Arnaud Monty Grégory Mahy

Post-invasion evolution of an invasive plant : altitudinal differenciation in germination, phenology and growth

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gembloux
faculté universitaire
des sciences agronomiques


1. Introduction

Studied taxon:
Senecio inaequidens DC.

- Perrenial herbaceous shrub from South Africa and Lesotho
- Numerous yellow capitulae; Plumed wind-dispersed achenes
- Rapid germination, no dormancy
- Early flowering (1st Year), long flowering period
- Pioneer species, invading mainly roadsides and railways



Studied taxon:
Senecio inaequidens DC.

- In the indigeneous range: diploid and tetraploid populations
- In the introduction range: tetraploids only
- **Introduction history:**
  - Wool alien at the end of the 19th century
    - Verviers (Belgium) : 1892
    - Bremen (Germany) : 1896
    - Mazamet (France) : 1936
    - Verona (Italy) : >1940
  - Lag time: populations only found in wool industry areas
  - 1950-1970: Rapid spread through western Europe

Senecio inaequidens DC.:
…an appropriate model for evolutionary studies!

- Invasion history precisely known
- Independant introduction spots (link between all populations of a country)
- Spread, from these spots, through climate contrasted areas
- Climate = potentially the main selection agent :
  - Few natural ennemies altering fitness
  - Little variability in invaded soils
  - Anemochorous dispersion
  - Little competition (pioneer species)
  - Generalist pollination system

Appropriate model for evolutionary studies considering **climate** as a selection agent

Invasion process:
…two main evolutionary phases

- **Primary evolution phase:** **(More studied)**

  Introduction ➔ Naturalisation ➔ Primary invasion

- **Secondary evolution phase:** **(Less studied)**

  Primary invasion ➔ Secondary invasion (contrasted climatic conditions)

Objectives of the study:

Using common garden experiment to assess the species differenciation :

1) Between cytotypes
2) Between continents (Primary evolution phase)
3) Along climatic gradients in Europe (Secondary evolution phase)

… considering

1) Germination
2) Flowering phenology
3) Plant size


2. Material and methods

Seed collection:

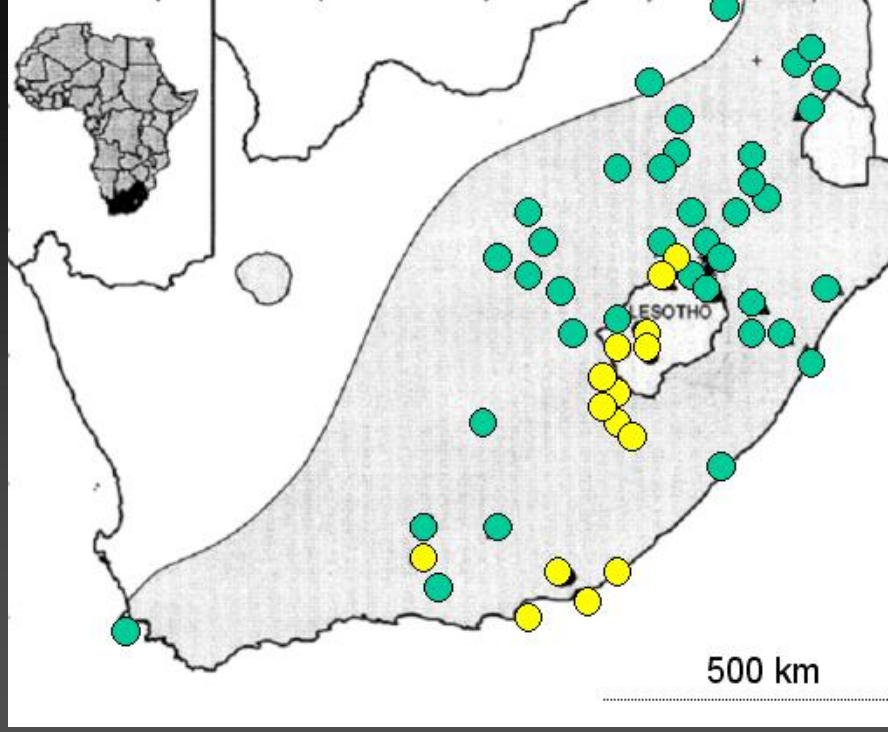
South Africa:

Tetraploid « control » zone

➔ **2 populations** x 10 individuals

Diploid zone

➔ **2 populations** x 10 individuals



[Lafuma, 2003]

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Europe:

2 altitudinal/climatic transects

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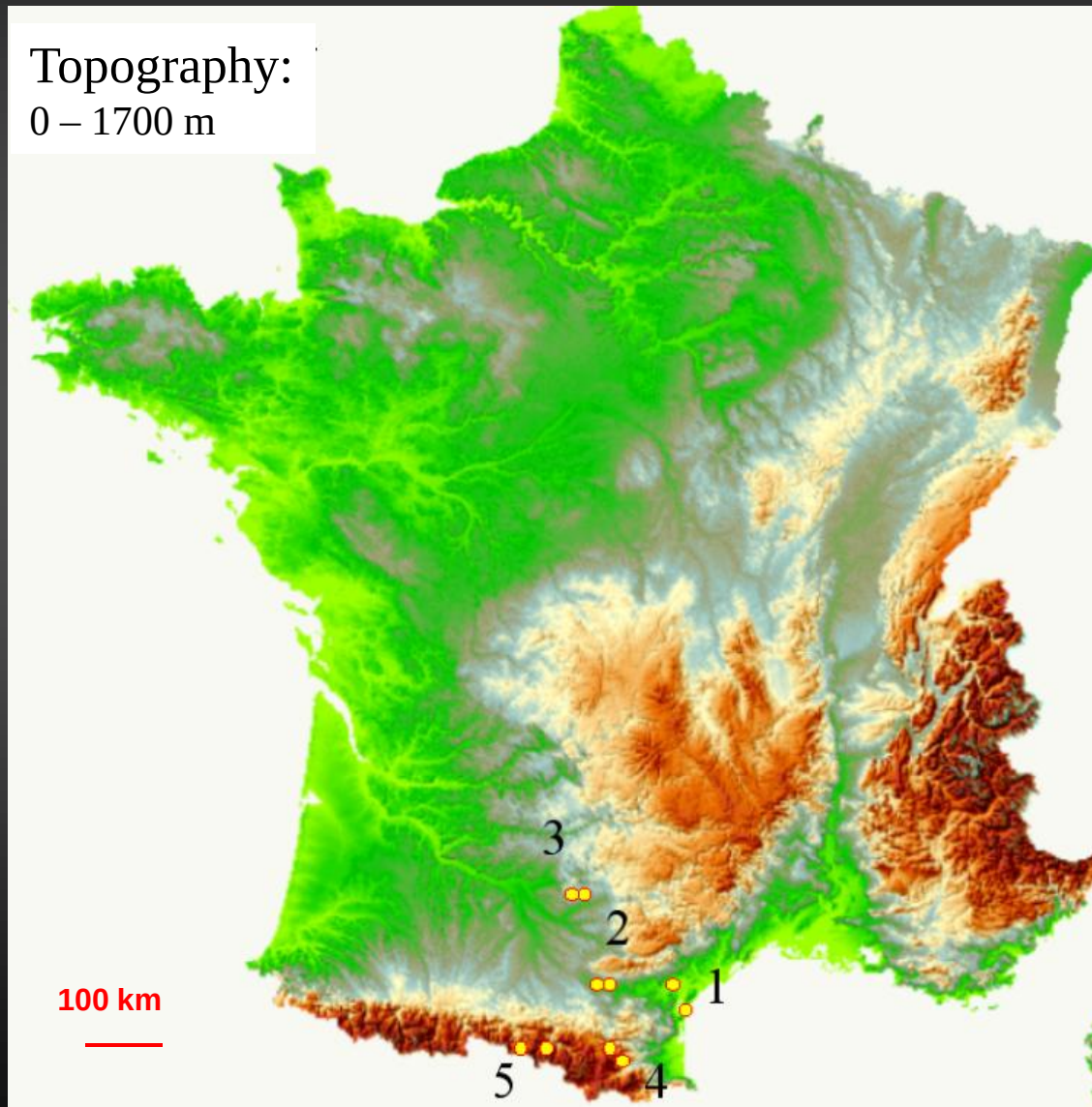
Europe:

2 altitudinal/climatic transects

France:

➔ **5 zones** x **2 populations** x 10 individuals



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Diploid zone

➔ **2 populations** x 10 individuals

Europe:

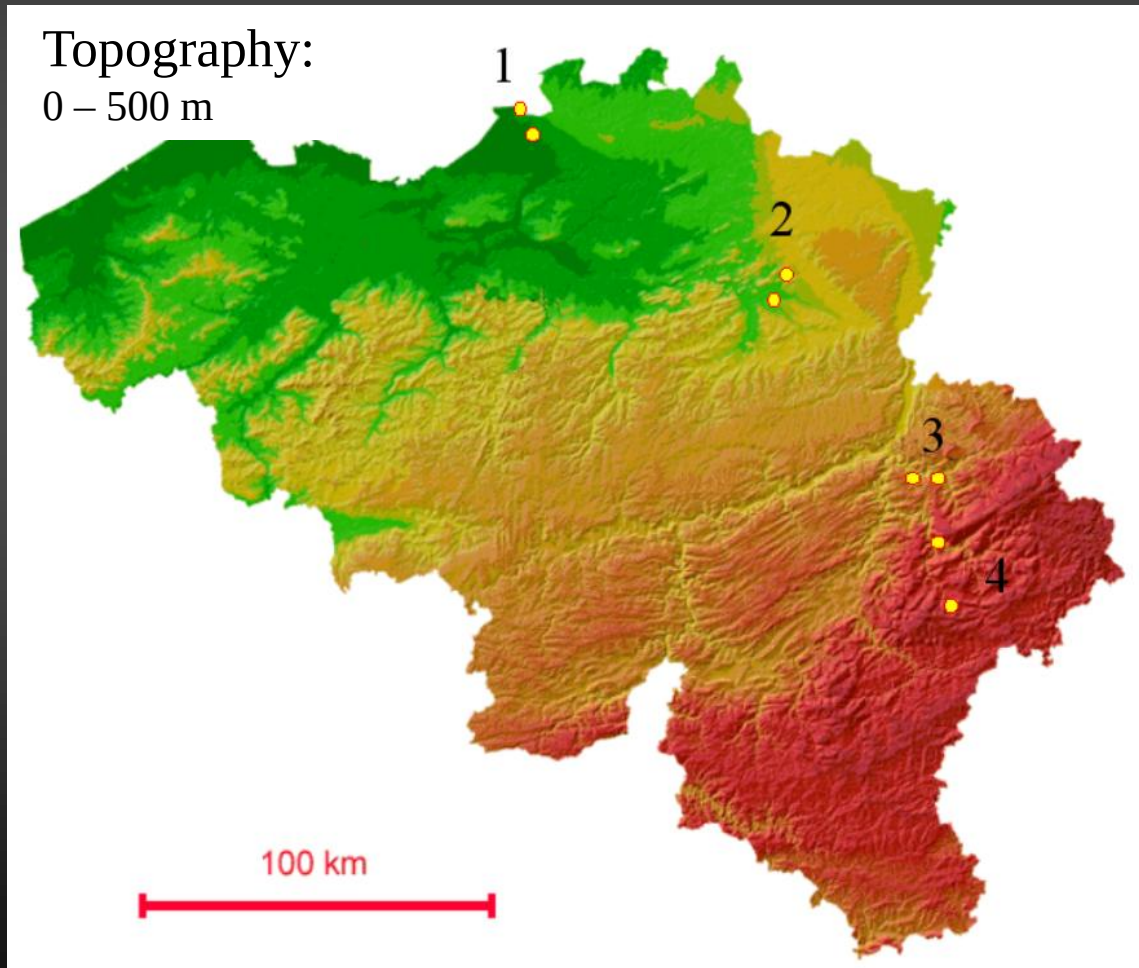
2 altitudinal/climatic transects

France:

➔ **5 zones** x **2 populations** x 10 individuals

Belgium:

➔ **4 zones** x **2 populations** x 10 individuals



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South Africa:

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Diploid zone

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Europe:

2 altitudinal/climatic transects

France:

➔ **5 zones** x **2 populations** x 10 individuals

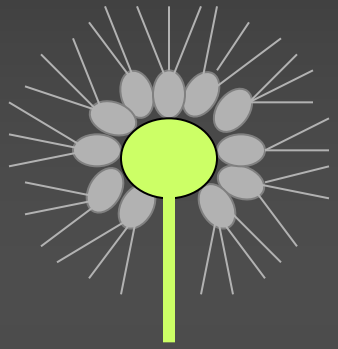
Belgium:

➔ **4 zones** x **2 populations** x 10 individuals

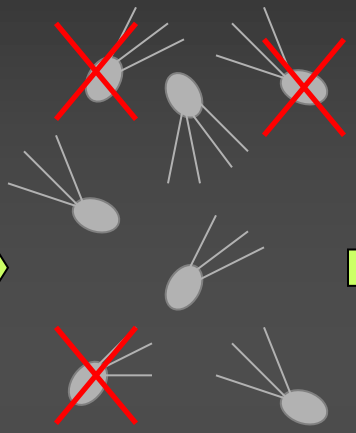
Total : 240 parent individuals

Elimination of maternal effects:

Parent individual



Capitulae collected



Sorting of achenes

10 biggest achenes without anomaly

Sowing and measurements:

10 biggest achenes without anomaly

Sown in one pot

1 plant was kept (6 months)

One plant per parent individual

Sowing and measurements:

10 bigger achenes without anomaly

Sown in one pot

Germination study
(n = 2400)

1 plant was kept (6 months)

Phenology and growth study
(n = 240)

One plant per parent individual

Sowing and measurements:

10 bigger achenes without anomaly

Sown in one pot

1 plant was kept (6 months)

One plant per parent individual

- *Germination delay (2 days)*
- *Germination window (2 days)*
- *Germination rate (2 days)*

- *Flowering delay (since germination) (everyday)*
- *Flowering delay (since sowing) (everyday)*

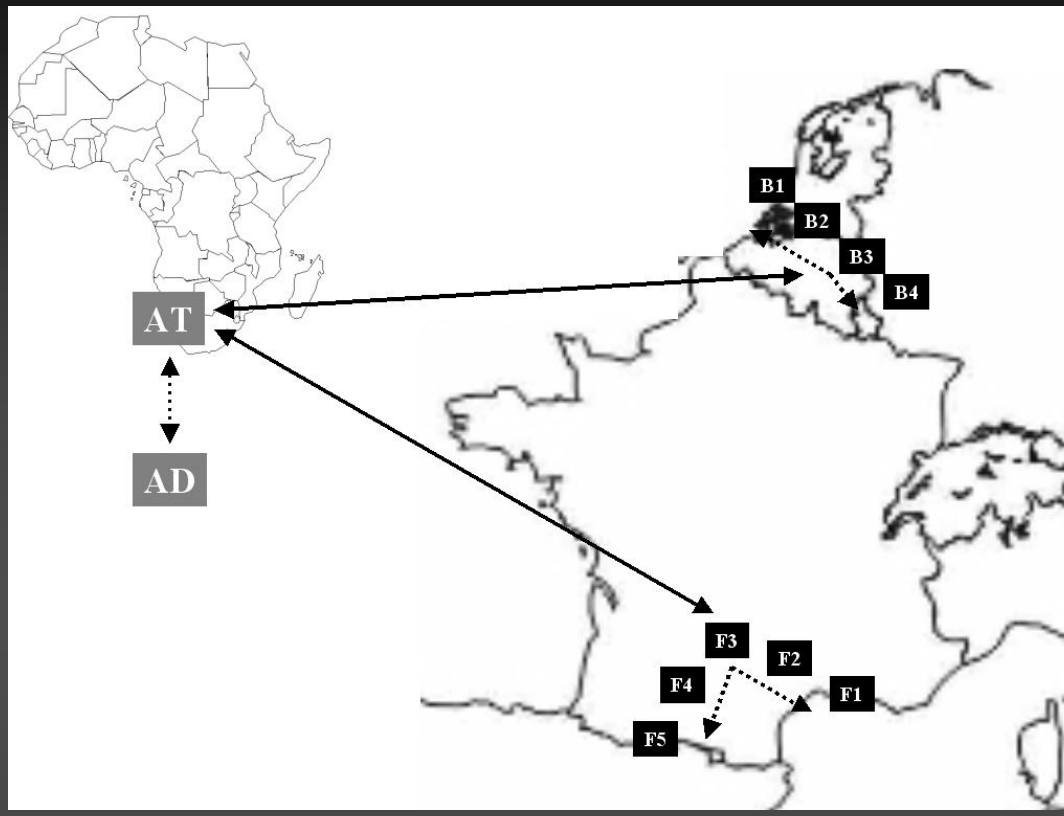
- *Plant height (every 25 days)*
- *Plant volume (every 25 days)*

4 measurements

Common garden experiment: *randomized bloc design*

Statistical analysis:

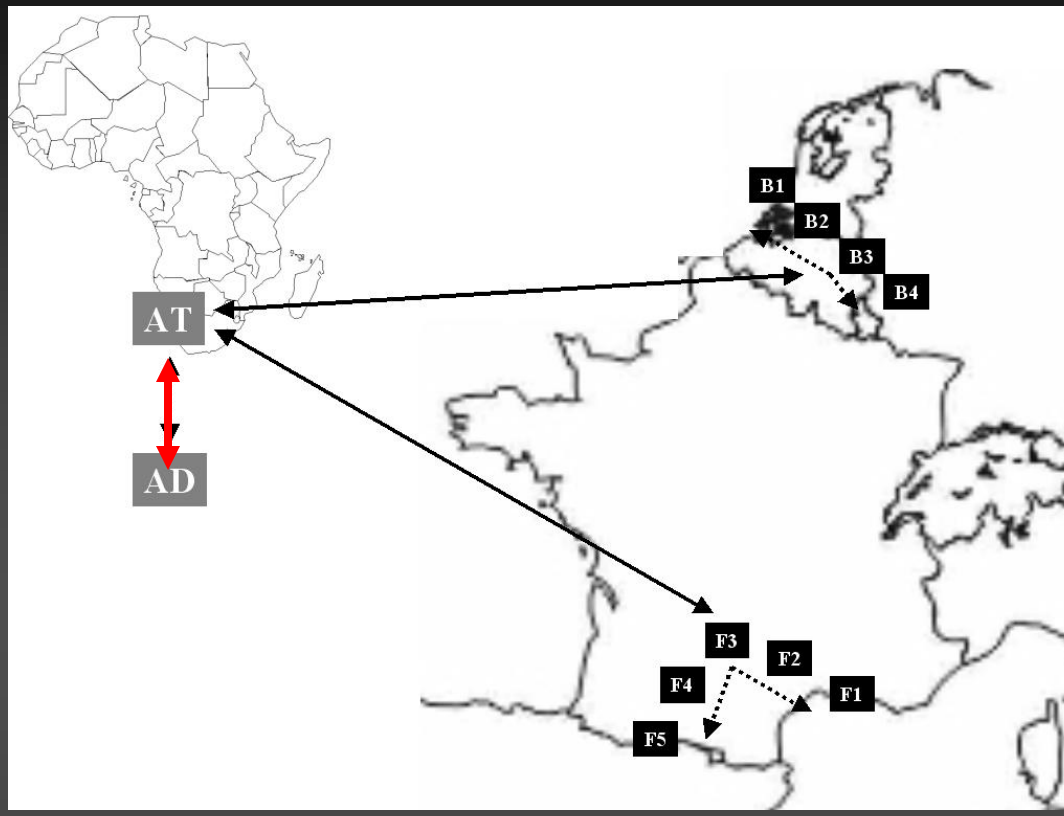
Comparison: 3 way - ANOVAs



Statistical analysis:

Comparison: 3 way - ANOVAs

- Between cytotypes

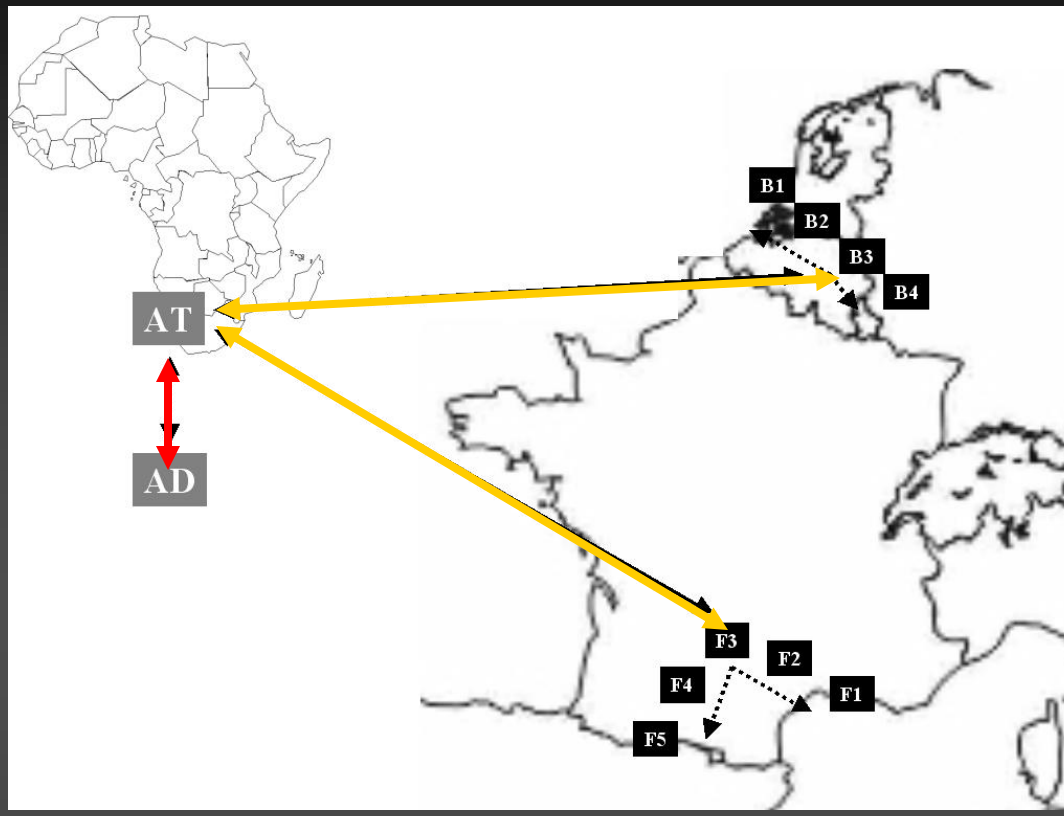


Statistical analysis:

Comparison: 3 way - ANOVAs

- Between cytotypes

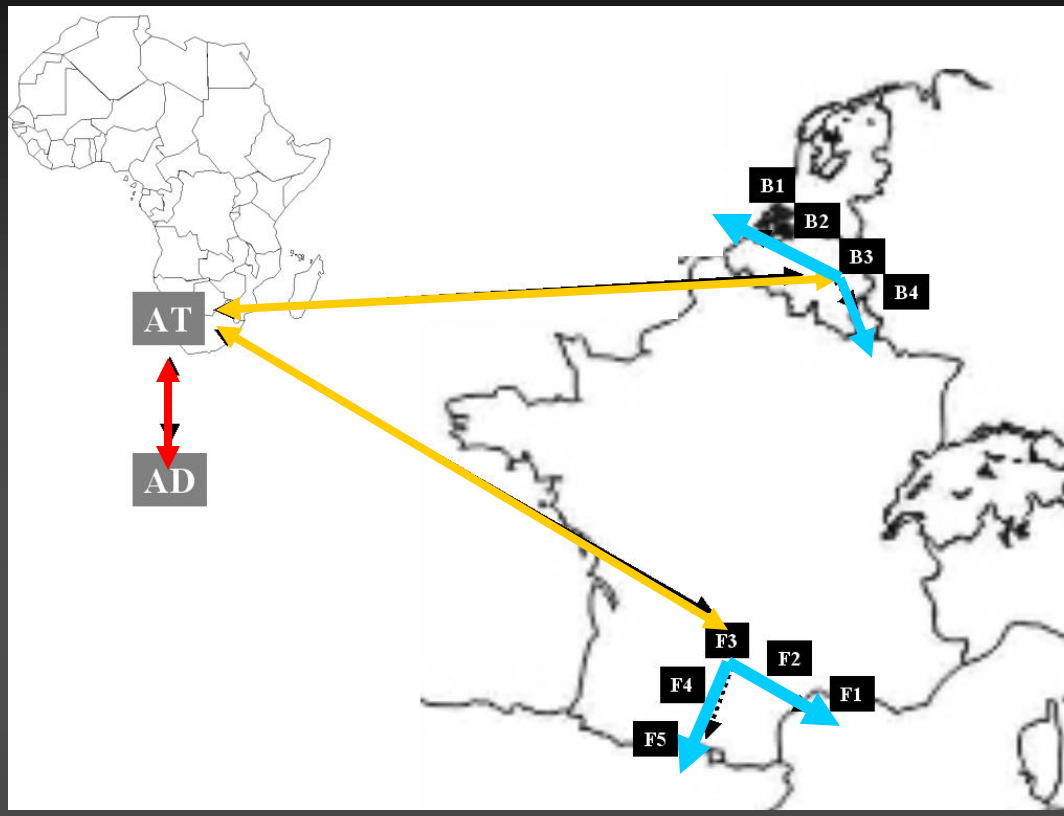
- Between African control and introduction areas (Verviers & Mazamet) *(Primary evolution phase)*



Statistical analysis:

Comparison: 3 way - ANOVAs

- Between cytotypes
- Between African control and introduction areas (Verviers & Mazamet) *(Primary evolution phase)*
- Between zones of each gradient *(Secondary evolution phase)*



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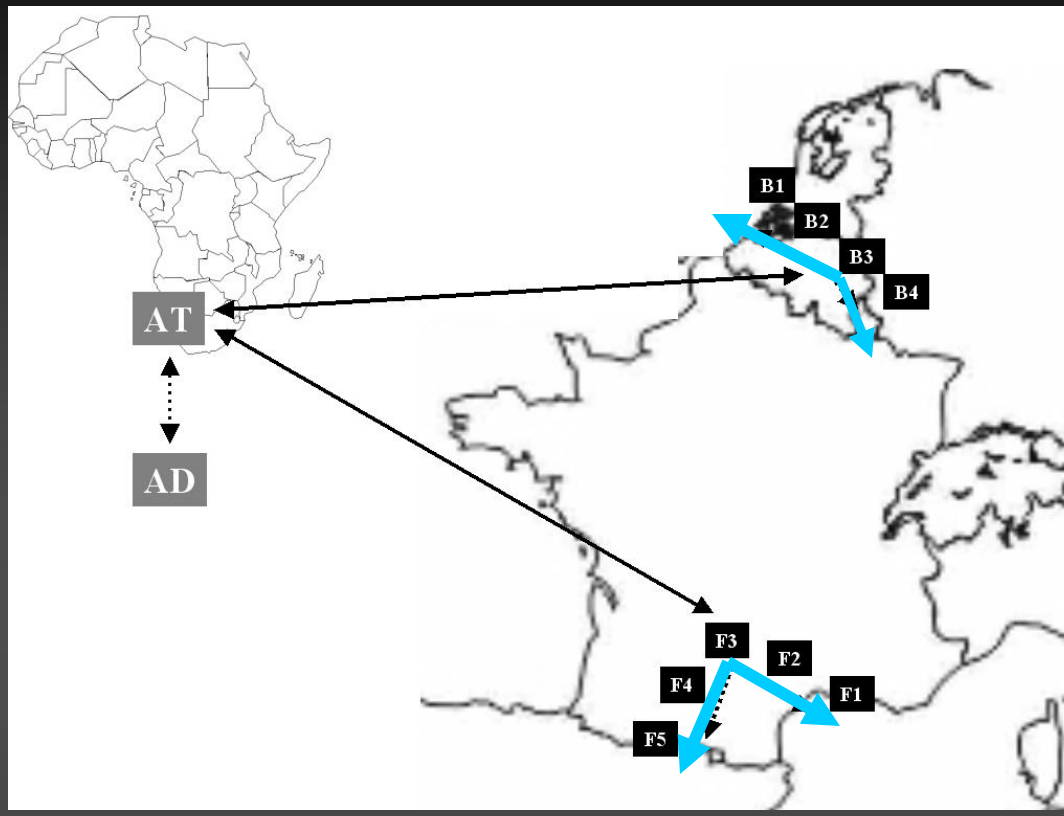

Correlation analysis: Pearson's r (linear), Spearman's R (non-parametric)
(Secondary evolution phase)

For each gradients: Population means *vs* Altitude
Population means *vs* gradient zones


3. Results

Results presentation:

For each trait:

Comparison (ANOVA)	N	p value	Correlation with altitude (p value)		Correlation with transect zones (p value)	
			r Pearson	R Spearman	r Pearson	R Spearman
Cytotypes	60	p				
Primary evolution phase	80	**p**				
Zones of French transect	100	p	p	**p**	p	p
Zones of Belgian transect	80	p	p	p	p	**p**

Significant result

Germination

- Germination delay

Comparison (ANOVA)	N	p value	Correlation with **altitude** (p value)		Correlation with **transect zones** (p value)	
Cytotypes	60	0,913				
Primary evolution phase	80	0,445	r Pearson	R Spearman	r Pearson	R Spearman
Zones of French transect	100	0,313	0,165	**0,046**	0,059	0,086
Zones of Belgian transect	80	0,179	0,169	0,091	0,166	0,073

- Germination window

Comparison (ANOVA)	N	p value	Correlation with **altitude** (p value)		Correlation with **transect zones** (p value)	
Cytotypes	60	0,913				
Primary evolution phase	80	0,889	r Pearson	R Spearman	r Pearson	R Spearman
Zones of French transect	100	0,897	0,591	0,476	0,5	0,561
Zones of Belgian transect	80	0,758	0,486	0,736	0,82	0,818

- Germination rate

Comparison (ANOVA)	N	p value	Correlation with **altitude** (p value)		Correlation with **transect zones** (p value)	
Cytotypes	60	0,348				
Primary evolution phase	80	0,611	r Pearson	R Spearman	r Pearson	R Spearman
Zones of French transect	100	0,213	0,532	0,7	0,683	0,683
Zones of Belgian transect	80	0,65	0,148	0,126	0,177	0,145

Germination

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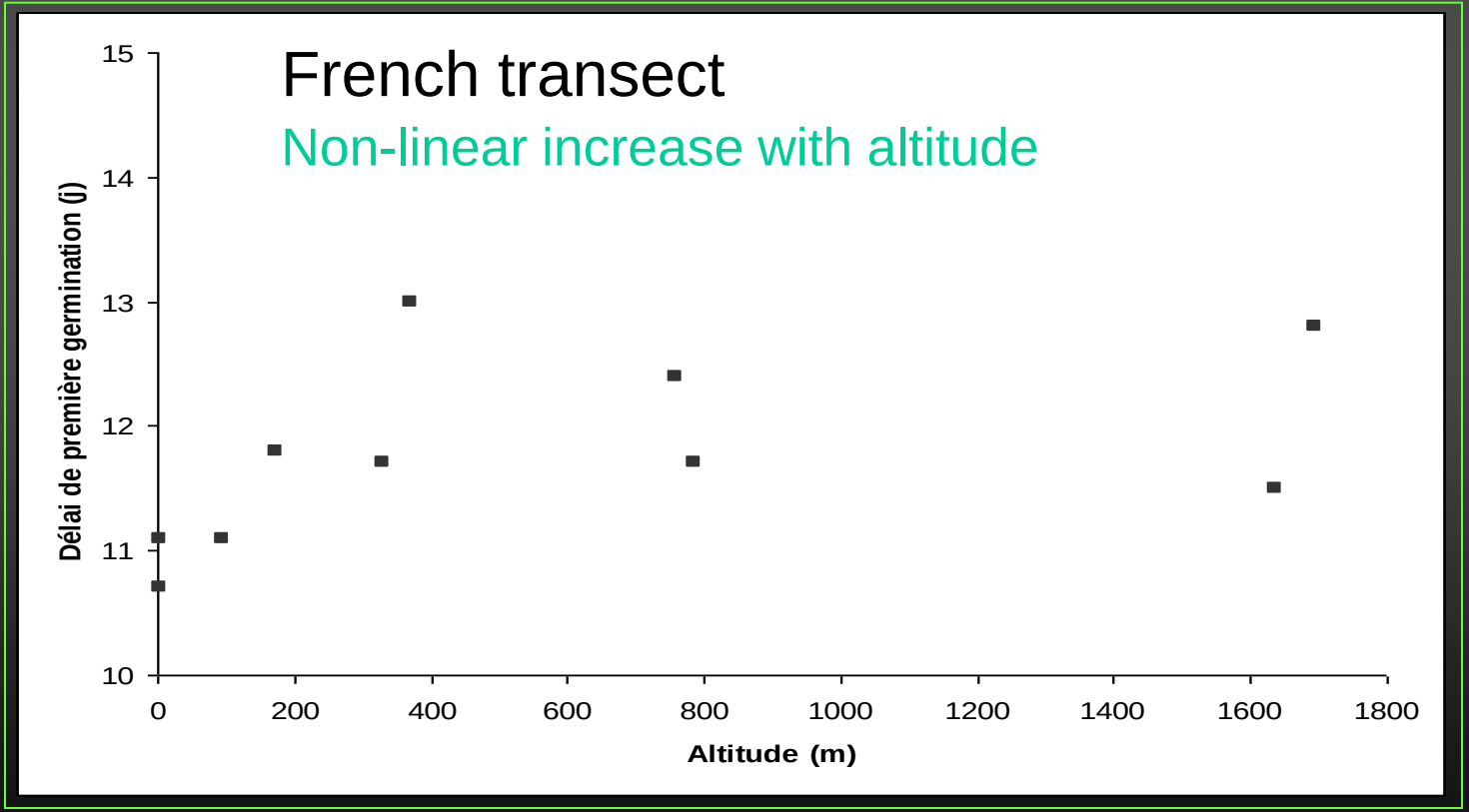

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Flowering phenology

- Flowering delay (since germination)

Comparison (ANOVA)	N	p value	Correlation with **altitude** (p value)		Correlation with **transect zones** (p value)	
Cytotypes	60	0,15				
Primary evolution phase	80	0,662	r Pearson	R Spearman	r Pearson	R Spearman
Zones of French transect	100	0,226	**0,04**	0,08	**0,019**	0,051
Zones of Belgian transect	80	0,716	0,17	0,57	0,218	0,643

- Flowering delay (since sowing)

Comparison (ANOVA)	N	p value	Correlation with **altitude** (p value)		Correlation with **transect zones** (p value)	
Cytotypes	60	0,061				
Primary evolution phase	80	0,657	r Pearson	R Spearman	r Pearson	R Spearman
Zones of French transect	100	0,589	0,123	0,192	0,116	0,125
Zones of Belgian transect	80	0,285	0,227	0,217	0,156	0,217

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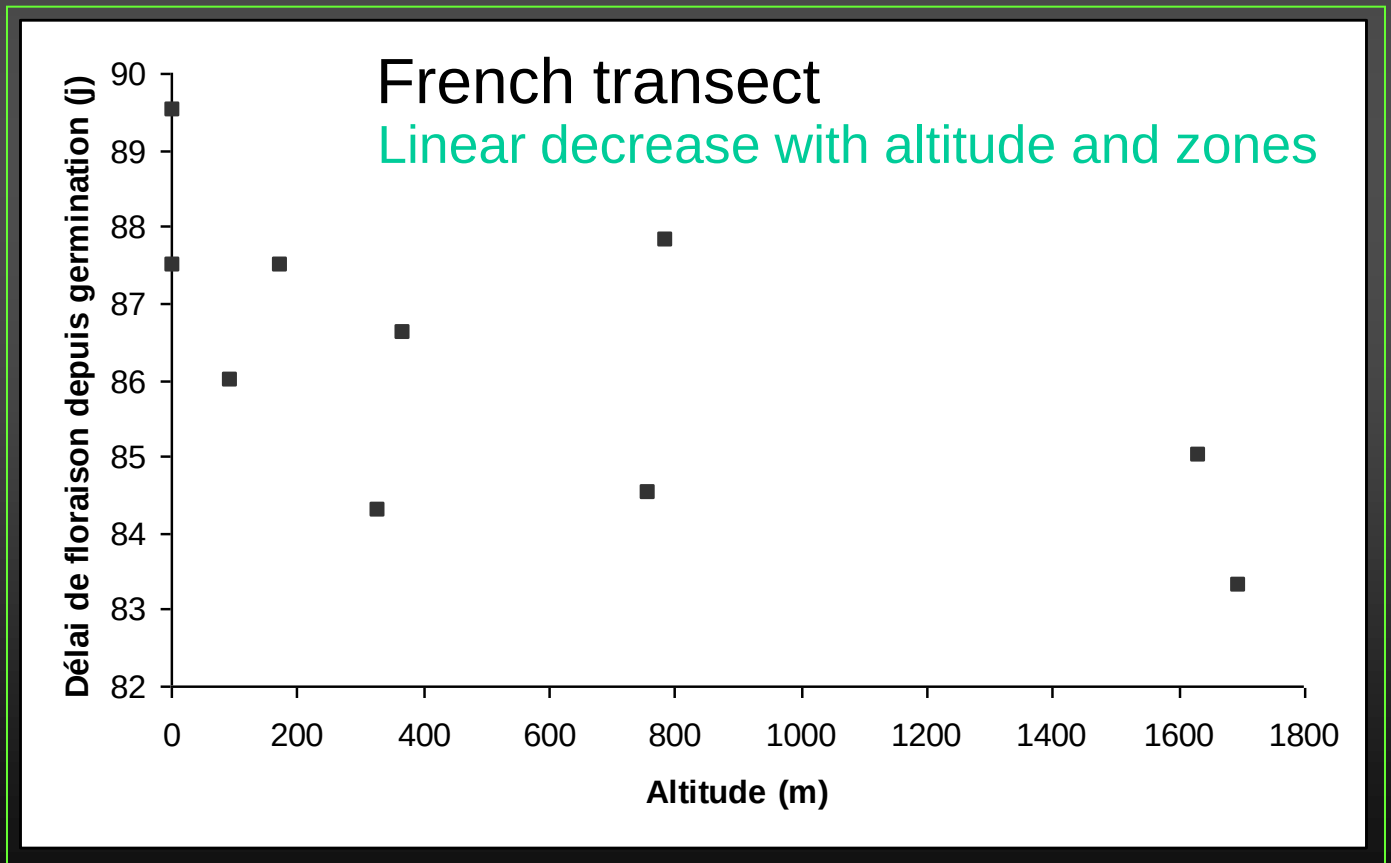

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Plant height

- Height (date 1)

Comparison (ANOVA)	N	p value	Correlation with **altitude** (p value)		Correlation with **transect zones** (p value)	
			r Pearson	R Spearman	r Pearson	R Spearman
Cytotypes	60	0,527				
Primary evolution phase	80	0,46				
Zones of French transect	100	0,128	0,13	**0,008**	**0,028**	**0,01**
Zones of Belgian transect	80	0,171	0,231	0,289	0,333	0,482

- Height (date 2)

Comparison (ANOVA)	N	p value	Correlation with **altitude** (p value)		Correlation with **transect zones** (p value)	
			r Pearson	R Spearman	r Pearson	R Spearman
Cytotypes	60	0,439				
Primary evolution phase	80	0,077				
Zones of French transect	100	0,172	0,321	**0,041**	0,084	**0,044**
Zones of Belgian transect	80	**0,04**	0,096	0,07	0,078	0,062

- Height (date 3)

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Cytotypes	60	0,493				
Primary evolution phase	80	0,622				
Zones of French transect	100	**0,01**	**0,006**	**0,003**	**0,003**	**0,003**
Zones of Belgian transect	80	0,562	0,872	1	0,897	1

- Height (date 4)

Comparison (ANOVA)	N	p value	Correlation with **altitude** (p value)		Correlation with **transect zones** (p value)	
			r Pearson	R Spearman	r Pearson	R Spearman
Cytotypes	60	0,443				
Primary evolution phase	80	0,901				
Zones of French transect	100	0,058	**0,027**	**0,039**	**0,004**	**0,017**
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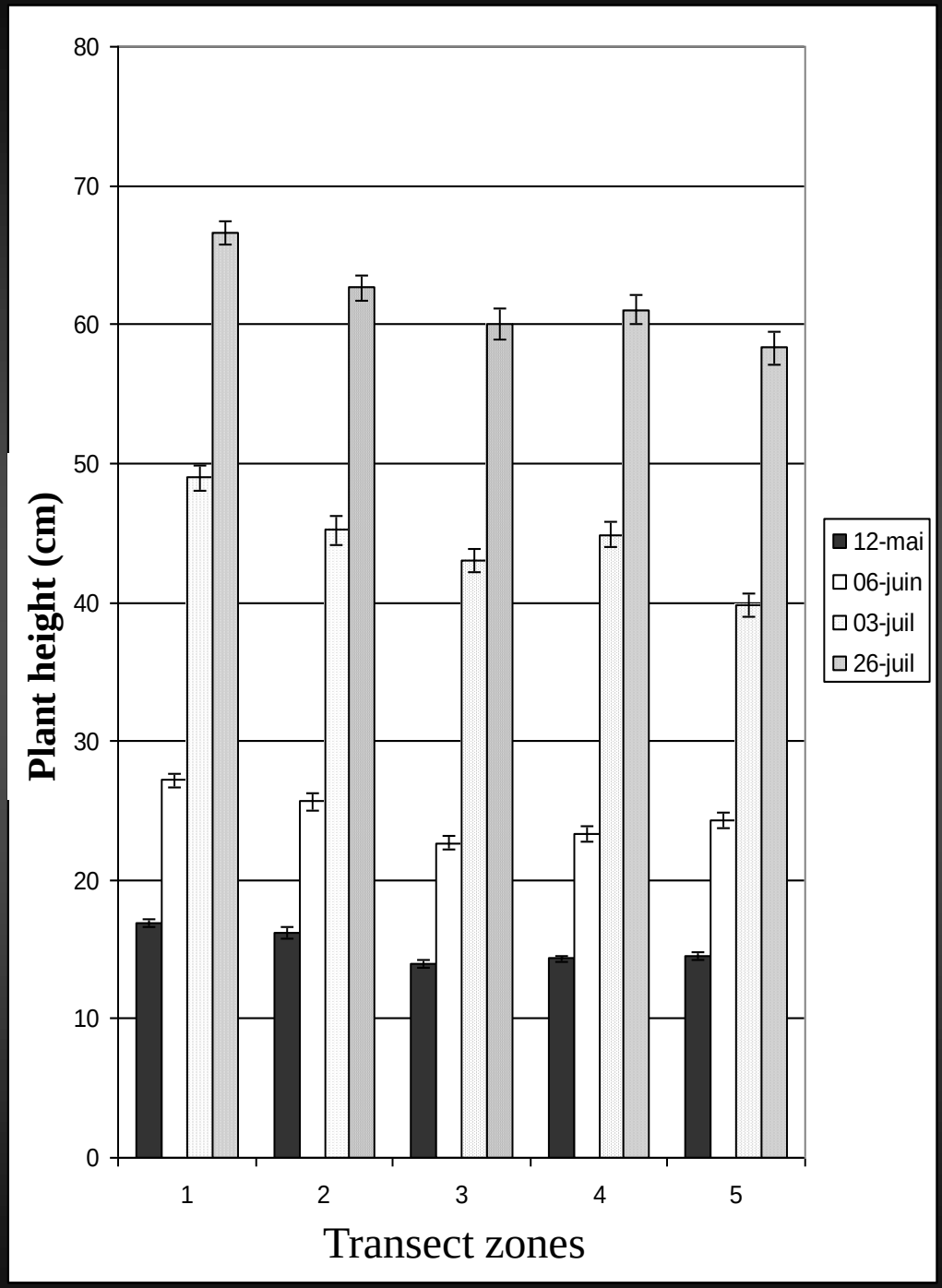
Plant height

French transect

Decrease with altitude and zones for each measurement date



Plant height

French transect

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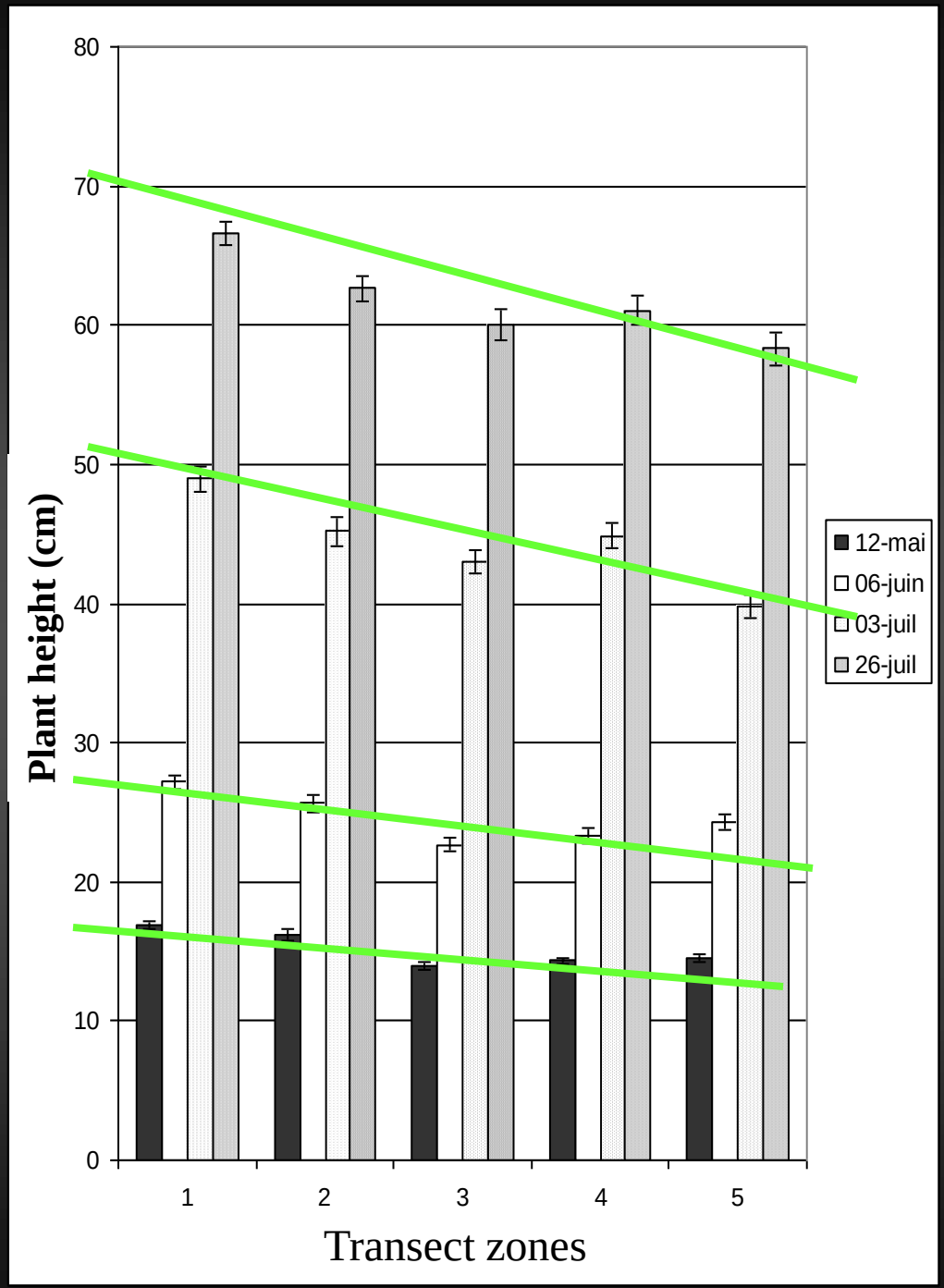

Plant volume

- Volume (date 1)

Comparison (ANOVA)	N	p value	Correlation with **altitude** (p value)		Correlation with **transect zones** (p value)	
			r Pearson	R Spearman	r Pearson	R Spearman
Cytotypes	60	0,345				
Primary evolution phase	80	0,579				
Zones of French transect	100	0,055	0,249	0,098	**0,05**	0,106
Zones of Belgian transect	80	0,648	0,343	0,736	0,755	1

- Volume (date 2)

Comparison (ANOVA)	N	p value	Correlation with **altitude** (p value)		Correlation with **transect zones** (p value)	
			r Pearson	R Spearman	r Pearson	R Spearman
Cytotypes	60	**0,008**				
Primary evolution phase	80	**0,024**				
Zones of French transect	100	0,242	0,205	0,074	0,083	0,106
Zones of Belgian transect	80	0,058	0,648	0,61	0,676	0,729

- Volume (date 3)

Comparison (ANOVA)	N	p value	Correlation with **altitude** (p value)		Correlation with **transect zones** (p value)	
			r Pearson	R Spearman	r Pearson	R Spearman
Cytotypes	60	0,084				
Primary evolution phase	80	0,178				
Zones of French transect	100	**0,039**	**0,014**	**0,001**	**0,001**	**0,001**
Zones of Belgian transect	80	0,836	0,614	0,867	0,82	0,909

- Volume (date 4)

Comparison (ANOVA)	N	p value	Correlation with **altitude** (p value)		Correlation with **transect zones** (p value)	
			r Pearson	R Spearman	r Pearson	R Spearman
Cytotypes	60	0,379				
Primary evolution phase	80	0,233				
Zones of French transect	100	**0,001**	**0,016**	**0,001**	**0**	**0**
Zones of Belgian transect	80	0,537	0,131	0,233	0,157	0,22

Plant volume

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Cytotypes	60	0,084				
Primary evolution phase	80	0,178				
Zones of French transect	100	**0,039**	**0,014**	**0,001**	**0,001**	**0,001**
Zones of Belgian transect	80	0,836	0,614	0,867	0,82	0,909

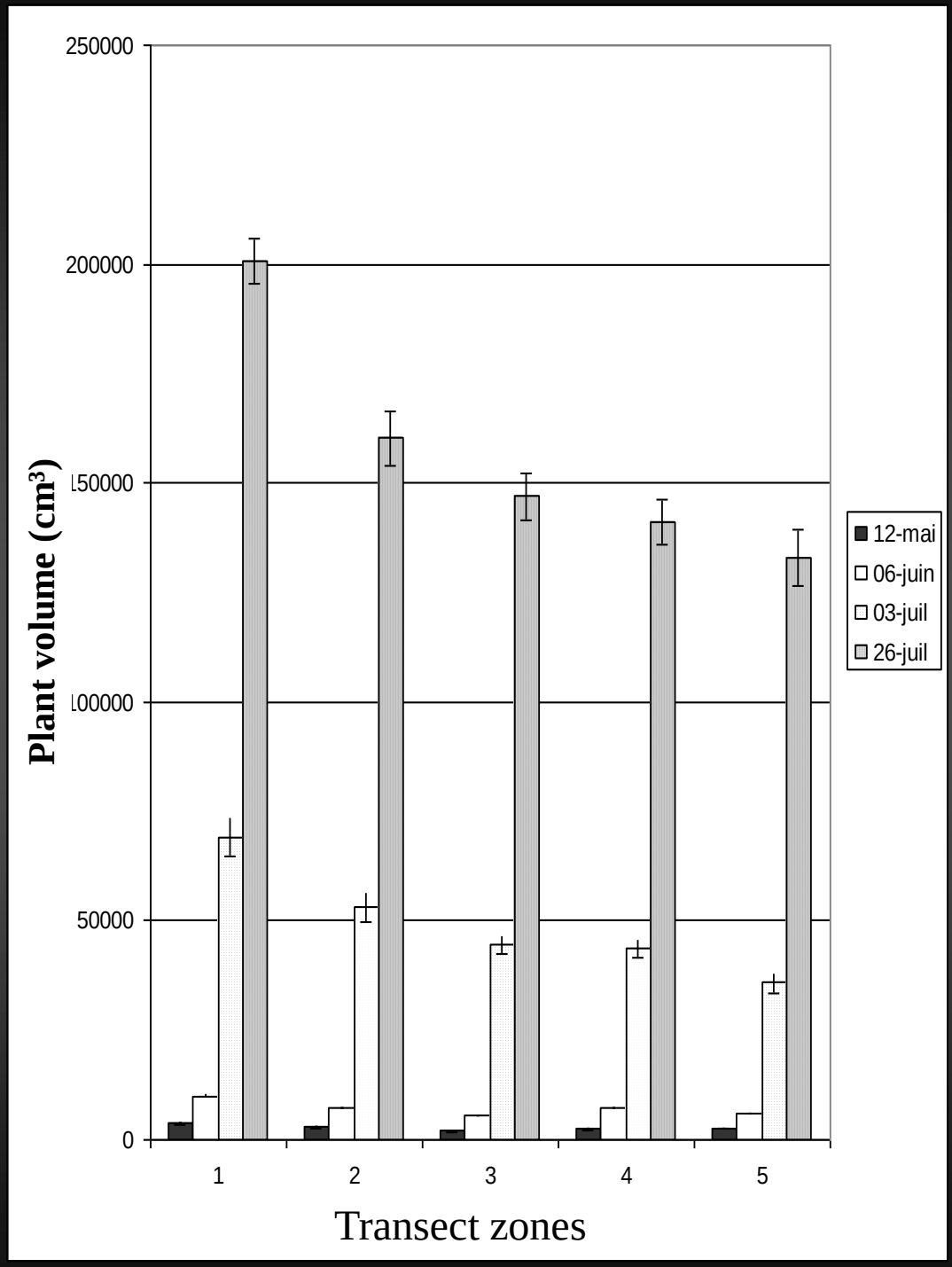
- Volume (date 4)

Comparison (ANOVA)	N	p value	Correlation with **altitude** (p value)		Correlation with **transect zones** (p value)	
			r Pearson	R Spearman	r Pearson	R Spearman
Cytotypes	60	0,379				
Primary evolution phase	80	0,233				
Zones of French transect	100	**0,001**	**0,016**	**0,001**	**0**	**0**
Zones of Belgian transect	80	0,537	0,131	0,233	0,157	0,22

Plant volume

French transect

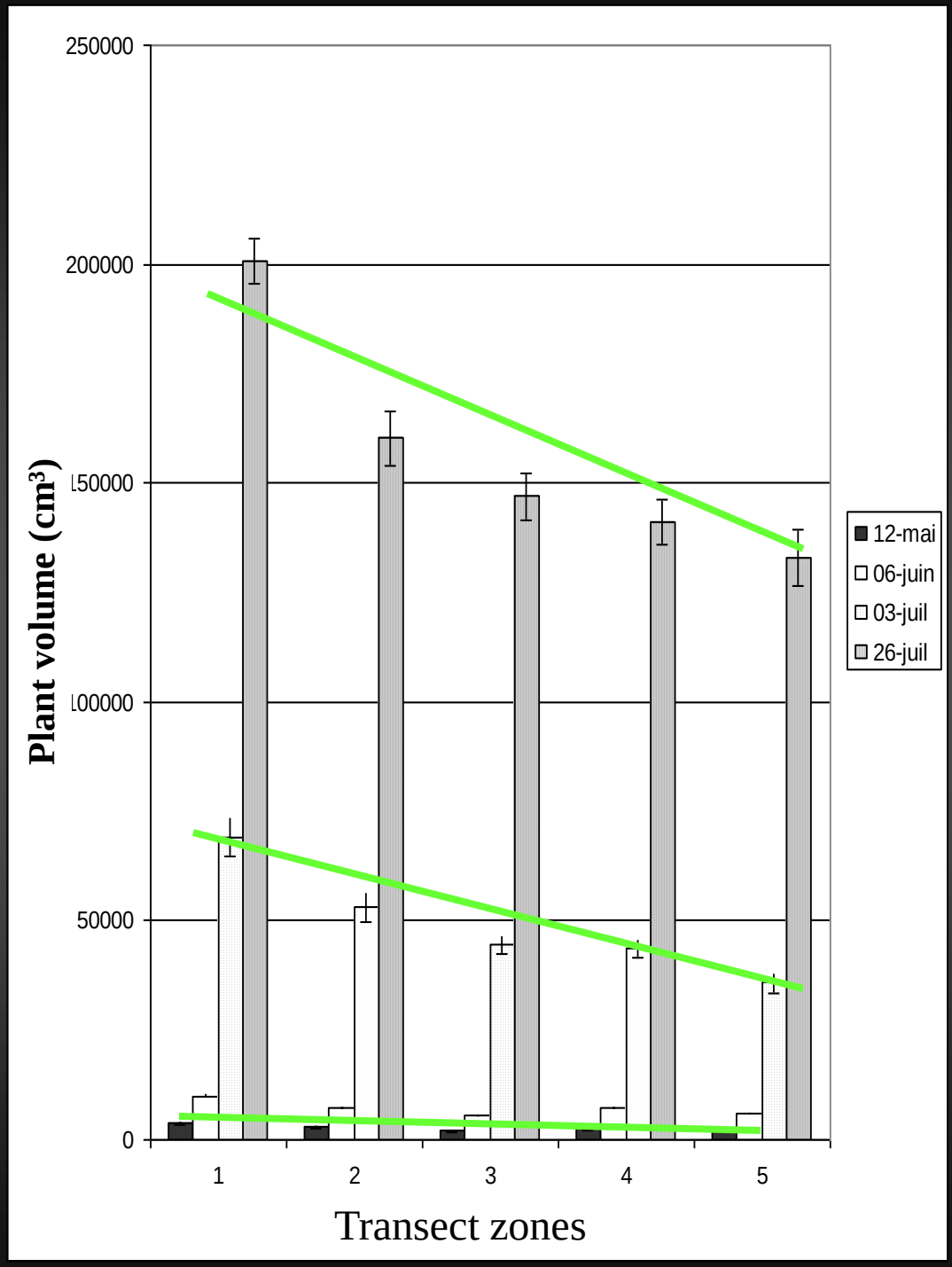
Linear decrease with altitude and zones



Plant volume

French transect

Linear decrease with altitude and zones




4. Discussion

Discussion: differences between cytotypes

- Almost no differences between cytotypes
- These results cannot explain the absence of diploids in Europe…

Discussion: primary evolution phase

- Almost no differences between (a) African tetraploid control populations and (b) Introduction areas populations

- These results don’t support the hypothesis of a primary evolution phase…

  ➔ Phenotypic plasticity ?

  … further data is needed (about reproductive success, winter survival, biomass, …) to fully characterise the primary invasion.

NB: More African control populations could be suitable…

Discussion: secondary evolution phase

- Almost no differences along belgian transect…

  …But **clear differenciation along the French transect** (more contrasted) !

- Secondary evolution phase (rapid evolution) correlated with altitude

- In France, plants originating from high elevations:

  - Germinate later : *already shown for non-alien species*…
  - Bloom at a lower age : *adaptation to shorter vegetation period ?*
  - Remain smaller : *harsher conditions, difference in trade-off between reproduction and growth ?*


5. Conclusion and perspectives

Conclusion and perspectives

- **Difference between cytotypes**
- **Primary evolution phase**

} Further data needed !

- **Clinal evolution along altitudinal and climatic transect:**
  - ❖ Rapid evolution phenomenon in a secondary evolution phase
  - ❖ In the future:
    - Finer analysis: correlation with direct meteorological data (real selection agent)
    - Reciprocal transplants along the french gradient
      - ➔ Understanding the adaptative benefit of the evolution
      - ➔ Collaboration needed…. **?!**


Thank you for your attention !