Highlights on recent heterogeneous population research results

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Heterogeneous populations of self-fertilizing cereal species

- A possibility to involve large genetic/phenotypic diversity
- Have the ability to evolve and adapt to particular environments while cultivated there for a number of seasons
- **Composite cross populations (CCPs):**
  - mixtures of dialell crosses between around 5-10 parental genotypes
- **Dynamic Populations (PopDyn)**
  - created by mixing seeds of certain number of genotypes
- **Diversified Oriented Populations (DOPs)** – a new approach
  - A mixture of large number (30 on average) of genebank accessions elaborated according to farmers' specific criteria

Outline

- Research on spring barley and wheat **CCPs** (AREI, Latvia)
- Winter wheat CCP versus **Dynamic Populations** (ITAB/INRAE, France)
- **Diversified Oriented Populations** (DOPs) of underutilized cereal species (ITAB/INRAE, France)

Research on spring barley CCPs (AREI, Latvia)

Material and methods

- First three CCPs created in 2013 (crosses)
  - 10 parents = 90 cross combinations per CCP
- Up to now 14 CCPs using same/different/modified methodologies
  - Covered and hulless grain
  - Different parental material: advanced local breeding lines + resistance sources + various geographical origin
  - Main aim: agronomic traits essential for organic growing
  - Specific aims: food use, resistance to seed born/leaf/fusarium diseases, NUE
  - Methodologies: using male sterility, crosses with existing CCPs, line selection from CCPs, mass selection for resistance within CCP etc.

Research on spring barley CCPs (AREI, Latvia)

CCP-1= population Mirga

Applied for EC Temporary Experiment on marketing of heterogenous populations (2017-2021)

Research on spring barley CCPs (AREI, Latvia)

CCP-1= population Mirga

Growing on farms

Research on spring barley CCPs (AREI, Latvia)
Field trials

- 1st step: 2015-2018, 14 environments, 4 seasons, 2 locations, organic and conventional management systems
  - First created CCPs along with mixtures and more simple population types
- 2nd step: 2019-2021, 3 organic and 1 conventional location (=12 environments)
  - 12 CCPs along with mixtures of parents and checks (including 2 Danish)
- Main traits of interest: yield and stability, weed suppression ability, nitrogen use efficiency (NUE), disease severity

Research on spring barley CCPs (AREI, Latvia)

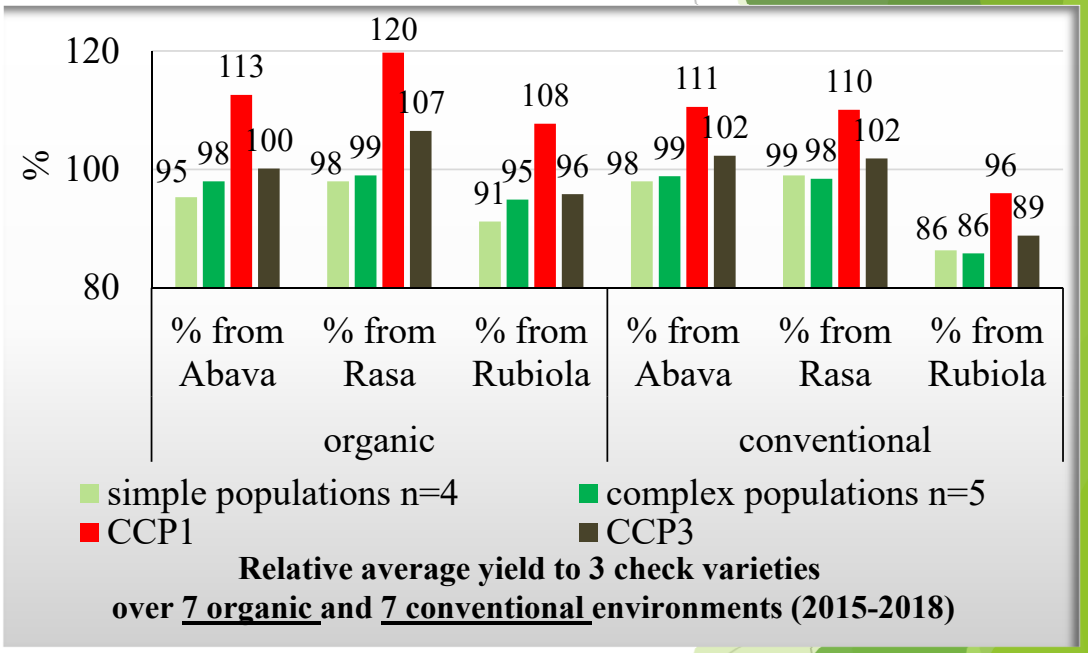
Results:

Yield ranking and stability (2019-2020, 8 environments)

Organic sites (n=6)			Conventional sites (n=2)		b overall
	yield t/ha	b org		yield t/ha	
CCP-4	2.17	1.06	Anakin	5.71	1.32
CCP-7	2.13	0.90	Rubiola	5.49	1.17
pop.Mirga	2.13	1.15	pop.Mirga	5.01	1.06
CCP-5	2.12	1.09	CCP-6	4.97	1.05
CCP AB PL	2.02	1.20	CCP-4	4.94	1.01
CCP-6	1.98	1.02	Irbe HB	4.84	1.15
Rubiola	1.98	0.96	CCP-5	4.76	0.98
CCP-3	1.94	0.89	Abava	4.69	0.98
Anakin	1.91	1.23	CCP-3	4.65	0.94
Abava	1.85	0.89	CCP AB PL	4.60	1.00
Rasa	1.75	1.00	CCP-7	4.51	0.86
Irbe HB	1.56	1.09	Rasa	4.48	0.98
CCP-3 HB	1.49	0.78	CCP-3 HB	4.29	0.94
CCP-7HB	1.37	0.73	CCP-2 HB	3.75	0.92
CCP AB HB	1.36	0.77	CCP AB HB	3.73	0.82
CCP-5 HB	1.32	0.85	CCP-5 HB	3.57	0.81
CCP-2 HB	1.17	0.91	CCP-7HB	3.48	0.75
average	1.81		average	4.61	
LSD0.05	0.27		LSD0.05	0.63	

b org - coefficient of regression over organic sites
b overall - coefficient of regression over all sites
HB - hulless barley

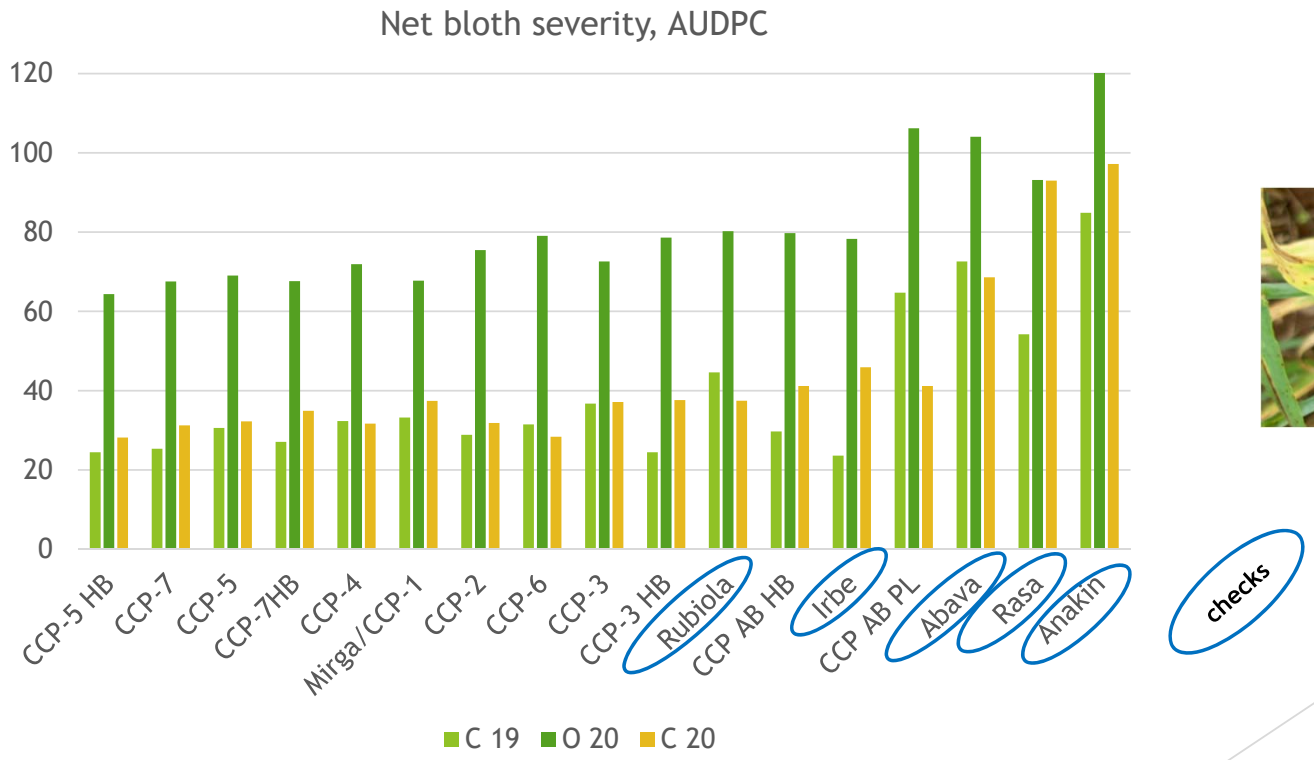
Relative yield to checks



Populations	Yield of populations	Yield of checks, org 2018 (drought)		
		Abava	Rasa	Rubiola
CCP1	2.79a	2.78a	2.19b	2.20b
CCP3	2.81a			
CCP4	3.02a			
CCP5	2.99a			

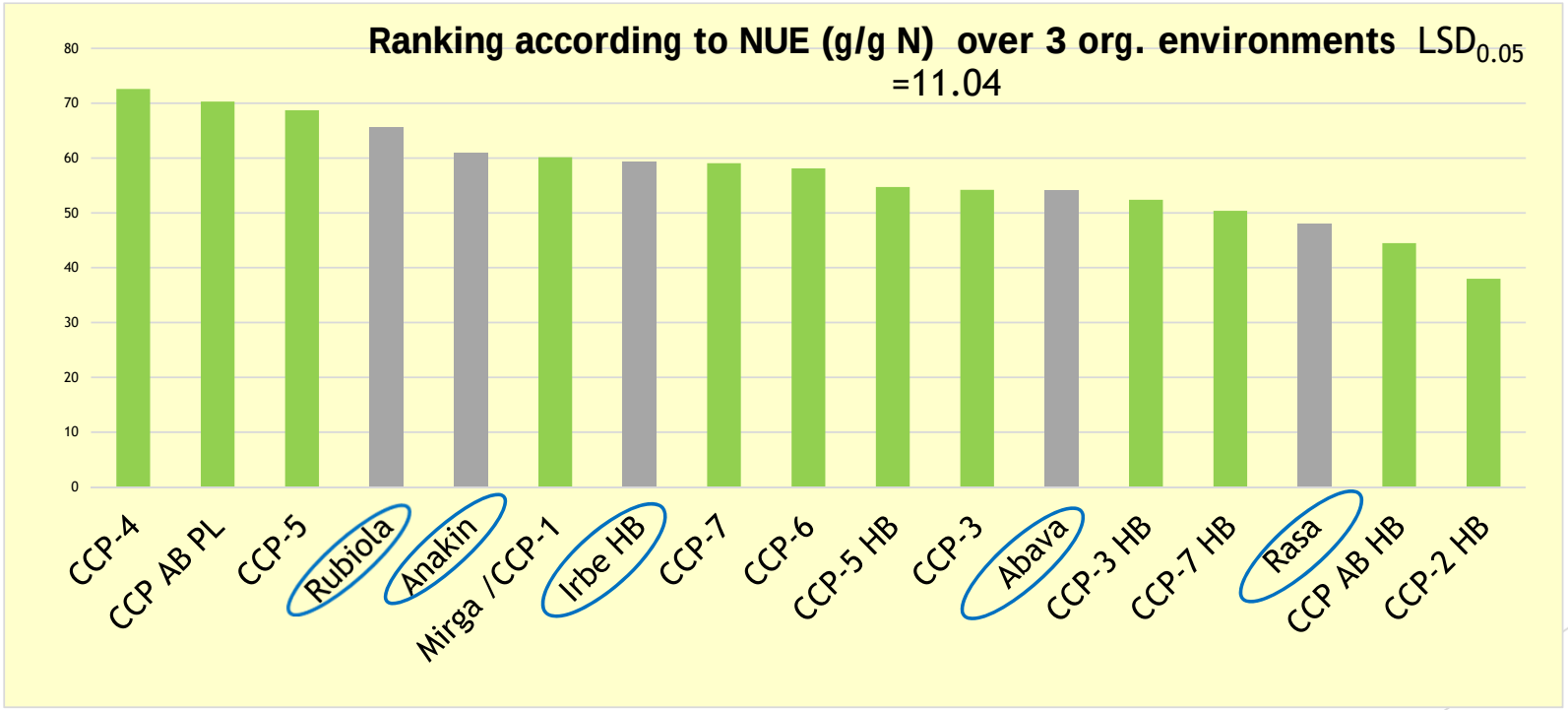
Research on spring barley CCPs (AREI, Latvia)

Results: net blotch severity (3 environments)



Research on spring barley CCPs (AREI, Latvia)

Results: nitrogen use efficiency (NUE)



Research on spring barley CCPs (AREI, Latvia)
Main findings

- YIELD: **CCPs superior under organic** farming system
  - all except one ranked higher
  - yield advantages **under stress conditions** (drought)
  - most of CCPs tended to outyield the respective mixture under organic; opposite trend under conventional
- STABILITY: **CCPs stable yielding** over all environments; varieties – most unstable
  - CCPs tended to be more stable than the respective mixtures over organic environments; less differences over organic+conventional environments
- DISEASES: **advantages for CCPs** over varieties **for net blotch severity**
  - powdery mildew severity in between the most resistant and most susceptible varieties
  - susceptibility to loose and covered **smuts can be a problem**
- NUE: CCPs can be superior in comparison to check varieties
- WEED SUPPRESSION ABILITY: close to that of homogenous varieties in most cases

Research on spring/winter wheat CCPs (AREI, Latvia)

- Testing of spring and winter wheat CCPs from Denmark, Germany and Hungary in comparison to local check varieties (2019-2021)
- Local CCPs are being created
  - 2 spring wheat CCPs tested for 2 seasons
  - Crosses for winter wheat CCP (2021)
- Spring wheat CCPs showed similar yield in comparison to check varieties; some of them provided superior grain quality

Winter wheat CCP versus Dynamic Populations (ITAB/INRAE, France)

Research question:

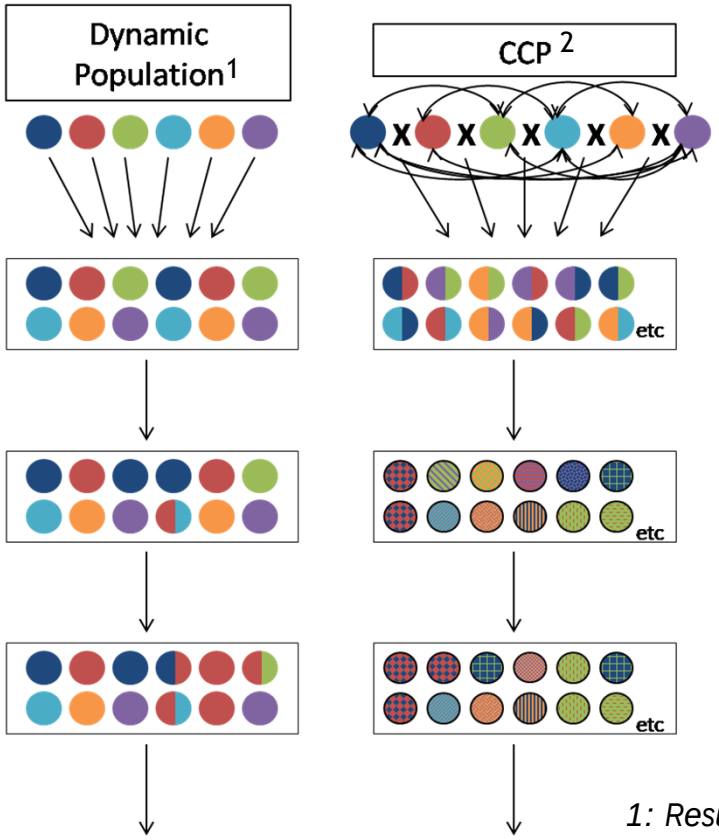
What are the differences between **CCP and Dynamic Population** in terms of agronomical characteristics and of diversity through time?

Hypotheses:

- For the same generation, CCP's diversity is higher than mixture's one
- Selection location has an influence on the agronomical behavior and diversity level of the populations
- Human selection influences the agronomical behavior of the populations and homogenizes them

Winter wheat CCP versus Dynamic Populations (ITAB/INRAE, France)

Method



- Started in 2014 in the frame of COBRA 3 project
- Parents/components 6 landraces
- On two sites
- Study the influence of :
  - (1) Site
  - (2) Population building method (CCP/PopDyn)
  - (3) Human selection: a farmer and two bakers did a selection in both populations
- Phenotypic characteristics and yield components were observed on all the populations (2019-2020)

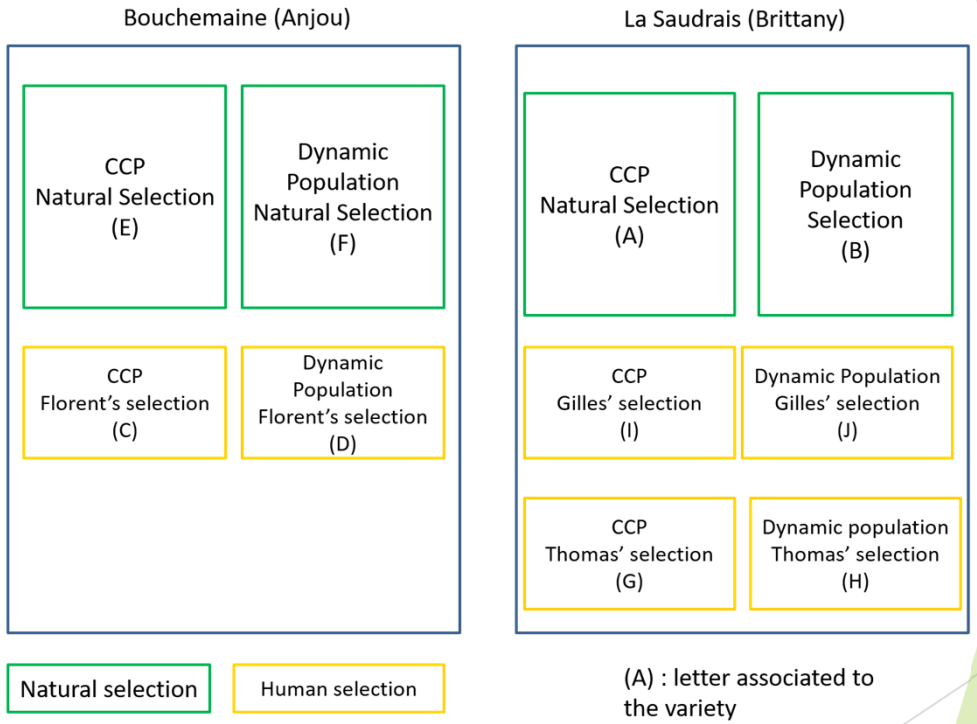
1: Resulting from variety mixutres (PopDyn)
2: Composite Cross Population
3: Coordinating Organic plant BReeding Activities for diversity, Core organic project

Winter wheat CCP versus Dynamic Populations

(ITAB/INRAE, France)

Method

- MATERIAL: 10 entrees in total
  - 2 types of populations: CCP and PopDyn
  - For each population: natural selection or human selection (1 farmer, 2 bakers)
- Main traits assessed:
  - Quantitative traits: straw and spike height, plant height , number of sterile and fertile spikelets, thousand kernel weight, number of grains per spike
  - Qualitative traits: shape; color and darkness of the spike, shape of the awns, presence of husks



Human selection = 60 spikes per population

Winter wheat CCP versus Dynamic Populations (ITAB/INRAE, France)

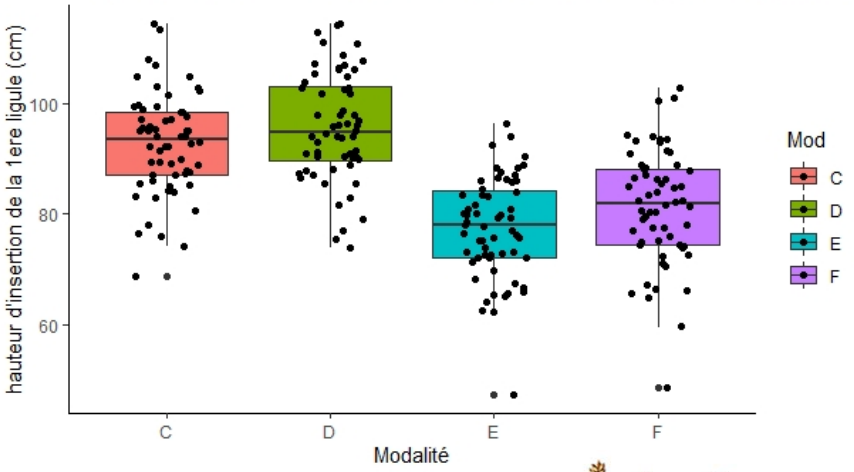
Method

CCP population, measurement – 2018

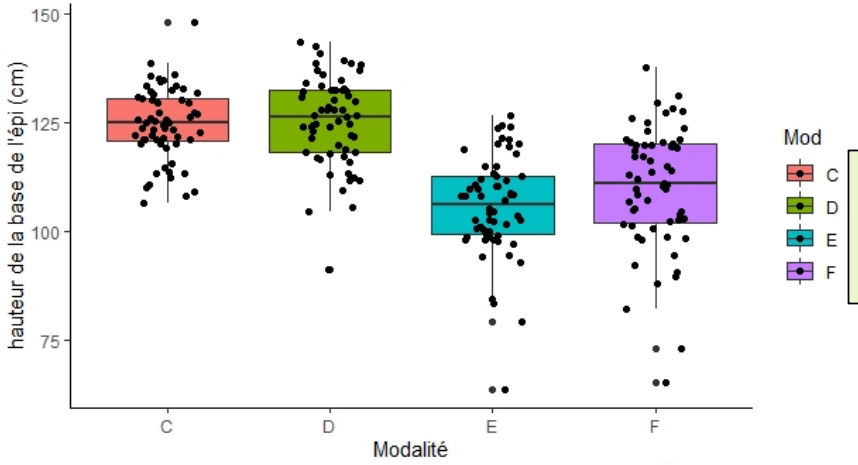
CCP population, Brittany – 2019

Winter wheat CCP versus Dynamic Populations (ITAB/INRAE, France)

Results : Quantitative traits: descriptive statistics



First ligule's base height (2020)



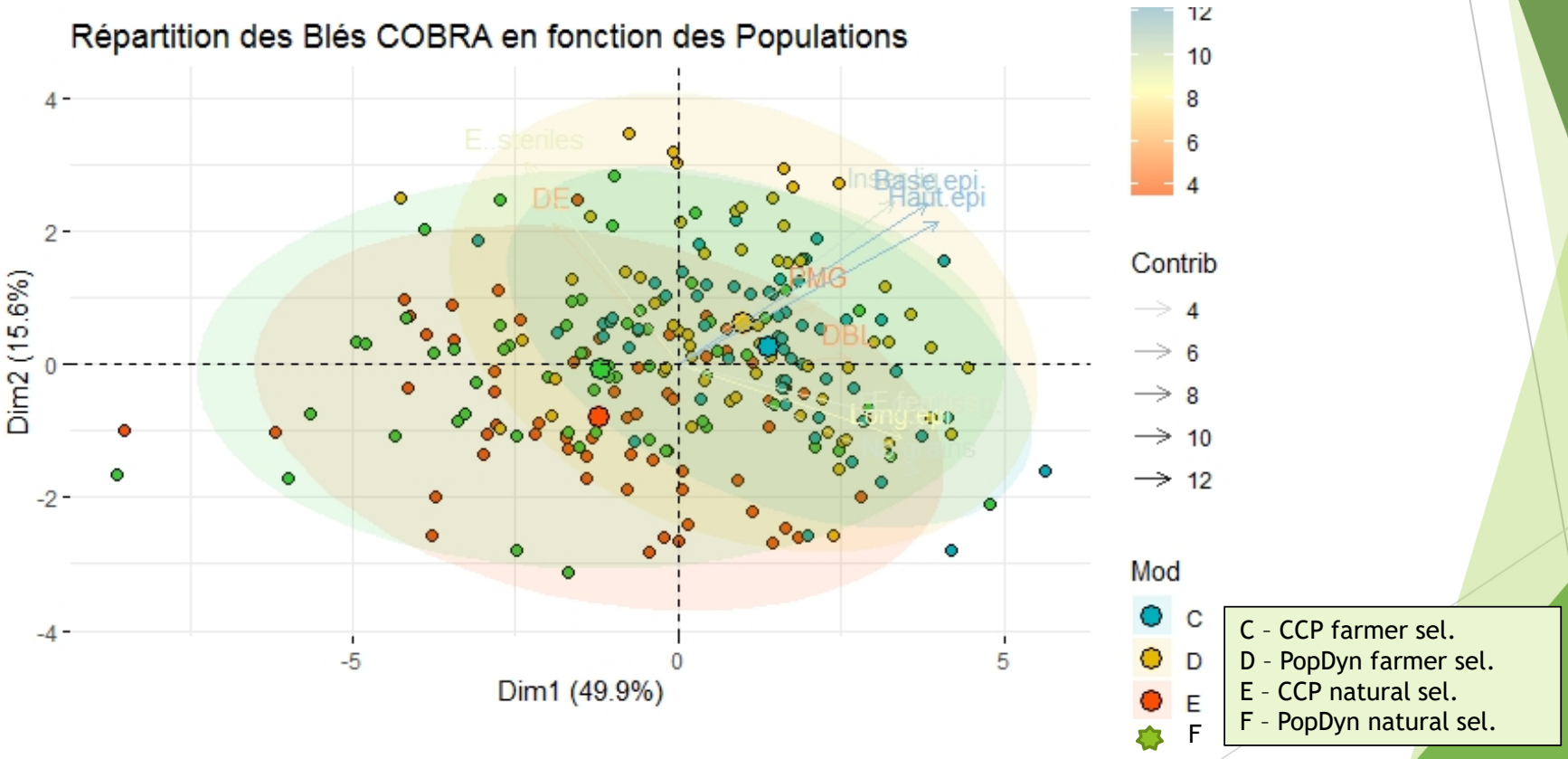
C - CCP farmer sel.
D - PopDyn farmer sel.
E - CCP natural sel.
F - PopDyn natural sel.

Height of the spike's base (2020)

→ For those traits farmer's selection had a positive significant impact

Winter wheat CCP versus Dynamic Populations (ITAB/INRAE, France)

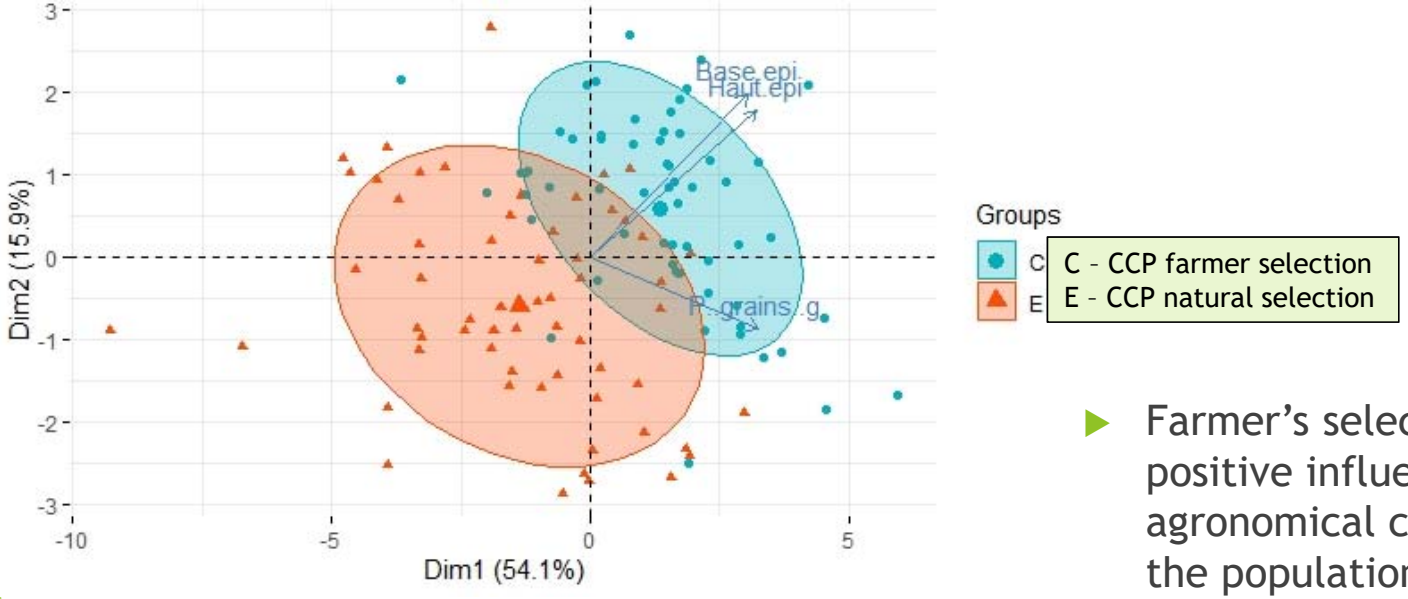
Results : Quantitative traits: PCA



PCA with all the populations and the correlation circle (2020)

Winter wheat CCP versus Dynamic Populations (ITAB/INRAE, France)

Results : Assessing the influence of human selection

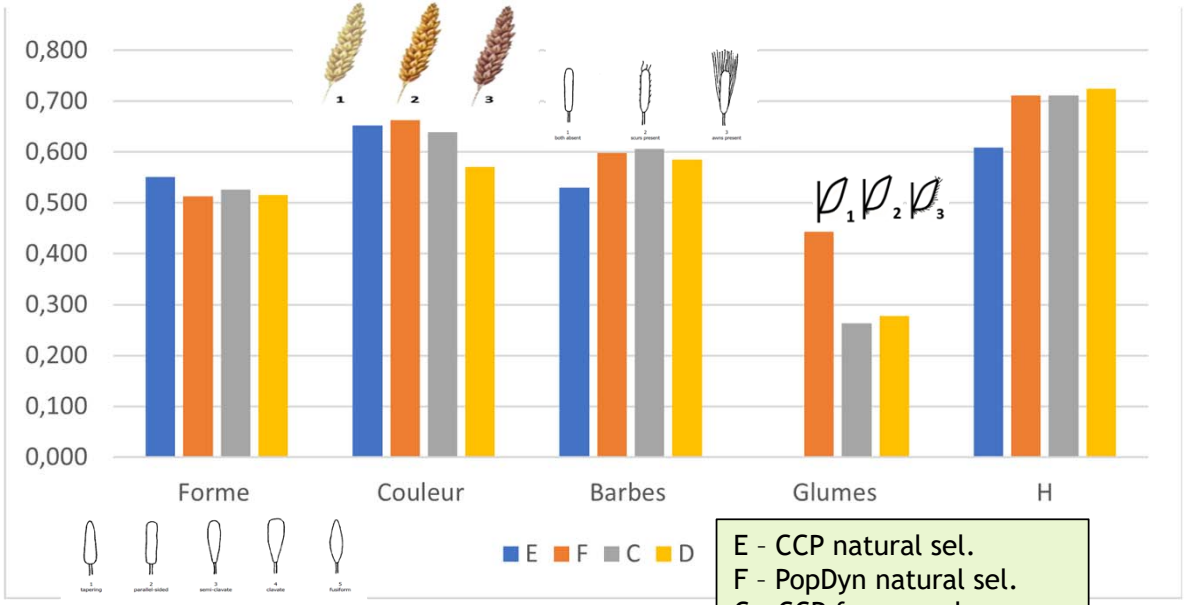


PCA of the CCP populations (E=natural selection, C=Farmer's selection) 2020

- Farmer's selection had a positive influence on the agronomical characteristics of the population
- This is consistent with the results of the previous years

Winter wheat CCP versus Dynamic Populations (ITAB/INRAE, France)

Results : Qualitative traits: Nei index



Nei indexes (2020)

H=Average phenotypic intra-varietal diversity

→ Intra-varietal diversity was equivalent for CCP and PopDyn
→ Human selection did not seem to reduce diversity

Winter wheat CCP versus Dynamic Populations (ITAB/INRAE, France)

Conclusions

- Human selection had a greater impact on agronomical characteristics than the population building method (CCP or PopDyn)
- Human selection had a positive impact on some agronomical characteristics of the populations
- Human selection did not seem to reduce the intra-varietal diversity
- No diversity difference was observed between CCP and PopDyn

Diversified Oriented Populations (DOPs)

(ITAB/INRAE, France)

- **DOP is a "personalized" mixture of several accessions with one or several common phenotypic traits requested by a farmer**
- Based on a large number of *ex-situ* accessions (range 3-77)

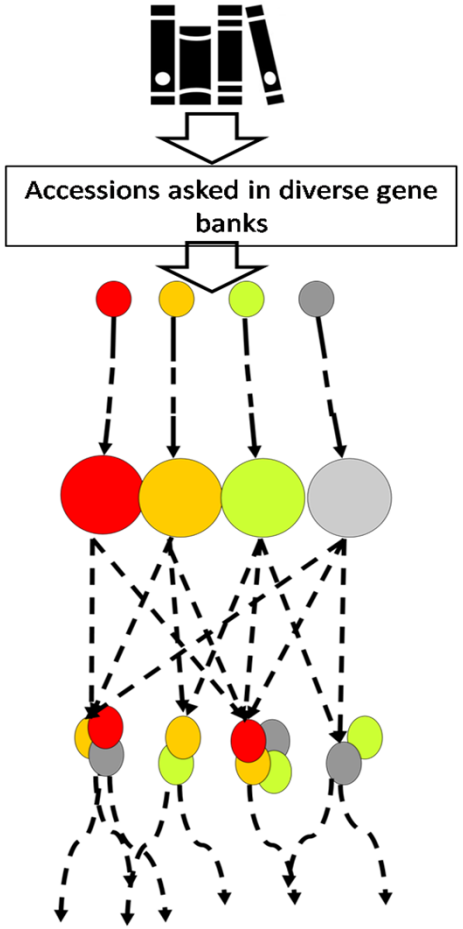
- The objective is to provide basic diversified population to the farmers
  - supposed to represent a huge potential of adaptation, but targeted on some characteristics
  - in order to speed the breeding process and to facilitate the adoption by farmers

This methodology has been put in place on underutilized cereal species: rivet wheat, spelt and oat

Diversified Oriented Populations (DOPs)

(ITAB/INRAE, France)

Method



Year 1: Monograph of the species (gathering information on the species story, cultivation and breeding)

2 to 4 years: Multiplcation and observation (phenotipyc critera at least)

From year 3 to 5: Creation of diversified and personlalized populations by mixing varieties according to the farmers' requests

From year 4: Dynamic evolution in the farms

Diversified Oriented Populations (DOPs)

(ITAB/INRAEDiversifie, France)

Implementation: the example of rivet wheat

Measurement of the height of straw of a rivet wheat grown in Brittany, 2018.

Extracted from the data obtained for each variety from the agronomic observations of the team

Levée	Port au tallage	Tallage	Port des feuilles	Couverture	Enherbement	Couleur
4	4	4	C	5	1	2
4	4	3	D	4	1	3
4	2	4	SD	4	2	3
4	3	3	SD	3	1	3
4	1	4	I	3	1	3
4	4	3	SD	2	2	3
3	3	3	D	3	3	3
5	2	4	SC	3	1	2
5	3	4	SD	4	2	2
4	3	4	I	2	1	2
5	5	3	SD	2	1	2
4	3	3	D	3	3	3
4	3	4	I	2	1	2
4	2	3	SD	4	3	3

Diversified Oriented Populations (DOPs)

(ITAB/INRAE, France)

Results: rivet wheat

24
farmers received populations

29
diversed and personalized populations created

172
Varieties of rivet wheat

30
varieties on average per population

24
criteria used to create populations

2018 : first year of distribution

Diversified Oriented Populations (DOPs)

(ITAB/INRAE, France)

2019: 2nd year of distribution, 1st of follow up

Distribution: 11 farmers received a total of 40 samples

Follow up: 14 farmers submitted results

2020: 2nd of follow up

Follow up: 9 farmers submitted results

Photo credit : Florent Mercier

Diversified Oriented Populations (DOPs)
(ITAB/INRAE, France)

Conclusion of the two years of follow up for rivet wheat

- The majority of the farmers were satisfied with the populations
- Most populations corresponded to the requested criteria (qualitative observations)

- Some farmers mixed the different populations
- Some farmers started their selection among the populations… and some others need to multiply more before starting a selection
  - → Sent quantities were too low for several farmers

- The experimentation goes on with spelt and oats

Summary and future perspectives

- Diversity within a crop field can ensure comparable and in certain conditions better performance if compared to homogenous material
- Yield stability, performance under stress conditions and reduced leaf disease severity were main advantages found
- Interest and active involvement of farmers/producers is essential
- Multi-component mixtures might be of equal value to CCPs
  - More results on comparing several CCPs with mixtures of their parents on agronomic traits are expected at AREI after this season

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