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EMERGING INFORMATION ON AGRONOMIC TRAITS CONTRIBUTING TO DROUGHT RESISTANCE IN PERENNIAL RYEGRASS AND TALL FESCUE

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Contributors

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Talk outline

- The water supply situation;
- Defining drought & drought tolerance;
- What to measure;
- What we have found out:
  - "Mediterranean" and "European" tall fescue;
  - "Mediterranean" ryegrass;
  - "Commercial" ryegrass cultivars - comparative performance;
- Concluding remarks.

The water supply situation

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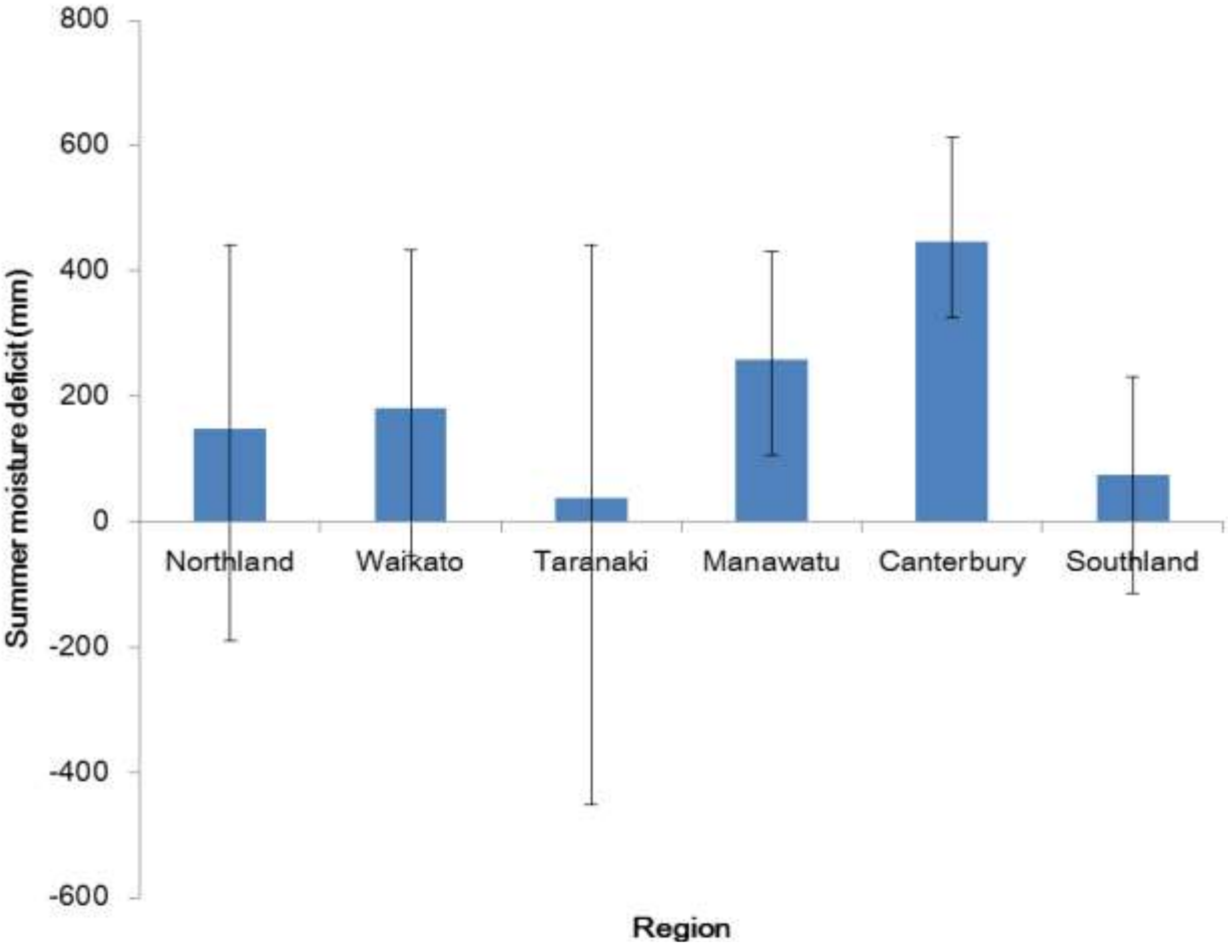
Regional variation in summer moisture deficit



Additional Nov. to March rainfall (mean range, 2001 – 2010) req'd for ryegrass to meet biological potential.

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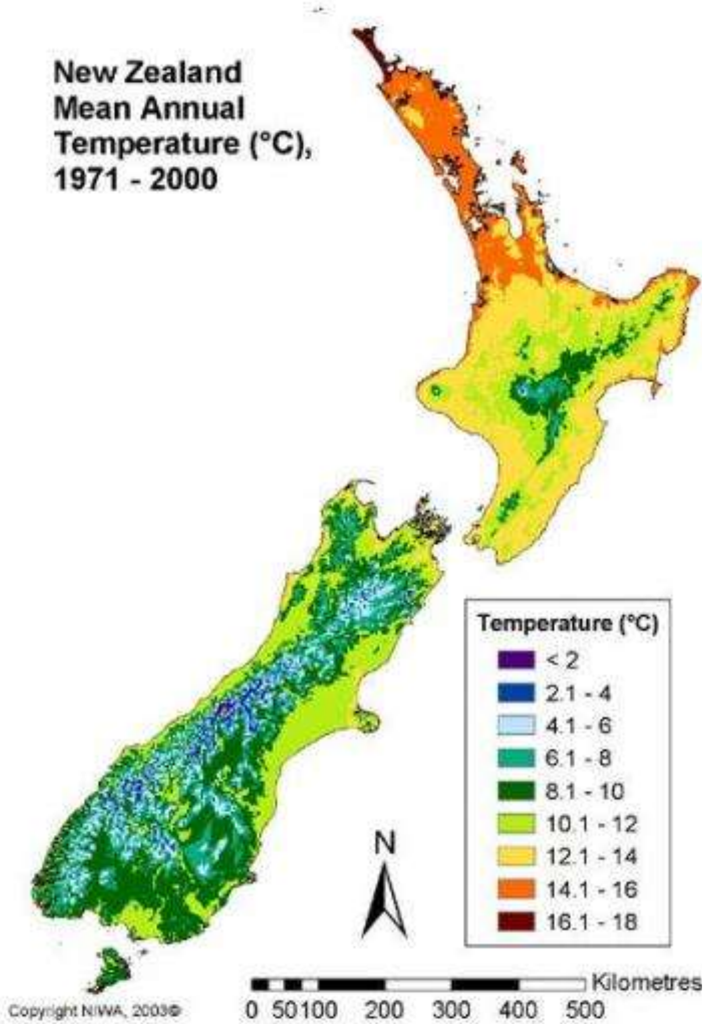

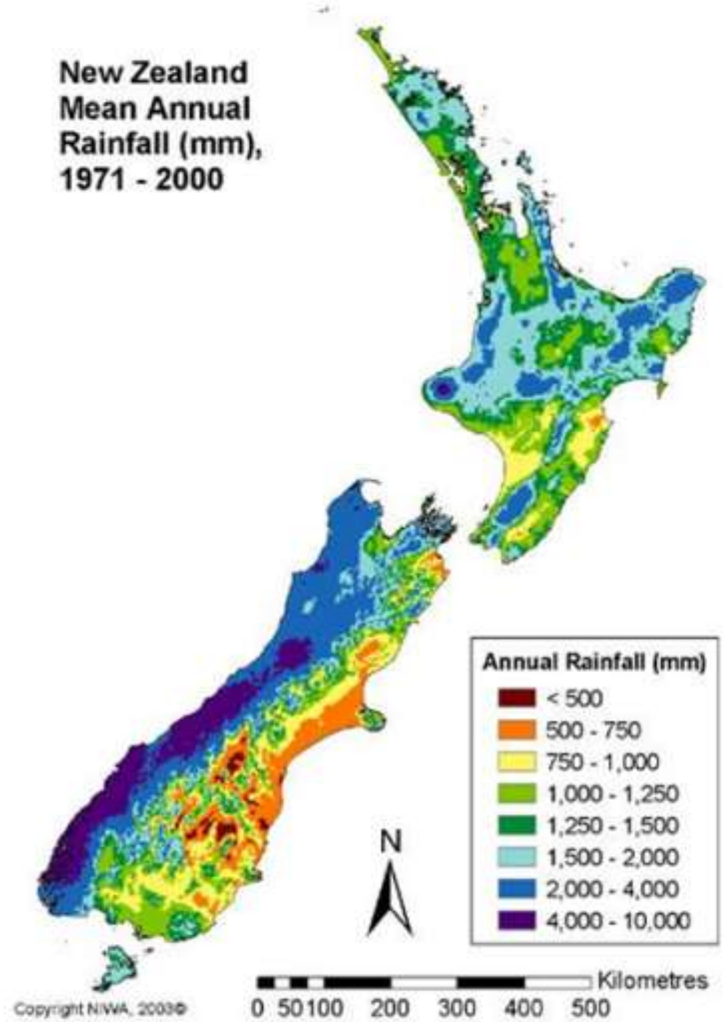

Maps: NIWA, 2012

Summary: Orange and red areas on the NIWA rainfall & temperature maps are respectively too warm (high water use) or have insufficient rainfall, for optimal growth of ryegrass.

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Drought definition & drought tolerance

"Sub-optimal rainfall that limits plant productivity"
(Mishra & Singh 2010: J Hydrology 391: 202 - 216)

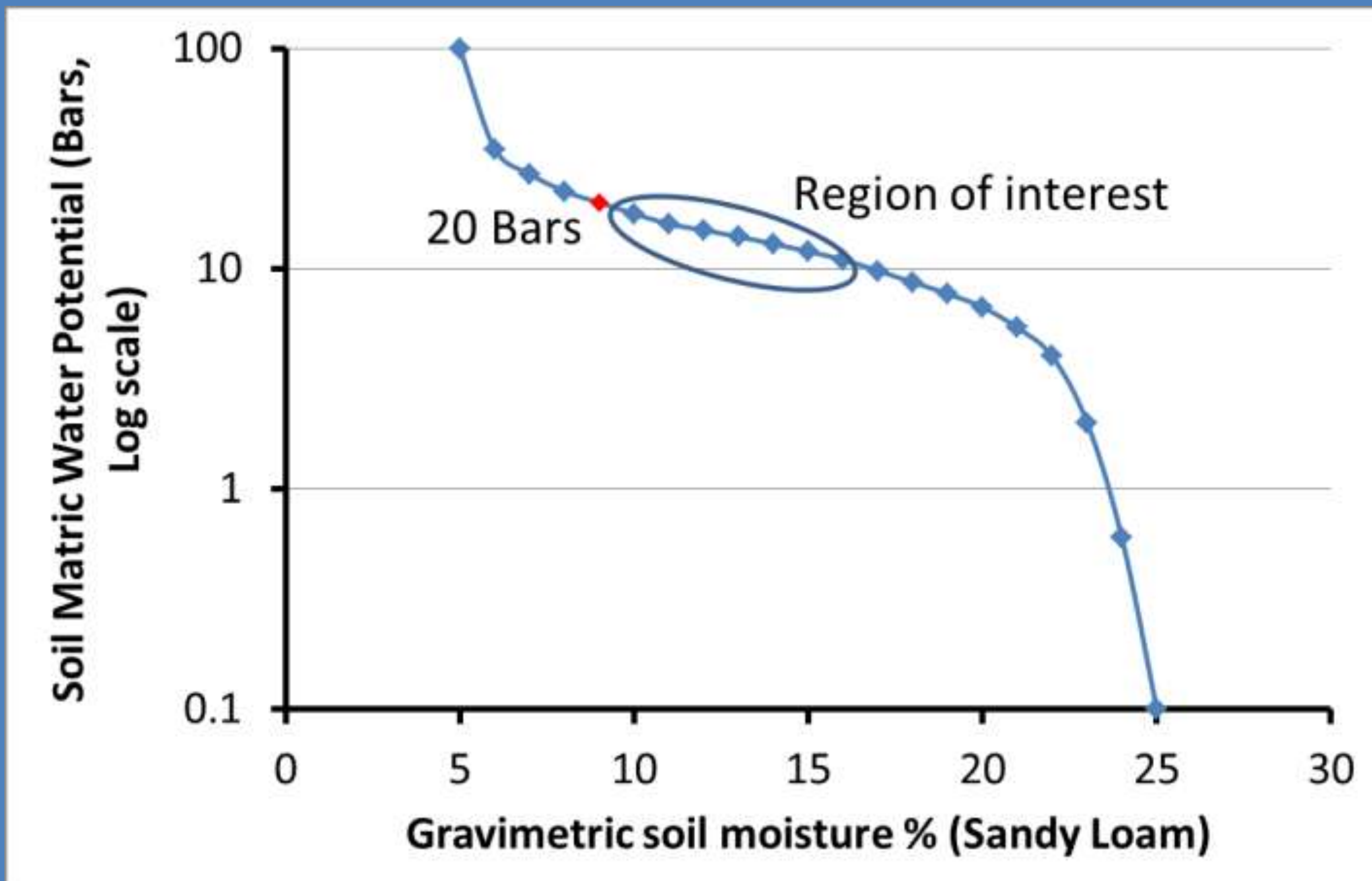
Key points: Natural, temporary, unpredictable.

Strategies available to a plant:

- Drought escape
  - Annual plant setting seed before drought; dormancy.
- Dehydration postponement
  - Increase water capture (root depth; osmotic adjustment
  - Reduce water loss (stomatal conductance; osmotic adjustment)
- Dehydration tolerance
  - Membrane stability and protoplasmic dehydration tolerance

(Turner 1986: Adv. Agronomy 39: 1 – 51)

Soil moisture extraction curve facing the plant:



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Plants are in a "tug of war" to extract scarce moisture from dry soil!

Sarah Matthew, Raoul Island

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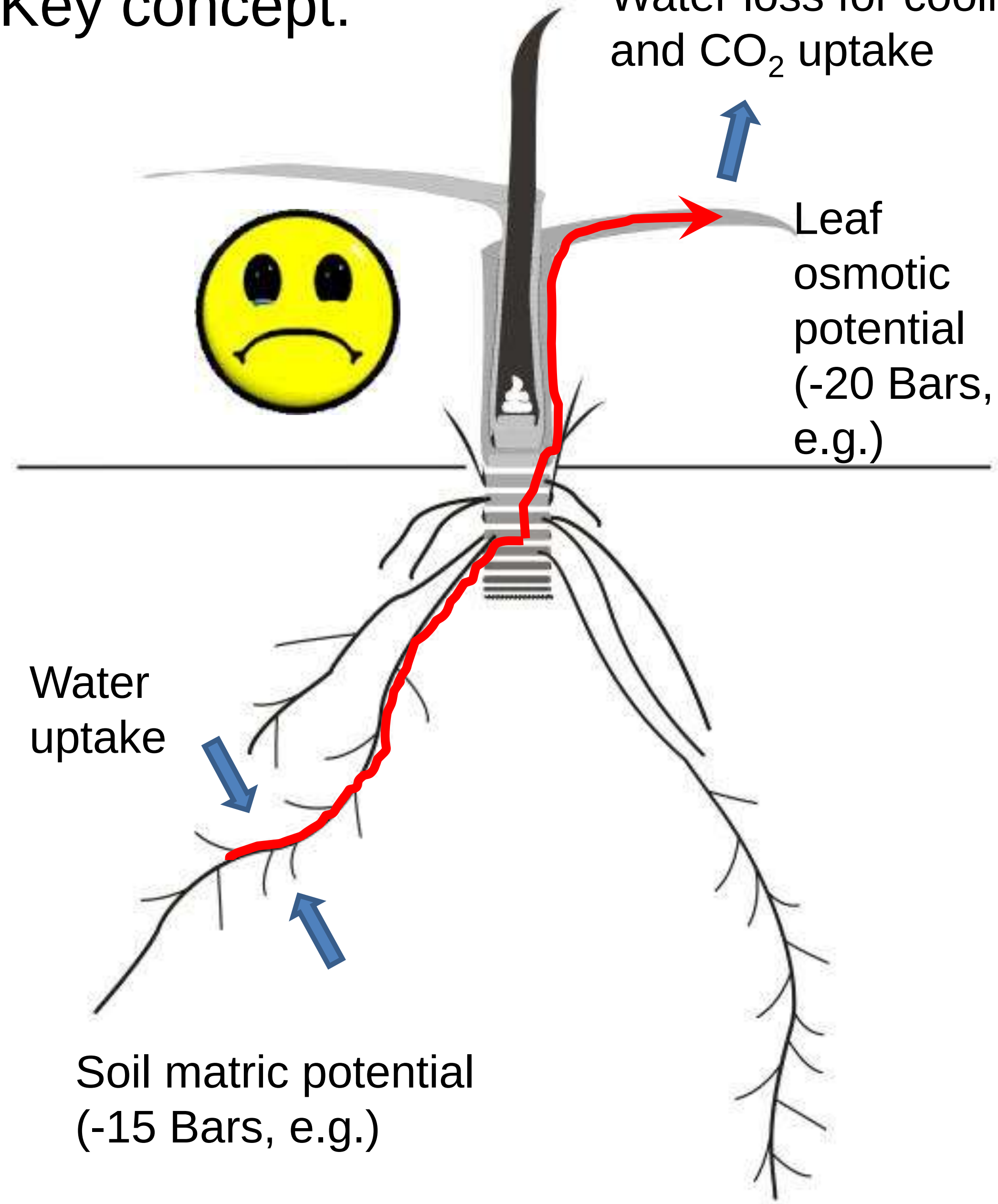
Key concept:



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Simplistically:

$\Psi w = \Psi s + \Psi p$

LWP = OP + Turgor

Strategies:

- ↑ Osmotic Potential (pull harder)
- ↑ Root depth (find more water)
- ↑ CO_2 in / unit water out (WUE) (*m* of Blum 2009)

Dormancy response = senesce leaves & “cocoon” apical meristem;

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What to measure

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Shoot Growth	Water Capture	Leaf Water Status & Gas Exchange
Shoot Dry Weight	Root mass (and length ?) in soil layers (D1 , D2, D3)	Net photosynthesis (Pn)
Plant tiller number	Soil moisture % (D1, D2, D3)	Stomatal conductance (Cs)
Leaf elongation rate	Root:shoot ratio	Leaf relative water content (RWC)
Leaf senescence	DW allocation to D2 & D3 roots	Leaf water potential (LWP)
	Pot weight loss per day	Leaf osmotic potential (OP)
		Osmolyte concentrations (e.g. proline)
		Cell membrane integrity

A drought physiologist's tools of trade:

Clockwise:

- Scholander pressure chamber (LWP);
- Wescor HR33T Thermocouple psychrometer (OP);
- CIRAS portable photosynthesis system (Pn, Cs)

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- 1 m deep pots used;
- Drought induction not straight forward;
- Endophyte status affects plant water relations;
- Principal component analysis a good tool for analysing multiple plant measures as an interacting system.

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What we found out ….

‘Mediterranean’ & ‘European’ tall fescue differ in drought tolerance strategy ….

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	El palenque* (European)	Maris Kasba (Mediterranean)
Chromosome number	2n = 42	2n = 70
Plant DW (g)	8.43	4.72
Stressed leaf OP (Bars)	40	28
Root:Shoot ratio	0.25	0.40

SG Assuero 1998; Ph D Thesis ; * Similar results for Grasslands Advance Tall Fescue

Grasslands ‘Flecha’ (Mediterranean, 2n = 56; L He 2013)

- Greater % plant DW as root at 60 – 90 cm soil depth;
- Increased Stomatal Conductance and ↑Gs/Pn ratio;

Compared to ryegrass plants in identical conditions.

When the two types had inter-mingled roots the European type with higher OP got the water!

% Shoot Dry Weight as dead tissue when El Palenque (European) & Maris Kasba (Med.^{n}) grown together.

	El Palenque* (European)	Maris Kasba (Mediterranean)
Well Watered	22.2	21.0
Moderate stress	27.6	33.3
Severe stress	32.2	45.8

MK	EP	MK
EP	MK	EP
MK	EP	MK
EP	MK	EP
MK	EP	MK

‘Mediterranean’ perennial ryegrass ‘Medea’

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PhD study of Sajjad Hussain (6 Experiments)

Research Objectives:

1. To explore drought resistance traits of summer dormant Mediterranean germplasm (cultivar Medea) & compare with current NZ cultivars (especially Grasslands Samson);
2. To evaluate Medea for its suitability for introgression with Grasslands Samson through trait inheritance studies.

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Characteristics of Medea and Medea x Grasslands Samson F_2 Hybrids

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Negative

- Summer dormancy (ie reduced plant DW compared to Grasslands Samson, ? greater DW reduction when warmer) and associated lower soil moisture extraction;
- “Prolific flowering” (? contamination with *L. rigidum*);
- Indication of high stomatal conductance

Positive

- Higher root shoot ratio, and increased allocation of DW to deep roots (below 30 cm soil depth);
- Higher proline contents.

6 family groups of F2 hybrids were evaluated and one family group demonstrated recombination of desirable traits from the two parents (↑DW, ↑ deep rooting, ↑leaf proline concentration)

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A Chance Discovery – discarded F_2 Medea x Grassland Samson plants unwatered 90 days

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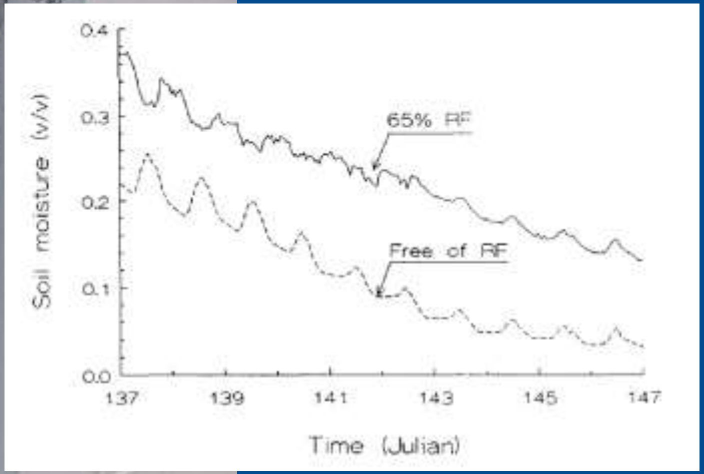
Speculative suggestion – is high Gs of 'Mediterranean' plants a "dew catching mechanism"?



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Commercial ryegrass cultivars demonstrate desirable water use traits

- Major germplasm sources recognised by Alan Stewart (2006) include: (i) persistent strains from old pastures, (ii) the ‘Mangere’ ecotyppe, (iii) Spanish germplasm, (iv) fescue introgression;
- Grasslands Samson derives from (i) and (ii);
- Ceres One50 (type iii) and Matrix (iv) extracted more water from 0 – 60 cm root depth than Grasslands Samson and produced ↑ plant DW (12, 22 & 25 g/pot, respectively; Tolosa (type iii) produced equal DW to G. Samson with less soil water used.

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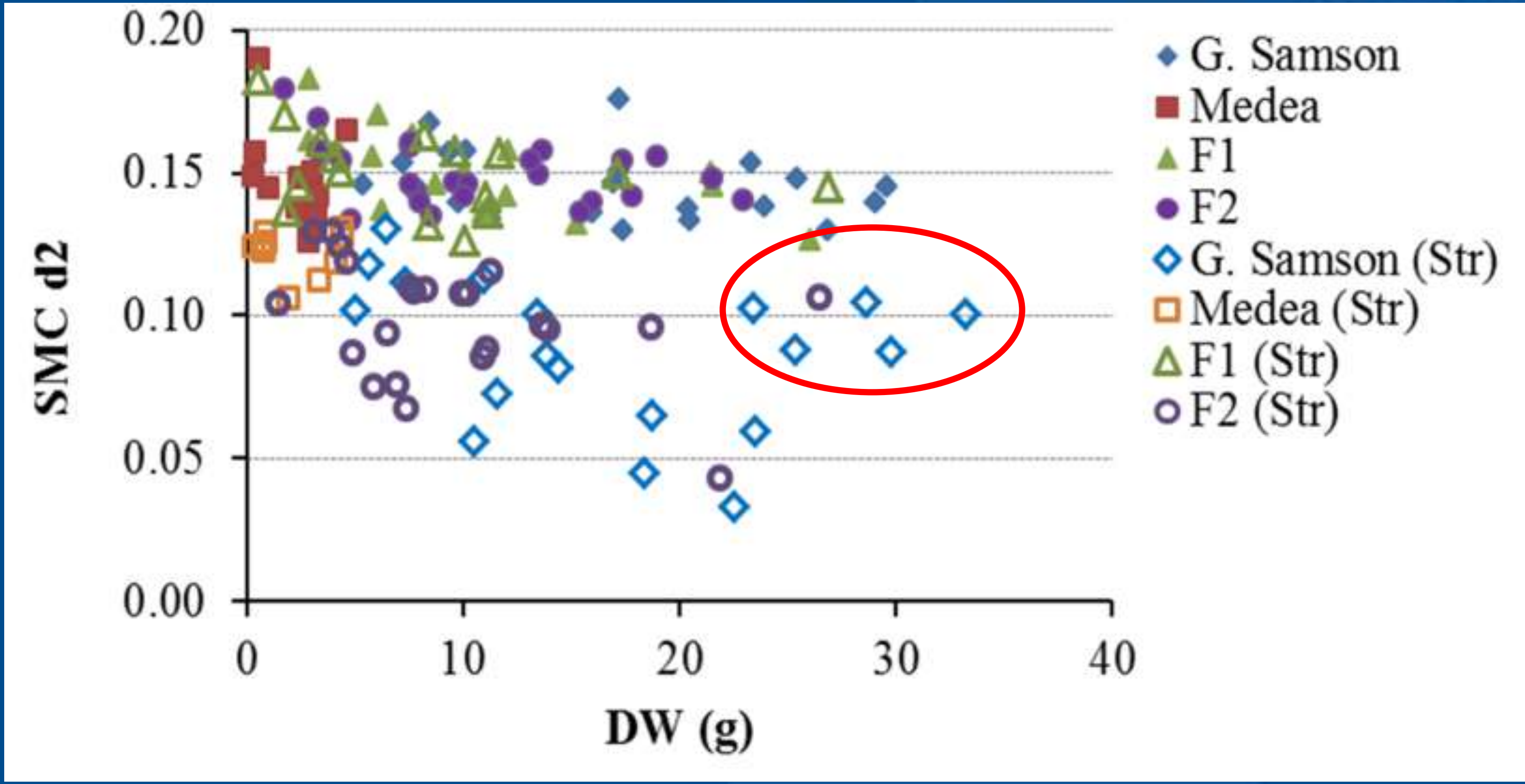
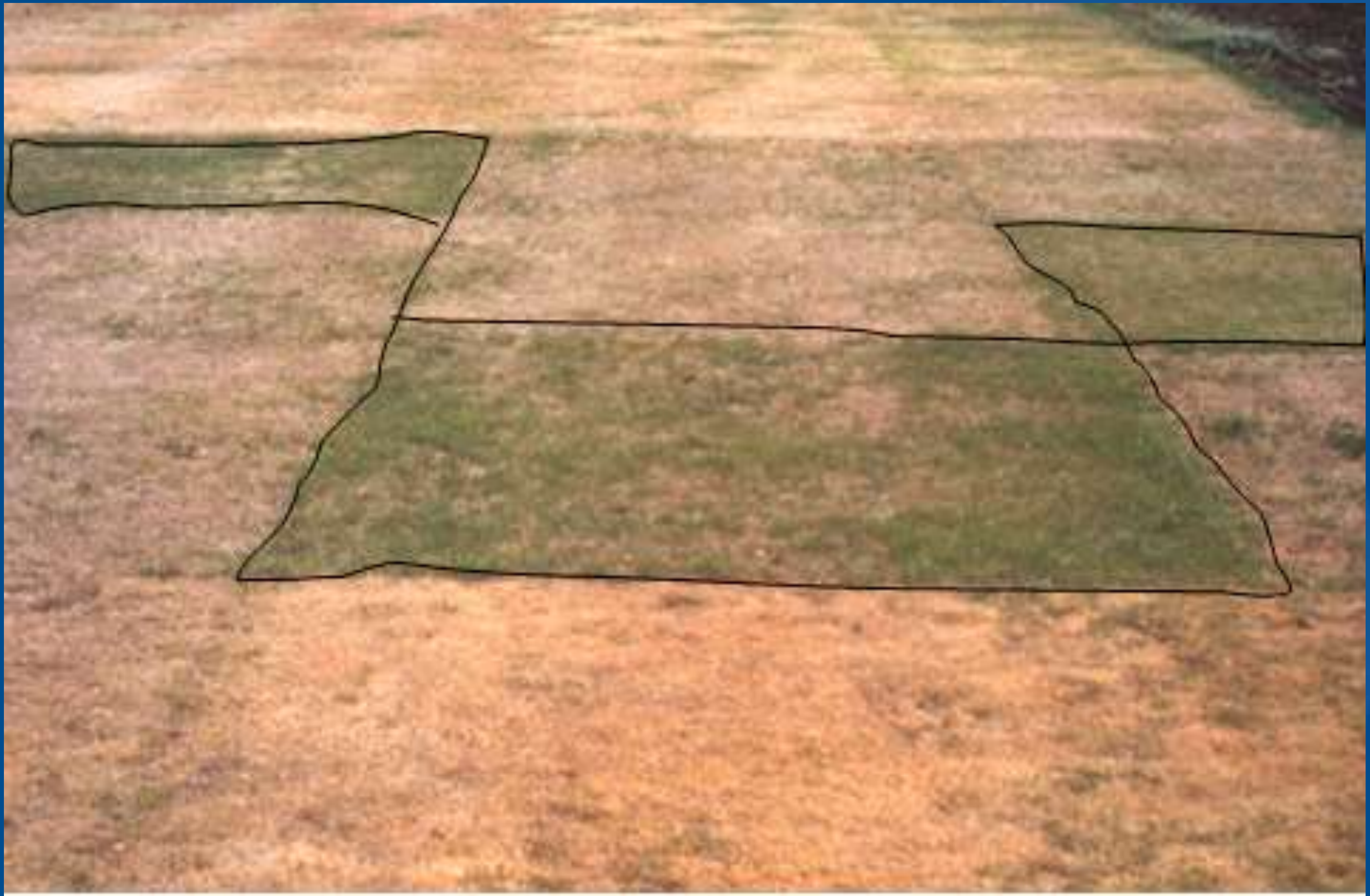
Potential for selection of G. Samson for improved DW per unit water used (Hussain 2013)



Parallel findings from an AgResearch study (Hatier et al.) looking for drought tolerance QTL. (IGC 2013)

Endophyte effects



Greener plots have endophyte; Photo A. Stewart

Endophyte effects

- Anecdotally widely agreed that endophyte enhances drought resistance;
- Strong endophyte strain x plant genotype interactions;
- Assuero (1998) detected only non-significant trends for endophyte effects on LWP & OP (but plant DW ↓ 10%), but some significant plant x endophyte interactions;
- He (2013, NZGA in press) obtained $P < 0.10$ for endophyte x water interaction for LWP (Bars) (similar result for RWC):

Well watered		Stressed	
E-	E+	E-	E+
-2.6	-4.5	-12.9	-8.5

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Concluding remarks

- Often hard to predict how molecular/cellular responses will scale up to the field level (or measure them precisely enough);
- Even simple measures such as SMC that integrate effects over time of operative plant processes can be informative;
- Company-commercial breeeding has delivered advances;
- Selection to exploit genotypic variation in WUE offers potential for rapid gain (equiv. to changing *m* of Blum 2009);
- Options to increase rooting depth exist; but knowledge of how root morphology determines function remains basic;
- Above changes equivalent to 100 mm ↑ summer rainfall (?);

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Matthew, C

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