Pi = Gi + ei.

Stability across Environments of the Coffee Variety Near Infrared Spectral Signature

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Heredity, 2008

Purpose of the study

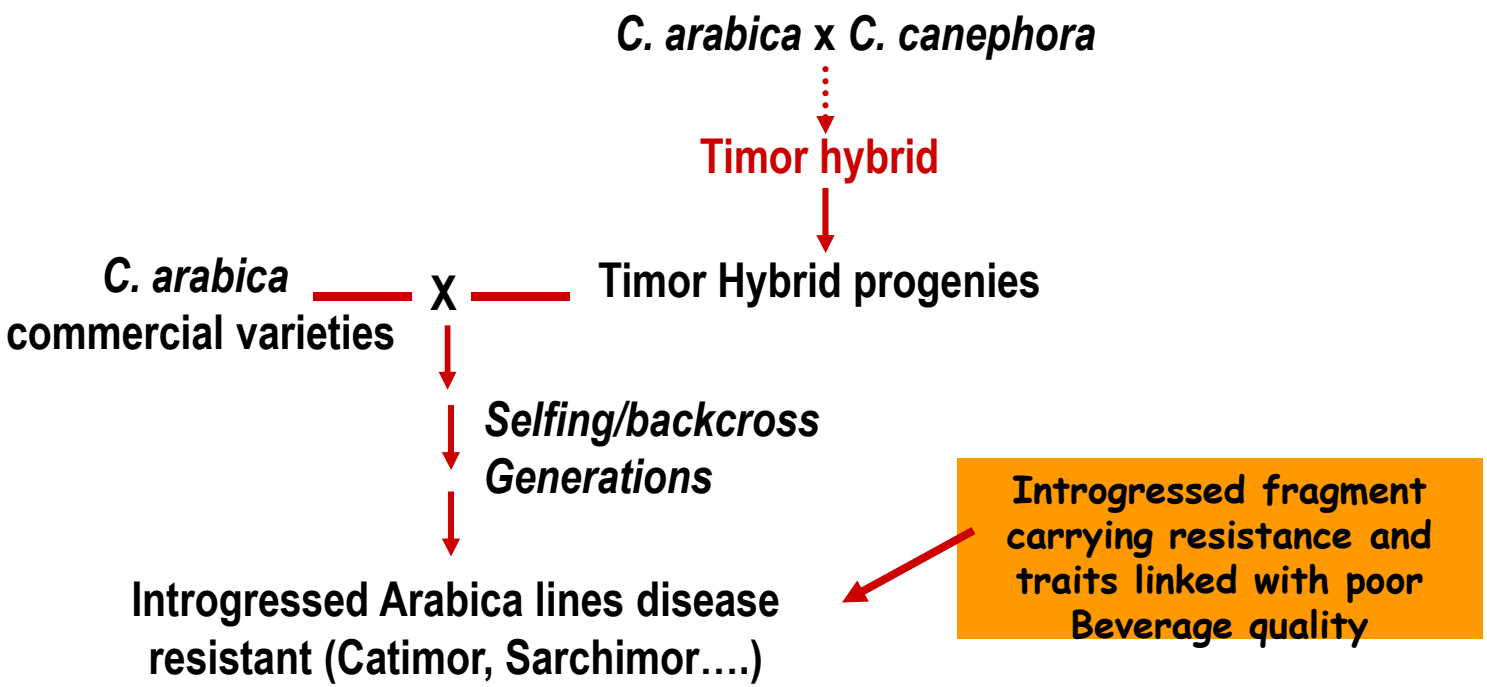
The chemometric discrimination of the two coffee species *C. arabica* and *C. canephora* have been tested with success (Downey et Boussion 1996., Esteban-Diez et al., 2002…).
Based on NIR spectra treatment, we also investigated ways of discriminating between introgressed varieties and non-introgressed (Bertrand et al. 2005).

The purpose of this study was to assess the application of a Near Infrared Spectroscopy (NIRS) methodology to assist in the selection of introgressed lines.

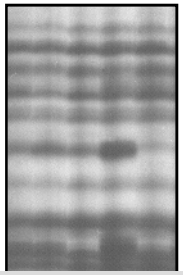
Hypothesis: the NIRS signature is heritable across environment

The **Timor Hybrid**, a natural hybrid originating from an interspecific cross between *C. arabica* and *C. canephora (Robusta)* is being extensively used as the main source of resistance to diseases for arabica breeding.

Introgression into *C. arabica* (4x) from *C. canephora* (2x)



Identification of resistance-linked AFLP markers



Genetic map of the introgressed fragment carrying *Mex-1*

length of time needed for coffee tree generation,

the high cost of field trials,

the lack of accuracy in the current strategy to restore the genetic background of the recipient cultivar and thereby ensure the good quality of the improved variety.

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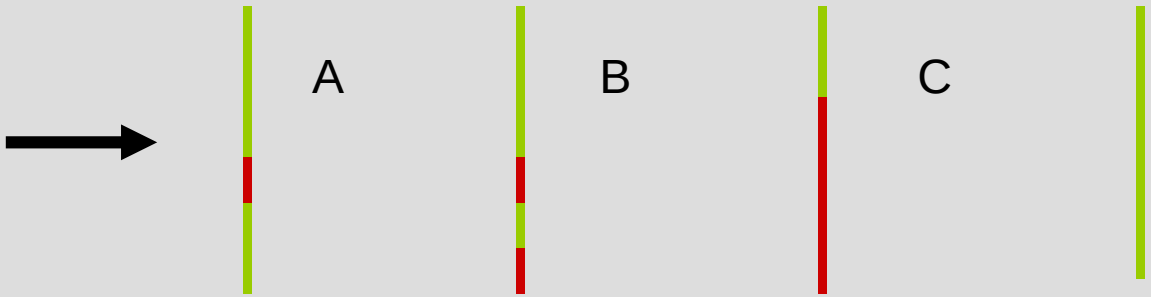


Mat. & Meth.

Harvest Year 1 – 3 samples (=3 blocks= 10 trees)

Year 2 – 3 samples ((=3 blocks= 10 trees)

mer
lyse
IFC
spectively ‘Chinchina, ‘Paraguicito’, ‘Rosario’.
ove sea level).

		Location 2	***Location 3***
	(1381 m.a.s.l)	**(1250 m.a.s.l)**	**(1635 m.a.s.l)**
A	X	X	X
B	X	X	X
C	X	X	X
D	X	X	X
		X	X
		X	X
		X	X
		X	X
		X	X
		X	X
		X	X
		X	

Mat. & Meth.

NIRS phenotyping

- NIR reflectance spectra were collected using a scanning monochromator NIRsystems spectrophotometer (model 6500, Perstrop Analytical Inc, 1201 Tech Road Silver Spring, MD 20904 USA) driven by NIRS2 (4.0) software (Intrasoft Intl., LLC, RD109, Sellers Lane, Port Matilda, Pa 16870).
- The analyses were performed on green coffee (50 g) after grinding (ground to < 0.5 mm). For each sample, a NIR spectrum was acquired in reflectance (R) mode.

Results

if we consider the variety Caturra, which was the control variety as it is the most widely planted variety in the world, it can be seen that the distances from the other varieties were not the same between the two harvests.

Consequently, it is evident that it is not possible to propose selection according to relations of proximity between the variety Caturra and introgressed lines based on a single harvest.

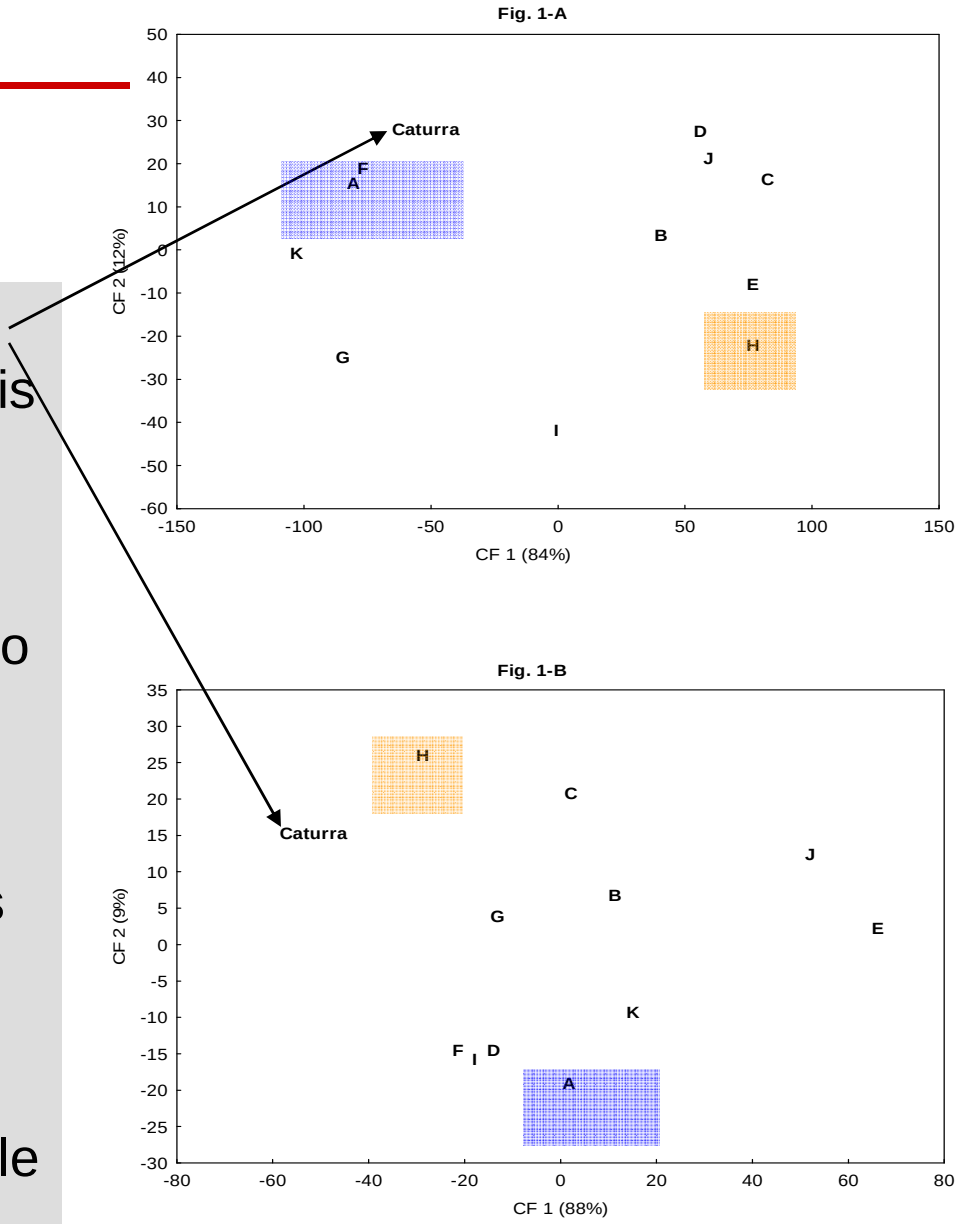


Figure 1.

Results

Heritability as a function of wave number

- The near infrared diffuse reflection spectra (log 1/R) for the ground green coffee obtained for harvest 1 were very similar to those obtained for harvest 2 (Fig.2). The heritabilities calculated for harvest 1 and for harvest 2 were also very similar, making it possible to calculate a mean heritability (h^2 mean).

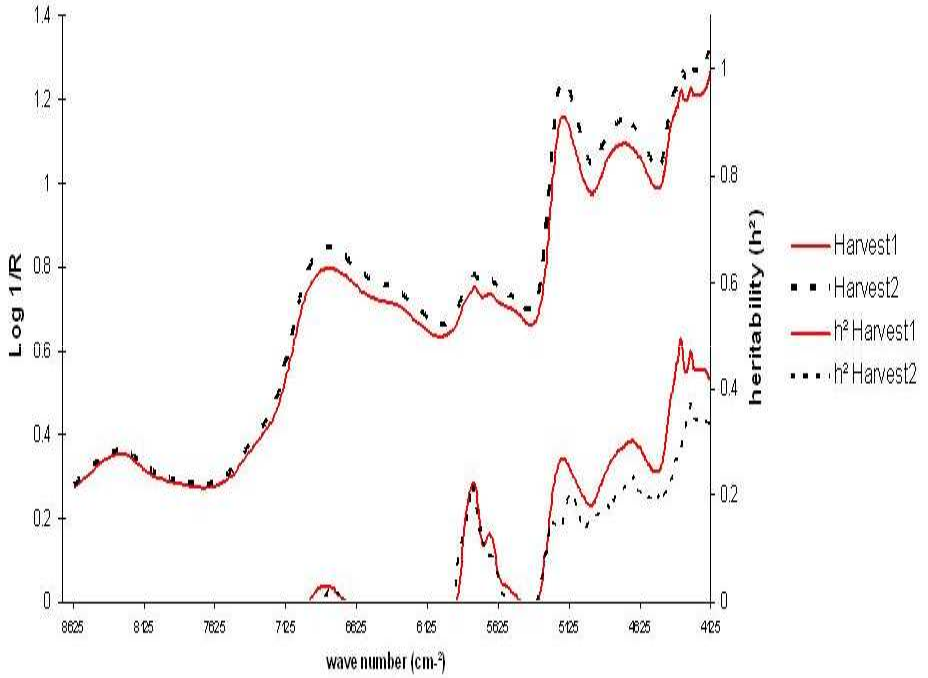


Figure 2.

$$H_b^2 = \sigma^2 F / (\sigma^2 F + \frac{1}{3}\sigma^2(F3) + \frac{1}{(2x3)}\sigma^2 e)$$

Results

NIR spectral signature across environments

For each site and each harvest, square Euclidean distances between the 12 accessions were estimated based on NIR spectra. The distance matrices between varieties obtained in that way were compared by a Mantel test to determine whether there existed any correlation between two matrices

Results

Pairwise comparisons of distance matrices between varieties determined at 3 different sites (numbered 1, 2, 3). The tables indicate correlations between sites for harvest 1 (tables 1-A and 1-B), for harvest 2 (tables 1-C and 1-D) and for the mean of the two harvests (tables 1-E and 1-F). In tables 1-A, 1-C and 1-E, the correlations were calculated from the distance matrices obtained from the whole spectrum; in tables 1-B, 1-D and 1-F, the correlations were calculated from the distance matrices obtained from the heritable values. For each site, square Euclidean distances between the 12 varieties were estimated based on NIR spectra. Matrix correlation coefficients between matrices are indicated and assessed according to the Mantel test.

1-A Harvest 1, all wave numbers

Site	1	2
3	-0.07 (0.55)	0.21 (0.11)
2	0.72 (0.00)	

1-B Harvest 1, [5,800-5,767], [5,235-4,000] cm^{-1} intervals

Site	1	2
3	0.63 (0.00)	0.56 (0.00)
2	0.55 (0.00)	

1-C Harvest 2, all wave numbers

Site	1	2
3	0.05 (0.31)	0.03 (0.56)
2	0.04 (0.42)	

1-D Harvest 2, [5,800-5,767], [5,235-4,000] cm^{-1} intervals

Site	1	2
3	0.02 (0.58)	0.03 (0.53)
2	0.18 (0.16)	

1-E Mean of Harvest 1-2 all wave numbers

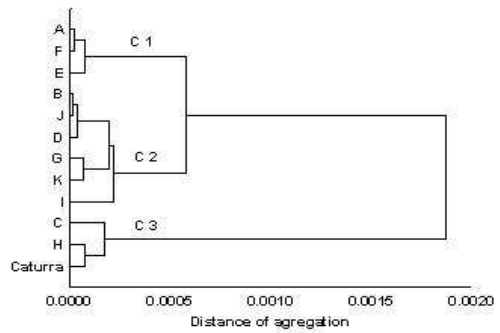
Site	1	2
3	0.49 (0.00)	0.21 (0.06)
2	0.42 (0.01)	

1-F Mean of Harvest 1-2, [5,800-5,767], [5,235-4,000] cm^{-1} intervals

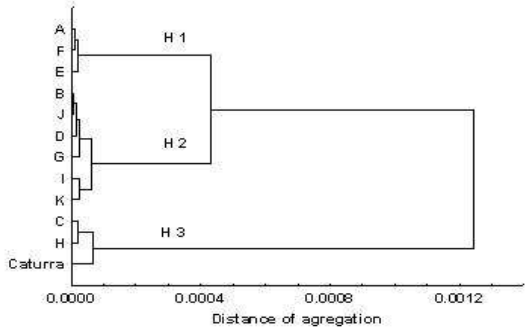
Site	1	2
3	0.81 (0.00)	0.56 (0.00)
2	0.55 (0.00)	

Results

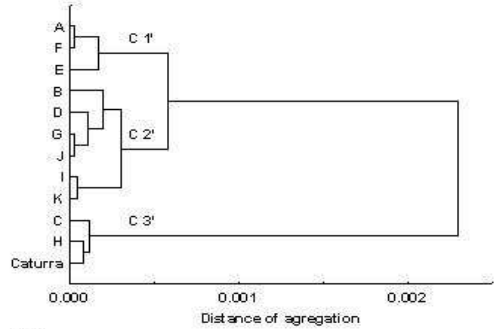
The results suggested stability across environments for inter-variety relationships determined using NIRS-based square Euclidean distances.



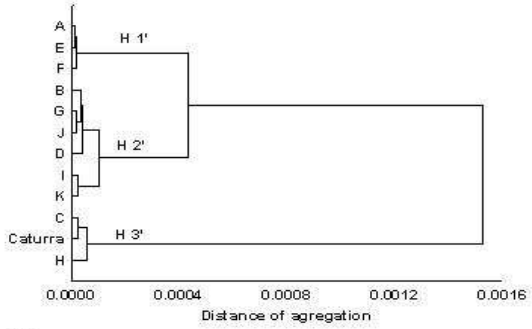
4-1



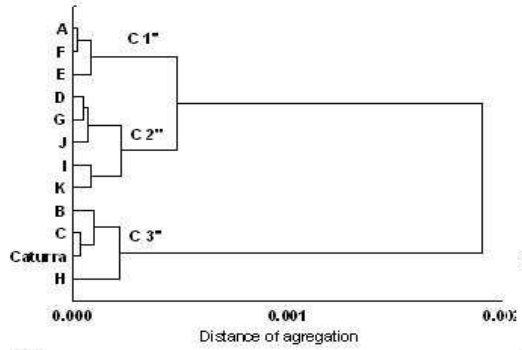
4-4



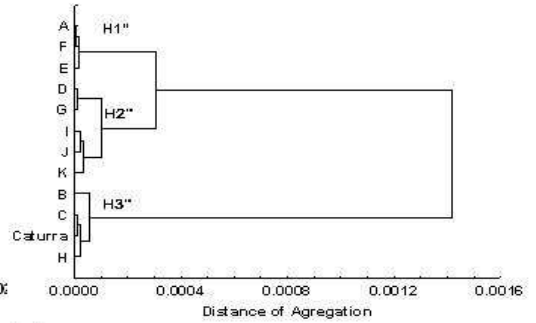
4-2



4-5



4-3



4-6

Figure 4.

Conclusion

After many other authors, we show the power of the NIRS signature which proves to be much less expensive than traditional chemical analyses for discriminating between varieties.

The introgressed varieties were easily distinguished from the standard arabica variety (i.e. Caturra) used as the reference variety in the trials and the recurrent parent in the backcrosses.

Unfortunately, we also show that the differences between varieties prove not to be stable from one harvest to another. Obviously, NIRS profiles are strongly affected by environmental factors. We therefore sought to minimize environmental effects.

Conclusion

When calculating the distances over two harvests, the relations between lines were very stable from one site to the next. The established relationships between lines appeared to be well conserved across locations. The NIRS-based inter-variety relationships determined at one site appeared to be stable across environments.

The efficiency of the method was greatly increased if only certain zones of the spectrum were kept. To select those zones of the spectrum, we treated infrared spectra as a sequence of discrete variables that displayed a genetic variance and an environmental variance. The ratio of genetic variance to the sum of variances amounted to heritability. Spectral regions where absorbance displayed high heritability and spectral regions where heritabilities were not significant or null were revealed.

Conclusion

The signature becomes a trait on which selection can be based through comparison with ideotypes. For example, in the dataset we analysed one of the possible applications was to select lines closest to cv ‘Caturra’, which is an acknowledged standard in terms of cup quality. Indeed, it can be assumed that the closer a line is to cv ‘Caturra’, the closer its biochemical composition will be and the less it will display sensory differences from the reference variety.

Conclusion

We concluded that the NIRS methodology will be an efficient tool to assist in the selection of introgressed lines.

Our results confirm that infrared spectroscopy is an inexpensive high through-put phenotyping tool that can be used by breeders for indirect selection based on biochemical composition, and consequently on cup quality, in the coffee tree, but probably also in other species.

Prédiction des enfants à partir de la Valeur propre des parents

A partir des parents moyens, est-il possible de prédire les hybrides ?

⇨ Limiter le nombre de croisements à réaliser

⇨ Optimiser les choix

• **Méthode**

Comparaison Parents moyens *vs* hybrides réels

⇨Test de Mantel

Sur intervalles héritables

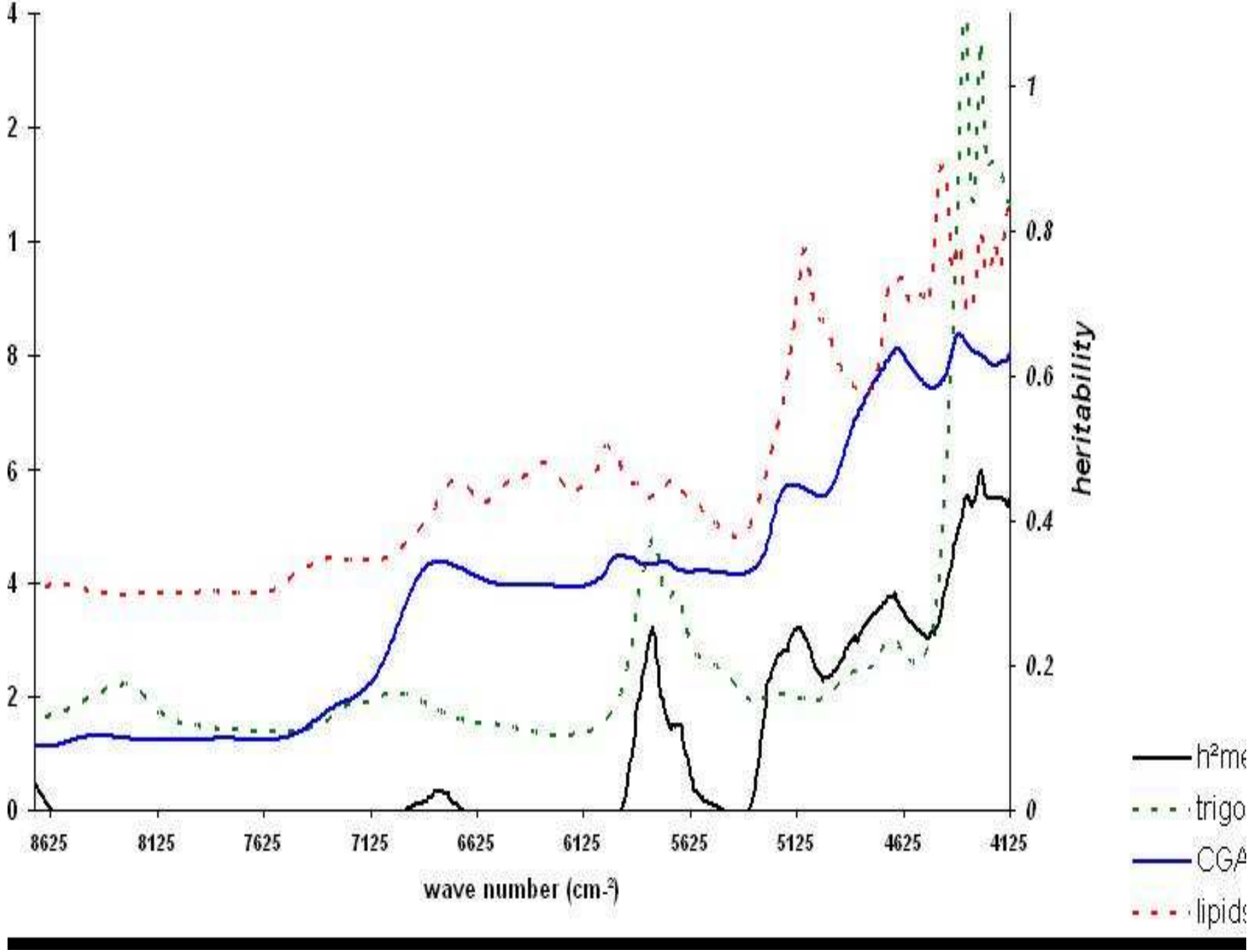
• Données : Dispositif diallèle

M D^2 Mahalanobis –Parents moyens / M D^2 Mahalanobis – hybrides observés

Test de Mantel : r =0.51 avec p=0.001

La structure de la population hybride peut être approchée à partir de la population parentale par l'intermédiaire des parents moyens.

Forte additivité signature NIRS


4
2
1
8
6
4
2
0
1
0.8
0.6
0.4
0.2
0
heritability
8625
8125
7625
7125
6625
6125
5625
5125
4625
4125
wave number (cm-2)
h²me
trigo
CGA
lipids