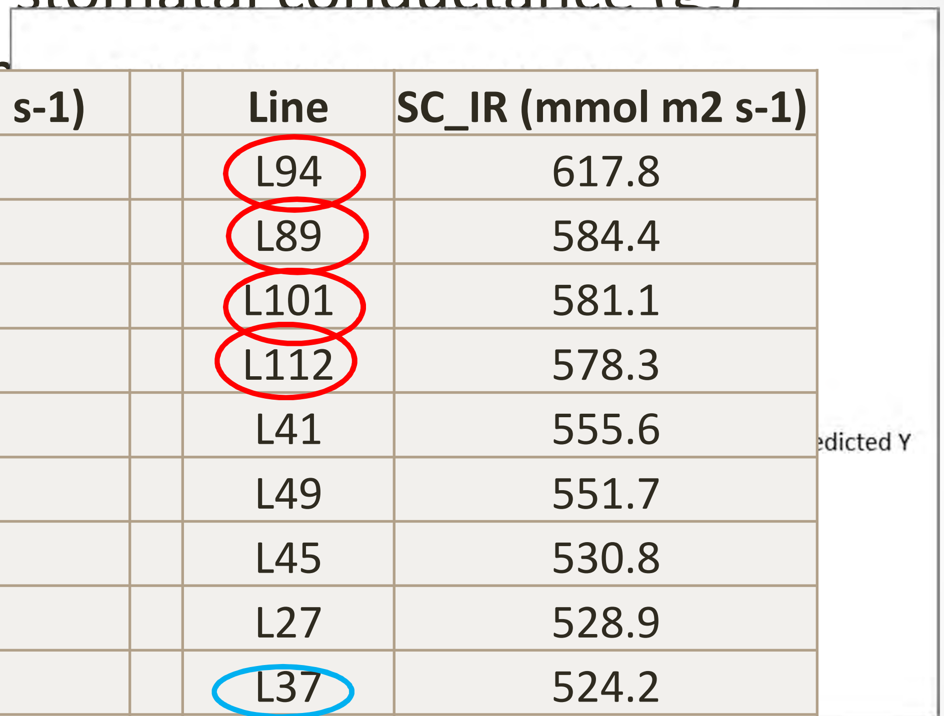
A reduction in g_s as a result of a mild drought implies that the regulation of stomata (closure) is one of the early responses of Bambara groundnut in response to drought.

Stomatal conductance

- Grand mean values for stomatal conductance (g_s) dec… 54…

Line	SC_D (mmol m2 s-1)		Line	SC_IR (mmol m2 s-1)
L101	274.1		L94	617.8
L89	269.3		L89	584.4
L112	262.0		L101	581.1
L94	261.8		L112	578.3
L27	234.1		L41	555.6
L45	224.9		L49	551.7
L49	204.6		L45	530.8
L37	193.6		L27	528.9
L7	185.9		L37	524.2
L5	166.1		L7	519.4
L41	162.7		L5	432.8





Some lines have high g_s under both drought and irrigation conditions, e.g. L89, L94, L101 while others have low g_s e.g. L5, L7, L37.

Leaf carbon (Delta C^{13}) isotope analysis

- Significant differences between the two parental lines for δC^{13} ($p<0.01$) were found.
- Lower δC^{13} - associated with higher yield as observed in DipC compared to Tiga Nicuru.
- There were no significant difference between irrigated and drought plants.

Sample	Treatment	Average δC^{13}	Average yield (g/plant)
DipC	Drought	17.85	33.02
DipC	Irrigation	17.77	31.58
Tiga Nicuru	Drought	19.08	8.58
Tiga Nicuru	Irrigation	19.73	7.53

Stomatal density

- Higher stomatal density was observed in the drought plot (mean value: 11.64 pores cm^{-1}) compared to the irrigated plot (mean value: 10.07 pores cm^{-1}) at the significance level of $p<0.01$.
- NOTE: Leaf area was significantly reduced by drought.

Growth and development

High genetic variability

Traits	Treatment	Mean	SD	Min	Max	Skewness	Kurtosis	Normality	DipC		Tiga Nicuru	
									Min	Max	Min	Max
Days to emergence	-	7.374	0.611	6.458	9.833	1.302	2.807	1.2766^{**}	7.0	8.0	6.0	6.5
Days to flowering	-	31.84	2.536	27.33	41.17	0.806	1.397	0.4968^{ns}	28.0	33.0	28.5	35.0
Estimated days to	Drought	57.35	3.45	49.67	64.33	-0.1660	-0.4110	0.283^{ns}	55.0	61.0	50.0	56.0
Podding	Irrigation	57.31	3.24	50.33	63.67	-0.3920	-0.3290	0.7341^{ns}	53.0	58.0	51.0	54.0
Internode length (cm)	Drought	2.48	1.00	0.71	5.29	0.4690	-0.1370	0.3558^{ns}	1.74	2.22	2.54	3.04
	Irrigation	2.21	0.92	0.52	4.15	0.3260	-0.9180	0.8567^{*}	1.54	2.04	1.57	2.82
Peduncle length (cm)	Drought	3.50	1.48	0.60	7.28	0.1200	-0.6530	0.3779^{ns}	2.54	3.06	3.54	4.6
	Irrigation	3.12	1.48	0.57	6.15	0.1750	-0.9880	0.591^{ns}	1.65	2.38	1.945	3.56
Pod. No/plant	Drought	53.40	25.45	7.50	126.70	0.5030	0.0890	0.4647^{ns}	59.0	73.0	20.0	32.0
	Irrigation	46.79	23.76	3.00	105.70	0.4180	-0.2450	0.3895^{ns}	44.0	106.0	21.0	23.0
Pod weight (g/plant)	Drought	36.01	19.12	4.36	83.09	0.4780	-0.1290	0.4893^{ns}	39.21	49.64	11.32	14.36
	Irrigation	38.25	22.65	1.98	85.51	0.3330	-1.0590	1.1301^{**}	28.41	76.83	10.77	11.26
Seed. No/plant	Drought	53.47	26.60	6.50	129.30	0.5010	-0.0613	0.44^{ns}	58.0	72.0	26.0	28.0
	Irrigation	48.28	26.35	3.00	116.70	0.4990	-0.4690	0.6893^{ns}	38.0	105.0	15.0	16.0
Seed weight (g/plant)	Drought	26.47	13.96	1.95	62.36	0.4540	-0.1220	0.4681^{ns}	28.0	39.4.	8.57	8.59
	Irrigation	27.12	16.24	1.28	57.72	0.3350	-1.1490	1.3672^{**}	23.14	61.79	6.81	8.24
100-seed weight (g)	Drought	49.24	12.02	24.48	81.89	0.4230	0.1040	0.6622^{ns}	52.83	58.8	37.34	44.15
	Irrigation	53.55	12.53	26.67	89.42	0.3680	-0.1650	0.6843^{ns}	58.85	60.89	45.4	51.5
Shoot dry weight	Drought	50.62	16.83	17.03	100.20	0.6180	0.5990	0.5969^{ns}	44.75	51.36	26.23	32.96
(g/plant)	Irrigation	45.88	17.41	14.93	92.30	0.5840	0.1670	0.6102^{ns}	48.47	105.26	27.31	29.39
HI index	Drought	0.65	0.23	0.19	1.23	-0.1040	-0.3100	0.5175^{ns}	0.81	1.11	0.43	0.44
	Irrigation	0.77	0.31	0.10	1.65	0.0259	-0.1540	0.3979^{ns}	0.73	1.00	0.38	0.39

Growth and development

- As F5 is a segregating population, genetic variability between lines would be expected.
- Possible transgressive segregation was observed e.g. *internode length.*

- Mild drought stress did not significantly influence *estimated days to podding, pod weight per plant, seed number per plant* and *seed weight per plant*.

  Plant growth stage and drought treatment.

***100-seed weight* and *harvest index* were significantly reduced by drought (8% and 15.6%, respectively)**

Conclusions

- Bambara groundnut landraces adapted to arid environments – perform better under drought conditions

- Bambara groundnut landraces use a combination of mechanisms to overcome water stress – maintenance of relatively higher tissue water, stomata conductance and photosynthesis, reduced leaf area, osmotic adjustment.

- Variation in the segregating population would allow selection superior lines – better cultivars of Bambara groundnut

Policy implication:

Adaptive traits observed in crops such as Bambara groundnut enable these crops to perform well under stressful conditions.

Climate change and its consequences call for research on climate resilient crops - determine which crop species will be fit for future climates.

Bambara groundnut – a climate resilient crop

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