

DEFRA Project AR0714: A study of the scope for the application of crop genomics and breeding to increase nitrogen economy within cereal and rapeseed based food chains.

(Nov 2003 – Oct 2004)

UoN, NIAB & RR

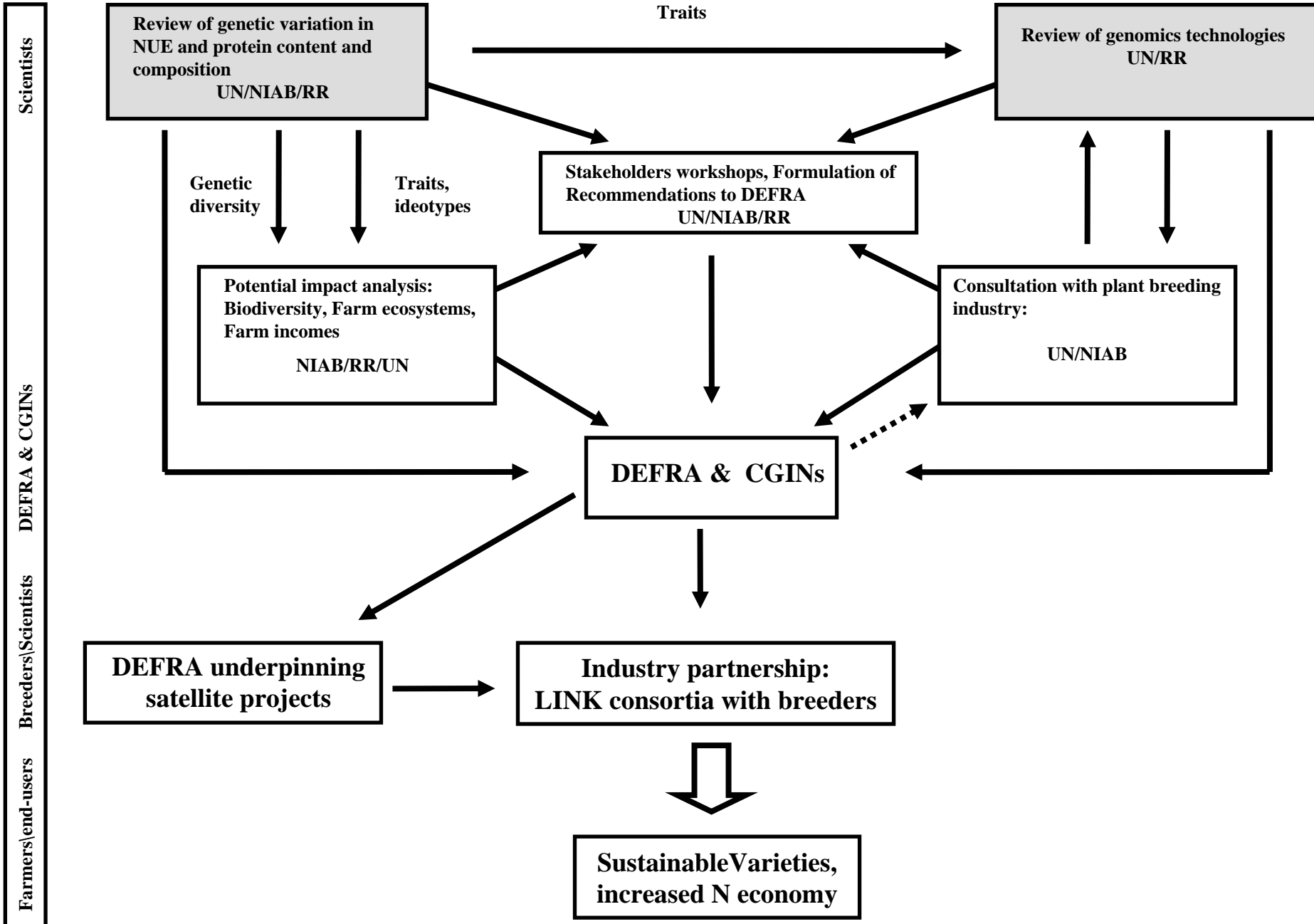
Drivers

- Major UK crops ~ cereals (23 M t p.a) and OSR (1.4 M t p.a).
- Annual UK use 1.2 M t of N fertilizer → 0.7 M t cereals & 0.1 M t OSR.
- N fertilizers →
 - cost for the grower
 - nitrate leaching (bread-making wheats & OSR high risk)
 - emissions of N₂O and ammonia, → eutrophication/ acid rain/climate change
 - production by industrial fixation uses fossil fuels
- 42% of UK cereals are used in livestock diets. The low value proteins → high N excretion.
- Minimising environmental impacts of fertilizer N inputs requires resource-efficient crops.
- Minimising N emissions from livestock diets requires the development of varieties with increased energy: protein ratios.

Objectives

- **Objective 1. Review of genetic variation in N-use efficiency and protein content and composition (trait prioritisation)**
 - a. Analysis of variety/N data sets
 - b. Physiology review
- **Objective 2. Review of genomics-based technologies**
- **Objective 3. Consultation with the breeding industry**
- **Objective 4. Environmental and economic potential-impact analysis**
 - a. Environment: N emissions (leaching and denitrification) ... impact on groundwater , biodiversity
 - b. Farm incomes
- **Objective 5. Guidance to DEFRA research policy**
 - a. Inform research strategies of the DEFRA GINs.
 - b. Inform DEFRA on the potential success of public investment to increase N economy in cereal and rapeseed-based food-chains.

APPENDIX 1: DEFRA AR0714 “SCOPE FOR CROP GENOMICS AND BREEDING TO INCREASE N ECONOMY”



Objective 1: Analysis of variety/N data sets

- **Data sets**
 - UK RL/NL trial series 1988 – 2003 (WW 148 trials (69 low N), OSR 161 trials)
- **Soil N supply estimated from soil type, previous cropping and winter rainfall**
- **Calculation of N economy characters**
 - 1. Crop N offtake = $[\text{Grain DM kg/ha}/0.78] \times \text{Grain N\%}$
 - 2. N-uptake efficiency = $\text{Crop N offtake kg/ha} / \text{Available N, soil + fert. N kg/ha}$
 - 3. N-utilization efficiency = $\text{Grain DM kg/ha} / \text{Crop N offtake kg/ha}$
 - 4. N-use efficiency = $\text{Grain DM kg/ha} / \text{Available N, soil + fert. N kg/ha}$
- **Search for varietal differences in variables in:**
 - Sub-set of low N fertilizer input trials.
 - Remaining moderate to high N fertilizer rate trials.
 - Relative performance under contrasting total N availability .

Winter wheat analysis

All extracted WW data 1988-2003

Treated

Removal single sites and varieties in single year

148 trials: 36 sites, 178 varieties

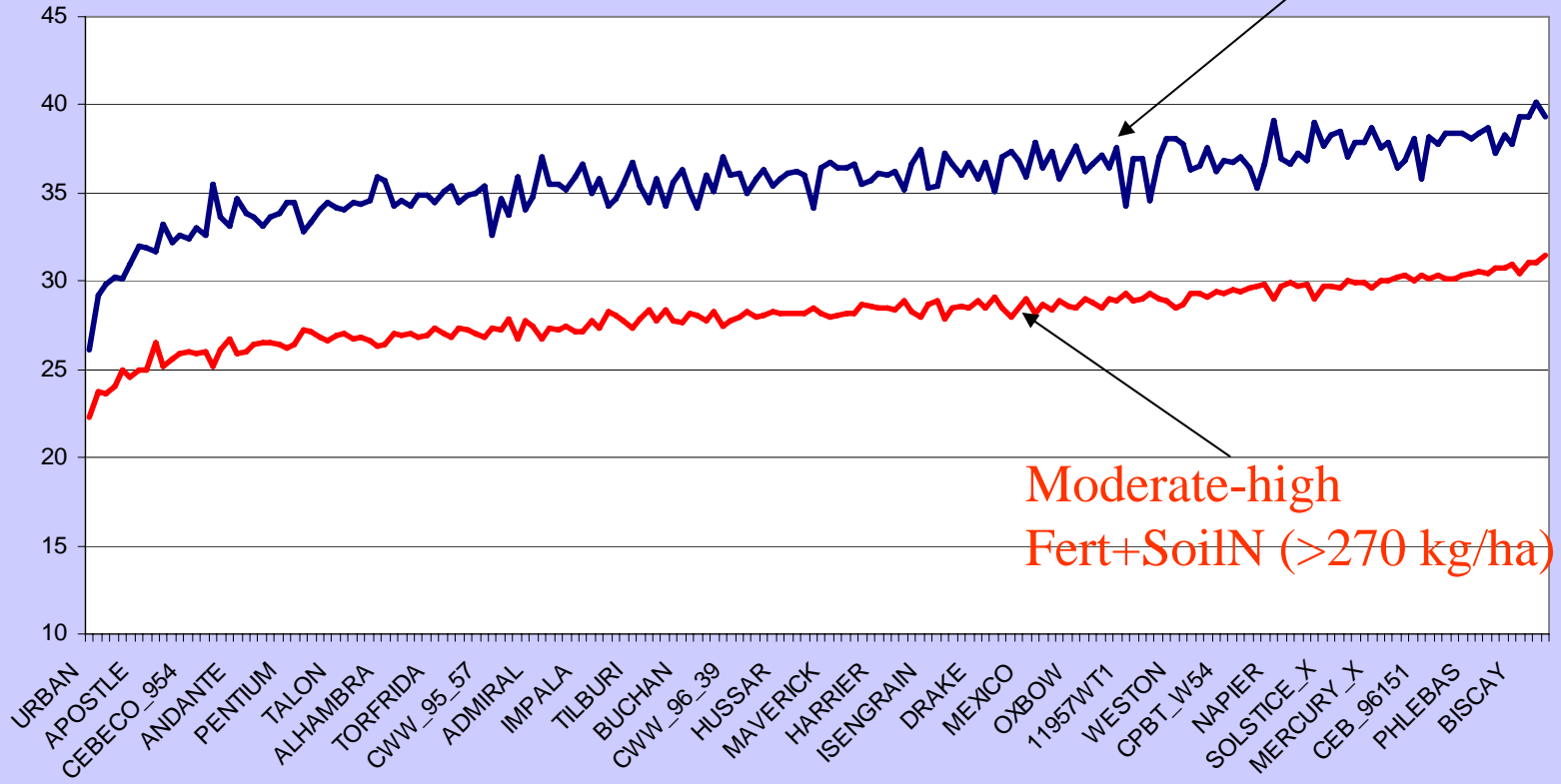
Looked at FertN+SoilN in 8 classes:

Added SoilN + Fert N (kgN/ha)

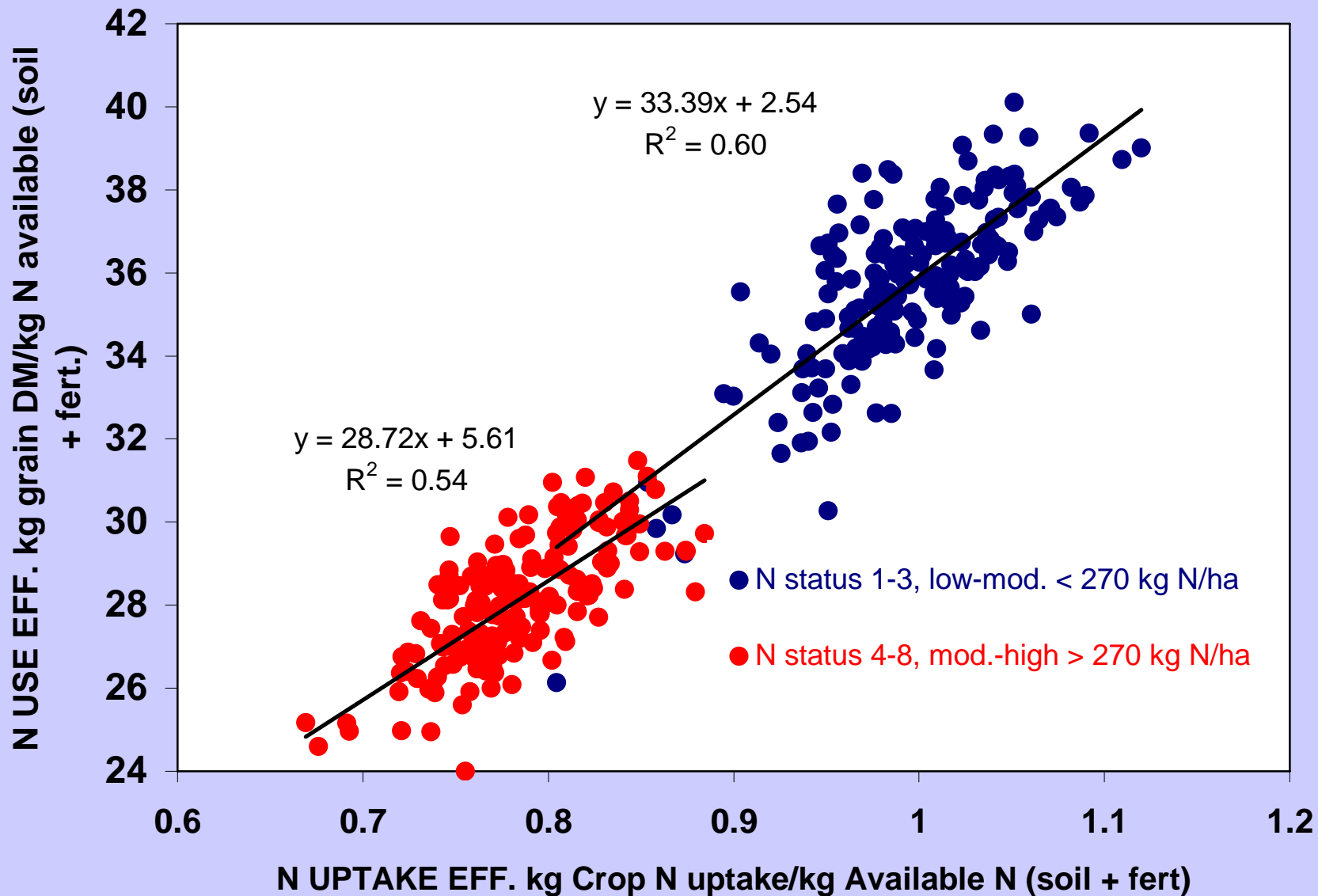
NStatus1	180_210	LOW
NStatus2	210_240	LOW
NStatus3	240_270	LOW
NStatus4	270_300	Rest
NStatus5	300_330	Rest
NStatus6	330_360	Rest
NStatus7	360_390	Rest
NStatus8	390_420	Rest

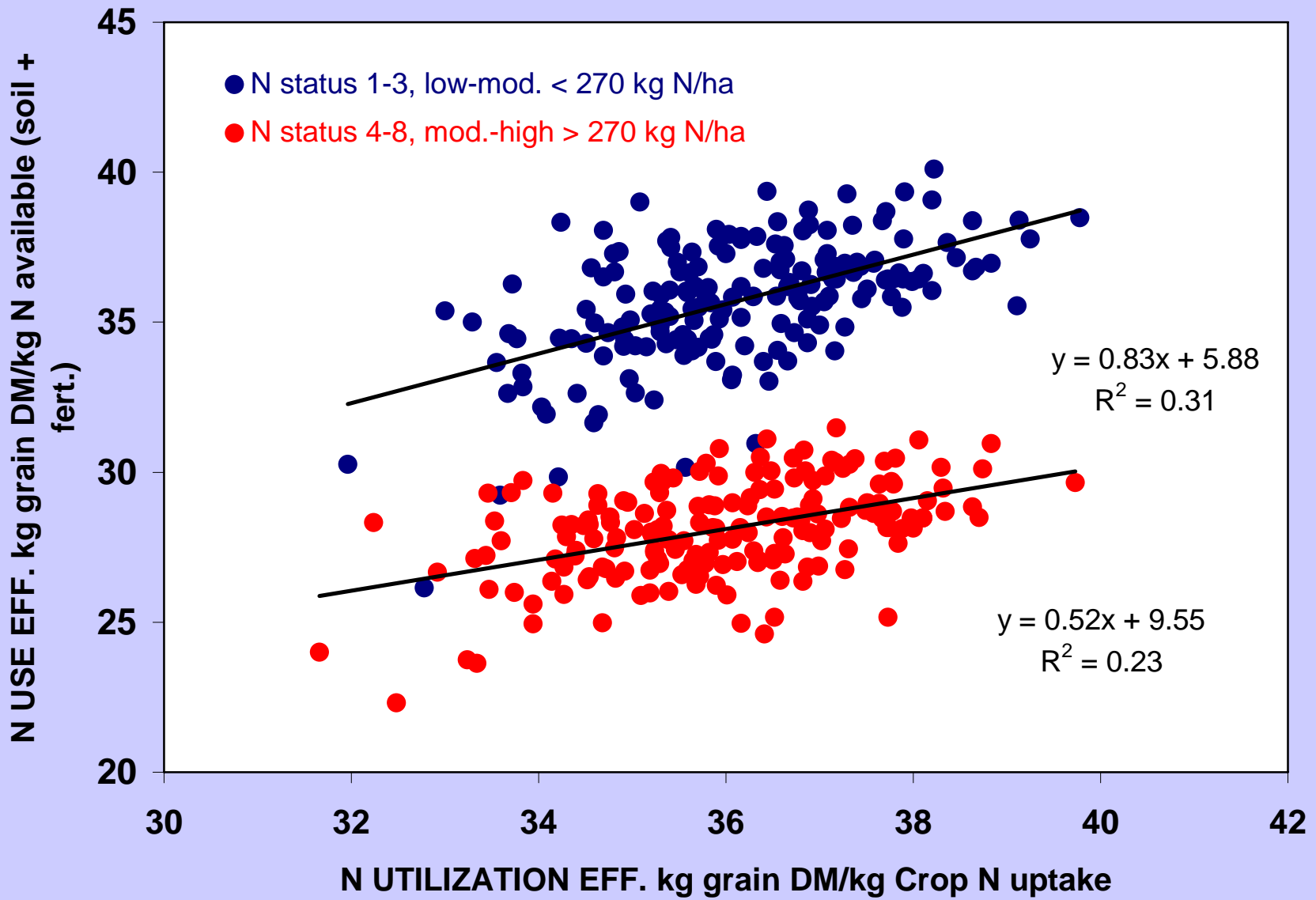
N-Use Efficiency, Status 1-3 v Status 4-8

NUE kg grain DM per kg available N (soil + fet.)



SED Variety: N1-3 = 1.32; N4-5 = 0.70





N-use efficiency and its determinants for the parents of the eight WGIN mapping populations

DH Population	Source	No	Molecular markers nos	Neconomy characters						
				NUE kg DM/kg N		NupE		NutE		
				NI-3	N 4-8	NI-3	N 4-8	NI-3	N 4-8	
Beaver x Soissons	JIC/UoN/ADAS	65	Only 48 lines mapped, 181 (SSR and AFLP)	Beaver	36.0	28.5	0.988	0.778	36.7	34.5
				Soissons	32.2	25.60	0.953	0.754	33.9	34.0
Rialto x Spark	JIC/UoN/ADAS	144	Only 40 mapped with a few SSR	Rialto	36.7	28.2	1.041	0.821	34.8	34.5
				Spark	32.6	26.0	0.985	0.769	33.7	33.7
Avalon Cadenza	JIC/UoN/ADAS	204	74 SSR and STMP on 60 lines	Avalon	29.2	23.8	0.874	0.715	33.6	33.2
				Cadenza	35.4	26.8	1.025	0.782	34.5	34.3
Arina x Riband	JIC	120	200+ (SSR + AFLP)	Arina	-	-	-	-	-	-
				Riband	36.1	28.1	0.949	0.743	38.2	38.0
Lehmi x Claire	JIC	100		Lehmi	-	-	-	-	-	-
				Claire	37.0	29.0	0.994	0.775	37.6	37.5
WEK0609 x Hobbit	JIC	60	200+ (SSR + STMP)	WEK0609	-	-	-	-	-	-
				Hobbit	-	-	-	-	-	-
Milan x Catbird	JIC		126 SSR	Milan	-	-	-	-	-	-
				Catbird	-	-	-	-	-	-
Chinese spring x SQ1	JIC		300+ (RFLP, SSR, AFLP)	Ch. Sprg	-	-	-	-	-	-
				SQ1	-	-	-	-	-	-
				Min	26.1	22.3	0.80	0.68	31.7	32.0
				Max	40.1	31.5	1.11	0.88	39.7	39.8
				Mean	35.7	28.1	0.99	0.78	36.1	28.1
				SED	1.32	0.70	0.082	0.022	0.55	0.70

Objective 1: Analysis of data sets: summary

- Cultivars differed significantly in NUE in both N backgrounds.
- Trend for lower yield potential NABIM groups 1 and 2 to exhibit lower NUE.
- N-uptake eff. increased at low N, but no change in N-utilization eff.
- N-uptake eff. and N-utilization eff. positively associated with NUE, but N-uptake eff. accounted for more of the variance in NUE.
- No relationship between N-uptake eff. and N-utilization eff. amongst the cultivars.
- WGIN DH mapping populations:
 - Avalon x Cadenza may be useful for genetic analysis of NUE and N-uptake eff.
 - Genetic analysis of N-utilization eff. may require other populations.
 - More generally, in UK germplasm apparent lack of significant variation in N economy characters independent of yield potential.

Objective 1: Physiology review (trait prioritisation)

- **Traits for improving N-uptake efficiency**
 - Root development, morphology and size
 - Cellular/molecular physiological processes influencing root functioning
- **Traits for improving N-utilization efficiency**
 - N assimilation
 - Leaf and canopy photosynthesis
 - N remobilization to the seed
 - N/S interactions
- **Scope for modifying protein content/composition of quality varieties**
- **Scope for modifying protein content/composition of feed varieties**
 - Collaboration with DEFRA Project IS0208 A theoretical analysis of how the protein requirements of livestock in England and Wales might be best met (Reading University, ADAS, IGER)

Trait prioritisation

- For each trait area:
 - Define quantitatively target trait(s)
 - Review current knowledge from scientific literature
 - Suggest future research priorities

Tentative comments: Cereals

- **N uptake**
 - **Roots** → Since root length density at depth insufficient, quantify genetic diversity in RLD and improve physiological and genetic understanding of underlying traits.
 - **Root phenotyping** → Requirement for high-throughput techniques (phenotyping and/or genotyping) that are well correlated with field expression of RLD at depth.
 - **Root functioning** → Search for gene expression associated with transporters/unit area and uptake from low solution concentrations.
- **N utilization**
 - **Leaf photosynthesis** → Limited variation in P_{max} , introducing C4 phytochemistry into C3 cereals (long term)
 - **Canopy photosynthesis** → Elucidate composition and function of stem proteins (fundamental studies).
→ Model ideotypes to optimise canopy architecture/canopy N distribution.
 - **Remobilization** → Grain protein content “source determined”, so most effective way to modify protein content by manipulate the amount of N transported into the grain.

Tentative comments: Oilseed rape

- **N uptake**

- **Roots** → OSR more root limited than winter cereals? Quantify the extent of available genetic diversity in root traits, at present unknown?

- **N utilization**

- **Canopy** → *reduce over-dense pod canopies (shading of lower pods) and/or improve low photosynthetic efficiency of pods (long term?).*
- **Remobilization** → *Increase transport of N from leaves to stems/taproots, which serves as a store to supply pods/seeds? Genetic diversity in remobilisation, at present unknown.*

Time-lines

- **Physiology and genomics reviews**

1st drafts sent out to scientific experts for feedback in June 2004

- **Breeders consultation**

2nd drafts of reviews sent out in July 2004 for feedback followed by visits to individual breeders

- **Stakeholders' Meetings**

October 2004

- **Report to DEFRA**

November 2004