NIRS uses for breeding purposes

- 1) Breeding Purposes:
  Targets and means.
- 2) Laboratory Samples Analysis :
  For Ground or Whole seeds
- 3) On Line NIRS Plots Analysis :
  For Fresh forage or fresh kernels.
- 4) NIRS as a breeding tool, summary.

NIRS uses for breeding purposes:
1) Breeding Purposes: Targets and means.

- 1.1) Summary of Main Breeding Crops Targets:

Breeding Purposes *Crops Targets* Summary:				
Species	***Fields Criteria***	***Maturity***	***Quality criteria***	***Process***
Field Crops Grain:				Food & Feed
Wheat (s)	Yield, diseases, lodging	%Water	Protein, Starch	Bakery
Barley (s)	Yield, diseases, lodging	%Water	Protein, Starch	Brewery
Peas	Yield, diseases, lodging	%Water	Protein, Starch,	Crushing
Maize	Yield, diseases, lodging	%Water	Starch, Protein, Oil	Dry & Wet Milling
Rapeseed	Yield, diseases, lodging	%Water	Oil, Protein, Gluco, F A	Crushing
Sunflower	Yield, diseases, lodging	%Water	Oil, Protein, Fatty Acids	Crushing
Soya	Yield, diseases, lodging	%Water	Oil, Protein	Crushing
Field Crops Forages:				Feed
Maize	Yield, diseases,	%HDM	Digest, NDF, Protein	Silage
Grass	Yield, diseases,	%HDM	Digest, NDF, Protein	Hay & Silage
Legume	Yield, diseases,	%HDM	Protein, Digest, NDF	Hay & Silage
Vegetables Crops:				Food
Roots	Yield, diseases	%Water	Sugars, colour, life	Fresh & Canned
Fruits	Yield, diseases	%Water	Sugars, colour, life	Fresh & Canned
Others	Yield, diseases	%Water	....	

NIRS uses for breeding purposes:
1) Breeding Purposes: Targets and means.

- 1.2) Summary of Main Breeding Means:
- Breeding means use either natural (Germplasm) or biotech tools…

Breeding Purposes ***Crops Targets and means*** Summary:

Fields Criteria	***Expression***	***Method***	***End use***	***Comments***
Yield	To/ha	Plot Weighting	Farmer Income	*with an average yearly increase around 1%*
Maturity	%HDM %Water	Fresh & Dry Weight Oven drying Or *Electric Resistivity*	Geographical planting & harvesting	***Indicate maturity group area Earliness***
Diseases	% Attack	Hand counting	Yield limitation	More pressure to resists to more pests (bacteria, viruses…) and insects (borer, worms…) attacks
Lodging	%Fall	Hand counting	Yield limitation	Resistance to stem breaking from wind storm
Quality criteria		***a) Biochemistry***		
Protein, Amino Acids	%DM %DM	Kjeldahl, HPLC	Bakery Brewery Feed	Highest value for Wheat Lowest value for Barley Lysine complementation
OIL, Fatty Acids Glucosinolates	%DM %DM %FA M. moles	SOXTEC GC HPLC	FOOD FEED	extraction, Omega 3 ratio Regulation Energy Intake
Starch, Amylose Soluble Sugar	%DM %DM % Starch %DM	Ewers, Extract + Iodine Coloration	FEED Wet Milling ….	Energy intake Starch recovery, Starch functionality Taste, Energy recovery
Fibre, NDF, ADF, ADL	%DM %DM	Weende, Van Soest	FEED	Celluloses Cell Wall contents
Cellulasis IVDM	%DM	DeBoever, Aufrere	FEED	In Vitro Digestibility

NIRS uses for breeding purposes:
1) Breeding Purposes: Targets and means.

- 1.3) Summary of Main Breeding Means:
- Process methods are time consuming !

Breeding Purposes ***Crops Targets and means*** Summary:

Quality criteria	***Expression***	***Method***	***Comments***
b) Process Method		***FOOD***	
BREWERY	% As Is	MALT Extraction	Barley uses
BAKERY: W, P, L or other European References …	% As Is	Chopin Bread Making Sedimentation Tests	Wheat uses for different European bread needs…
DRY Milling	% As Is	LAB. Mini Mill Grinding	% Flour or Semolina on Wheat & Maize recovery
Flour or Semolina quality	% As Is	Particules sizes distribution by sieves	Wheat & Maize final uses (Flakes/cakes)
WET Milling	% As Is	Starch extract functionalities	Maize Starch industrial uses (coating, …)
CRUSHING	% As Is	LAB Oil Seeds Crusher	Sunflower oil extraction
CANNED FOOD	% As Is	LAB process	Fresh pea industrial uses…
….			
c) Process Method		***FEED***	
In Vivo Digestibility	% DM	From Beef, Ship	Silage & Hay % off efficient use by ruminants, On Maize, grass & legume
In Vivo Energy	MJ	Calorimetric bomb On before/after intakes	Metabolisable energies for Pig & poultry On Cereals Grains
….			

NIRS uses for breeding purposes:

1) Breeding Purposes: Targets and means.

- 1.4) Summary of Main Breeding Means:
- For all those criteria this means hundred of thousand of breeding lines & next to be varieties plots to be :
  - 1) Planted,
  - 2) Observed in many location with climatic stress,
  - 3) Selfed or crossed, or open pollinated,
  - 4) Harvested by hand (nurseries) or by harvesters/choppers (plots)
  - **5) Crops samples have to be collected, treated and analysed in a few weeks just after harvest.**
  - **6) Inbred seeds quality must be checked before next planting in winter (south hemisphera) or spring…**
- **All new varieties must fit end users needs for food & feed. Most process in formations are connected to biochemistry analysis**
- **Quality criteria must be checked from very early stage of breeding process.**

NIRS uses for breeding purposes:

1-5) Breeding Purposes: Breeding schema, Summary.

Year	Source	F.Generation I		%Purety	Nursery	Plots	Field Criteria	Quality Criteria
1	GermPlasm	R 0	R 0	0.1%	10		Diseases, Lodging, Maturity	Biochemistry
2	GermPlasm	R 1	R 1	0.1%	100		Diseases, Lodging, Maturity	Biochemistry
3	GermPlasm	R 2	R 2	0.1%	1 000		Diseases, Lodging, Maturity	Biochemistry
1	Cross 1	C 1	C 1	50.0%	100			
	Cross 2	C 2	C 2	25.0%	50			
2	Cross 3	C 3	C 3	12.5%	25			
1	Self	S. 1	S. 1	50.0%	100			
2	Self	S. 2	S. 2	75.0%	50			
3	Self	S. 3	S. 3	97.5%	30	5 000	Yield, Diseases, Lodging, Maturity	Biochemistry
4	Self	S. 4	S. 4	98.0%	20	2 000	Yield, Diseases, Lodging, Maturity	Biochemistry
5	Self	S. 5	S. 5	98.4%	10	1 000	Yield, Diseases, Lodging, Maturity	Biochemistry
6	Self	S. 6	S. 6	98.8%	10	1 000	Yield, Diseases, Lodging, Maturity	Biochemistry
7	Self	S. 7	S. 7	99.2%	10	1 000	Yield, Diseases, Lodging, Maturity	Biochemistry
8	Self	S. 8	S. 8	99.6%	10	1 000	Yield, Diseases, Lodging, Maturity	Biochemistry, Process
	Hybrids	H. 1	H. 1	100%	100		Yield, Diseases, Lodging, Maturity	Biochemistry, Process
9	Test 1	Premium tests			80	5 000	Yield, Diseases, Lodging, Maturity	Biochemistry, Process
10	Test 2	Final Tests			60	2 000	Yield, Diseases, Lodging, Maturity	Biochemistry, Process
11	Test 3	**Official Tests**						
12	Test 4	**Official Tests**			**10**	1 000	Yield, Diseases, Lodging, Maturity	Biochemistry, Process
1		Commercial use				**100**	Yield, Diseases, Lodging, Maturity	Biochemistry, Process
2		Commercial use				1 000	Yield, Diseases, Lodging, Maturity	Biochemistry, Process
3		Commercial use				2 000	Yield, Diseases, Lodging, Maturity	Biochemistry, Process
4		Commercial use				1 000	Yield, Diseases, Lodging, Maturity	Biochemistry, Process
5		Commercial use				100	Yield, Diseases, Lodging, Maturity	Biochemistry, Process

NIRS uses for breeding purposes

- 1) Breeding Purposes:
  Targets and means.
- 2) Laboratory Samples Analysis :
  For Ground Dry Matter or
  Intact Whole seeds (non destructive)

NIRS uses for breeding purposes :

2-1) Powder Analysis for Forages & Ground Grain and for Small Grain Whole Seeds Analysis:

- 2.11) Main fields crops: Silage Maize, Wheat, Barley, Rape seeds, Sunflower, Grass….

NIRS uses for breeding purposes :

2-121) Powder Analysis for Forages & Ground Grain and for Small Grain Whole Seeds Analysis:

- A) Forages & Grain Samples preparation: Drying & Grinding with hammer mill (D. 1mm holes)

NIRS uses for breeding purposes :

2-122) Powder Analysis for Forages & Ground Grain and for Small Grain Whole Seeds Analysis:

- B) Scanning: A volume of less than 5 cc of forage/grain powder or small Whole Seed is enough for NIRS spectra with the Mini cell :

2-1) NIRSystem +Auto Sampler:
2.13) Powder Analysis & Small Whole Seeds Analysis (Rape, Wheat, Barley…)

- **An average of 300 cups or samples can be recorded per day !**

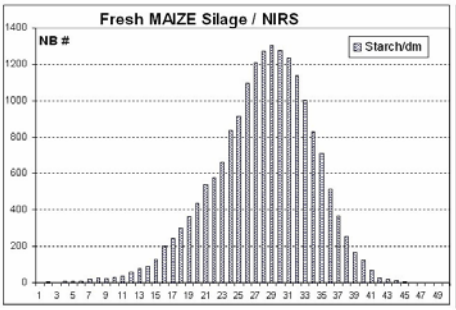
NIRS uses for breeding purposes :
2-14) Powder Analysis for Forages or Ground Seed,

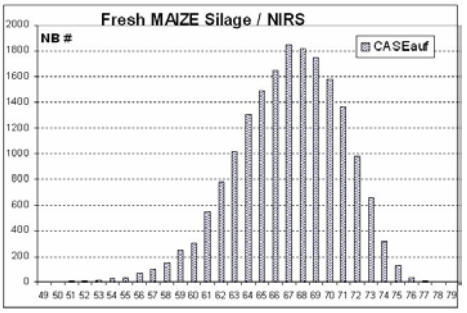
- Powder NIRS analysis :
  * Need drying and grinding of fresh forage samples.
  * Is a destructive method for all ground grain !
  Only Homogeneous grain samples must be ground…
- Mean spectra of Ground samples are done in one minute:
  * Sample preparation is similar to biochemistry process.
  * NIRS precision (SECV) is very close to wet chemistry and slightly better than whole Seeds analysis.
- Prediction of either biochemistry or process value on :
  * Plants parts such as Stover+leaves & ear or grain.
  * Experimental open pollinated plot samples.
  * Samples from Grain or Silage silo as final products (variety)

NIRS uses for breeding purposes :

2-15) Powder Analysis for Forages or Ground Seed,

- Example #1: NIRS Prediction distribution for Fresh Silo Maize Samples (dry & ground) on 18 000 #
- SECV : Starch/dm = 1.6 Cellulase IV/dm = 2.0

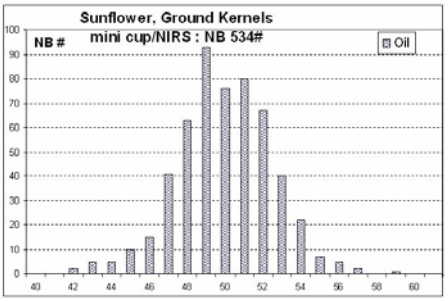


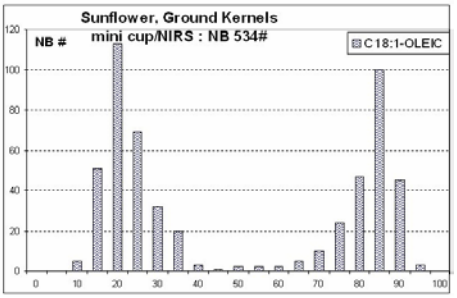


NIRS uses for breeding purposes :

2-16) Powder Analysis for Forages or Ground Seed,

- Example #2: NIRS Prediction distribution for Ground Sunflower Samples on 534 #
- SECV : Oil/dm = 1.10 Oleic/FA = 3.2





NIRS uses for breeding purposes :

2-2) Whole Seeds Analysis for Large Grain Crops (Maize, Soy, Bean, Pea ...) :

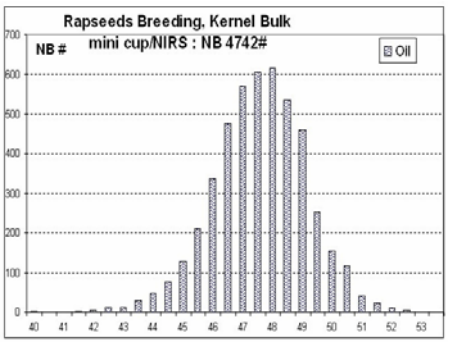
- NIRS analysis on whole grain is :
  * a non destructive method !
  All Selfed ear seed are send back to the breeder !
  * a very quick and cheap application.
- Mean spectra of Bulk analysis for:
  * Small Seeds vial with 5 cc only
  (=1 ear grain size on wheat or barley).
  * Large Seeds vial with 15 to 25 cc.
  They are recorded in 1' to 1'1/2.
- Prediction of either biochemistry or process value on :
  * Selfed ear shelled grain,
  * Experimental plot harvested grain Sample,
  * Grain Silo or bin samples as end products.

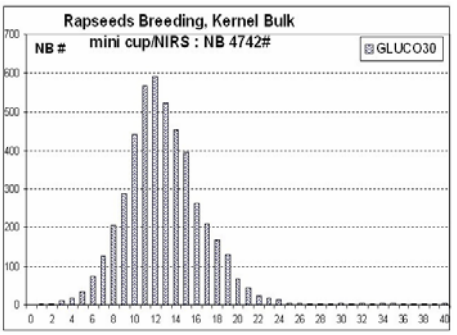
  NB: Industrial Process value are only available for Whole seed!

NIRS uses for breeding purposes :

2-21) Whole Seeds analysis on small grain

- Example #3: NIRS Prediction distribution for Rape Seeds Samples on 4 742 #
- SECV : Oil/dm = 1.10 Glucosinolates M.moles = 3.2

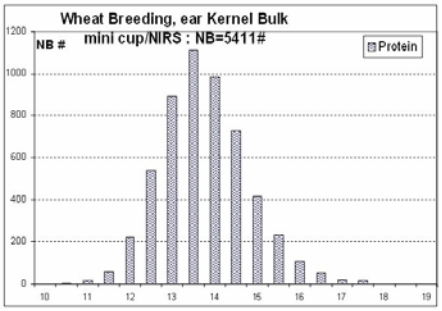


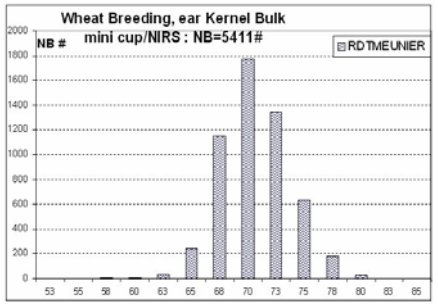


NIRS uses for breeding purposes :

2-22) Whole Seeds analysis on small grain

- Example #4: NIRS Prediction distribution for Wheat Grain breeding on 5 411#
- SECV : Protein/dm = 0.35 Mill Recovery = 3.3





NIRS uses for breeding purposes :

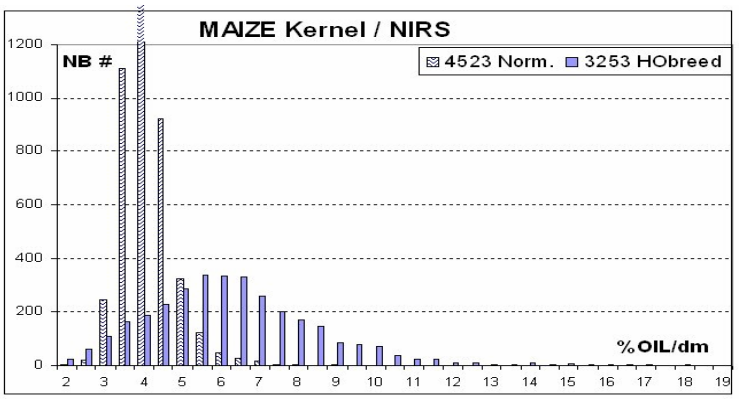
2-23) NIRSystem +Transport Module:
Whole Seeds Analysis for Large Grain Crops (Maize, Soy, Bean, Pea ...) :

- An average of 250 Maize samples can be recorded per day with the large cell.

NIRS uses for breeding purposes :

2-24) Whole Seeds Analysis for Large Grain Crops

- **Example #5: NIRS Prediction distribution for Maize Grain Samples on Whole Seed bulks:**
- **left = 4 523 normal field samples (grey line),**
- **right= 3 253 ear to row "HO breed" (blue lines) SECV : Oil/dm = 0.50**



NIRS uses for breeding purposes :

2-3) NIRS Single Seeds Analysis

For S.S.A. on large size grain crops two apparatus are available, depending on :

- Low Number of kernels per vial (<300K):

-> NIRSystem + auto sampler + Mini cell.

An average of 350 hand sorted kernels in 8 hours for:

* Oil, protein, starch, Amylose...
* Or others fine biochemistry contents.

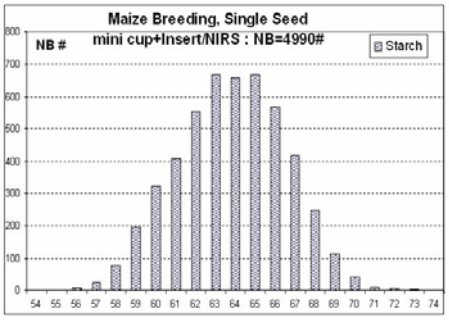
All steps are done by hand…

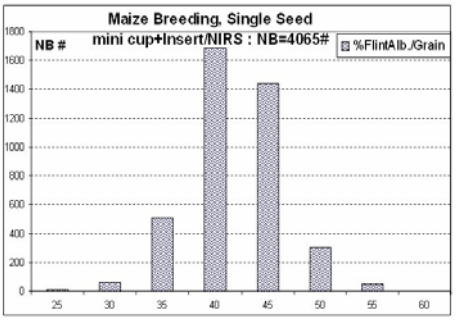
- For High Number of kernels per vial (>300K to 3 kg) we must use the -> BRIMROSE SEED MEISTER

NIRS uses for breeding purposes

2-31) NIRS Single Seeds Analysis

- Example #6: Maize Kernels, Single Seeds Analysis
  Left to Right : Dent, Dent x Flint, Flint germ plasm
- SECV : Starch/dm = 1.9 %Flint Albumen/WS = 6.0

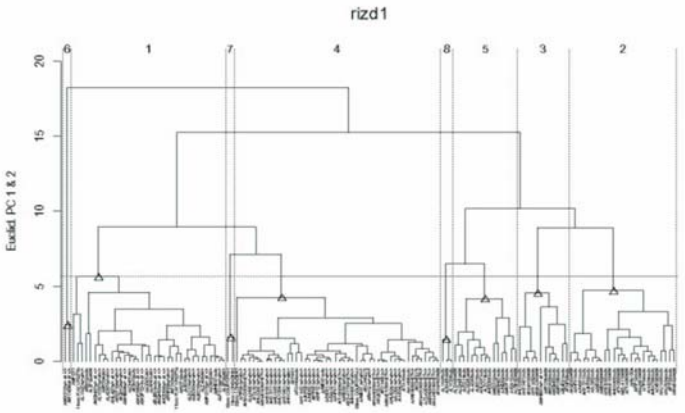




NIRS uses for breeding purposes

2-32) NIRS Single Seeds Analysis

- Example #7: NIRS Rice kernels Single Seeds Factorial Discriminant Analysis (cluster)



NIRS uses for breeding purposes

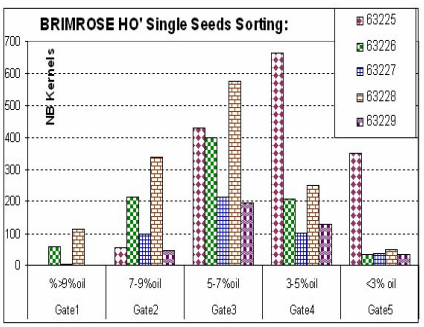
2-4) High Kernels Number Per Vial (< 3 Kg):

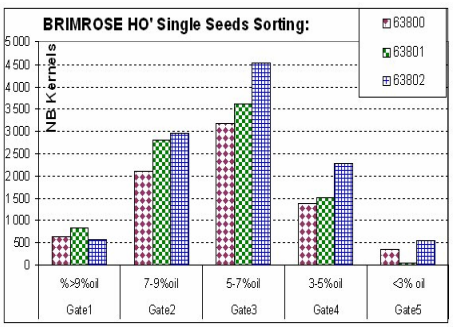
- BRIMROSE Seed Meister :
  An average of 300 automated sorted kernels *per hour* !

NIRS uses for breeding purposes

2-41) High Kernels Number Per Vial (< 3 Kg):

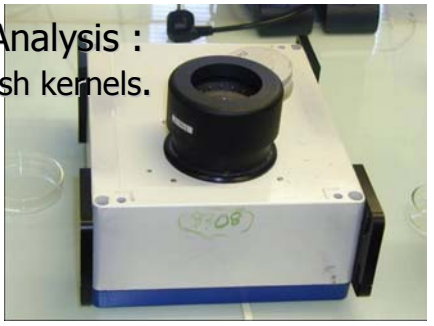
- Example #8: NIRS Prediction & Oil sorting for Single Seeds on Maize Grain for High Oil Breeding





NIRS uses for breeding purposes

- 1) Breeding Purposes:
  Targets and means.
- 2) Laboratory Samples Analysis :
  For Ground or Whole seeds
- 3) On Line NIRS Plots Analysis :
  For Fresh forage or fresh kernels.



3) On Line NIRS Plots Analysis :

3-101) NIRS ON LINE for Research Plots Harvester;

ZEISS CORONA Outside Laboratory Analysis:

- I) At Line Analysis:
  * Used for dedicated application on collected samples, when no harvester or chopper are available…
- II) One Line Analysis :

a) Harvest plot" flow measurement for chopped whole plant or threshed grain :

b) Each harvest plot flow is multi scanned & spectra averaged *in less than 3 seconds*, with no added delay while harvesting silage or grain crops…

c) Crop Spectra are treated and stored on special on board enforced computer,

d) NIRS prediction are done on the spot and used by breeder team the same day, like fresh weight & moisture information.

3) On Line NIRS Plots Analysis :

3-102) NIRS ON LINE for Research Plots Harvester ZEISS CORONA;

- On & At line prediction available for :
  - *Dry matter* for grass, legume and maize fresh silage on whole plants or Stover.
    or *Water contents* for fresh cereals grain (Wheat, Barley, Maize…) and Rapeseeds grain,
  - *Main biochemistry* variable for fresh silage & cereals grain : protein, oil, starch, fibre…
  - *Process information* for end users :
    + Some industrial *food* quality information for dry milling process on Maize Grain & Wheat.
    + Some Animal *feed* process variable for Maize Grain & Wheat.
- Reference samples are picked up by automated device on board on request in order to check & update NIRS calibration.
- *High Moisture crops PLS NIRS prediction are more difficult to build than on low moisture crops…*

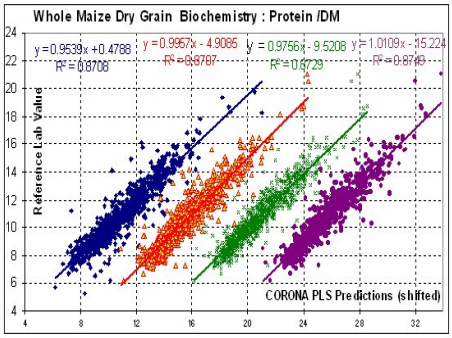
3) At Line NIRS samples Analysis with ZEISS CORONA :

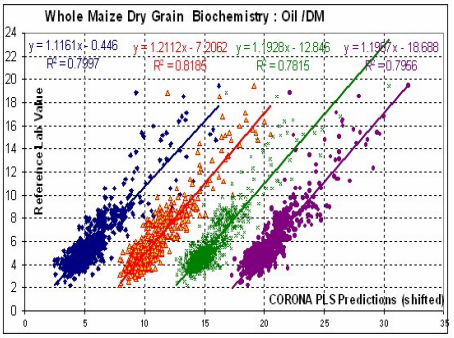
3.111) At Line Applications (near by the oven) for Fresh forages samples or any else!

3) At Line NIRS samples Analysis with ZEISS CORONA::

3.112) Maize Dry Grain same PLS calibration checks on 4 #:

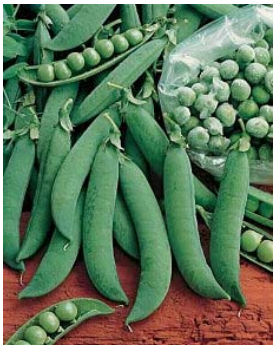
Validation #1: Corona reproducibility, Protein & Oil prediction /4#





3) At Line NIRS samples Analysis with ZEISS CORONA::

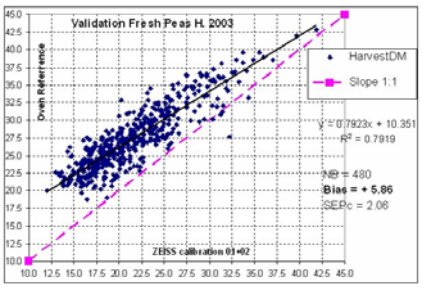
3.121) Fresh Peas harvests for canned food with At Line application:

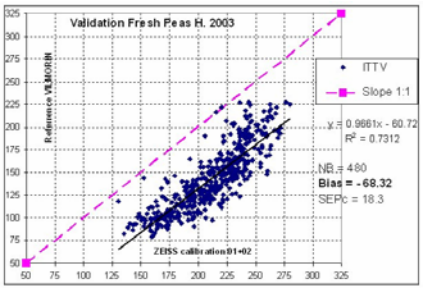


3) At Line NIRS samples Analysis with ZEISS CORONA::

3.122) Fresh Peas harvests for canned food At Line application:

Validation #2: Validation Results from Harvest 2003:
Dry Matter (Left) & Tenderness (Right)





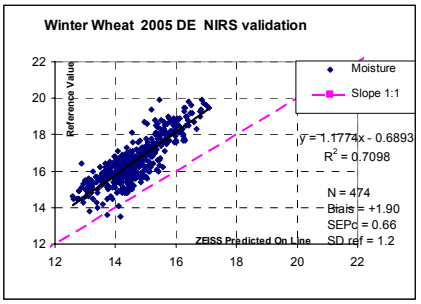
3) At & On Line NIRS samples Analysis with ZEISS CORONA:

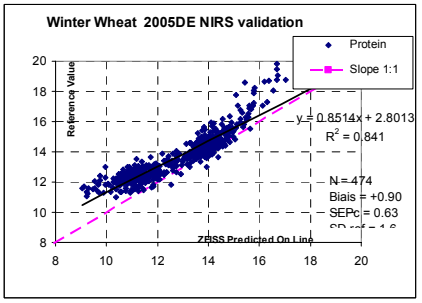
3.131) For Wheat, Barley, Rape Seeds Samples :

At Line = Calibration (Left) & On Line = monitoring (Right):

3) ***At Line NIRS samples Analysis with ZEISS CORONA:***
3.132) Wheat Samples At Line for On Line monitoring:

Validation #3: Wheat Samples Moisture & Protein prediction for harvest 2005





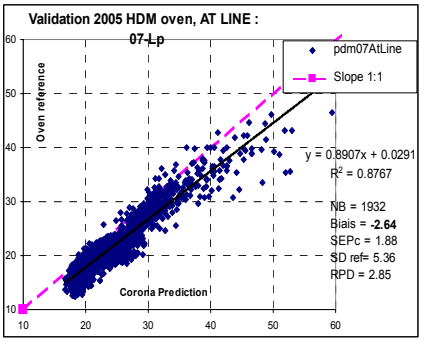
3) On Line NIRS Plots Analysis ZEISS CORONA :

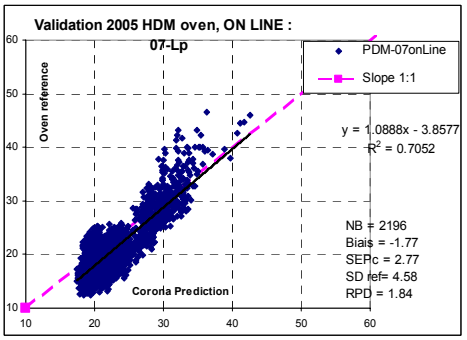
3.201) On Line Applications @DLF FR :
Fresh forages plots at DLF Trifolium FR location
=> canopy measurement since 2004 harvests:

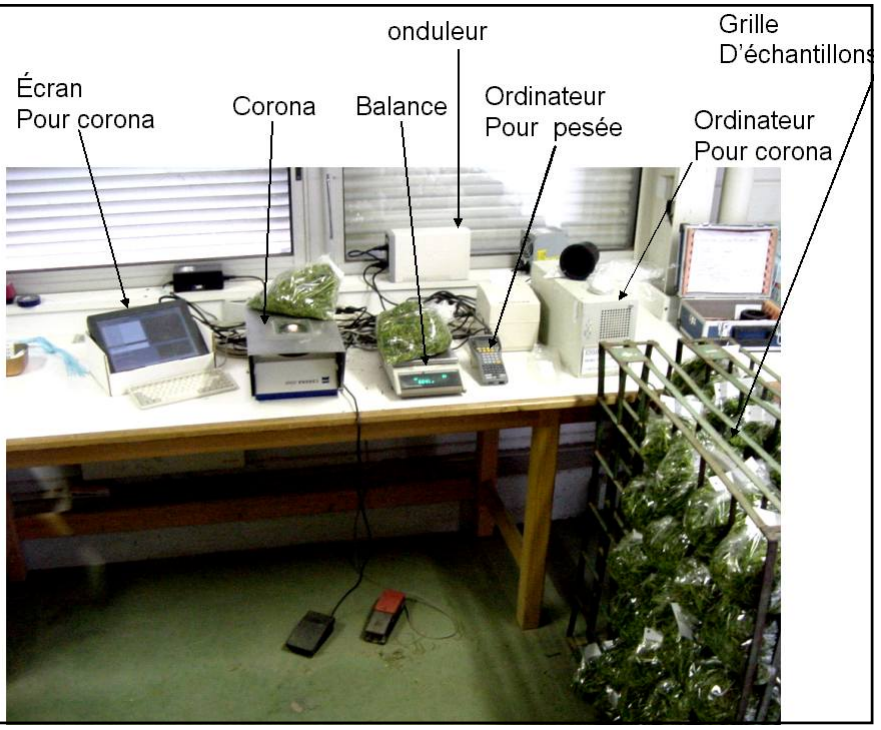
3) On Line NIRS Plots Analysis ZEISS CORONA :

3.202) DLF FR Harvests 2002-2005, HDM Oven value:

Validation #4 On & At Line HDM validation for Harvest 2005*:*
At Line (left) & On Line (right)







3) On Line NIRS Plots Analysis :

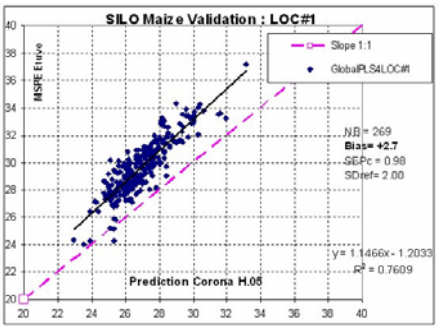
3-301) NIRS ON LINE for Research Plots Silage Harvester ZEISS CORONA;

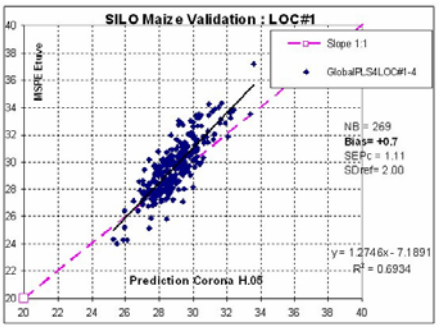
- Flow measurement of chopped maize whole plant.

3) On Line NIRS Plots Analysis ZEISS CORONA :

3-302) Harvest Dry Matter prediction validation

- **Validation #5: On Fresh Chopped Maize Whole Plants :**
- **Two PLS models "local #1" &"global #2", validation on an Independent set of 270#**





3) On Line NIRS Plots Analysis :

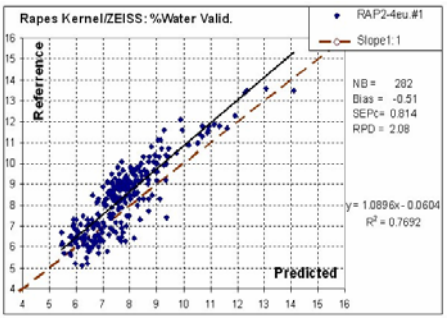
3-400) NIRS ON LINE for Research Plots Grain Harvester ZEISS CORONA;

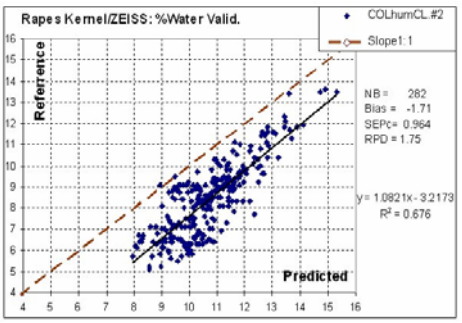
- Flow measurement of whole plot grain flow.

3) On Line NIRS Plots Analysis :

3-51) Water prediction validation ZEISS CORONA

- **A) Validation #6, On Fresh Rapes Seeds :**
- **Two independent PLS models ("DB #1" &"DB #2") validation on an Independent set of 280#.**

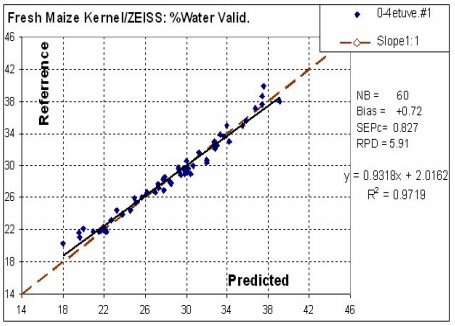


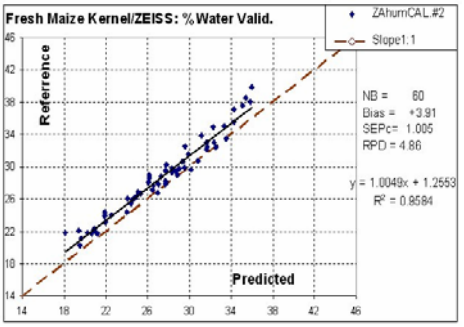


3) On Line NIRS Plots Analysis :

3-52) Water prediction validation ZEISS CORONA

- **B) Validation #7, On Fresh Maize Grain :**
- **Two independent PLS models ("DB #1" & "DB #2") validation on an Independent set of 60#.**





NIRS uses for breeding purposes

- 1) Breeding Purposes:
  Targets and means.
- 2) Laboratory Samples Analysis :
  For Ground or Whole seeds
- 3) On Line NIRS Plots Analysis :
  For Fresh forage or fresh kernels.
- 4) NIRS as a breeding tool, summary.

4) NIRS uses for breeding purposes, summary.

4-1) Their are many possible Ways to help Breeders!

- **A) "Plant to plant" analysis:**
  * Fresh chopped dry & ground single maize plant upper parts for digestibility traits before Selfed ear harvest.
  * Nursery Selfed ear grain after harvest for biochemistry content.
  * Single Seeds sorting before planting for biochemistry traits.

- **B) "Plants parts" samples:**
  * Grasses Stem+leaves for cell wall digestibility & husked maize ear,
  * All field crops dry grain, *even ground sunflower!*
  * Vegetable roots or fresh fruits, *carrots, peas, melon, tomatoes...*

4) NIRS uses for breeding purposes, summary.

4-2) Their are many possible Ways to help Breeders!

- **C) "Plot bulks" or Seed production vials:**
  * Germ Plasm (parents) stored seed bags,
  * Control trials networks samples from harvesters.
  * Whole plot On line analysis from choppers.
  * Vials homogeneity by flow analysis.

- **D) What could be Next, *maybe*?**
  Single plant (or spotted) analysis in nursery, greenhouse...

4) NIRS uses for breeding purposes, summary.

- **E) Basic rules :**
  NIRS application can works only if we can bring together :
  - **Large Germ Plasm variability on parents for food & feed end use.**
  - **Good reference value from laboratory or suitable process.**
  - **NIRS cheap & representative spectra on provided samples or flow plots.**
  - **Non destructive method for whole or single seeds only.**
  - **Efficient NIRS calibration uses and updates for breeding works.**
  - **Very quick feed back quality information to breeders for all NIRS routine analysis data (to Breeders' Computer Data Bases).**
  - ***NIRS is a team work !***
  - *Many thanks to :*
    Dr P. DARDENNE CRAW,

a) NIRS ON LINE presentation & publication:

• GEMBLOUX, Belgium, November 2004,
• BRAUNSCHWEIG, Germany, Marsh 2003,
• Diode array near infrared instrument to analyse fresh forages on a harvest machine.
Dardenne P., Féménias N., 1999, In: Davies A.M.C. and Giangiacomo R. (eds),
Near Infrared Spectroscopy : Proceeding of the 9th Conference. NIR Publications, UK, 121.

•b) Others NIRS publication:

• Prediction of the metabolisable energy value of maize in adult cockerels.
Lessire, M.; Hallouis, J.M.; Barrier-Guillot, B.; Champion, M.; Femenias N.,
In British Poultry Science, 44:813-814 N. 2003..

• Interaction entre la teneur en acides aminés et la... (Les Journées de La recherche Avicole)
Lessire Michel, Hallouis Jean Marc, Barrier-Guillot Bruno, Orlando D., Champion M., Féménias N. p253....

• Composition and nutritive value of whole maize plants fed fresh to sheep. I: Factors of variation, ANDRIEU J.; DEMARQUILLY C.; DARDENNE P.; BARRIERE Y.; LILA M.; MAUPETIT P.; RIVIERE F. ; FEMENIAS N. In Annales de zootechnie 1993, vol. 42, no3, pp. 221-249;

• Use of NIRS dermination of quality in a silage maize breeding program, Femenias, N., and T. Ronsin. 1990.. In Proc. Third Intern. Conf. on Near Infrared Spectroscopy. Brussels.

THANK YOU !

Noel FEMENIAS,
SPIRALE /NIRS Consultancy,
Vichy, France
email :
noel.femenias@laposte.net
Tel.:
+33 (0) 686 938 266