Cap Dev Lectures series:

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

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senior durum wheat breeder

@fillobax

- **Stage 3 yield trials**
  - Year effect: when will I be ready for release?
  - Selection index
  - Defining variety portfolio

- **Catalogue and its rules**
  - Purity needs
  - Intellectual property protection

- **Farmers uptake**
  - G1 to R2 rules
  - Demo plot, not always so easy
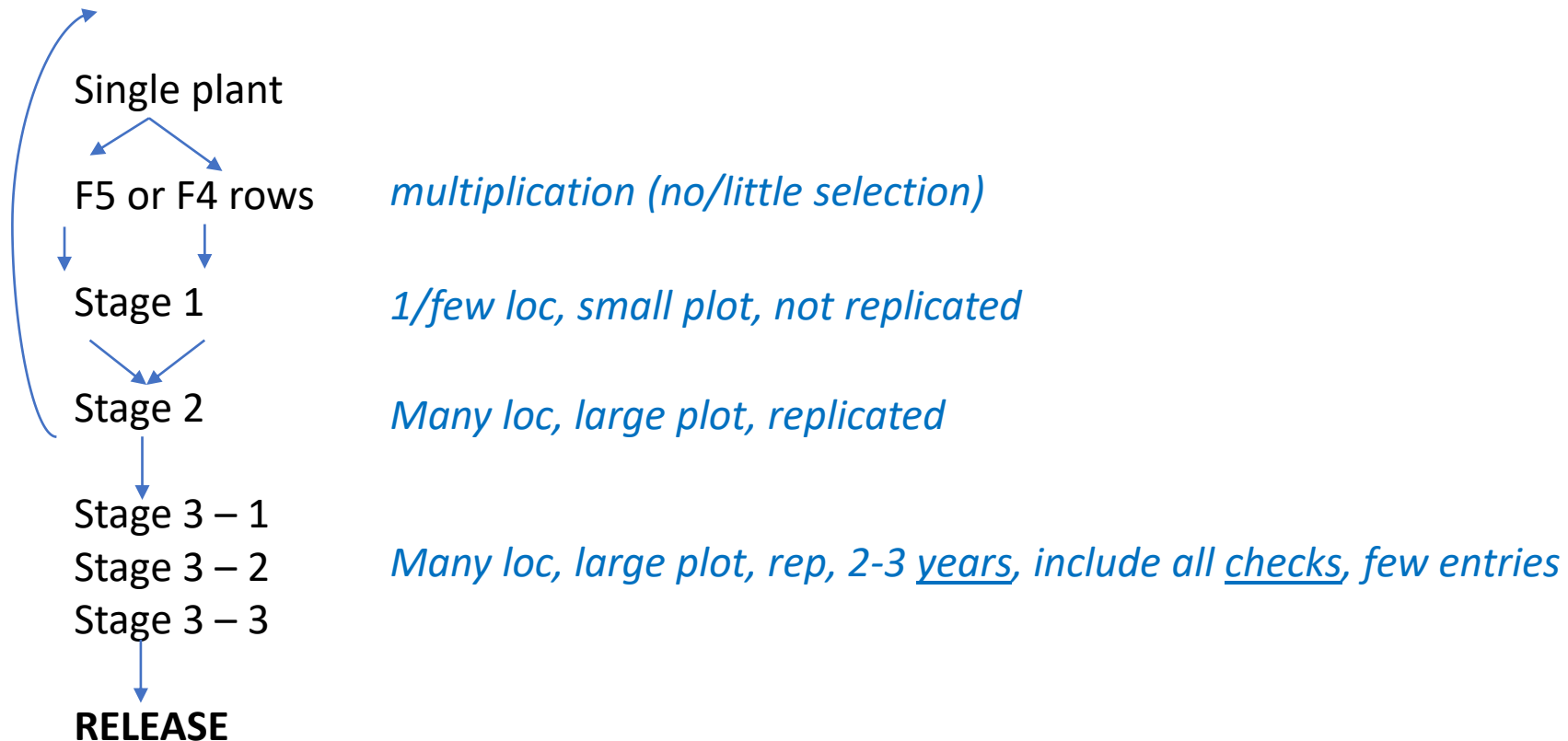 - Participatory approaches

Stage 3 yield trials: what is it?

- What would be the difference compared with Stage 1 and Stage 2?

Stage 3 yield trials: what is it?

- What would be the difference compared with Stage 1 and Stage 2?
  - It is the **End Game**, the trial that decides varieties
  - As such, there might **NOT be a variety in it..**

Single plant

F5 or F4 rows   *multiplication (no/little selection)*

Stage 1   *1/few loc, small plot, not replicated*

Stage 2   *Many loc, large plot, replicated*

Stage 3 – 1
Stage 3 – 2   *Many loc, large plot, rep, 2-3 years, include all checks, few entries*
Stage 3 – 3

RELEASE

Stage 3 yield trials: why multiple years?

- Annual variation is bigger than GxE
  - You are going to impact *farmers lives*..
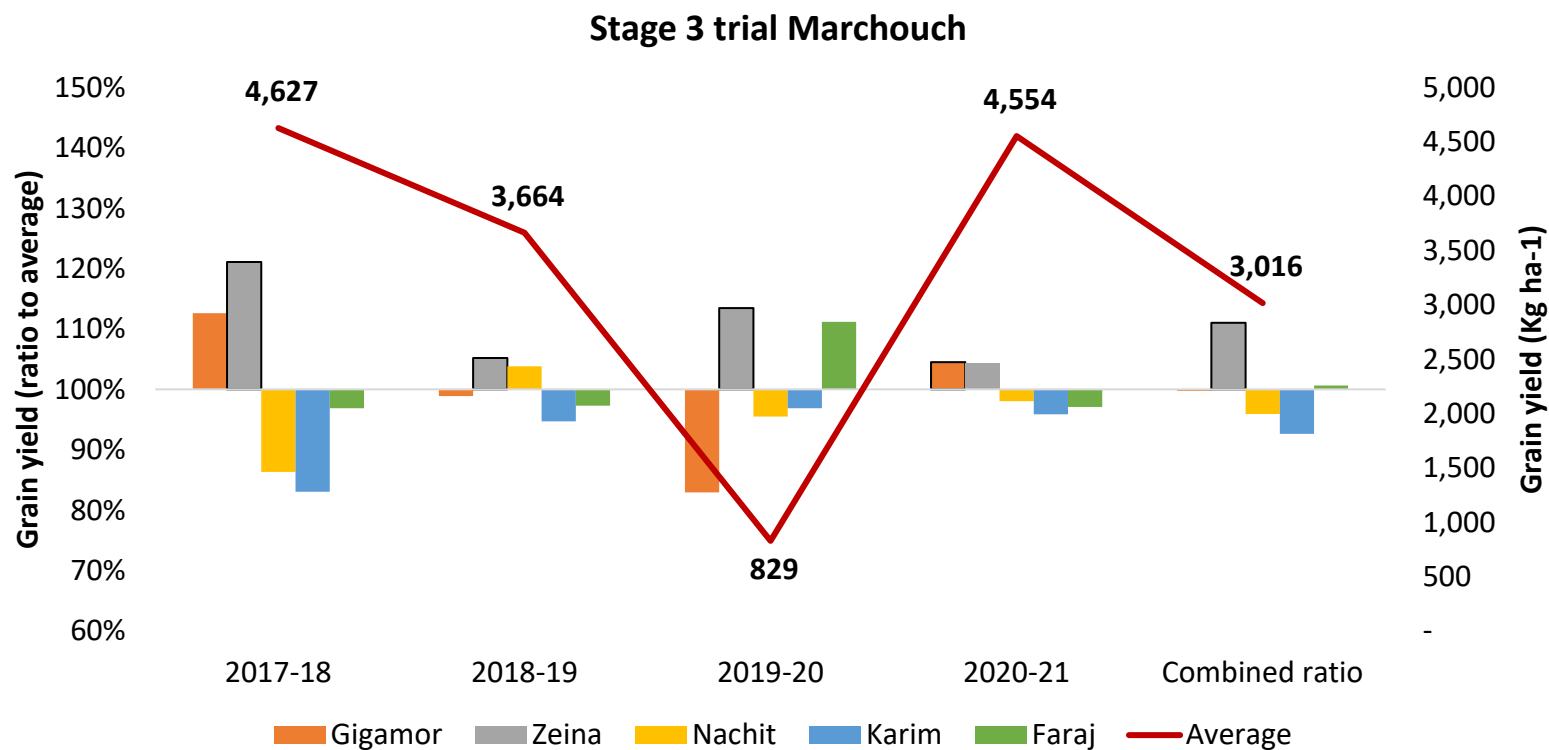
Stage 3 trial Marchouch

Stage 3 yield trials: cyclical rounds

- Each year:
  - New and better elites enter Stage 3
  - Older and not performing are discarded
  - Checks are kept updated

ID	Role	Year	2017-18
Karim	Check	4	3,844
Faraj	Check	4	4,483
Nachit	Check	4	3,994
Zeina		4	5,605
Gigamor		4	5,211
Boniduro	Check	3	
Hamadi	Check	2	
Ouaverve		2	
AV19-18		2	
Hoffmilmus		2	
MI-313		2	
MI-213		2	
MI-43		2	
Kanakis	Check	1	
Ittri	Check	1	
IDYN51-026		1	
Sebasabil		1	
IDYN51-032		1	

Stage 3 yield trials: cyclical rounds

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  - Checks are kept updated
  - *How to select the Stage 3 to discard?*

ID	Role	Year	2017-18	2018-19	2019-20
Karim	Check	4	3,844	3,471	803
Faraj	Check	4	4,483	3,567	922
Nachit	Check	4	3,994	3,804	792
Zeina		4	5,605	3,855	941
Gigamor		4	5,211	3,625	688
Boniduro	Check	3		3,957	828
Hamadi	Check	2			666
Ouaverve		2			928
AV19-18		2			862
Hoffmilmus		2			861
MI-313		2			823
MI-213		2			782
MI-43		2			641
Kanakis	Check	1			
Ittri	Check	1			
IDYN51-026		1			
Sebasabil		1			
IDYN51-032		1			

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Stage 3 yield trials: cyclical rounds

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  - New and better elites enter Stage 3
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  - Checks are kept updated
  - *How to select the Stage 3 to discard?*
  - *Why no new elites in year 3?*
  - *Is it bad to use poor checks?*

ID	Role	Year	2017-18	2018-19	2019-20	2020-21
Karim	Check	4	3,844	3,471	803	4,366
Faraj	Check	4	4,483	3,567	922	4,423
Nachit	Check	4	3,994	3,804	792	4,465
Zeina		4	5,605	3,855	941	4,754
Gigamor		4	5,211	3,625	688	4,760
Boniduro	Check	3		3,957	828	4,614
Hamadi	Check	2			666	4,354
Ouaverve		2			928	4,428
AV19-18		2			862	4,459
Hoffmilmus		2			861	4,395
MI-313		2			823	4,480
MI-213		2			782	4,385
MI-43		2			641	4,618
Kanakis	Check	1				4,548
Ittri	Check	1				4,206
IDYN51-026		1				4,645
Sebasabil		1				4,603
IDYN51-032		1				4,472

Stage 3 yield trials: selection index

- **1 to 1**0: how important is each of the following traits in the next variety?
  - *Yield potential*

  - *Yield stability*

  - *Yield at TPE*

  - *Grain size*

  - *Resistance to rust*

  - *Resistance to Septoria*

  - *Drought tolerance*

 - *Heat tolerance*

Stage 3 yield trials: selection index

- *How would you define it?*

80%

Target	TPE of S2	F.	PLH	Frost	HF res	YR res	SR res	LR res	Heat tol	Drought tol	Gluten str.	Yellow pig.	Yield stab.	TKW	Yield pot.
		BLUP		GY KFD	GH	Izmir	GH	GH	MAS		Mixo	b* sem	AWAI	BLUP	
MPP1	Tel Amara LEB	M	M			10%	10%			10%	10%	10%	15%	15%	20%
MPP2	Marchouch MOR	E	M		10%			10%		10%	10%	10%	15%	15%	20%
MPP3	*Sidi el Aydi MOR*	E	M				20%			10%	10%	10%	15%	15%	20%
MPP4	Amlaha IND	M	M				10%		10%	10%	10%	10%	15%	15%	20%
MPP5	Annoceur MOR	L	T	15%						10%	10%	10%	15%	15%	20%
MPP6	Fanaye SEN	E	M						20%		15%	15%	15%	15%	20%

How to use a selection index

- Each trait expressed as ratio to top (0>1)
- Each trait is multiplied by the weight (%) and sum
- Then plot that against grain yield at TPE
- Or combined as a single value: index * phenology * GY@TPE

- *When would you use this index?*
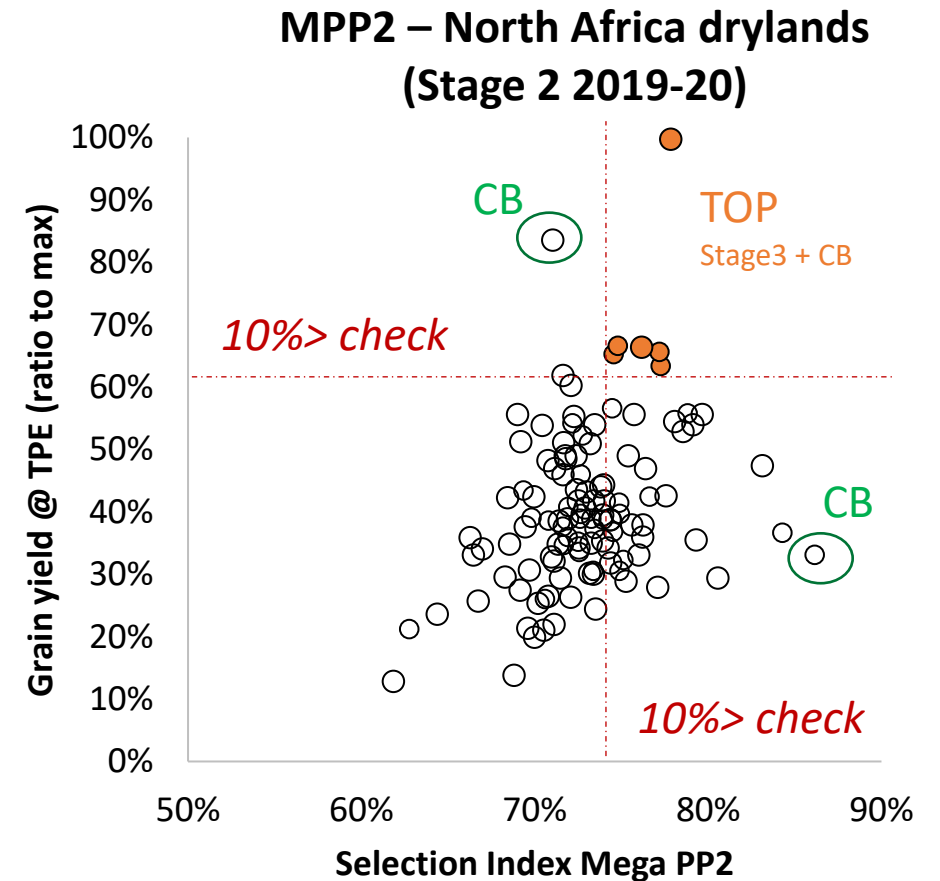
MPP2 – North Africa drylands
(Stage 2 2019-20)

You choose "the ONE": now what?

- What happens after you have selected the best entry based on Stage 3?

You choose "the ONE": now what?

- What happens after you have selected the best entry based on Stage 3?
  - *Should you try to release a new one each year?*

Know the rules: Catalogue trials

DUS (Distinctness, Uniformity and Stability)

- **Distinct:** A distinct plant variety has at least *one important characteristic* that is different from other varieties included in the National List.

- **Uniform:** A *uniform plant* variety has individual plants that share the same important characteristics.

- **Stable:** A stable plant variety *remains unchanged after 'repeated propagation'*, for example, reproduction from seeds, cuttings, bulbs or other plant parts.

VCU (Value for Cultivation and Use)

- **Multi environment test:** it is used to determine if a new plant variety shows a significant advantage over *existing registered varieties* and evaluates its agronomic performance.

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ONSAA DUS: 3 / 300 spikes
VCU: 6 locations for 2 years 2 checks

Know the rules: complain about it..

- *What do you think are the issues for DUS and VCU?*

Know the rules: complain about it..

- *What do you think are the issues for DUS and VCU?*

- Needs of strict **homogeneity**:
  - *No GG*
  - *Delays release*

- Needs of strict **distinctness**:
  - *No GG*
  - *Prevents the use of MAS backcrossing*

- **VCU***:*
  - *Only as good as the sites selected*
  - *Only as good as the checks selected*
  - *Prevents the release for specific products (i.e. landraces)*
  - *If poorly used prevents specific adaptation*
  - *All traits should be tested*

Homogeneity: traits used for assessment

- Over 35 traits assessed
- *Need to remain the same for 2 years*

CARACTERES	ECHELLE DE NOTATION DU CARACTERE				
	1	3	5	7	9
1-Coléoptile : Coloration anthocyanique	Absente				présente
2 - Plante : port au tallage	Dressé	Demi dressé	½dressé à ½étalé	Demi étalé	Etalé
3. Epiaison (premier épillet visible sur les épis de 50% des plantes)	Très précoce	Précoce	Moyenne	Tardive	Très tardive
4- Epi: glaucescence	Nulle / très faible	Faible	Moyenne	Forte	Très forte
5-Tige: glaucescence du col de l'épi	Nulle / très faible	Faible	Moyenne	Forte	Très forte
6-Tige:pilosité du dernier nœud	Nulle / T. faible	Faible	Moyenne	Forte	Très forte
7- Paille : section	creuse	¼ pleine	½ pleine	¾ pleine	pleine
8- Epi: forme dominante	Pyramidale	A bords parallèle	fusiforme	En demi massue	En massue
9- Epi : couleur	Blanc	Roux pâle	Roux	Brunâtre	Noirâtre
10- Epi : longueur	Très court	Court	Moyen	Long	Très long
11- Epi : compacité	Très lâche	Lâche	Demi lâche	Compact	Très compact
12- Barbes ou arrêtes: distribution	Seulement à l'extrémité	¼ supérieur	½ supérieur	¾ supérieur	Epi entier
13- Barbes ou arrêtes: présence		Les deux absentes	Arêtes présentes	Barbes présentes	
14- Epillet 1/3 moyen : Bec : longueur	Très court	Court	Moyen	Long	Très long
15- Epillet 1/3 moyen : Bec : Epaisseur	Très fin	Fin	Moyen	Epais	Très épais
16- Epillet 1/3 moyen : Glume inférieure : forme du bec	Droit	Légèrement coudé	Coudé	Fortement coudé	Genouillé
17- Epillet 1/3 moyen : Glume inférieure : largeur de la troncature	Très étroite	Etroite	Moyenne	Large	Très large
18- Epillet 1/3 moyen : Glume inférieure : forme de la Troncature	Inclinée	Arrondie	Droite	Echancrée	Echancrée +2 becs
19- Glume: pilosité externe	Nulle	Faible	Moyenne	Forte	Très forte
20- Epiaison: précocité	T. précoce	Précoce	Moyenne	Tardive	Très tardive
21- Epiaison : Oreillettes : Pigmentation anthocyanique	Nulle/très faible	Faible	Moyenne	Forte	Très forte
22- Epiaison : Oreillette : ciliation	Nulle/très faible	Faible	Moyenne	Forte	Très forte
23- Floraison : dernier nœud : Pilosité	Nulle/très faible	Faible	Moyenne	Forte	Très forte
24- Floraison: Epi : Glaucescence	Nulle/très faible	Faible	Moyenne	Forte	Très forte
25- Floraison: Col de l'épi: Glaucescence	Nulle/très faible	Faible	Moyenne	Forte	Très forte
26 –Floraison: Torsion du col de l'épi	Nulle/très faible	Faible	Moyenne	Forte	Très forte
27- Epillet 1/3 moyen : Bec : longueur	Très court	Court	Moyen	Long	Très long
28- Epillet 1/3 moyen : Bec : Epaisseur	Très fin	Fin	Moyen	Epais	Très épais
29- Glume inférieure : étendue de la pilosité interne		Faible	Moyenne	Forte	
30- Glume inférieure : empreinte interne	Très réduite	Réduite	Moyenne	Développée	T. développée
31- Grain : forme		Arrondie	Ovoïde	Allongée	
32- Grain : couleur	Blanc				Roux
33- Grain : longueur des poils de la base		Courts	Moyens	Longs	
34- maturité: précocité	Très précoce	Précoce	Moyenne	Tardive	Très tardive
35- Maturité :Alternativité : Type	Hiver	½ Hiver	½ Alternatif	Alternatif	Printemps
36- Plante : Hauteur à maturité	Très courte	Courte	Moyenne	Longue	Très longue

Homogeneity: the key for release

- How can you "purify" a variety?

Homogeneity: the key for release

- 75% of all Moroccan catalogue presentations are rejected due to Homogeneity

Gen	Inbr.	Homogeneity										
		Pedigree	Bulk F1	Bulk F2	Bulk F3	Bulk F4	Bulk F5	Bulk F6	Bulk F7	Bulk F8	Bulk F9	Bulk F10
F1	0.000	0.000	0.000									
F2	0.500	0.500	0.000	0.500								
F3	0.750	0.750	0.000	0.500	0.750							
F4	0.875	0.875	0.000	0.500	0.750	0.875						
F5	0.938	0.938	0.000	0.500	0.750	0.875	0.938					
F6	0.969	0.969	0.000	0.500	0.750	0.875	0.938	0.969				
F7	0.984	0.984	0.000	0.500	0.750	0.875	0.938	0.969	0.984			
F8	0.992	0.992	0.000	0.500	0.750	0.875	0.938	0.969	0.984	0.992		
F9	0.996	0.996	0.000	0.500	0.750	0.875	0.938	0.969	0.984	0.992	0.996	
F10	0.998	0.998	0.000	0.500	0.750	0.875	0.938	0.969	0.984	0.992	0.996	0.998
F11	0.999	0.999	0.000	0.500	0.750	0.875	0.938	0.969	0.984	0.992	0.996	0.998
F12	1.000	1.000	0.000	0.500	0.750	0.875	0.938	0.969	0.984	0.992	0.996	0.998

S1 yield trial (F5:6)

Release (F9:n)
2 / 300 spikes = 99.3%

Defining the goals: a portfolio of varieties

- *As a breeding company: how would you decide for which varieties to breed?*

Defining the goals: a portfolio of varieties

- *As a breeding company: how would you decide for which varieties to breed?*
    - *It needs to be a market*
    - *How competitive is it?*
    - *Do I have some advantages for it?*
    - *Is it rentable?*
    - *..*

- *Would you target each market with 1 or more varieties?*

Defining the goals: a portfolio of varieties

- *As a breeding company: how would you decide for which varieties to breed?*
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  - *Is it rentable?*
  - *..*

- *Would you target each market with 1 or more varieties?*
  - *It depends on the management practices followed*
  - *It depends on the harvest goals*
  - *It depends on the competitors also*

Defining the goals: a portfolio of varieties

- As for PP: you need to set your goals

- *Early vs late planting*
- *Top quality vs yield*
- *Conservation ag vs normal tillage*
- *Straw vs grains*
- *Organic vs intensive farming*

- *Farmers will have many options across companies*
- *You need to make them choose you...*

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TABELLA 2 - Elenco delle varietà in prova nei diversi areali nel 2014-2015

Criterio di scelta (¹)	Varietà	Cido (²)	Ditta fornitrice seme	Seme certificato 2013 (t % su totale)		Sud-Isole Sicilia	Sud-Isole Sardegna	Sud-Isole Sud	Centro-Nord Centro tirrenico	Centro-Nord Centro adriatico	Centro-Nord Nord	Anni di prova (n.)
B	Aureo	M	P.S.B.	1,0	↔	•	•	•				6
D	Gibraltar	M	Syngenta	0,2	↑	•	•	•				3
D	Orizzonte	P	F.lli Menzo	1,1	↑	•	•	•				1+1
D	Asterix	M	Syngenta	0,06	↑	•		•				2
B	Dorato	MT	Agroservice	0,2	↓	•		•				6 (4)
D	Homer	MT	Co.Na.Se.	0,1	↑	•		•				2
D	Ovidio	M	S.I.S.	0,6	↑	•						2
B	Karalis	P	Agris	0,4	↔		•					8
B	Achille	MT	Agroservice	3,3	↑				•	•	•	9
D	Athoris	M	Limagrain	0,3	↑				•	•	•	3
B	Colombo	T	ApsovSementi	1,1	↑				•	•	•	4

Intellectual protection: what is it?

- **International Union for the Protection of New Varieties of Plants (UPOV)** established in 1961 to protect breeders' rights.

- **Plant Variety Protection (PVP)**: is the most adopted method fort protection of breeders' rights and applies to all plant genera and species.
  - Ensures the exclusive rights to produce and market it
  - It can prevent the sales of non-certified seeds
    - Some countries have adopted the "farmer's exception" for saved seeds or commercialization of R3
  - Based on "breeder's exemption" all PVP material can be used in crosses and research

- **Plant Patents (PLP)** and **Patents for Inventions (PAT)** are stronger type of protections that prevent all uses of the resulting germplasm.

- **Material Transfer Agreement (MTA)** or **Standard MTA (SMTA)** are contracts between parties that regulate how to use material that is not yet under PVP.

What to do after release?

- A variety is released (GREAT JOB!!) and therefore protected under PVP: what now?

Seed certification process

- *G0 or Nucleus seed:* generated for the catalogue starting from 1 >F9 plant. It ss used in year 1, then stored.
- *G1 or Breeder seed or pre-base:* produced starting from >1,000 spikes from G0, then maintained from G2
- *G2 or Foundation seed or base:* generally 0.5 ha per variety from the G1. It produces the G1 spikes
- *G3 and G4 or Registered seed:* generally 5 ha per variety from the G2, and then 50 from G3

- *R1 and R2 or Certified seed:* commercial seed, normally there is little difference in price between the two
- *R3 or Good seed:* this is not allowed, it is not certified (no subsidies), and cost only a bit more than grains

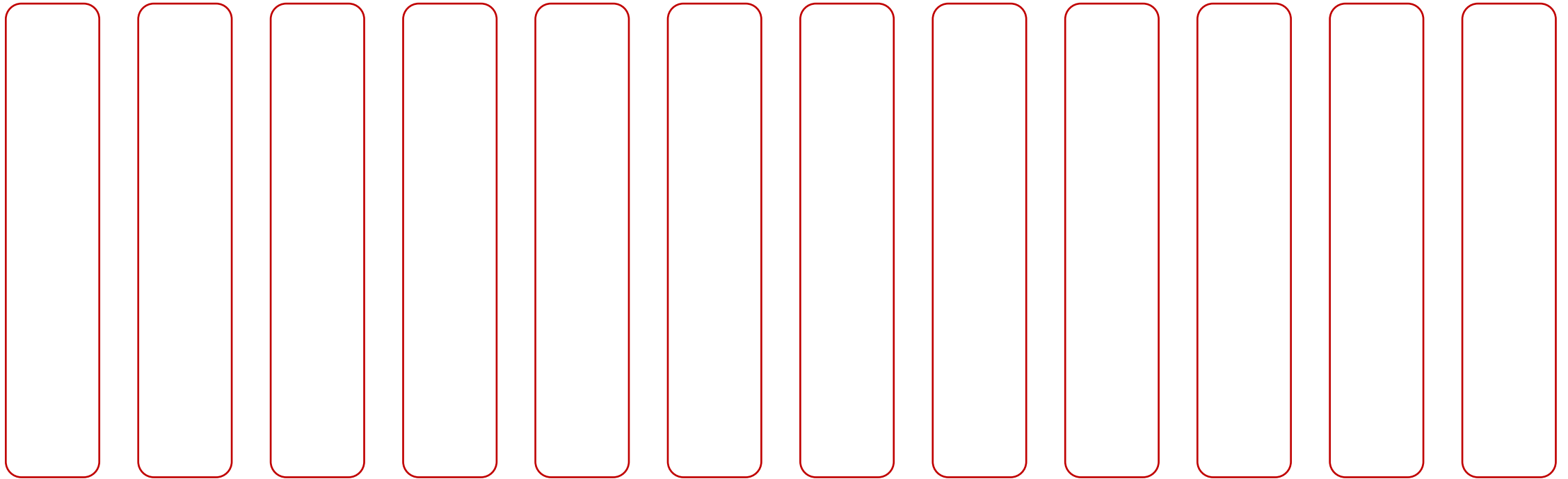| Generation	Isolation (same species)	Homogeneity (% off-types)	Impurity (% weed seeds)	Germination (% of tested grains)
G0	200m	0.15%	0.15%	85%
G1	100m	0.20%	0.20%	85%
G2	100m	0.20%	0.20%	85%
G3	100m	0.20%	0.20%	85%
G4	100m	0.20%	0.20%	85%
R1	50m	0.50%	0.20%	85%
R2	50m	1.00%	0.30%	85%

Demo plot: not always so easy..

- How would you set up your demo trial?

Demo plot: not always so easy..

- How would you set up your demo trial?
    - *How many entries: few*
    - *What entries: released or pre-release plus checks*
    - *Plot size: as large as you can*
    - *Maintain it: same as farmers around*
    - *..*

- What would you plant and why?
  - *Remember your audience!*

Demo plot: not always so easy..

- What could be improved?

Participatory approach: what is it?

- Getting farmers involved in the decision process: how?

Participatory approach: what are them?

- *Participatory Plant Breeding (PPB):* this is a way to engage FARMERS directly in the selection to inbreeding

- *Participatory Variety Selection (PVS):* this is a way to engage FARMERS at Stage 3 level

- *On farm validation (Demo):* this is a way to engage FARMERS after the release to promote sales

- *Participatory Weighted Selection (PWS):* this uses farmers survey to establish selection index that can be deployed at Stage1, 2, and 3, and also for parental selection

Crop Breed Genet Genom. 2020;2(3):e200014. https://doi.org/10.20900/cbgg20200014

Article

Participatory Farmers-Weighted Selection (PWS) Indicesto Raise Adoption of Durum Cultivars

Véronique Alary [1,2,*✉], Yigezu A. Yigezu [1], Filippo M Bassi [1]

Conclusion lecture 4

- The genetic gain equation drives all breeding decisions
- Selecting a variety requires time and the use of an index helps
- Release should not be sought each year
- The release process has its own rules: you need to play by those
- Defining a portfolio of needed varieties helps prioritize
- Release is not the end for breeders: at least G0, G1, and possibly also G2 are our responsibility
- Always use an MTA or SMTA, even with your friends!
- Engage farmers at the right time (PVS and PWS)
- Plan your Demo well: it is your showtime moment