Adapting cereals to drought: genetic and management solutions

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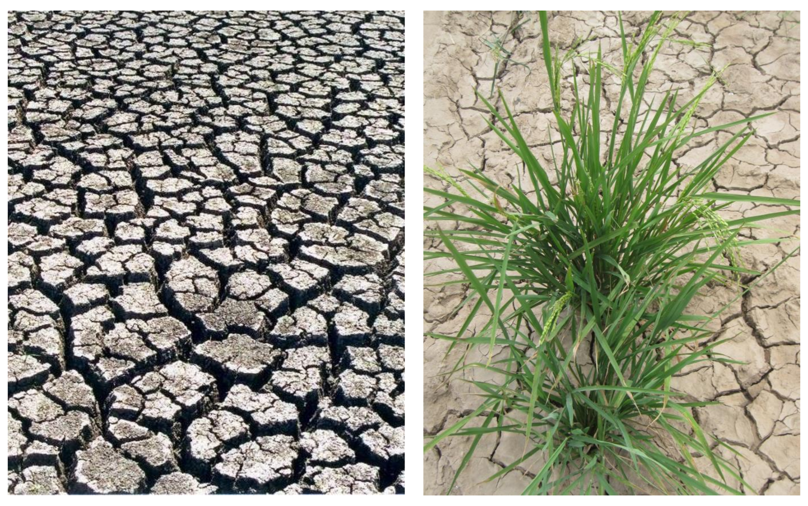
The challenge

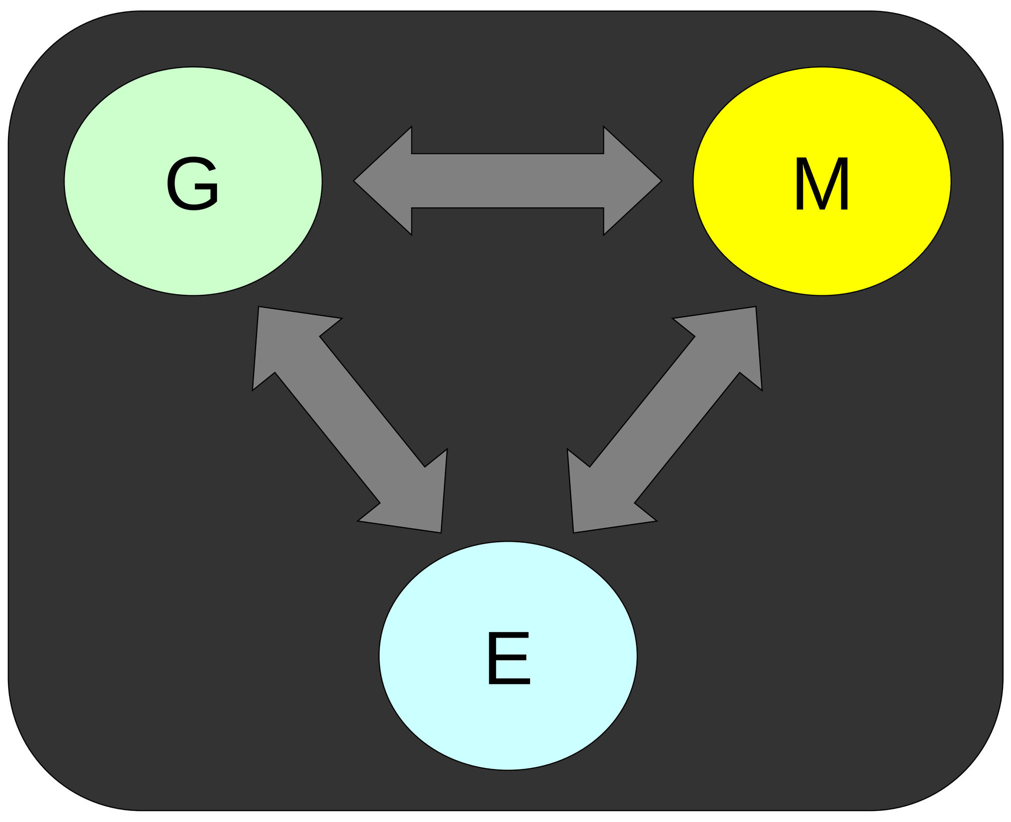
Drought is a major limitation to cereal production world-wide. Feeding more people with less water will require crops that are highly adapted to dry environments. Rain-fed farming is practised on 80% of cultivated land and accounts for 60% of the world's food production.



ABOVE : Drought is a major constraint to cereal production globally.

The GxMxE interaction

Adapting crops to drought requires genetic and management solutions. There are many possible management systems (e.g. combinations of planting dates, fertilizers, irrigation, row spacing, population, cropping systems) and many possible genotypes to combat drought. The challenge is to identify favourable combinations of genotypes and management practices in a complex system (1).



ABOVE:Understanding the interaction between genotypes (G), management (M) and the environment (E) is critical to improving grain yield under dry conditions.

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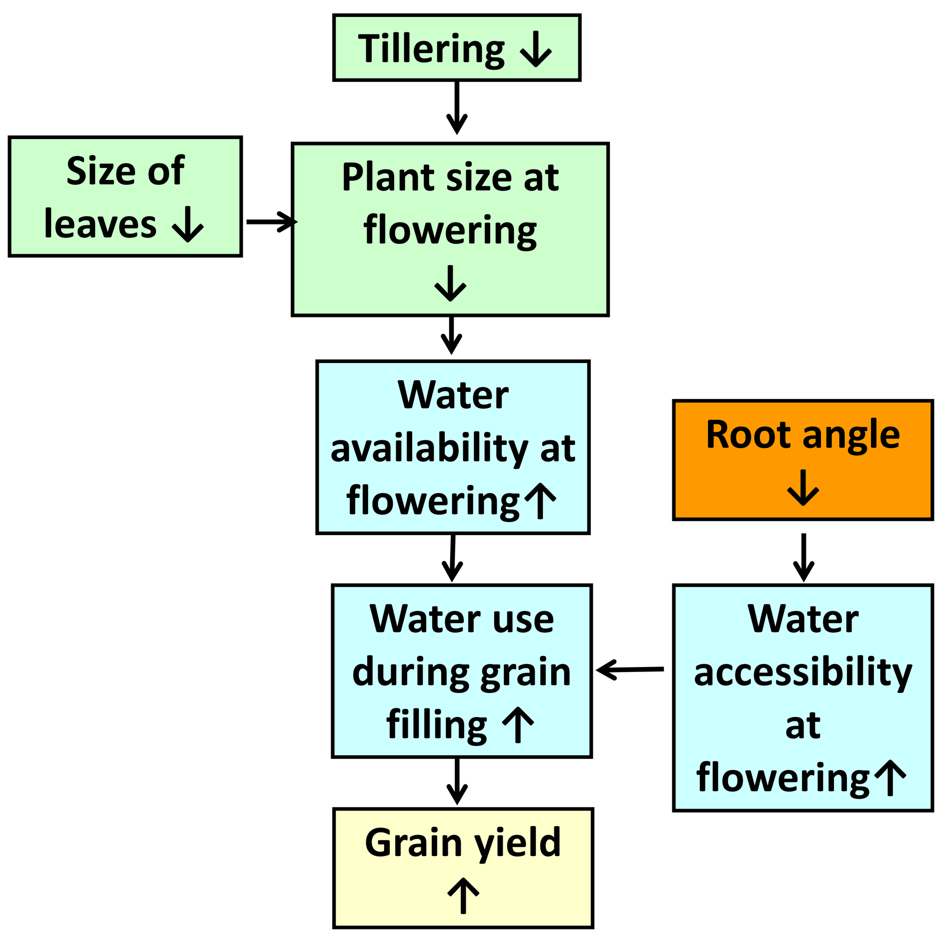
Genetic solutions: The stay-green drought adaptation trait

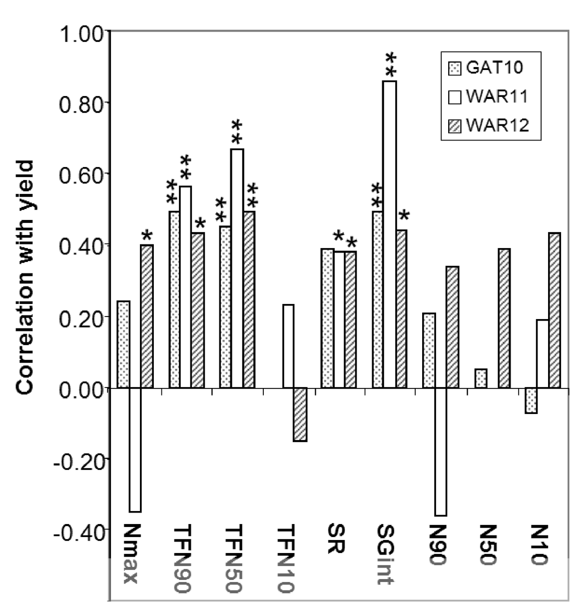
ABOVE: Sorghum plants of near-isogenic lines (NILs) differing for the parental allele at the stay-green2 (*Stg2*) QTL. Lines stg2/stg2 NIL (left) and Stg2/Stg2 NIL (right) were grown in the same conditions and were exposed to terminal water deficit.

The stay-green trait, an integrated drought adaptation trait characterized by a distinct green leaf phenotype during grain filling under terminal drought, is an example of a genetic solution. Alleles affecting stay-green in sorghum can reduce canopy size which decreases water demand, and can modify root architecture which increases water supply (2).



ABOVE: Flow chart of crop physiological processes regulated by *Stg* QTL that determine plant size and crop water use of sorghum at anthesis, with flow-on consequences for water uptake during grain filling and grain yield (2).

Stay-green and yield are also positively correlated in wheat (3).

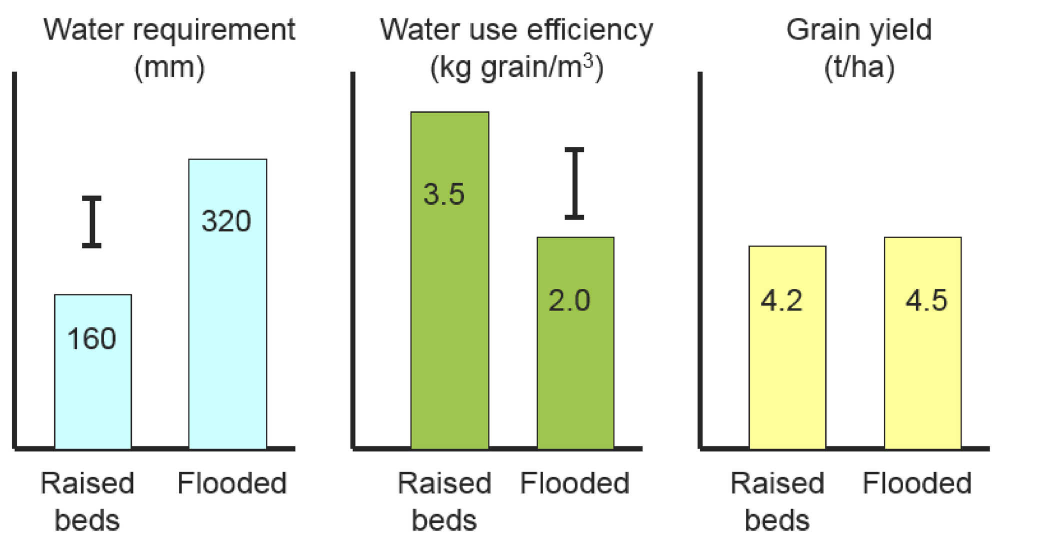


LEFT: Stay-green traits correlate with wheat yield, even with non-limiting rainfall (GAT10 & WAR11).
Nmax: Maximum leaf greenness
TFN90: Senescence onset
TFN50: Senescence midpoint
TFN10: Senescence end
SR: Senescence rate
SGint: Stay-green integral
N90: NDVI at onset senescence
N50: NDVI at mid senescence
N10: NDVI at end senescence
NDVI: Normalised Difference Vegetative Index (greenness)

Probability of correlations are indicated at less than 0.05 (*) and 0.01 (**) levels.

Management solutions: Novel water-saving technologies

Grain yield was equivalent for rice grown at Kawo, Indonesia, on raised beds and under flooded conditions, although the water use was halved using raised beds, significantly increasing water use efficiency (4).



ABOVE: The water requirement, WUE and grain yield of rice grown on raised beds and under flooded conditions at Kawo, Indonesia (4).

Studies carried out in the Andhra Pradesh and Telangana States of India found that the total methane emissions from traditionally flooded (NI) fields were 5-fold higher than from fields using alternative wetting and drying (AWD) irrigation (5), indicating significant environmental benefits from this water-saving strategy.

	Rabi 2013 (n = 2 ha from small farmer)		Kharif-2013 (n = 6 ha from big farmer)	
	kg CH_4-C	kg CO_2 equiv.*	kg CH_4-C	kg CO_2 equiv.*
NI	220	5500	660	16500
AWD*	44	1100	132	3300

* Calculated using the global warming potential of CH_4 = 25 times of CO_2 in 100 year time horizon (IPCC, 2007).

ABOVE: Estimated total CH_4-C emissions and CO_2 equivalent from NI and AWD rice fields during *rabi* and *kharif* seasons (5).

Examples of GxM combinations for water-limited environments could be a) stay-green genetics and low crop density for sorghum, and b) upland genetics and raised bed AWD systems for rice.

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