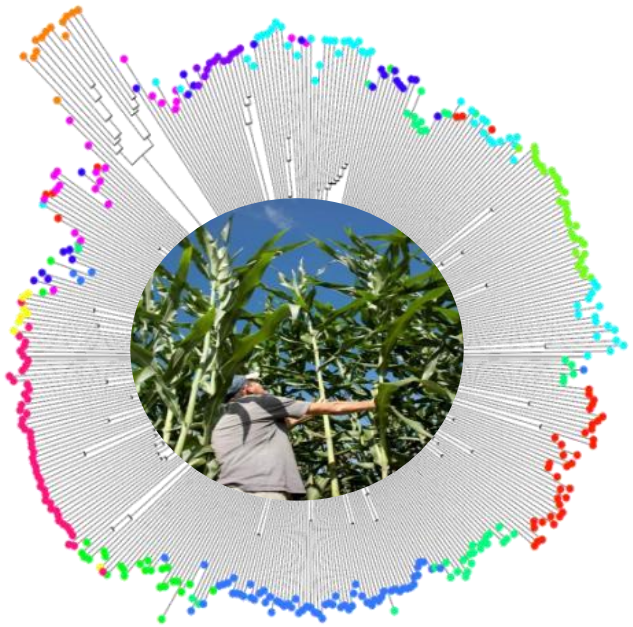
From the territories to the genes
Developing sustainable multi-purpose sorghum value chains



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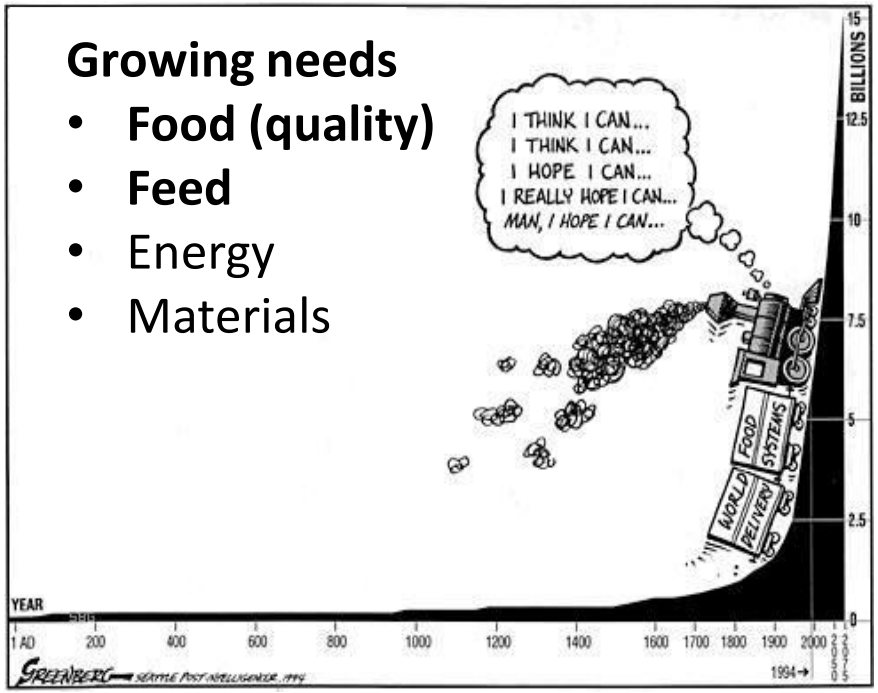
cirad
LA RECHERCHE AGRONOMIQUE
POUR LE DÉVELOPPEMENT

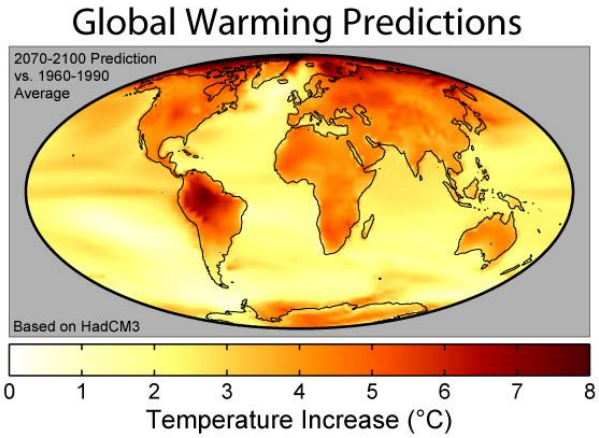
Sustainable intensification : The challenges

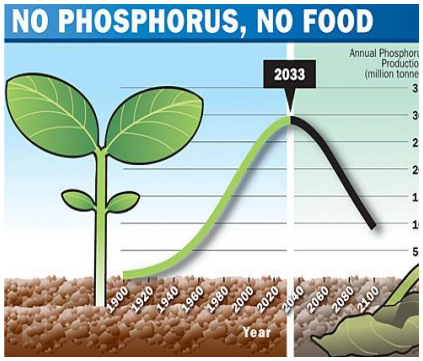


•Sustainable production

•Energy and Materials : a place to take !

- Low(er) C footprint
- Improve SOM





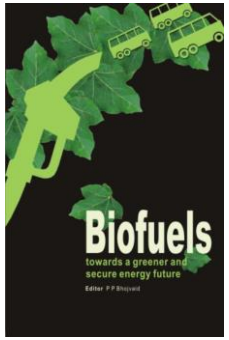
•Adaptation to local context

•Water / Nutrient use efficiencies

•Managment of interactions

• Uses

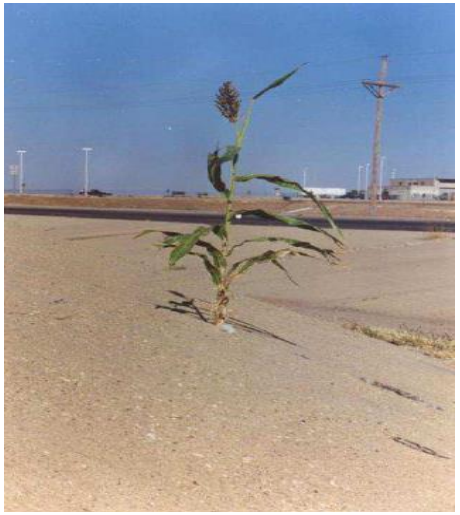
Sorghum : a « promising » sustainable and multi-purpose crop

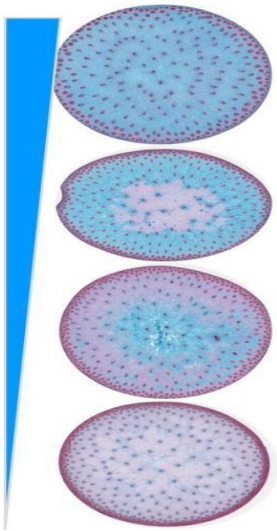


Value chains
Lack of adapted varieties
…

Yield potential (WUE, NUE…)
Diverse crop managment systems
Phenotypic / Genetic diversity
…

Understanding diversity / tackling future challenges

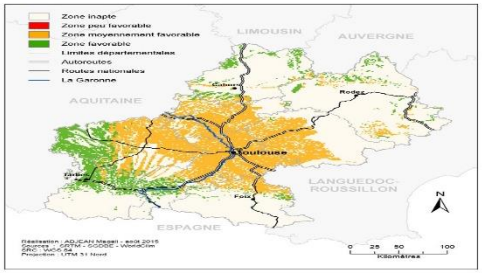




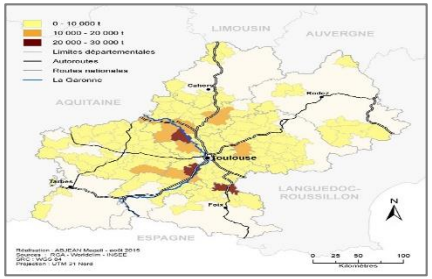
Dahlberg 2016

Developing value chains : Short and mid terms territories' needs

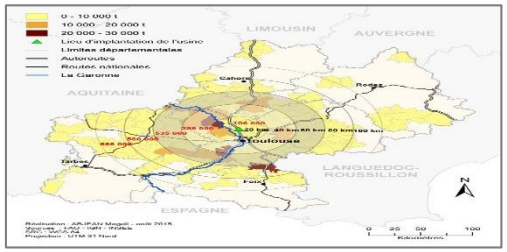
- **Mapping** crop production possibilities (climate / soil)



- **Mapping** the current agrosystems (natural ecosystems, cities, type of production)



- **Mapping** the current uses, logistic issues and industrial / transformation actors



Midi Pyrénées : 5 « energy » Scenarios

	Double Cropping « energy crops »			Dedicated Cropping « double purpose »	
					
	On-Farm Biogaz	**Collective Biogaz**	**Gaz injection**	**Feed + 2G Ethanol**	**Feed + 2G Ethanol with Maize substitution**
Number of cities eligible	250	100	77	_	_
Energy production (KwH)	2700	4400	5500	Too low biomass production	
Conclusion	Possible but weak energy potential	Possible but weak energy potential	Low number of cities but best energy production	Not possible	Possible but need optimized 2G Ethanol process

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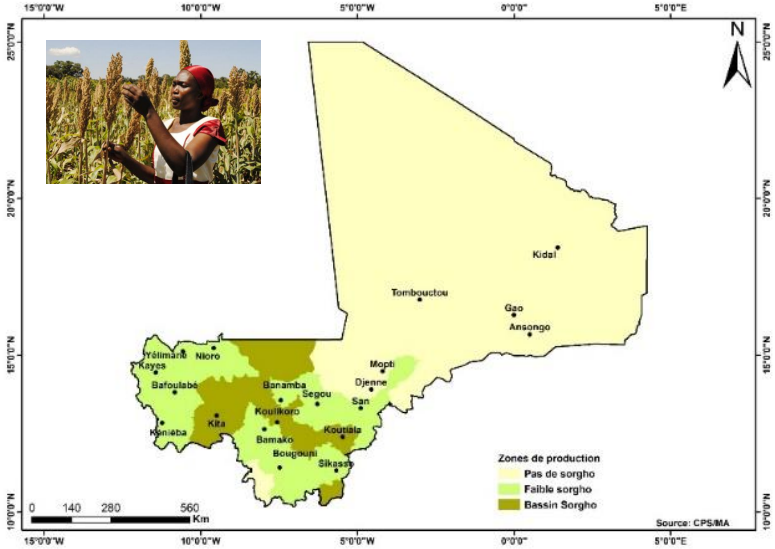
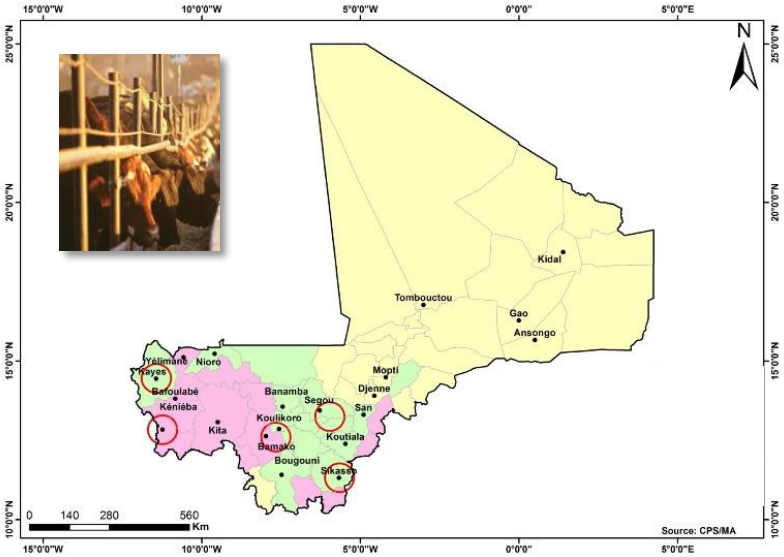
- Identification of the most relevant value chains
- A decision guide (regional, local, political, farmers)
- **Crop Management and Ideotype target at the local / regional level**

Mali: Food – Feed value chains opportunities



- **Relevant for Intensive milk production in the vicinity of cities**
- Not relevant for extensive cattle production (not the same regions)
- Need to explore the « Feed industry » opportunities (grains)



- **Type of variety to develop according to the local market needs**

Extending future opportunities : biocomposites

- Growing markets (automotive, decking, everyday products)
- Opportunity to increase producer incomes
- Environementally relevant

- Biocomposite production

Dried sorghum stems

Grinded sorghum at different size fractions

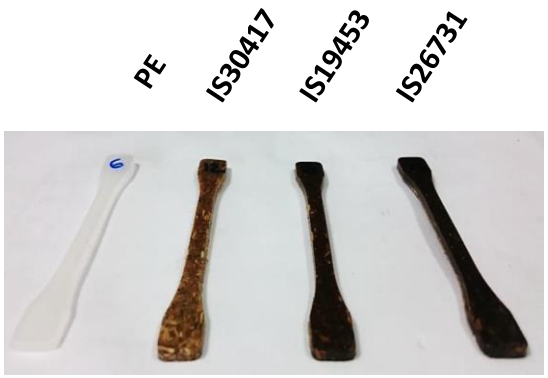
PE / PE-g-MA / sorghum compound

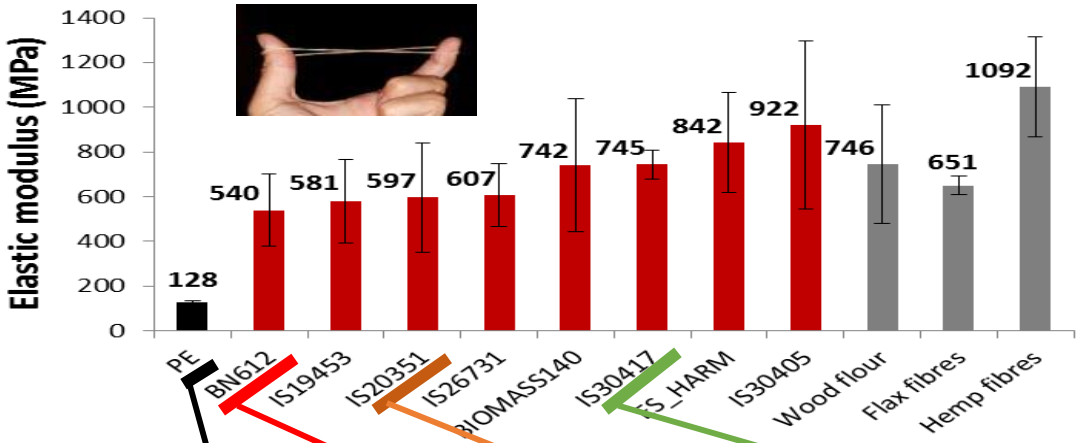
PE / PE-g-MA / sorghum composite samples

Grinding
Sieving

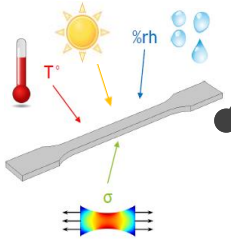
Internal mixing
Injection molding

Sorghum composites compete with current biocomposites and are durable

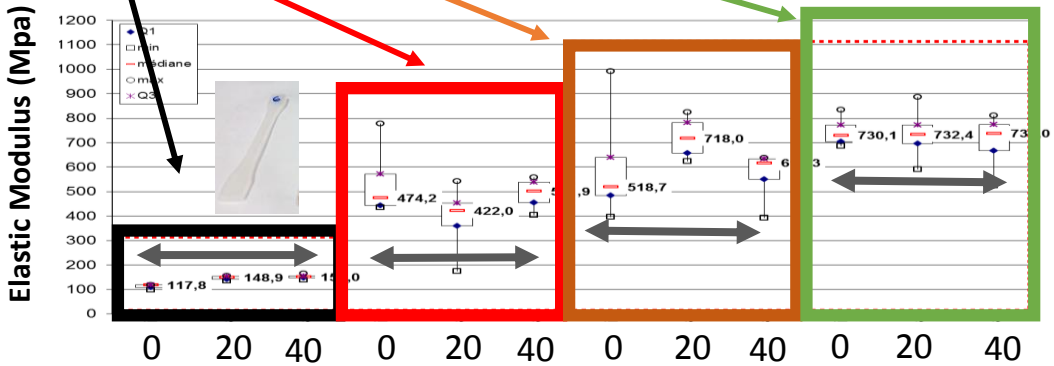


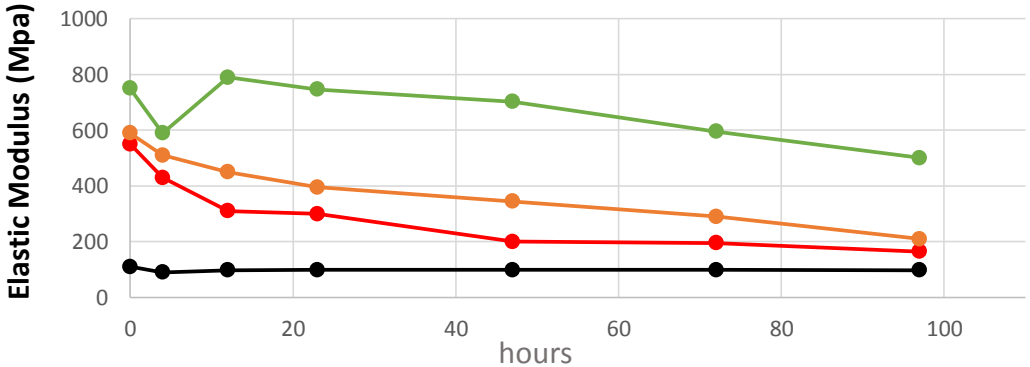


60 °C + UV, 1 day = 40 days

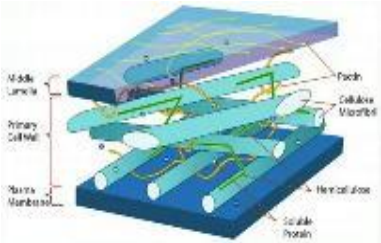


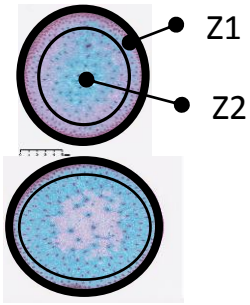
60 °C

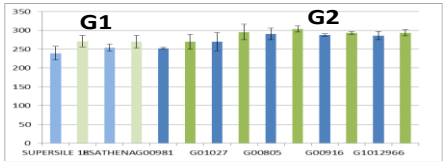


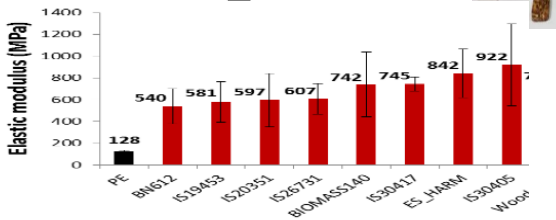


Identifying the plant traits that contribute to the end-product quality

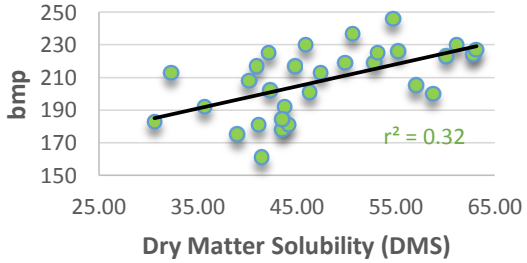


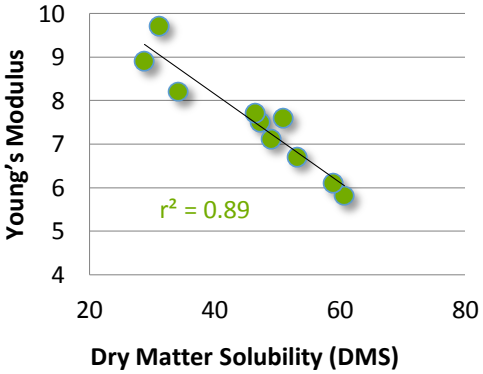






	bmp
Lignin	-0.61
Perc_bluez2	0.55
DMS	0.57

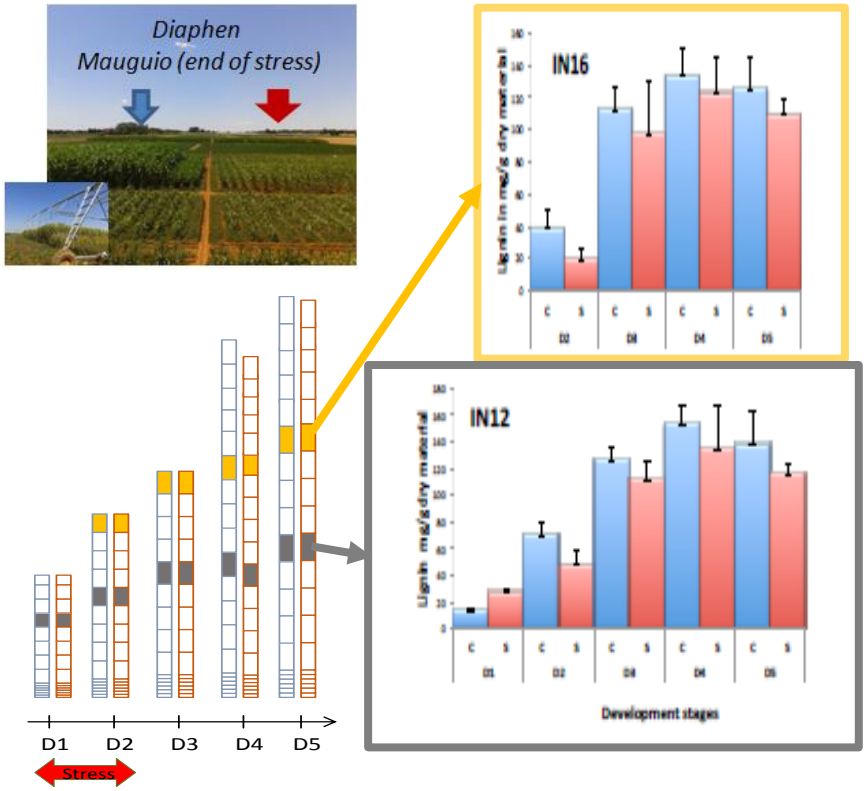


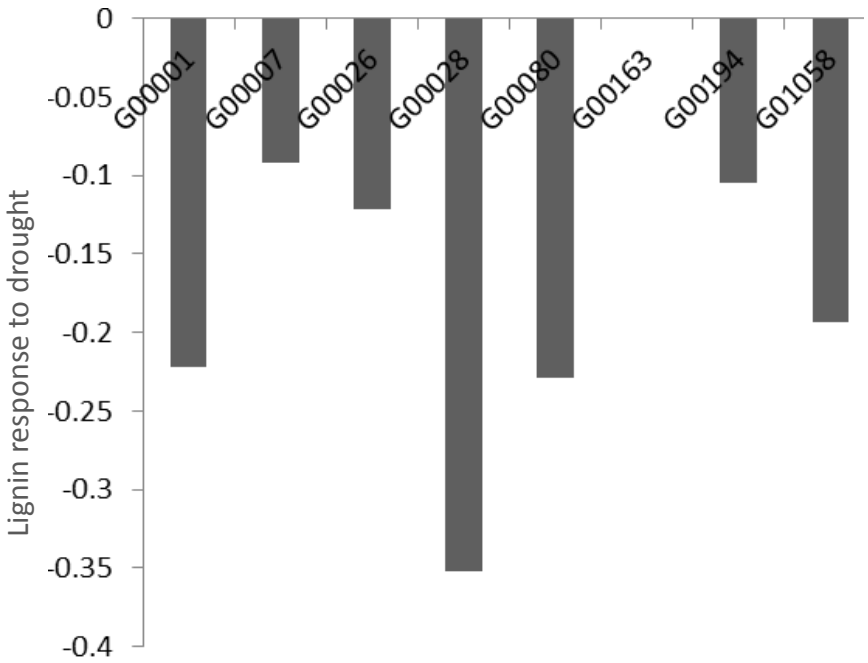


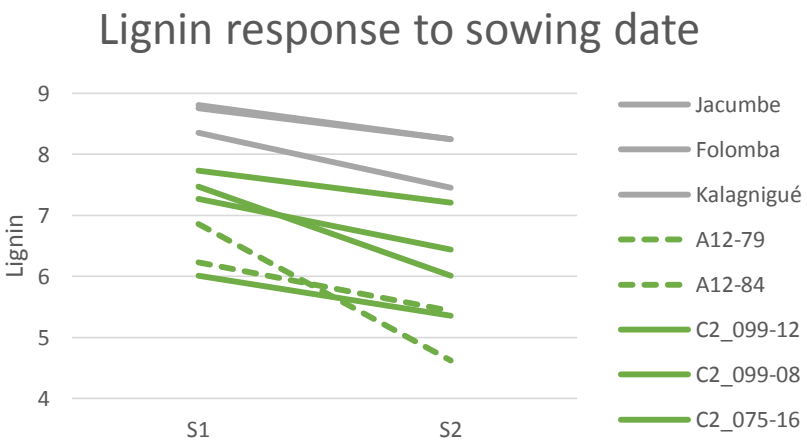
	Young's Modulus
DMS	-0.95
Perc_bluez2	-0.87
Lignin	0.77

- **Lignin** is one of the key traits that contribute to the end products properties

Lignin accumulation = f (age + water + sowing+ genotype…)

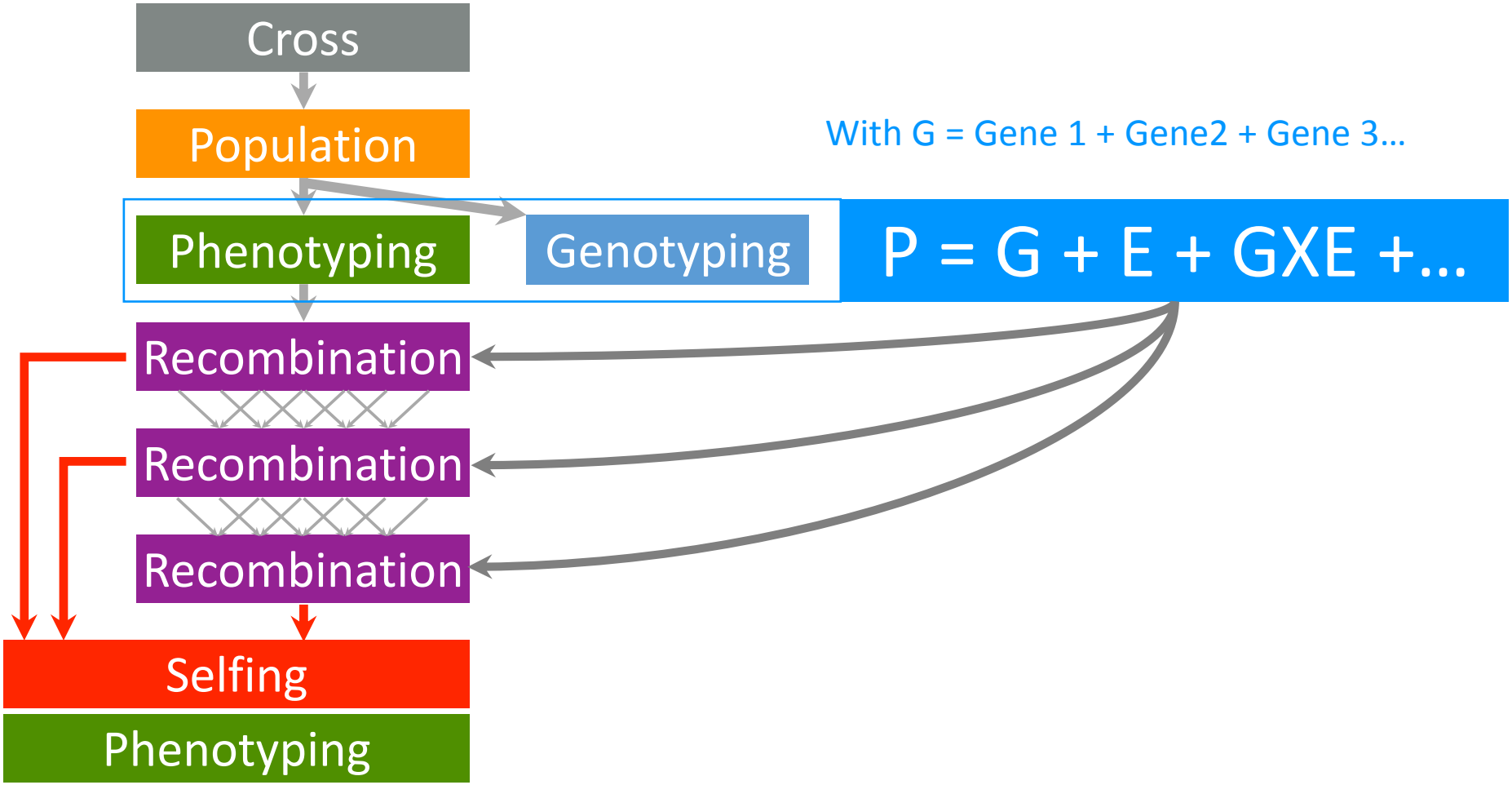






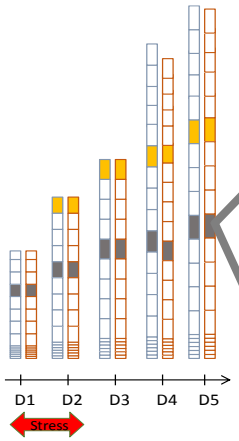
- Ability to monitor lignin through irrigation adjusment / sowing date
- Genotypic effects

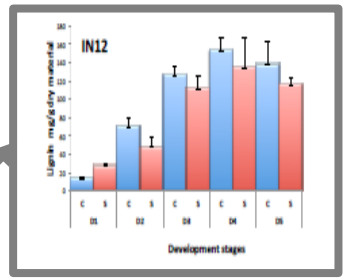
Breeding for lignin content

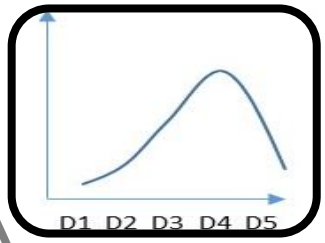


- 4 Bmr mutants genes : Used in breeding programmes, but some drawbacks : lodging
- Need to optimize the prediction model, identify the genes contolling lignin content

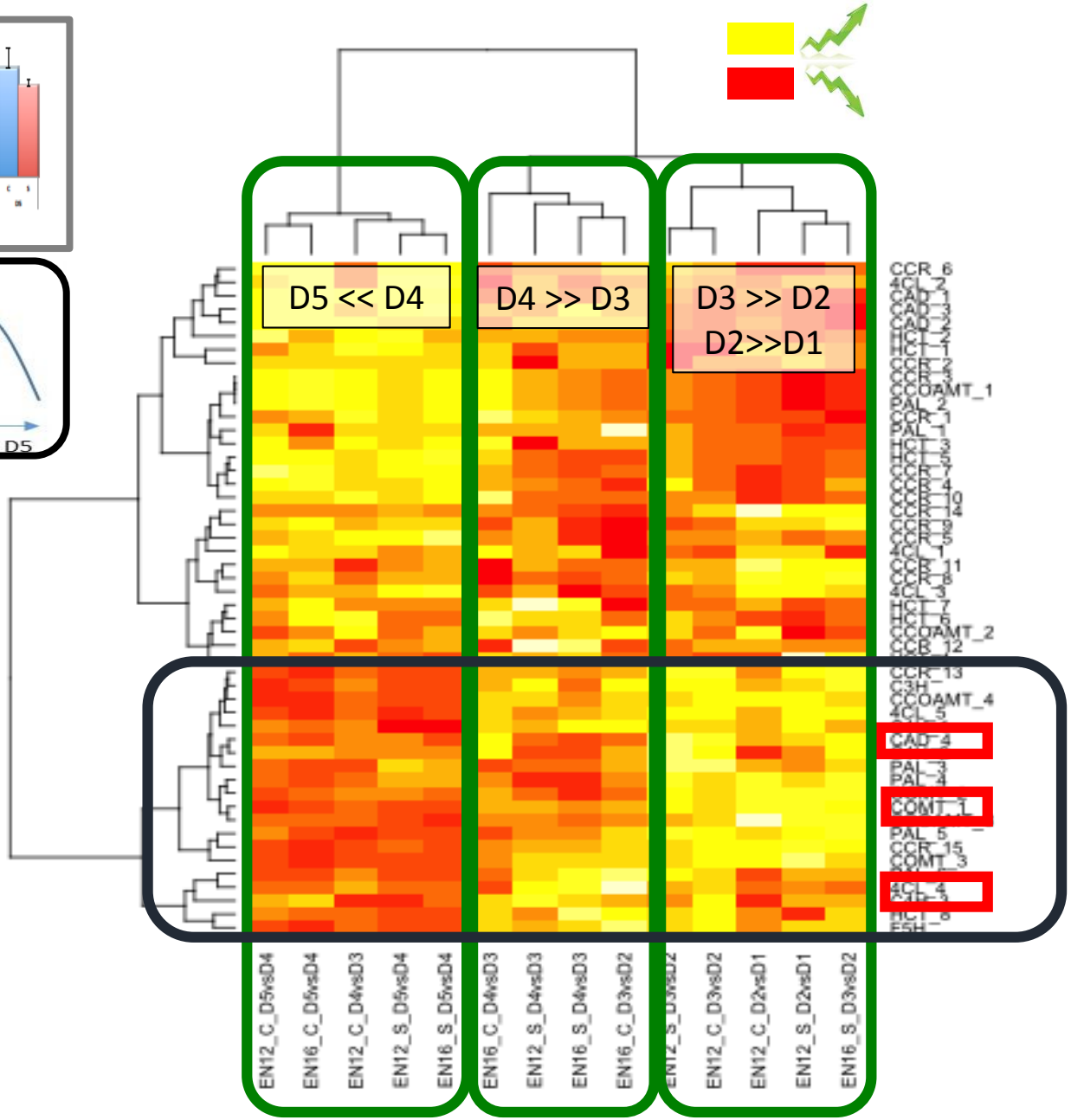
Deciphering lignin accumulation : molecular control



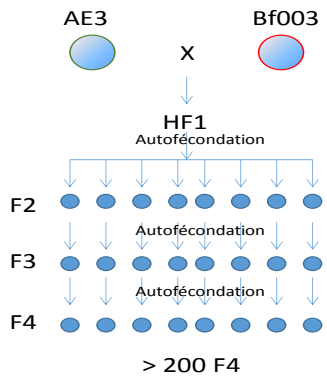


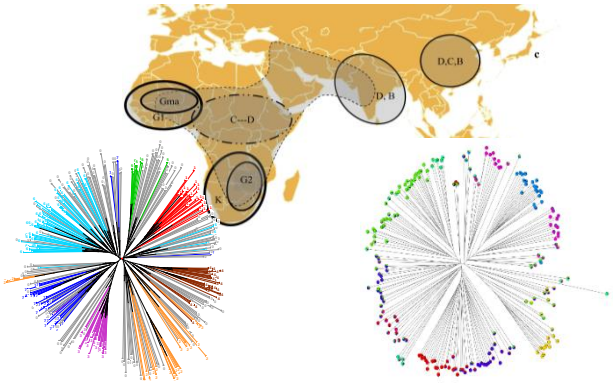


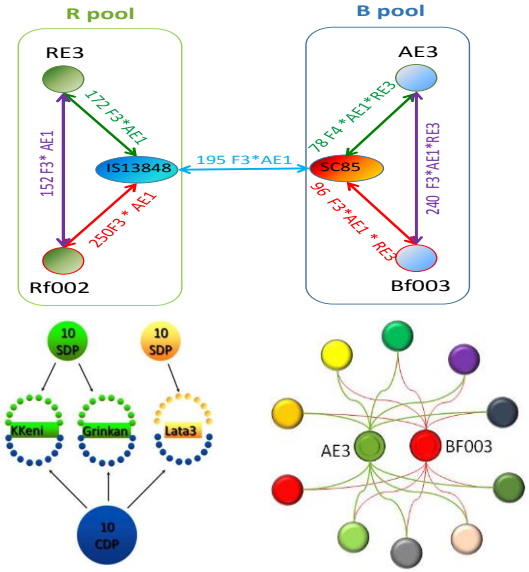
mRNA
Mapping
18 000 Genes
105 lignin genes



Deciphering lignin genotypic variability : breeding tools and breeding activities





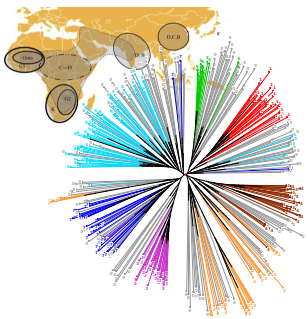


- Multi Environment trials : temperate / tropical LD / Tropical SD
- Highthrouput phenotyping : biochemistry, histology

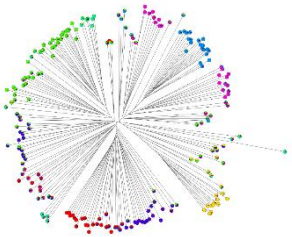
Time = €

NIRS calibrations

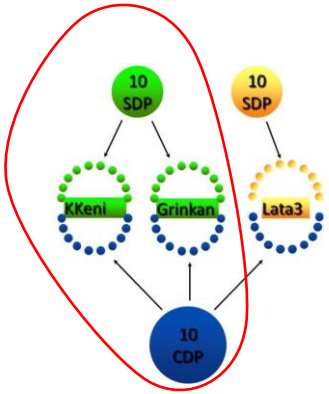
Genetic control of lignin content



Year	# Gen	Climate
2008	100	TEP
2009	100	TEP
2008	210	Mali TRPSD
2008	362	Mali TRPLD
2009	360	Mali TRPLD

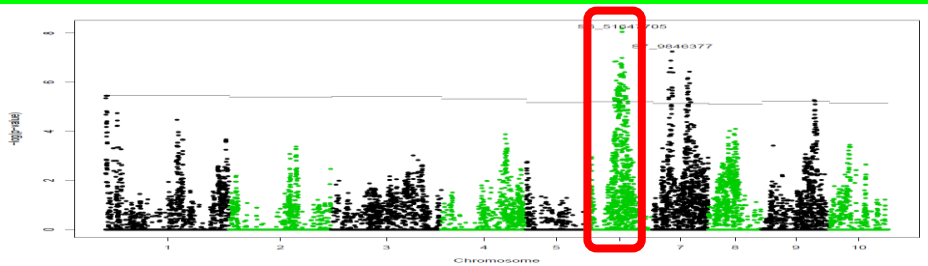


Year	# Gen	Climate
2014	167	TEP
2015	185	TEP



Year	# BC	# Gen	Climate
2014	29	1450	TRPLD
2015	29	1450	TRPLD

$h_{bs}^2 > 0.8$



Region	Chr	start	end	Climate
1	1	21 660 216	21 681 380	TRPLD
2	2	58 219 695	58 219 695	TRPLD
3	6	1 273 625	1 273 625	TEP
4	8	7 400 022	7 400 022	TEP
5	8	53 224 449	53 224 449	TEP
6	9	55 776 908	55 776 927	TEP
7	10	7 794 293	7 794 293	TEP
8	10	60 905 954	60 905 954	TRPLD

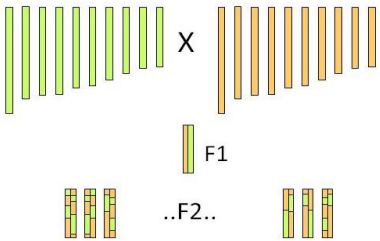
Region	Chr	start	end
1	1	3 980 850	4 024 346
2	2	7 220 677	7 264 975
3	6	51 495 504	51 535 504
4	6	51 599 588	51 639 588
5	6	51 767 343	51 827 894
6	7	3 684 754	3 724 754
7	7	63 616 936	63 656 936

Region	Chr	start	end
1	6	49 718 099	52 113 495
2	7	58 487 671	59 029 033

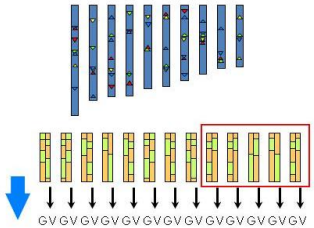
$$P = G + E + GXE + \ldots$$

Gene 1 + Gene2 + Gene 3…

Breeding in practice : multi-purpose sorghum

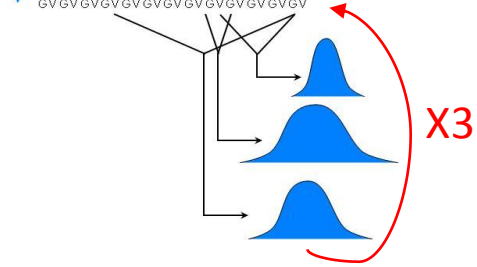


QTL detection

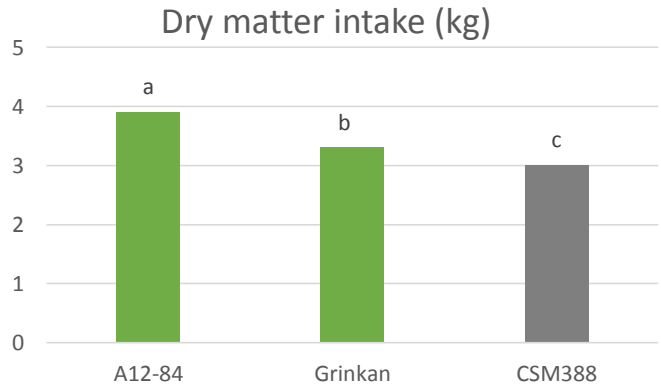


P = G + E + GXE +...

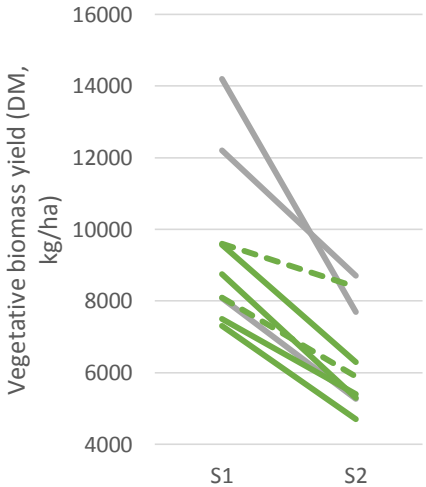
Multi-traits

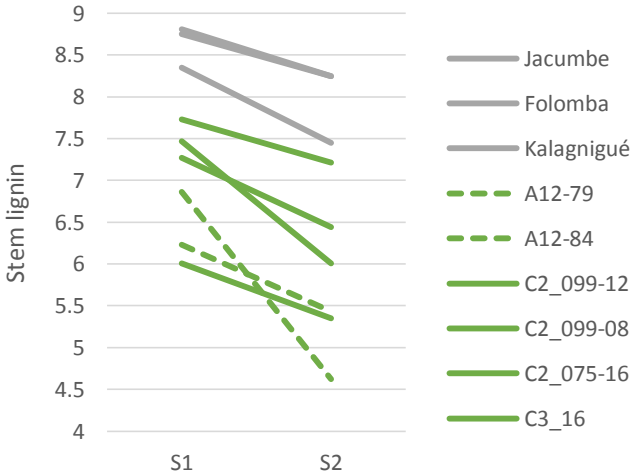


Bulls, 21 days

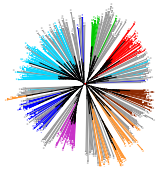


But waiting for weight gains

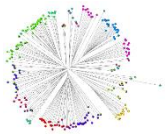




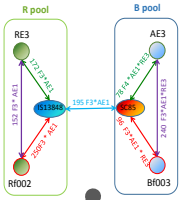
Integrating crop modelling in the prediction model

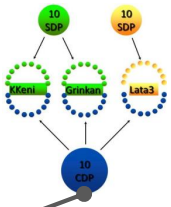


Worlwide

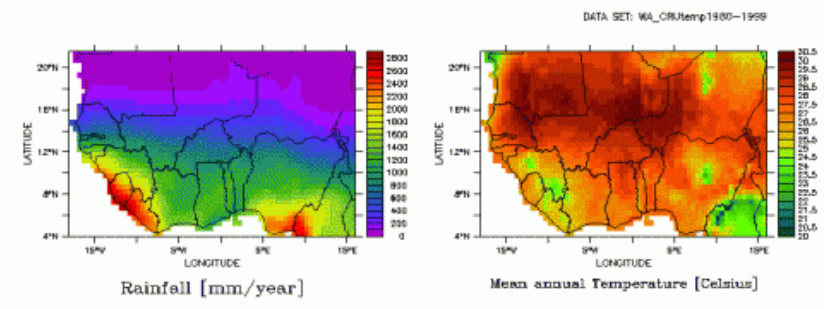


Non photoperiodic biomass





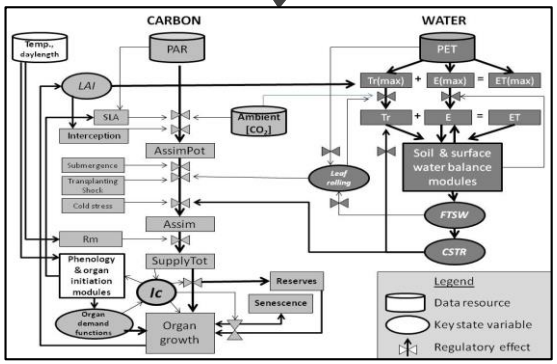
E



$$P = G + E + \boxed{GXE} + \ldots$$

Gene 1 + Gene2 + Gene 3…

M



Crop model(s)

(SAMARA, Ecomeristem, APSIM)

$$P = G + E + M + GXE + GXM + \ldots$$

- Production
- Ideotype definition
- Breeding

People and fundings

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Niaba Témé

Jean-François Rami

INRA SCIENCE & IMPACT

cirad

IER

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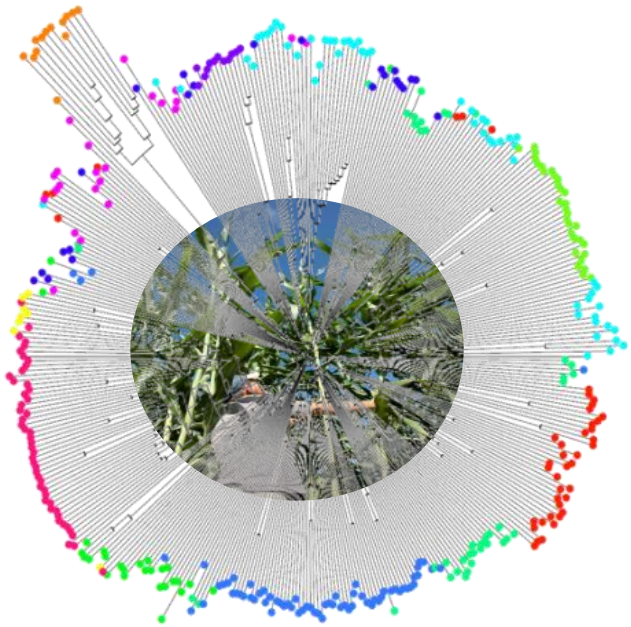
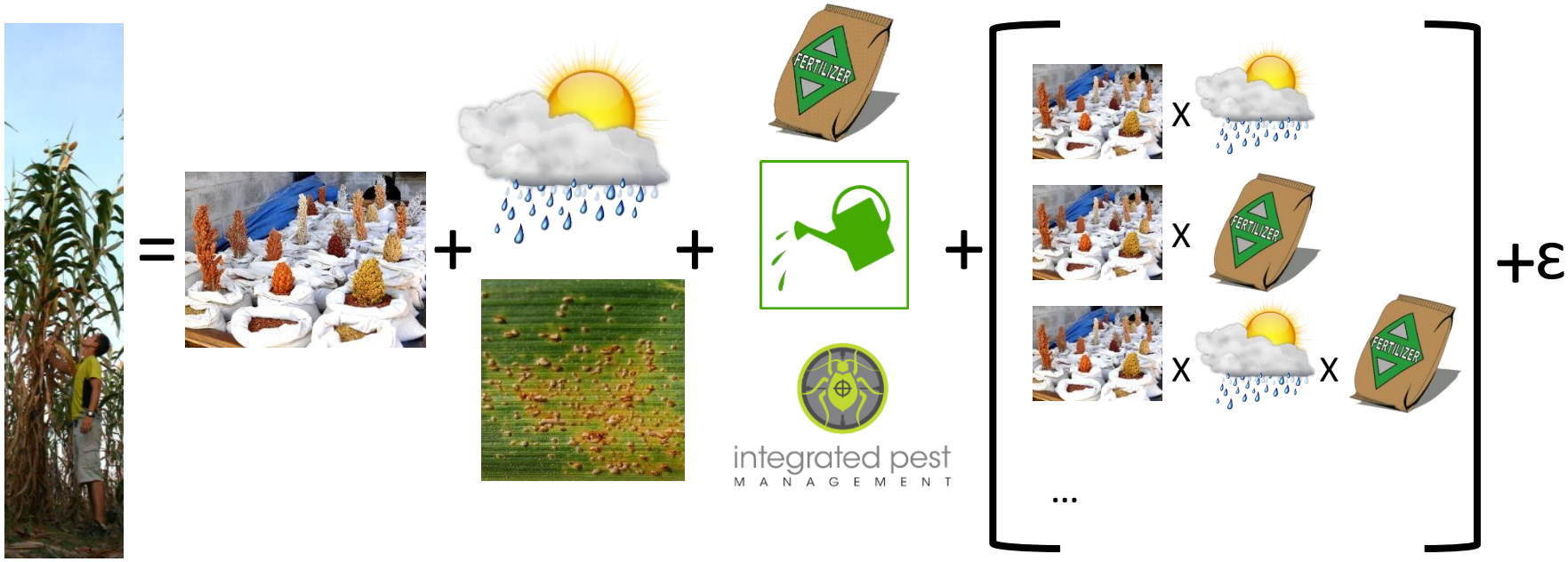
Questions !



Value chains / plant targets : produce it !
A geneticist centered point of view



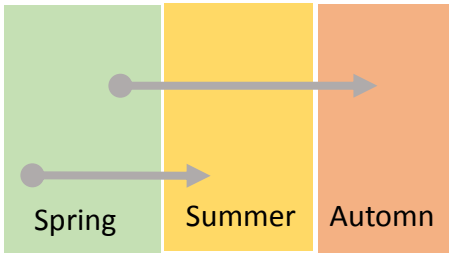
$$P = G + E + M + \left[\begin{array}{l} G \times E \\ G \times M \\ G \times E \times M \\ \ldots \end{array} \right] + \varepsilon$$

M

Sorghum-cowpea

Sorghum-maize

Double cropping



Early sowing