WP4.1: Nitrogen use efficiency in potato: an integrated agronomic, physiological and genetic approach

Cesar Ospina (WUR 2)
Maarten Vossen (Agrico 13)
Gerard van der Linden (WUR 2)
Sjefke Allefs (Agrico 13)
Edith Lammerts van Bueren (WUR 2)
Paul Struik (WUR 2)

WAGENINGEN UR
For quality of life

NUE-CROPS

AGRICO

Outline

- NUE in potato
- Project description
- Objectives
  - Field trial
  - Measurements
  - Data analysis
- Results
- Conclusions

NUE in potato (WP4.1)

- NUE is a complex trait: due to genotype specific **effects of N-supply** on **crop** physiological/morphological characteristics
  - Canopy development
  - Final tuber yield, N uptake

- It is known that potato cultivars have different requirements for N to perform well, but it is not yet know how to select for NUE for low N conditions.

- Performance under limited supply (e.g. under organic)
  - Which genotypes are more efficient in N use?
  - How is the genetic inheritance and which are the genes involved in this trait?

NUE... different starting points

- Farmers want highest yield with lowest cost
- Breeders looks for good performance under low input with good response to extra N
- Researchers and breeders want to understand mechanisms and physiology of this complex trait by dividing it in sub traits to look for heritabilities and QTLs related to the traits

Brief project description (WP 4.1.1 to .3)

1. Identify QTLs for rate of crop development and nitrogen accumulation in the SH×RH ***population*** (100 genotypes).
   - Previous experiments showed variation for Nit UE
   - Phenotyping experiment in 2011 under two N supply regimes

2. Phenotyping an extensive set of potato germplasm (200 varieties/genotypes)
   - To identify genetic variation by association mapping (as pilot study) 2009, 2010 experiments at AGRICO

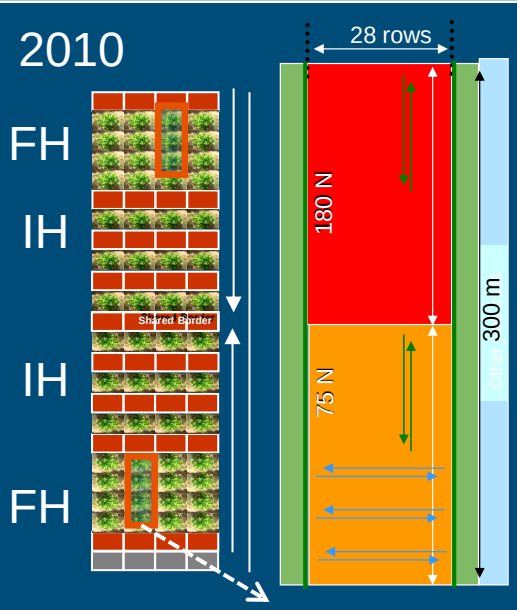
3. Quantify plasticity of Nit UE in selected genotypes under 2 N input types and 2 levels
   - Experiment at Wageningen University 2010 – 2011

Main objectives

- Phenotyping of an extensive set of potato germplams (200 varieties/genotypes) to identify:
  - Genetic variation for Nit UE under two N supply regimes for Nit UE, N uptake, dry matter content and canopy development.
  - Relationship between traits.
  - Which are the main factors explaining the phenotypic variation?
  - Association between markers and Nit UE related traits.
  - Target genes for Nit UE

Field trial Varieties set, Agrico

2010



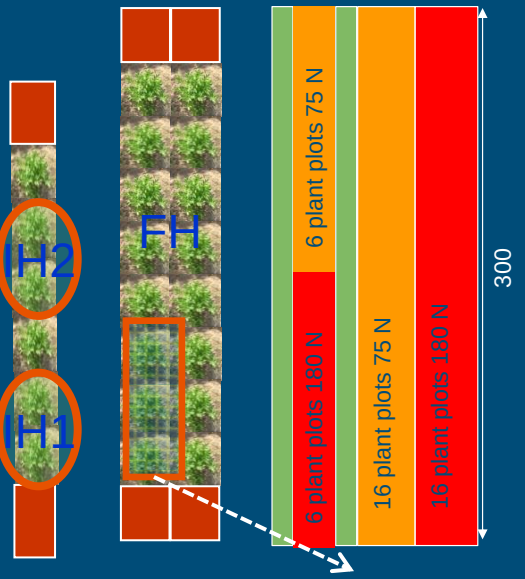
Soil coverage

188 genotypes
2 main plots: N levels
2 sub plots: maturity types
Genotypes nested in subplots

Measurements:

- Emergence
- Soil coverage: canopy development
- Final harvest
- Tuber size and weight distribution
- Yield
- DM
- Nitrogen uptake

2009



Soil coverage

WAGENINGEN UR
For quality of life

NUE-CROPS

AGRICO

Data processing summary

Experiments

Measurements	Processing	Variables	Units
Weekly Measurements			
Soil coverage	curve fitting	TM1	Thermal days
		T1	Thermal days
		T2	Thermal days
		Te	Thermal days
		Vmax	SC %
		AUC1	
		AUC2	
		AUC3	
		TAUC	
Final harvest			
Final yield		Y	kg/m^2
	*DM%	TDM	kg/m^2
Tuber size and weight distribution	curve fitting	wA	mm/tuber
		wB	mm/tuber
		wMAX	kg/m^2
		nA	mm/tuber
		nB	mm/tuber
		nMAX	kg/m^2
Tuber shape index			
Tubers per meter		Tbm	mm/tuber
Dry Matter %		DM%	%
Tuber N estimation		N[]	gr/Kg
Total N Uptake	N[]*TDM	TbNupt	gr/m^2
Nitrogen Uptake efficiency	TbNupt/Fkg	UptE	
Nitrogen utilization efficiency	DMkg/Ng	NUtE	
Nitrogen Use efficiency	DMkg/Fkg	NUE	
Canopy efficiency index	TAUC/Y	RdUE	

Photo analysis
Output compilation of soil coverage

+

Beta thermal time calculation

→ Input file for curve fitting In SAS → Parameters

Tubers weight / class / Mt → Input file for curve fitting In SAS → Parameters

Calculation →

Statistical analysis

WAGENINGEN UR
For quality of life

NUE-CROPS

AGRICO

Main effects Summary

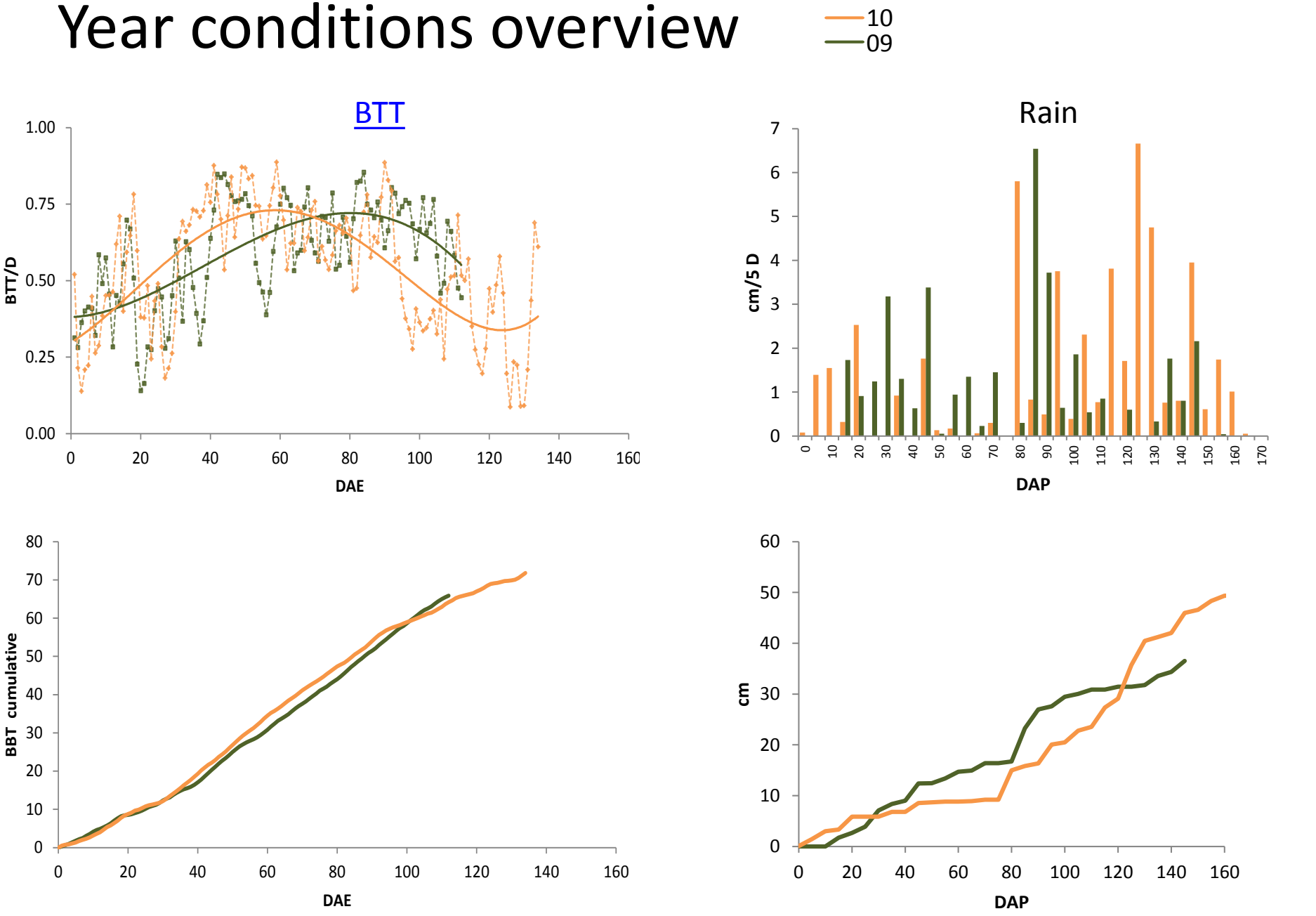
	Source of Variation					
Traits	**N_lv**	**yr**	**yr.N_lv**	**mm**	**N_lv.mm**	**yr.N_lv.mm**
SC_tm1	<0.001	<0.001	0.408	0.799	0.003	<0.001
SC_t1	0.015	<0.001	0.934	<0.001	<0.001	<0.001
SC_Vx	<0.001	0.004	0.215	<0.001	0.101	<0.001
SC_t2	0.001	<0.001	0.092	<0.001	0.092	<0.001
SC_te	<0.001	<0.001	<0.001	<0.001	0.28	<0.001
SC_Cm	<0.001	<0.001	0.007	<0.001	0.186	<0.001
AP1	0.401	<0.001	0.806	<0.001	0.002	<0.001
AP2	<0.001	0.003	0.277	<0.001	<0.001	<0.001
AP3	<0.001	<0.001	<0.001	0.534	0.137	<0.001
AUC	<0.001	0.011	0.034	<0.001	0.068	0.007
t2_t1	<0.001	<0.001	0.209	<0.001	<0.001	0.002
te_t2	0.81	<0.001	0.013	0.009	0.056	<0.001
DM%	0.93	<0.001	0.442	<0.001	0.021	0.07
Tf_DM	<0.001	0.01	0.207	<0.001	<0.001	<0.001
N	<0.001	0.009	0.192	<0.001	0.466	<0.001
N_Upt	<0.001	0.712	0.161	<0.001	0.001	<0.001
UptE	<0.001	0.772	0.274	<0.001	0.055	<0.001
NUtE	<0.001	0.009	0.093	<0.001	0.001	<0.001
NUE	<0.001	0.056	0.991	<0.001	<0.001	<0.001
RdUE	0.457	<0.001	0.011	0.313	0.514	<0.001
TbwMX	<0.001	0.061	0.316	<0.001	0.418	<0.001
TbwB	0.001	0.003	0.058	0.029	0.303	<0.001
TbwA	0.012	0.996	0.266	0.196	0.133	<0.001
TbnMX	0.444	<0.001	0.003	0.02	0.616	<0.001
TbnB	<0.001	<0.001	<0.001	0.022	0.439	0.07
TbnA	<0.001	<0.001	0.015	0.014	0.082	<0.001

Combination of 2 yr and 2 Nitrogen levels

The genotypes are nested within maturity group and are treated as random

Maturity, N_lv and yr showed differences in almost all traits.

Year conditions overview



Yield comparison

data link

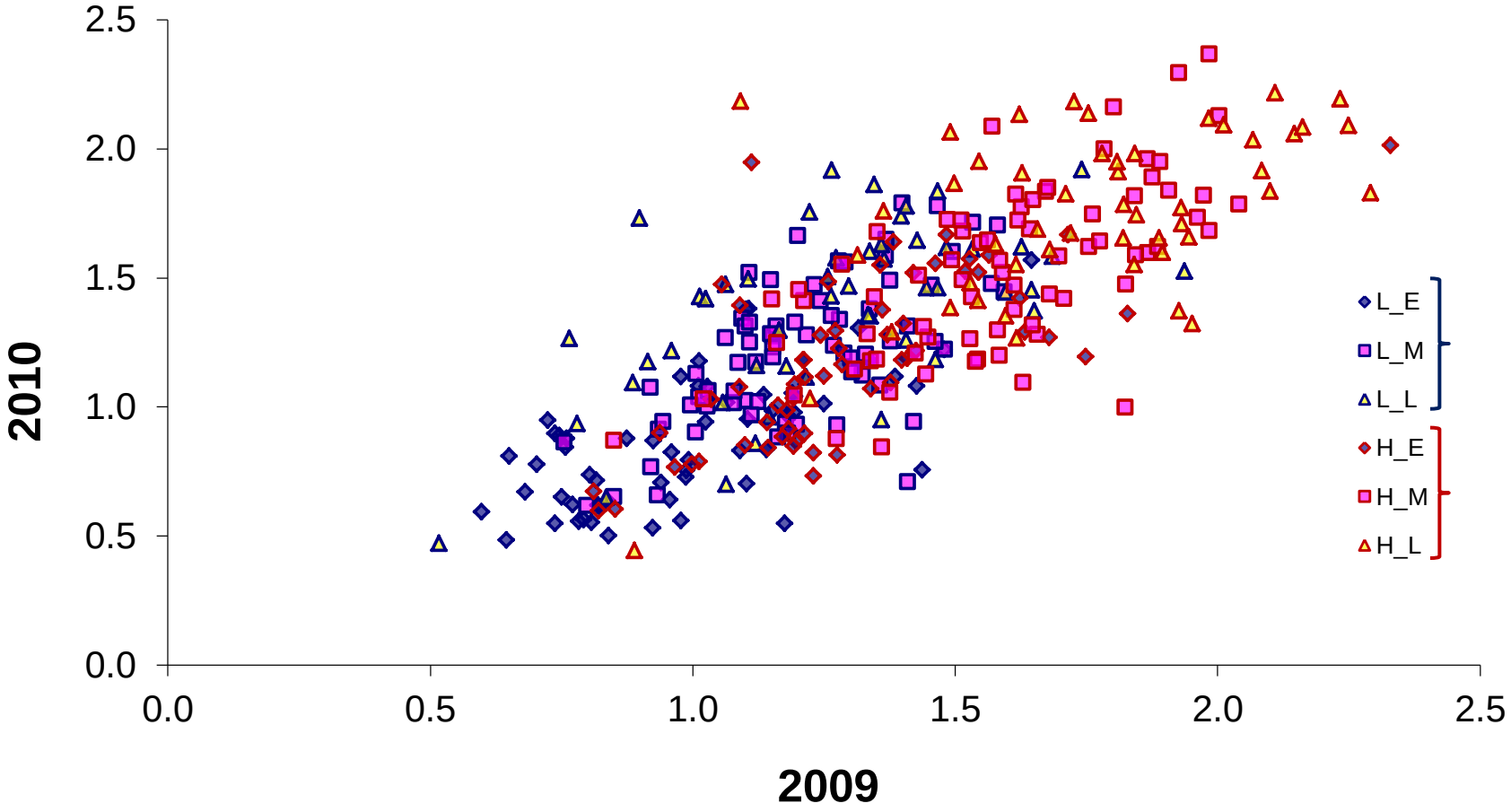
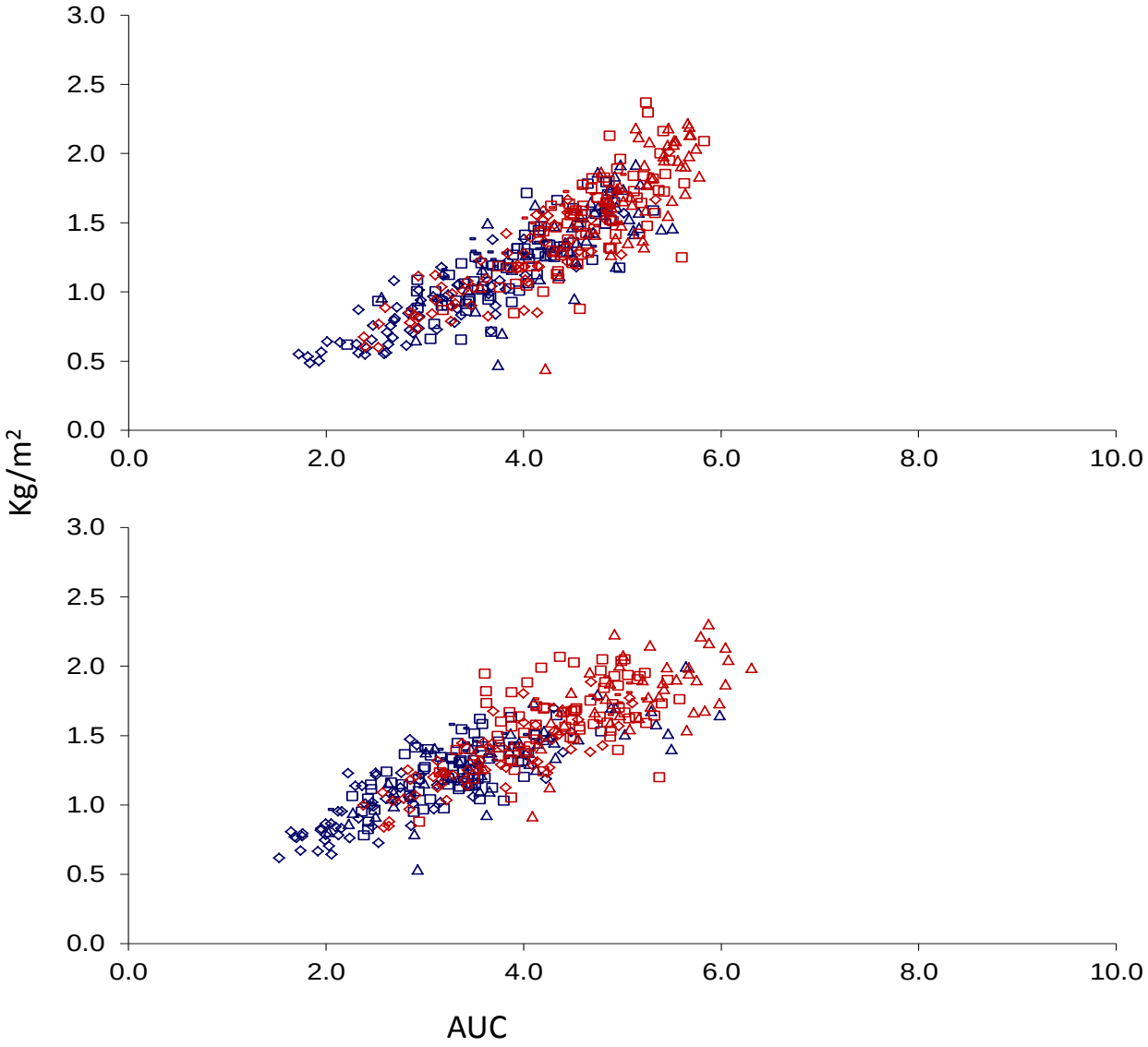


Figure Potato yield comparison in 2009 (X axes) and 2010 (Y axes), under two N levels; red border line (N1) 180 and blue border line (N2) 70 kg N/ha). Maturity groups base on breeders information are: E) early genotypes, M) intermediate and L) late.

r=0.748 H N

r=0.711 L N

Yield vs AUC



2010

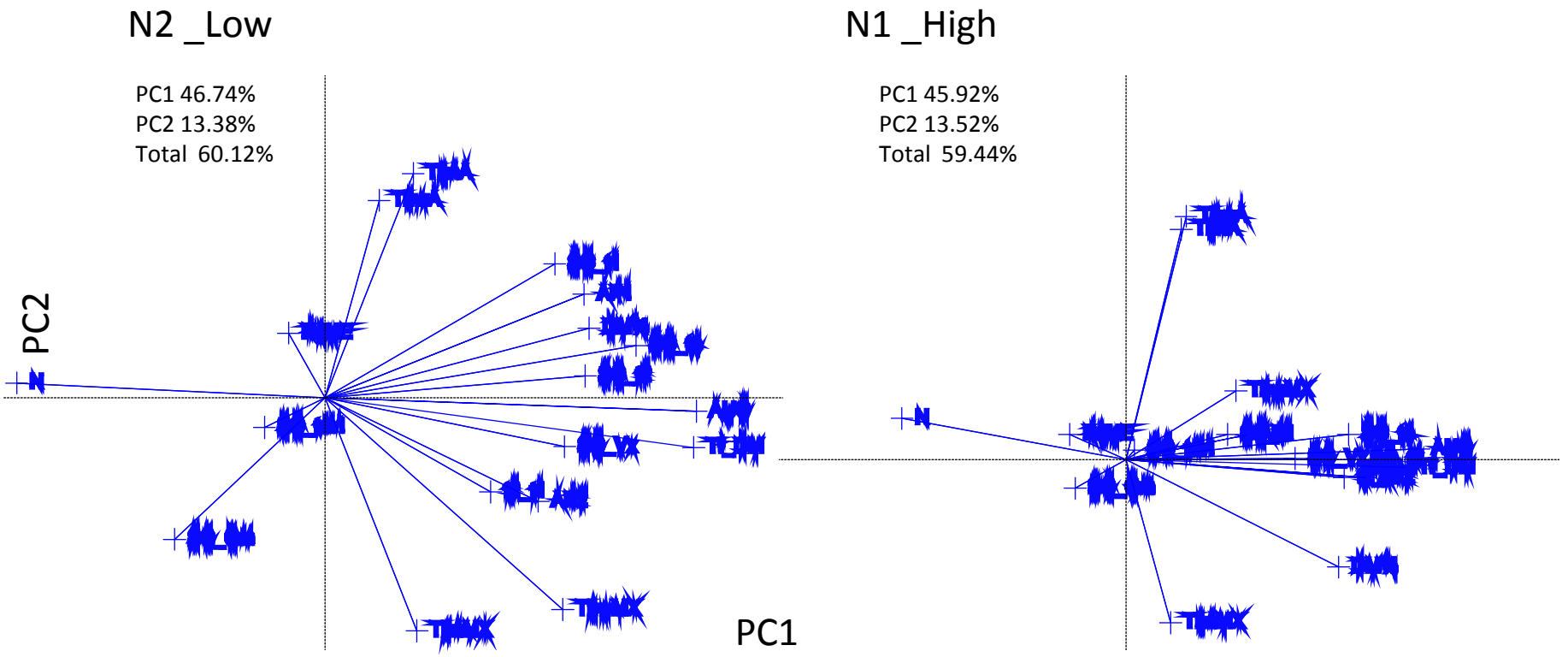
r=0.89

2009

r=0.86

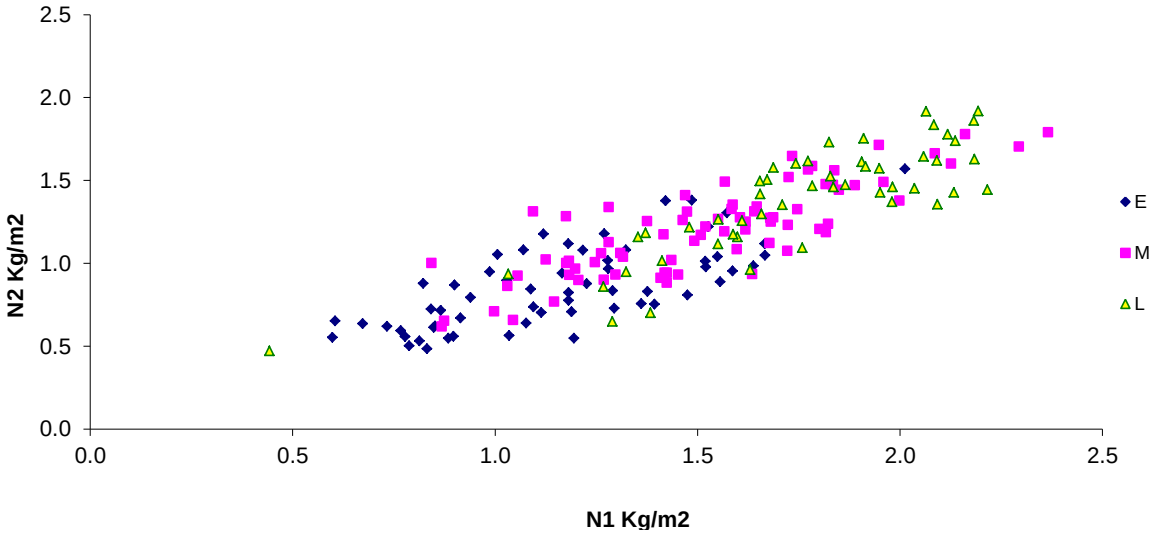
Figure relation AUC and potato yield in the 2010 experiment under two N levels. Red symbols are N1 (180kg/ha), blue symbols are N2 (70kg/ha); Maturity groups base on breeders information are: E) early genotypes, M) intermediate and L) late.

Trait relationships/ N level



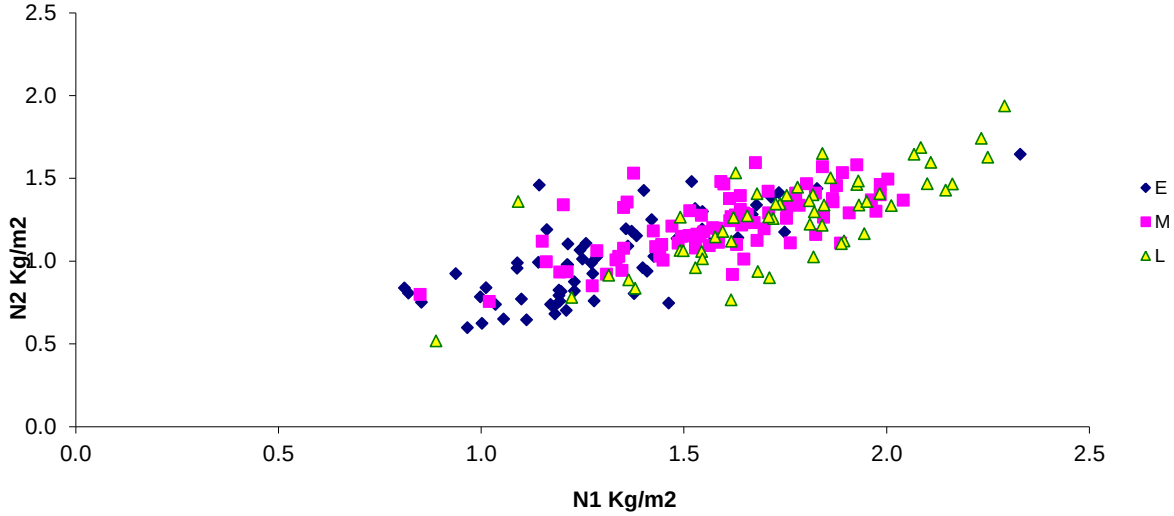
** data normalized previously per trait or column. Each column has two time each gen, for each year. Then data were arranged in a long form . No missing data allowed, therefore gen with missing values were discarded.
GGEBIPLOT [PLOT=scatter; DIMENSION=1,2; SCPLOT=vector; SCALING=environment; NORMALIZE=no;\
DIVISIONS=10] yz; GENOTYPES=G; ENVIRONMENTS=Tr

Yield / maturity



2010

2010	Correlation	Slope	Intercept	r^2
Early	0.725	0.576	0.190	0.526
Medium	0.829	0.687	0.155	0.687
Late	0.842	0.805	-0.026	0.709
Overall	0.870	0.759	0.026	0.758

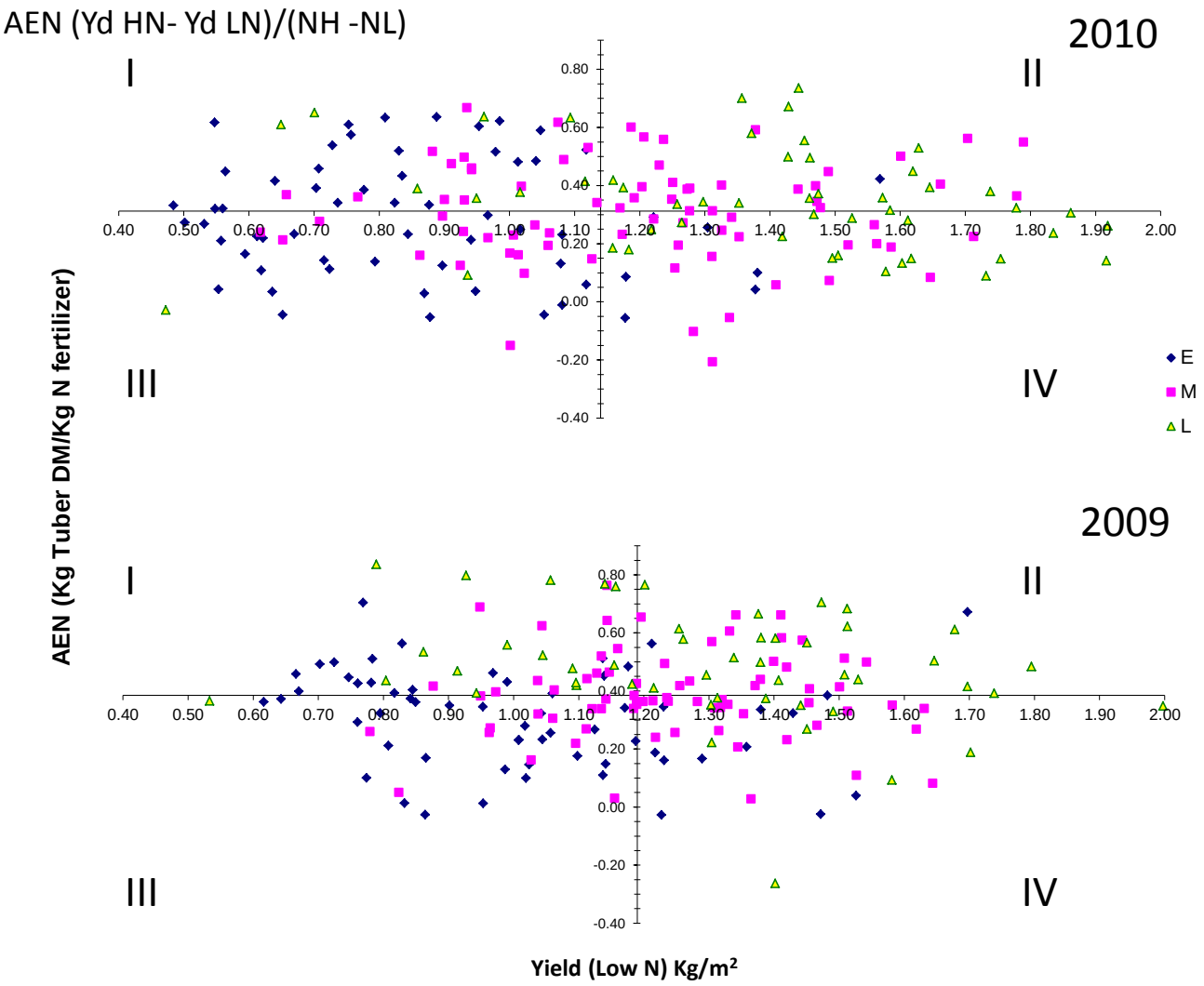


2009

2009	Correlation	Slope	Intercept	r^2
Early	0.742	0.689	0.106	0.551
Medium	0.678	0.526	0.385	0.460
Late	0.762	0.734	-0.023	0.581
Overall	0.778	0.636	0.183	0.606

Figure Potato yield, under two N levels; N1) 180 and N2) 70 kg N/ha). Maturity groups base on breeders information are: E) early genotypes, M) intermediate and L) late.

Response and performance / maturity



Genotypes/MT and Quadrant

2010	Quadrants				
MT	1	2	3	4	Total/MT
E	26	1	28	6	61
M	14	23	20	20	77
L	8	20	2	20	50
Total/Q	**48**	**44**	**50**	**46**	**188**

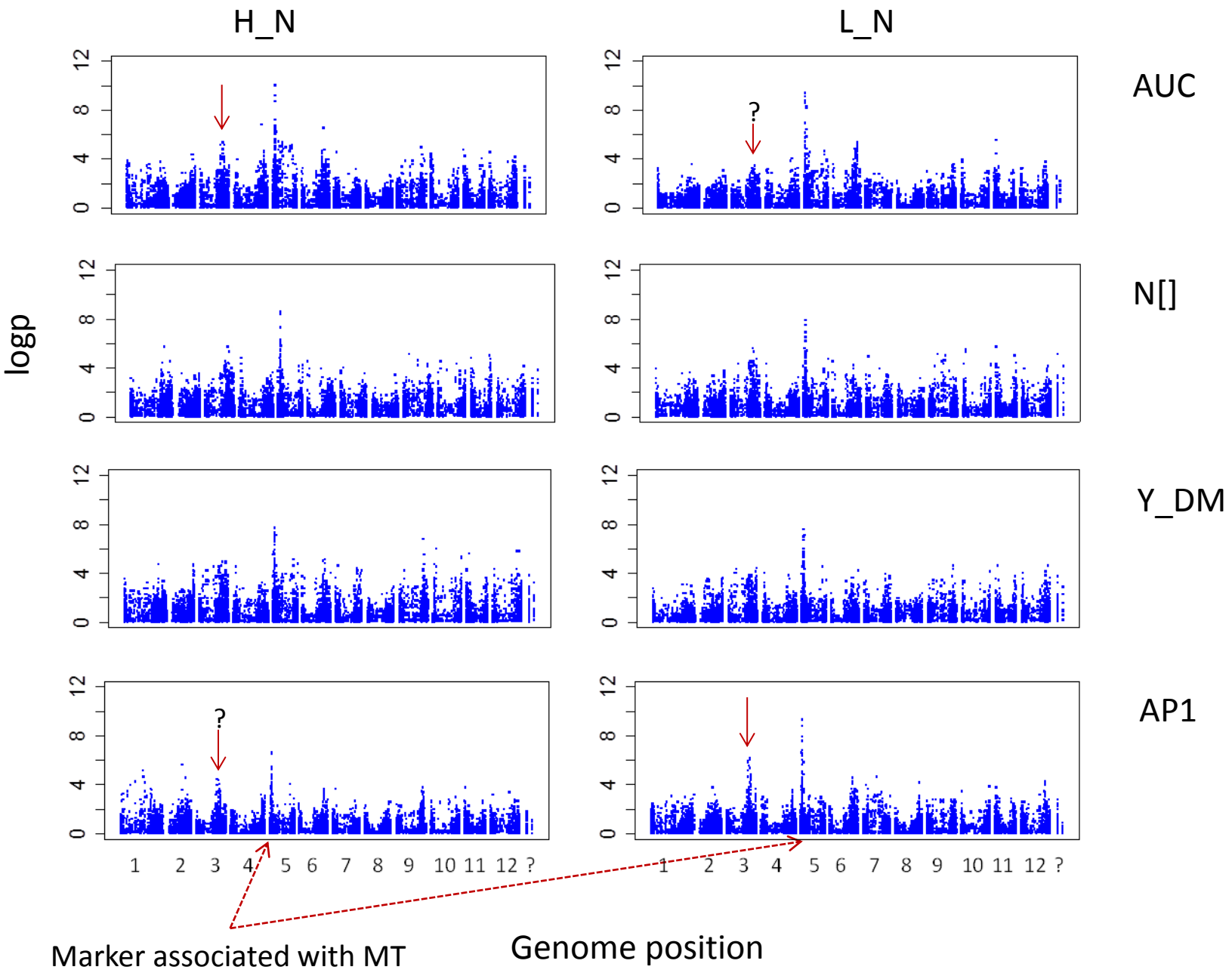
2009	Quadrants				
MT	1	2	3	4	Total/MT
E	16	2	31	12	61
M	14	19	18	26	77
L	15	21	2	12	50
Total/Q	**45**	**42**	**51**	**50**	**188**

% of genotypes/MT consistently in the same Quadrant

	Quadrants				
MT	1	2	3	4	Sum/MT
E	16	2	33	5	56
M	4	14	10	9	38
L	12	20	2	12	46
Total/Q	**10**	**12**	**15**	**9**	**46**

Figure 1 Response of Agronomic efficiency of N fertilizer applied from Low to high N input in relation to the performance under the low N input.
I= quadrant (Q)I , High response , low performance under low input. QII = high response and performance. QIII =Low response and performance. QIV= Low response and High performance

Preliminary association analysis



Conclusions

- Canopy development parameters are related with yield
- Maturity type affects most of the traits
- NUE decreases with more N input
- Low N conditions show better discrimination between traits
- Selection should combine performance under low input and response to N fertilizer
- Preliminary results show that markers associated with maturity are also associated with most of the traits
- There are some associations that are N dependent

Acknowledgements

- UNIFARM
- AGRICO team
- CSA
- Students

Thanks !!!!

WAGENINGEN UR
For quality of life

NUE-CROPS

AGRICO