



Cap Dev Lectures series:

Breeding autogamous cereals - a complete lecture from *Parents to Farms*

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senior durum wheat breeder



Lecture 3 – April 15th 2022

- **Stage 1 and Stage 2 yield trials**
 - Differences
 - Secrets of success
 - Logistics vs goals
- **Target population of environments**
 - What is a good station
 - Effect of climate on traits
 - New models to define TPE
- **Stability analysis**
 - What is GxE
 - How to control it



The breeder equation

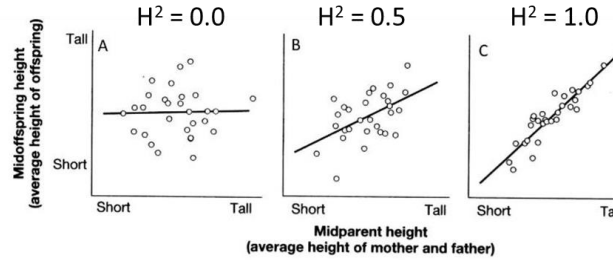


Good accuracy and good precision

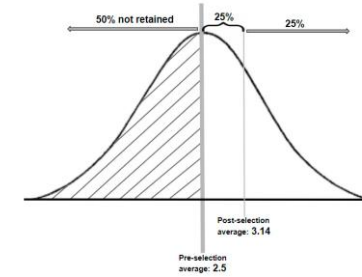


Bad accuracy but good precision

Accuracy: how close to the actual value



Heritability: how likely to move a trait from parents



Selection intensity: what proportion of the progenies is advanced each cycle

$$\text{Genetic gain}_{\text{year}} = \frac{\text{Accuracy} \times \text{Heritability} \times \text{Selection intensity}}{\text{Recycling time in years}}$$



Recycling time in years: how many years between crossing and re-crossing

Yield trials: why?

- Why do we do yield trials?

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We need to test all traits declared in the product profile



Yield trials: common aspects

- What information would you give to describe a yield trial?



Yield trials: common aspects

- What information would you give to describe a yield trial?

Size, plot size, entries, experimental design, location, ..



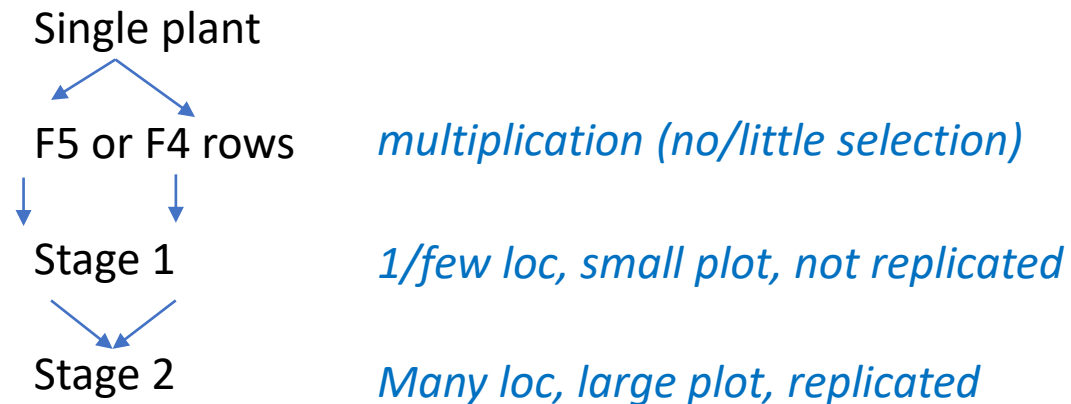
Yield trials: Stage 1 vs Stage 2

- Is there any difference between Stage 1 and Stage 2

Yield trials: common aspects

- Is there any difference between Stage 1 and Stage 2

The main difference is seed availability and number of progenies
It is then critical to conduct a Stage 1 that enables Stage 2



Stage 1 yield trial: What is it?

Stage	Entries
Crosses	100 pop
F1>F4	100 pop
F5 (pedig.)	100 x 24 progenies
Stage 1	2 400
Stage 2	240
Stage 3	24

- Stage 1 is when most of ***intensity*** happens
- Small plot size
- No reps/loc
- Lots of “bad” genotypes



Stage 2 yield trial: What is it?

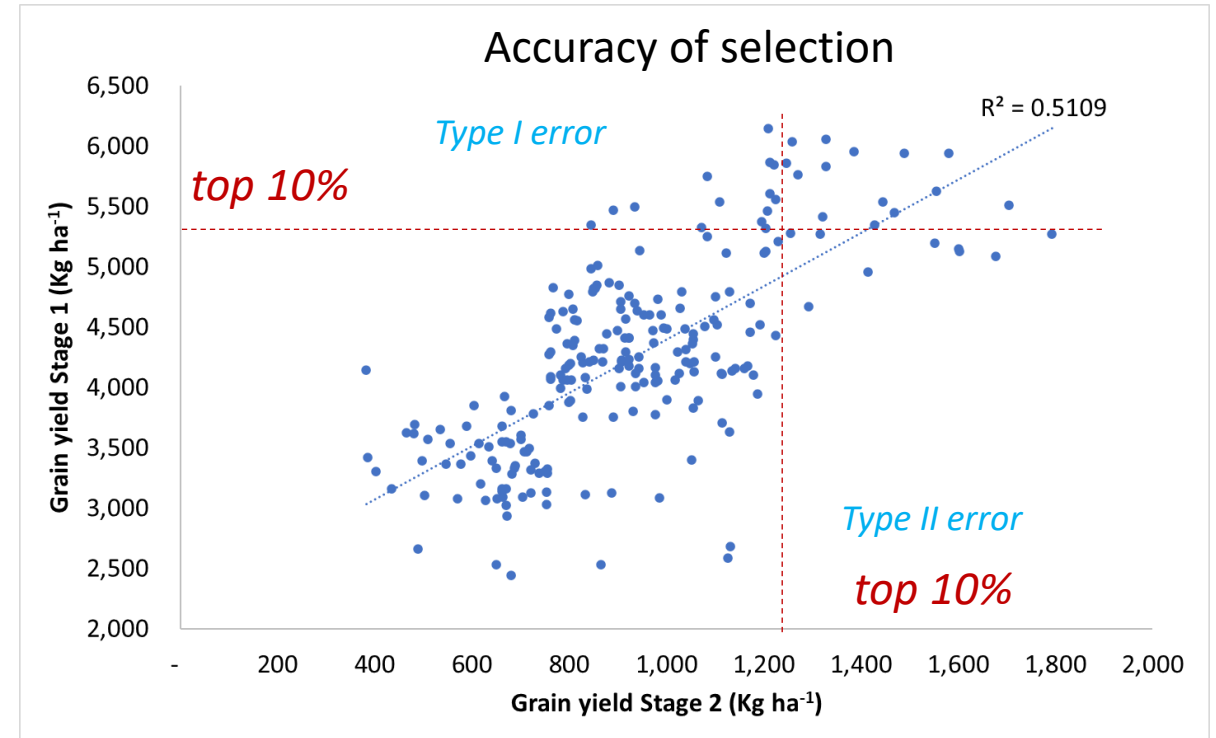
Stage	Entries
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- Stage 2 is when most of **accuracy** happens
- Large plots
- Across environments / reps
- Mostly “valuable” genotypes



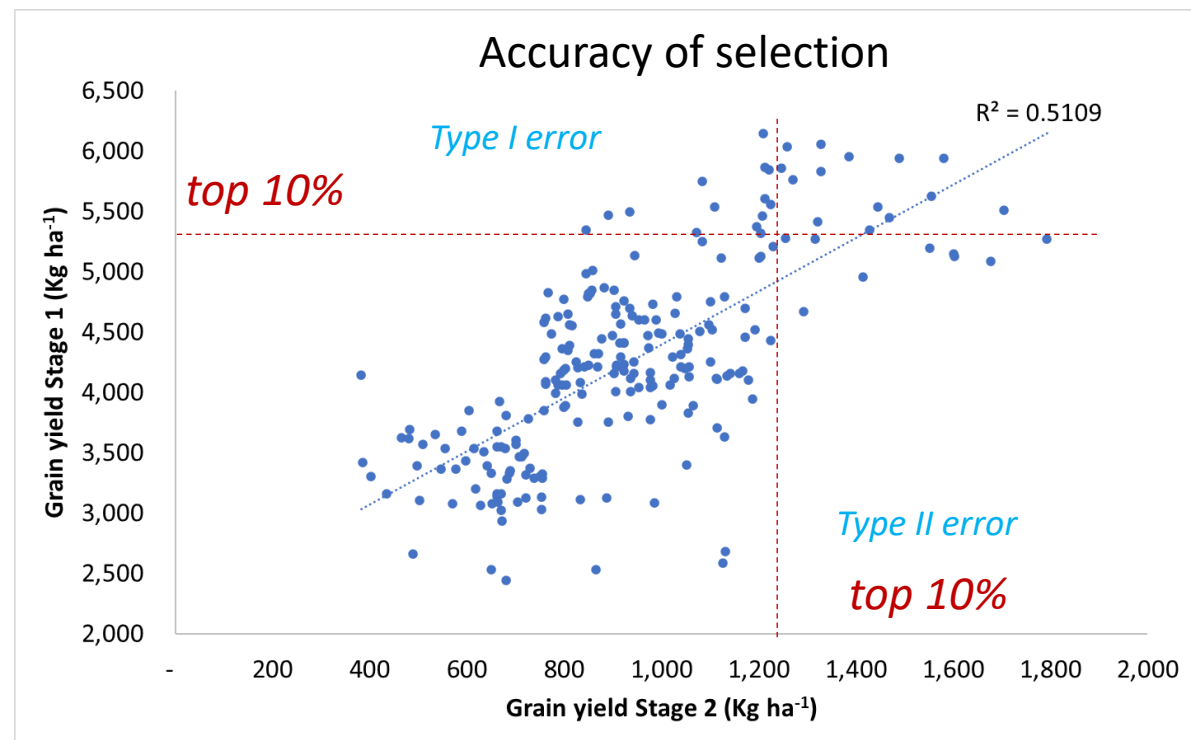
It is then an equilibrium between discarding in Stage 1 and assessing in Stage 2 with accuracy

Stage 1 yield trial: secrets of success



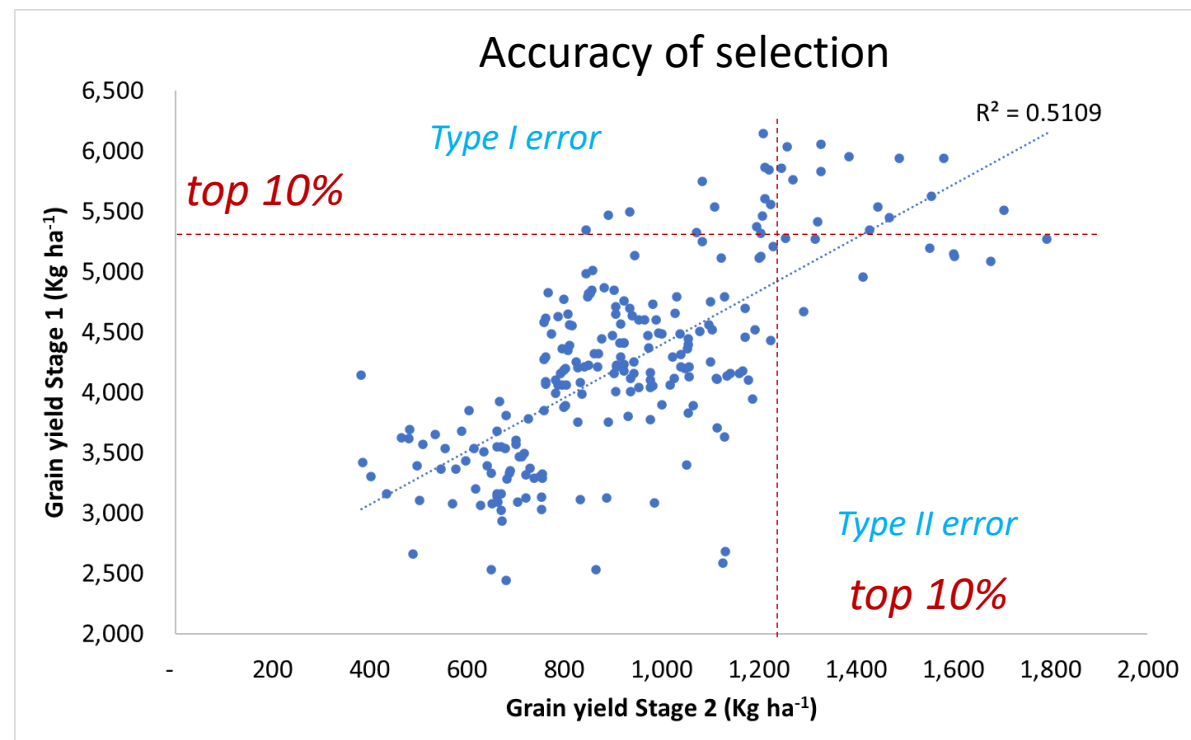
Stage 1 yield trial: secrets of success

- Reach it with as much *variation* as possible
- Reach it with as much *inbreeding* as possible
- Avoid testing any “*wrong*” progeny
- Dedicate to it lots of your budget
- Avoid *losing any useful lines before going to Stage 2*
- Maximize intensity at decent accuracy and heritability



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Optimizing breeding schemes //

Manual

Selection intensity



Stage 1 yield trial: intensity

- 10% pressure is often used
- What would be the risk of raising it to 5%? Or increasing the pop to 4 800?

Enhancing the rate of genetic gain in public-sector plant breeding programs: lessons from the breeder's equation

Joshua N. Cobb¹ · Roselyne U. Juma^{1,2} · Partha S. Biswas^{1,3} · Juan D. Arbelaez¹ · Jessica Rutkoski¹ · Gary Atlin⁴ · Tom Hagen^{5,6} · Michael Quinn^{5,6} · Eng Hwa Ng^{5,6}

Ratio (%)	Stage 1	Stage 2	STD differential	Genetic gain
10.0%	2 400	240	1.750	1.00
5.0%	2 400	120	2.063	1.18
1.0%	2 400	24	2.665	1.52
0.5%	2 400	12	2.892	1.65
0.1%	2 400	2-3	3.253	1.86

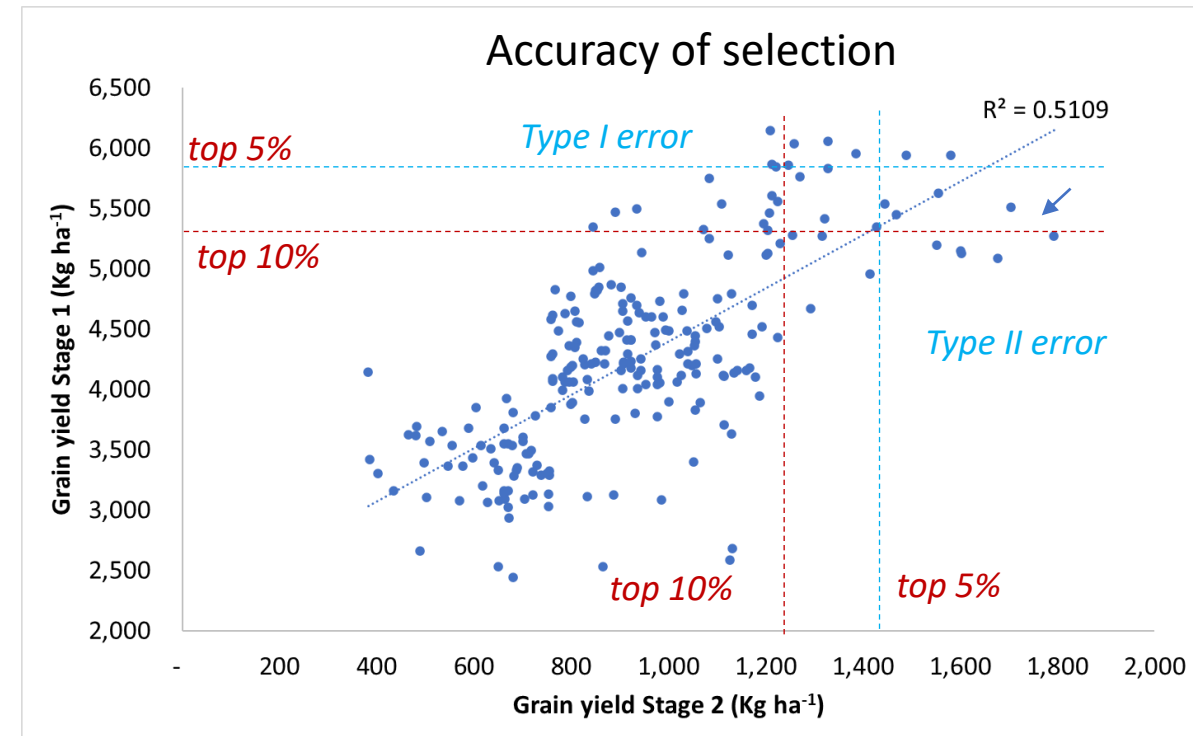
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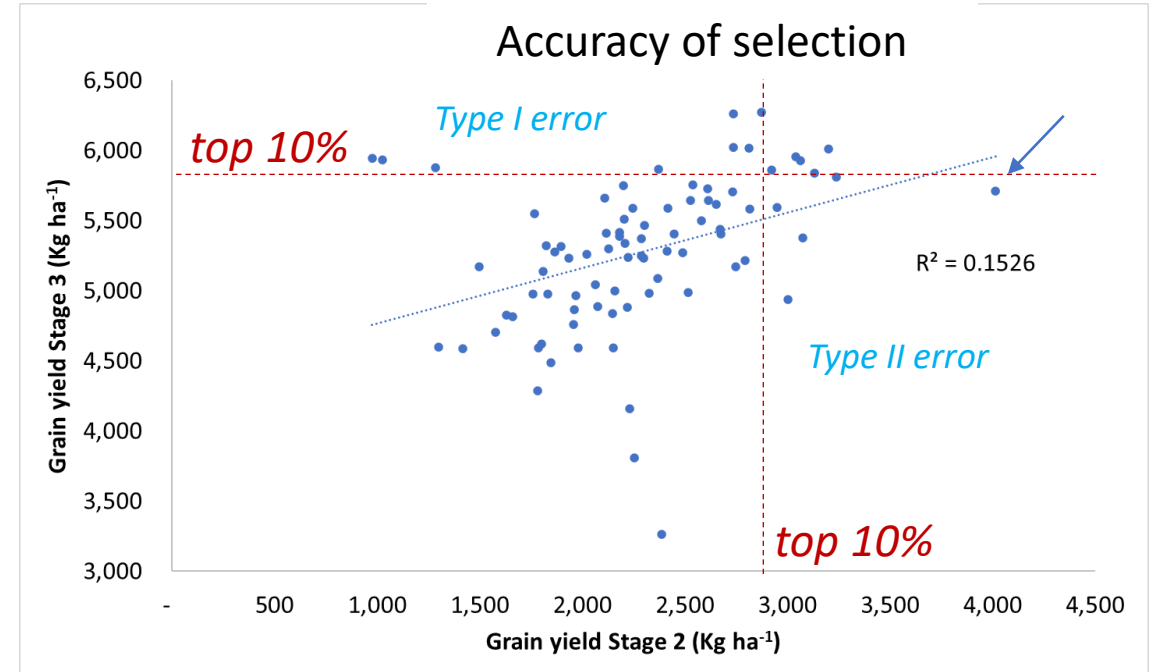
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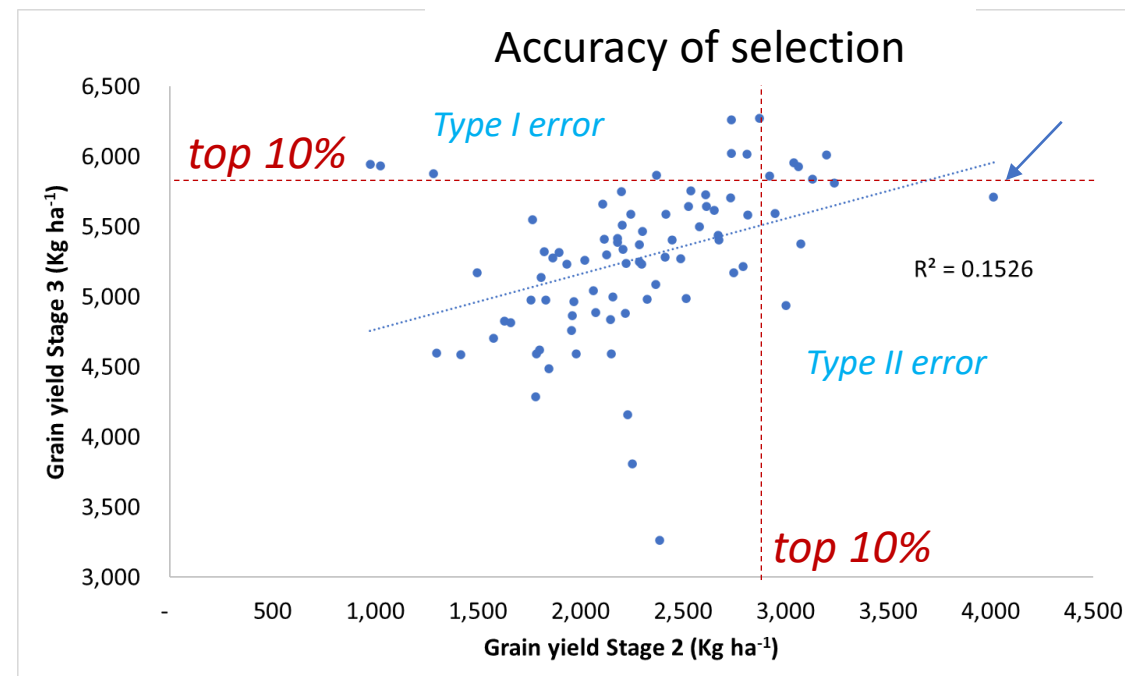


Stage 2 yield trial: secrets of success



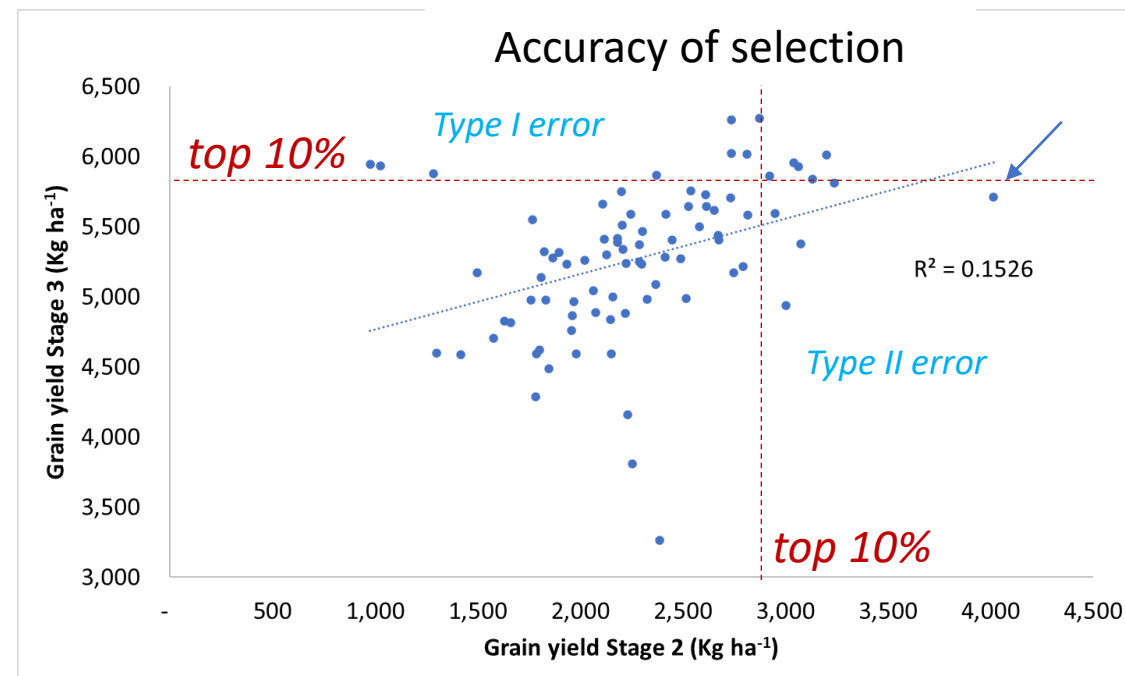
Stage 2 yield trial: secrets of success

- Most expensive step: it determines “numbers”
 - Include only top genotypes
 - Dedicate to it lots of your budget
 - Select environments carefully
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Stage 2 yield trial: secrets of success

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- Once lines are not advanced to Stage 3 they are out..
- Stage 2 are often the elites used as parents for crossing

Yield trials: decisions and logistics

	Env 1	Env 2	Env 3	Env 4	Env 5	Env 6
Distance (Km)	5	20	200	300	1000	2500
Cost	High	Medium	Medium	High	Low	Medium
Yield	Y	Y	N	Y	Y	Y
Disease	N	Y	Y	N	N	Y
Quality	Y	Y	N	N	N	N
Drought tol	N	Y	Y	N	N	Y
TPE	A	A	B	B	B	C

- Which one would you like as home station?

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- Which one would you like as home station?
- Where would you do yield trials for TPE B?

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- Which one would you like as home station?
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- What is the value of Env 6?

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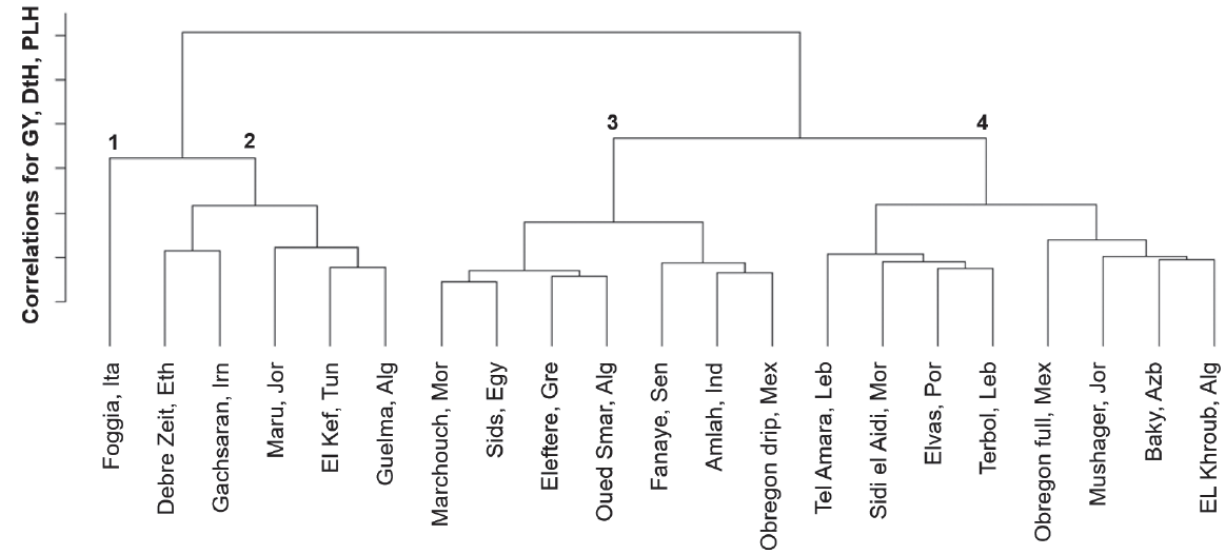
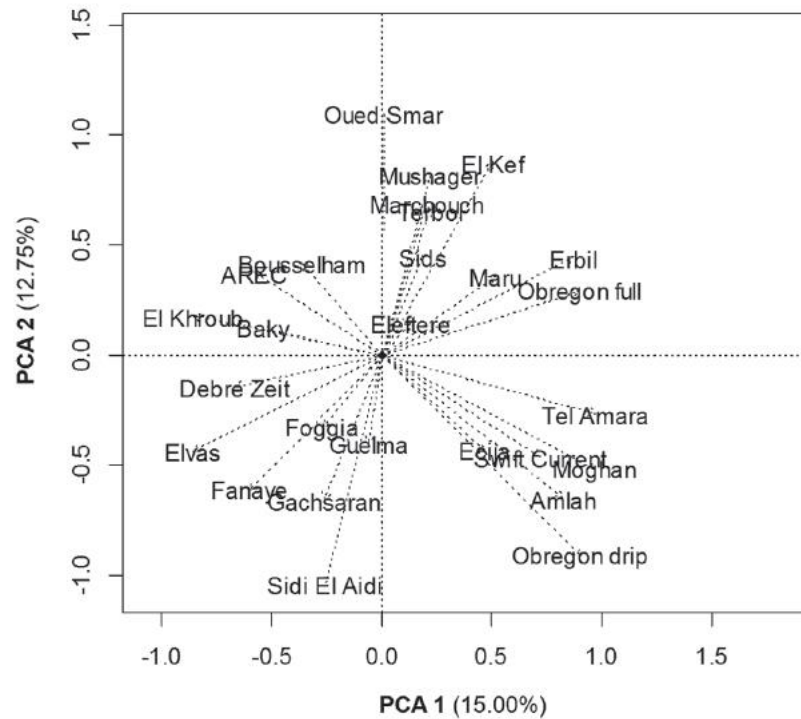


Target population of Environments: TPE

- It defines how well a station represents an agro-ecology
- How would you define it?

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Effect of climate on traits: climatic regressions

- There is an inherent issue in using traits to define environments, that will then be used to define traits
- Climatic factors are then better as they are “independent”
- Which climatic factors affect plant growth?

Effect of climate on traits: climatic regressions

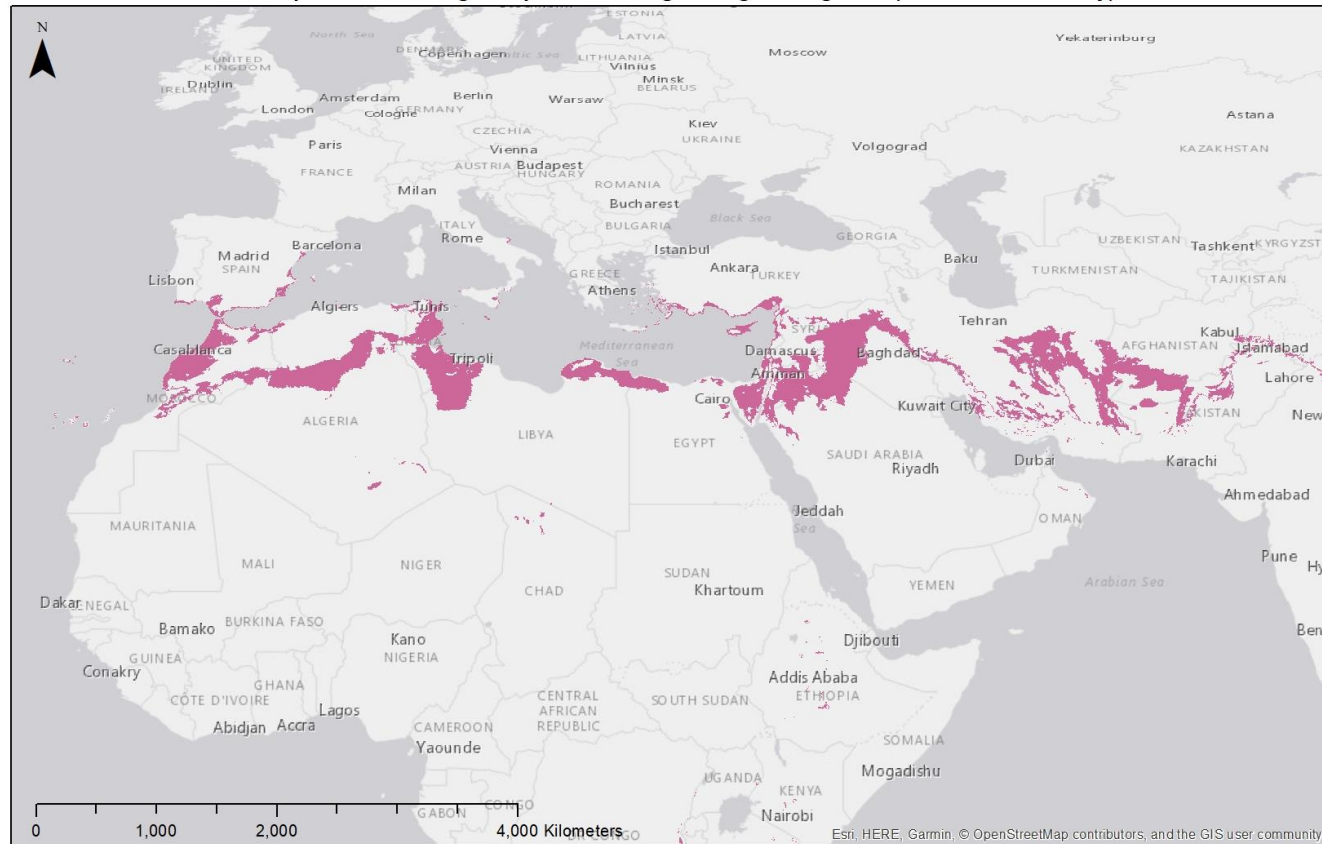
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- Which climatic factors affect plant growth?

Stage	Max temp				Min Temp				Moisture			
	GY	DtH	Spk.m2	TKW	GY	DtH	Spk.m2	TKW	GY	DtH	Spk.m2	TKW
Overall	(0.81)	(0.40)	(0.32)	(0.69)	(0.98)	(0.65)	(0.77)	(0.26)	0.23	0.18	0.25	0.26
Pre-planting	0.41	0.42	0.69	(0.07)	0.46	0.77	0.72	(0.60)	0.36	0.18	0.02	0.32
Vegetative grow	(0.62)	(0.64)	(0.85)	0.14	(0.87)	(0.66)	(0.80)	(0.01)	0.21	0.35	0.68	(0.29)
Flowering	(0.44)	(0.22)	(0.38)	(0.38)	0.66	(0.08)	0.14	0.92	0.45	0.06	0.09	0.69
Grain filling	(0.76)	(0.26)	(0.07)	(0.86)	(0.93)	(0.77)	(0.84)	(0.04)	0.75	0.43	0.46	0.52
Maturity	(0.59)	(0.23)	(0.26)	(0.63)	(0.95)	(0.44)	(0.58)	(0.59)	(0.66)	(0.82)	(0.84)	0.41

Defining TPE: climatic models

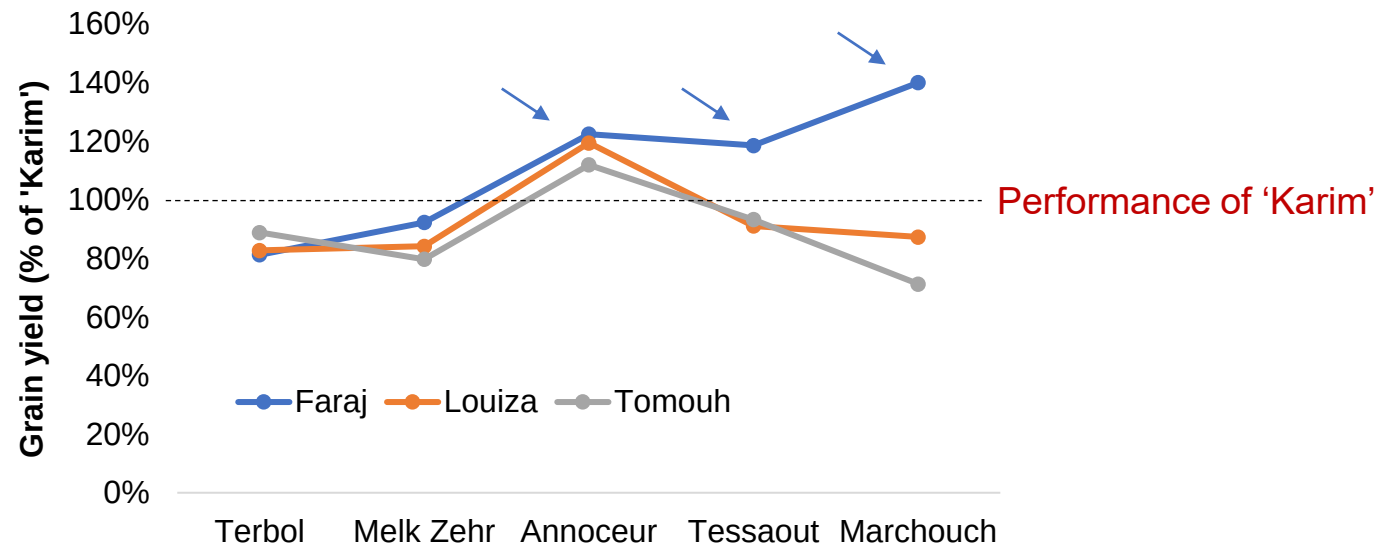
- Once the climatic boundaries of each station are defined (i.e. moisture, temperature, ..) these can be used to assess how much of the cultivation area that station represents.

North Africa and west Asia Map with max average temperature during the vegetative growth (December – February): 17 -20 C 2014 to 2018



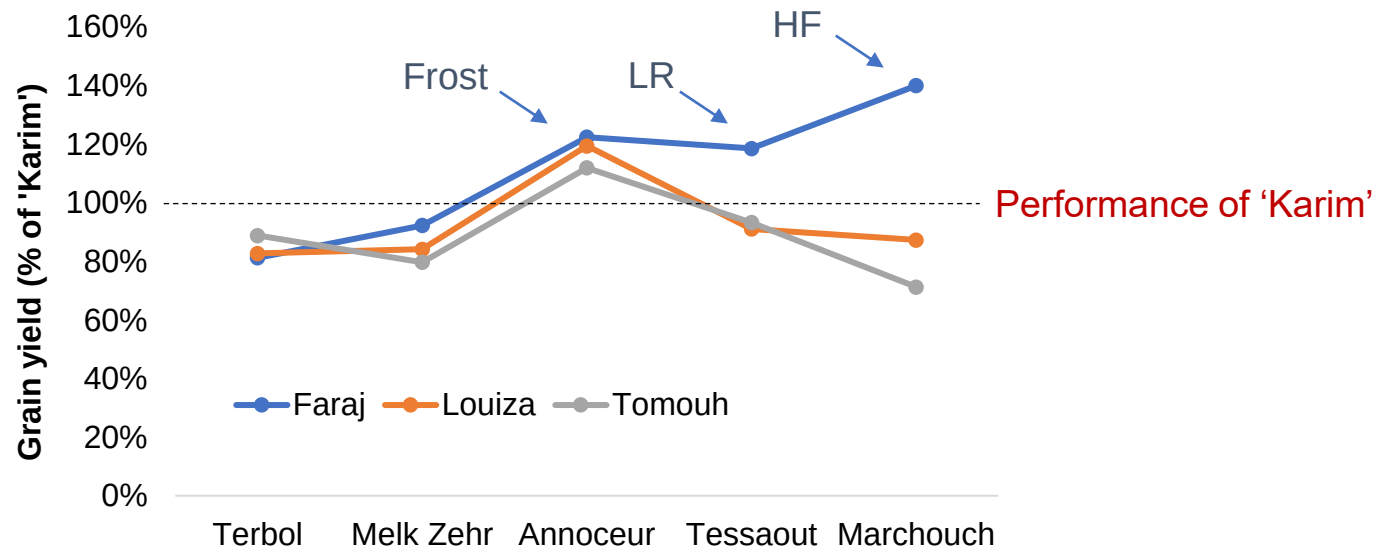
Genotype x environment: what is it?

- It represents the rank variation of genotypes performances between environments

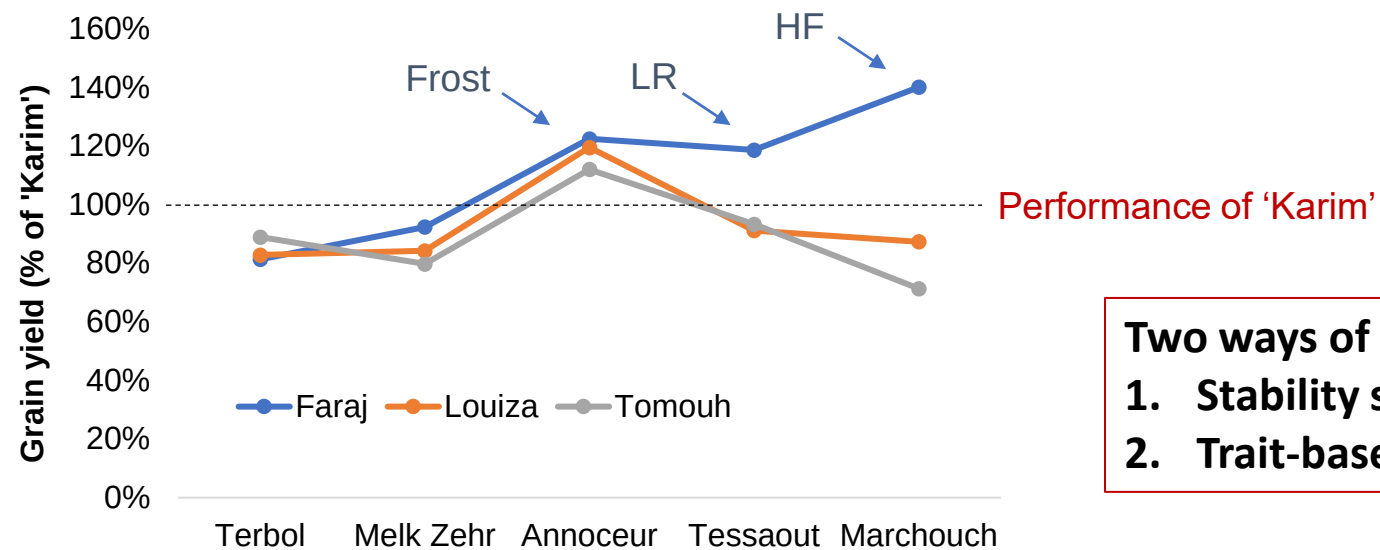


Genotype x environment: what is it?

- It represents the rank variation of genotypes performances between environments
- It is a factor that needs to be controlled, but that can also be exploited: how?



The secret factors of GxE



Two ways of controlling GxE:

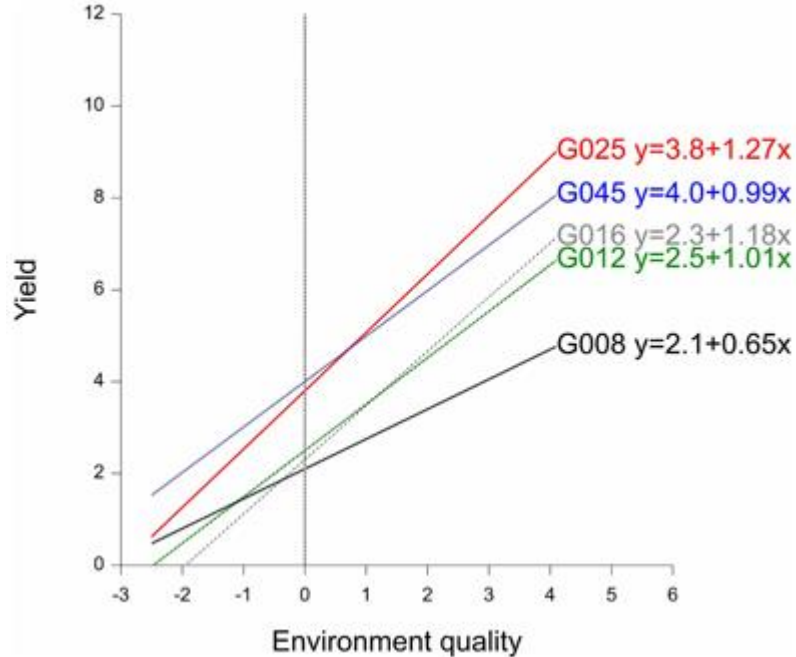
1. Stability studies
2. Trait-based research



Stability analysis: principles and solutions

- Methods to assess stability?

Finlay–Wilkinson regression

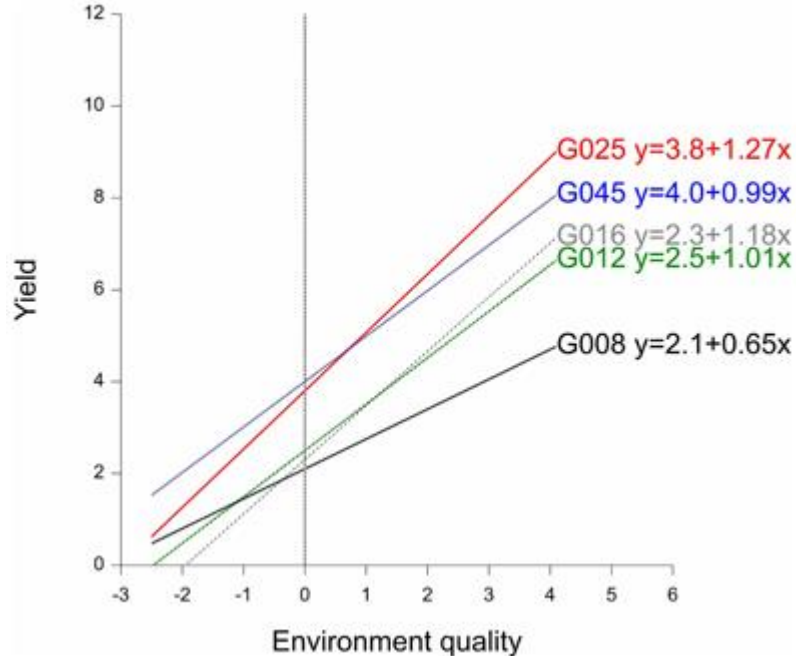


The statistical analysis of multi-environment data: modeling genotype-by-environment interaction and its genetic basis

Stability analysis: principles and solutions

- It is critical to have a quantification of “how stable” a line is vs another line
 - It is not always “the most stable” that we want

Finlay–Wilkinson regression

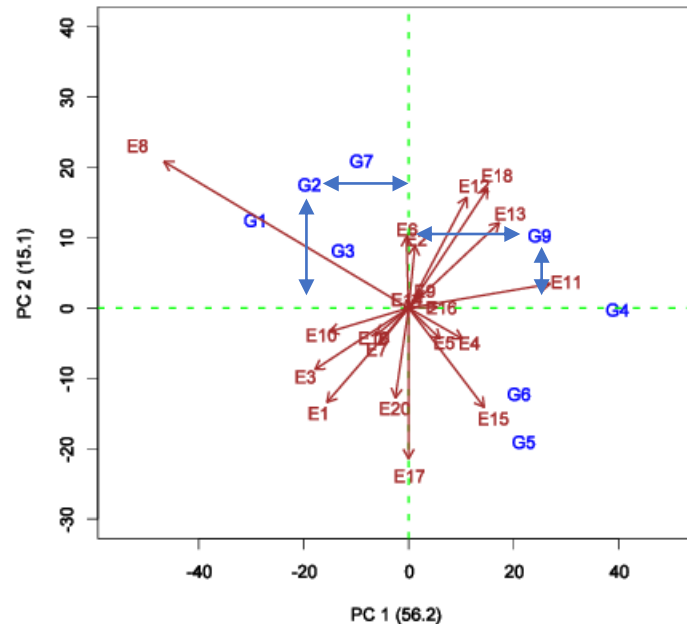


- This model provides:
 - b' which is the angle of the slope (GxE)
 - r^2 response of genotypes to inputs ($\approx G$)
 - *Among G25 and G45, which one is better?*

Stability analysis: principles and solutions

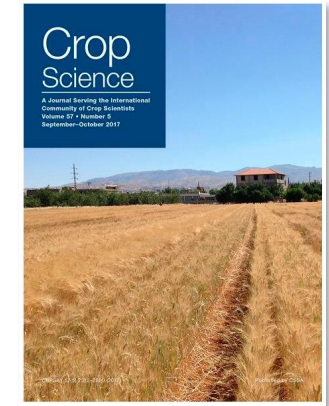
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AMMI wide adaptation index (AWAI)

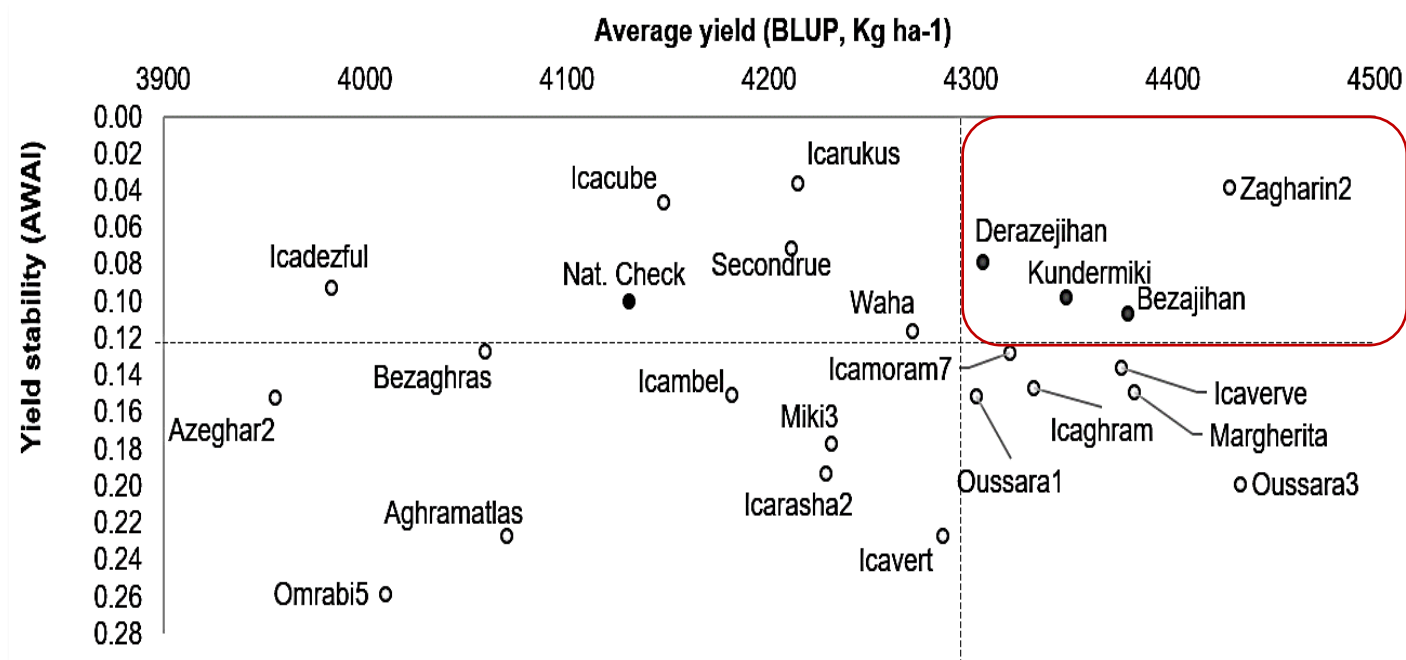


$$AWAI = \sum_i S_i * |PC_i|$$

- AWAI is a single value:
 - G2 has little GxE for PC1 and strong GxE for PC2
 - G9 has strong GxE for PC1 but little for PC2
 - Which one is more stable?*

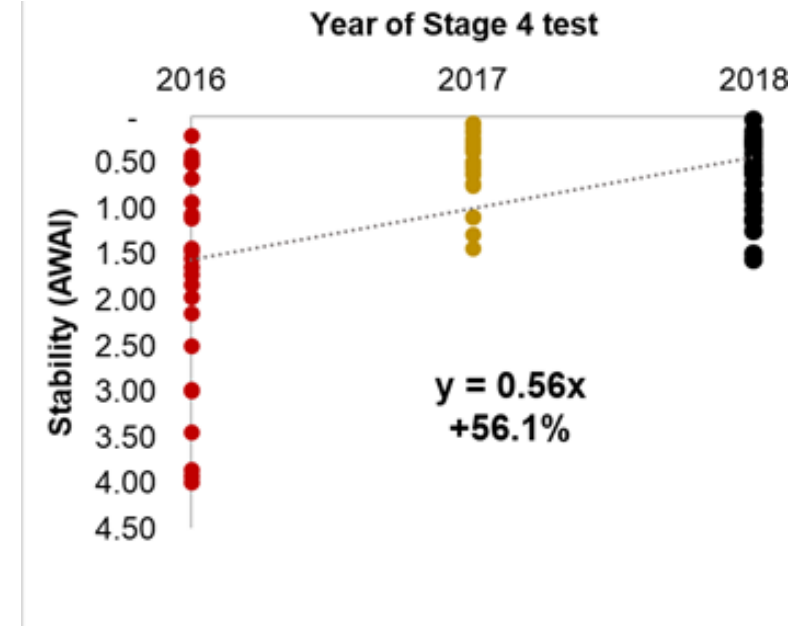
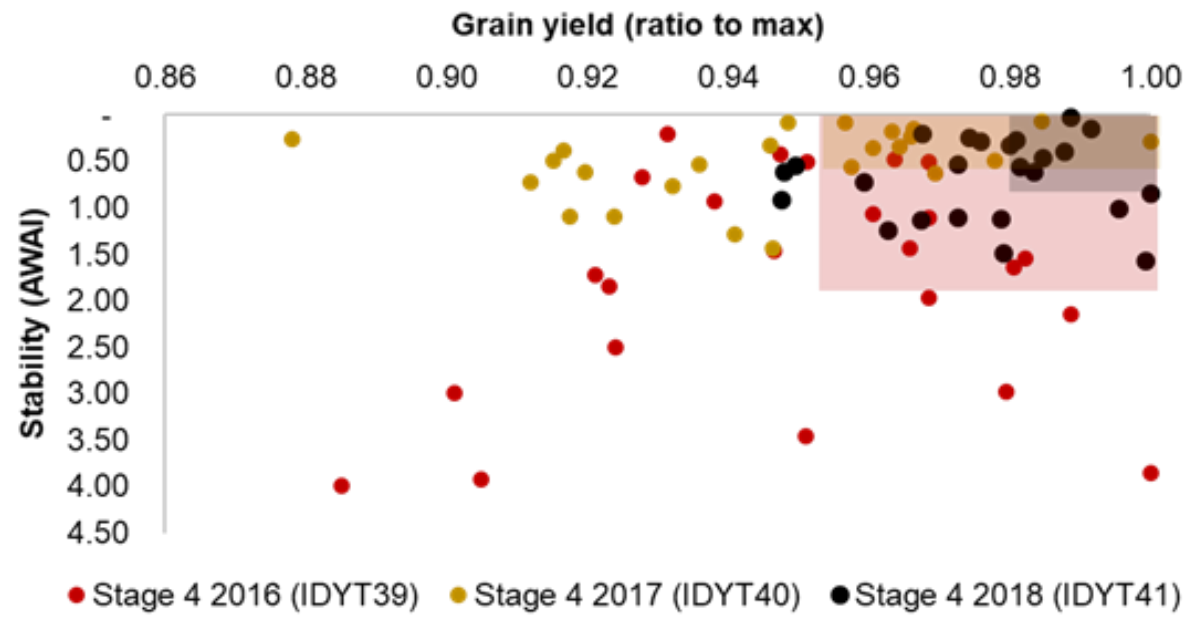


Controlling GxE: stability



- Pairing AWAI for GxE with BLUP for G ensures ideal selection

Genetic gain for G + GxE



- Since 2015 we have incorporated a selection index for stability (GxE) + yield potential (G)
- These graph show it was possible to make a rapid strong gain for stability, while increasing yield potential

Conclusion lecture 3

- The genetic gain equation drives all breeding decisions
- Stage 1 yield trials need to be designed to serve the exact purpose, keeping in mind logistics
- Stage 2 are vast investments that need to match the breeding goals (not one station just because I can)
- Defining TPE is fundamental to deliver on the set goals
- GxE and stability analysis are the bread and butter of breeders.. but not all models are useful
- Genetic gain for yield stability is possible

