UNIVERSITÄT HOHENHEIM

Protein use efficiency and stability of baking quality in winter wheat variety trails

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Overview

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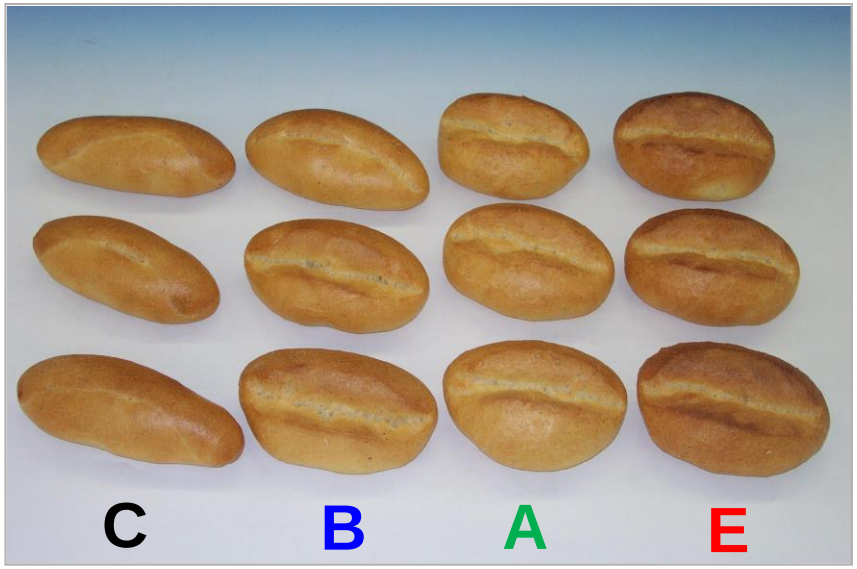
1. Baking qualtiy in winter wheat



Major criterion:
Loaf volume (V) (ml/100g) by
Rapid mixed test (RMT)

Grain protein content (GPC) + Protein quality > Loaf volume (V)

Nitrogen genetically determined

environment

1. Baking qualitiy in winter wheat

Major challenges of qualtiy wheat production

1. Reduction of N-fertilzation (-20%)
   - European Green Deal
   - National fertilization ordinance (DüngeVO)
   - Higher prices for fertilizer
2. Climate change
   more volatile wheater conditions >more variable baking quality

Consequences for variety breeding/testing

Varieties needed with

- higher ProtUE
- more stable baking quality across environments

Definition
Protein use efficiency (ProtUE):
Loaf volumen (RMT) which can be produced by 1% GPC>
ProtUE=V/GPC (ml/1% GPC) (Hüsken 2020)

2. Trial scheme and data

Cycle	years	1988	1989	1990	1991	1992	…	2017	2018	2019
1	1988-1990	S1	S2	S3						
2	1989-1991		S1	S2	S3					
3	1990-1992			S1	S2	S3				
…	…						…			
30	2017-2019							S1	S2	S3

Years 1988-2019
355 released varieties,
thereof 43 reference varieties, 7 years in trial
30 overlapping testing cycles of 3 years
8 locations per year
668 trials and 11,775 samples used for RMT
Trials conducted according to good local agronomic practice

3. Concepts of ProtUE and stability

1. Static ProtUE

Stability of V/GPC is assessed by the mean and variance over environments.

Linear model given by

$$V/GPC_{jk} = \mu_{V/GPC} + f_{jk} \qquad (1)$$

V/GPC_{jk} ProtUE of a variety in the j[th] year and k[th] location.

$\mu_{V/GPC}$ expected value of V/GPC, denoted as the static ProtUE,

f_{jk} random deviation of environments from $\mu_{V/GPC}$

Mean $\mu_{V/GPC}$ assumed to be year-specific, then Eq. (1) is changed to

$$V/GPC_{jk} = \mu_{V/GPC,j} + g_{jk} \qquad (2)$$

$\mu_{V/GPC,j}$ expected value of V/GPC of the *j*[th] year

g_{jk} random deviation from the expected value $\mu_{V/GPC,j}$ in *jk*[th] environment,

$\sigma^2_{V/GPC}$. variance

$\sigma_{V/GPC}$, standard deviation, demoted as static stability measure for V/GPC.

Estimator of $\mu_{V/GPC}$ (Eq. (1))	static ProtUE m_S
Estimator of $\sigma_{V/GPC}$ (Eq. (2))	static stability s_S

2. Dynamic ProtUE

ProtUE assessed by regression of V on GPC and stability by deviation from regression line.

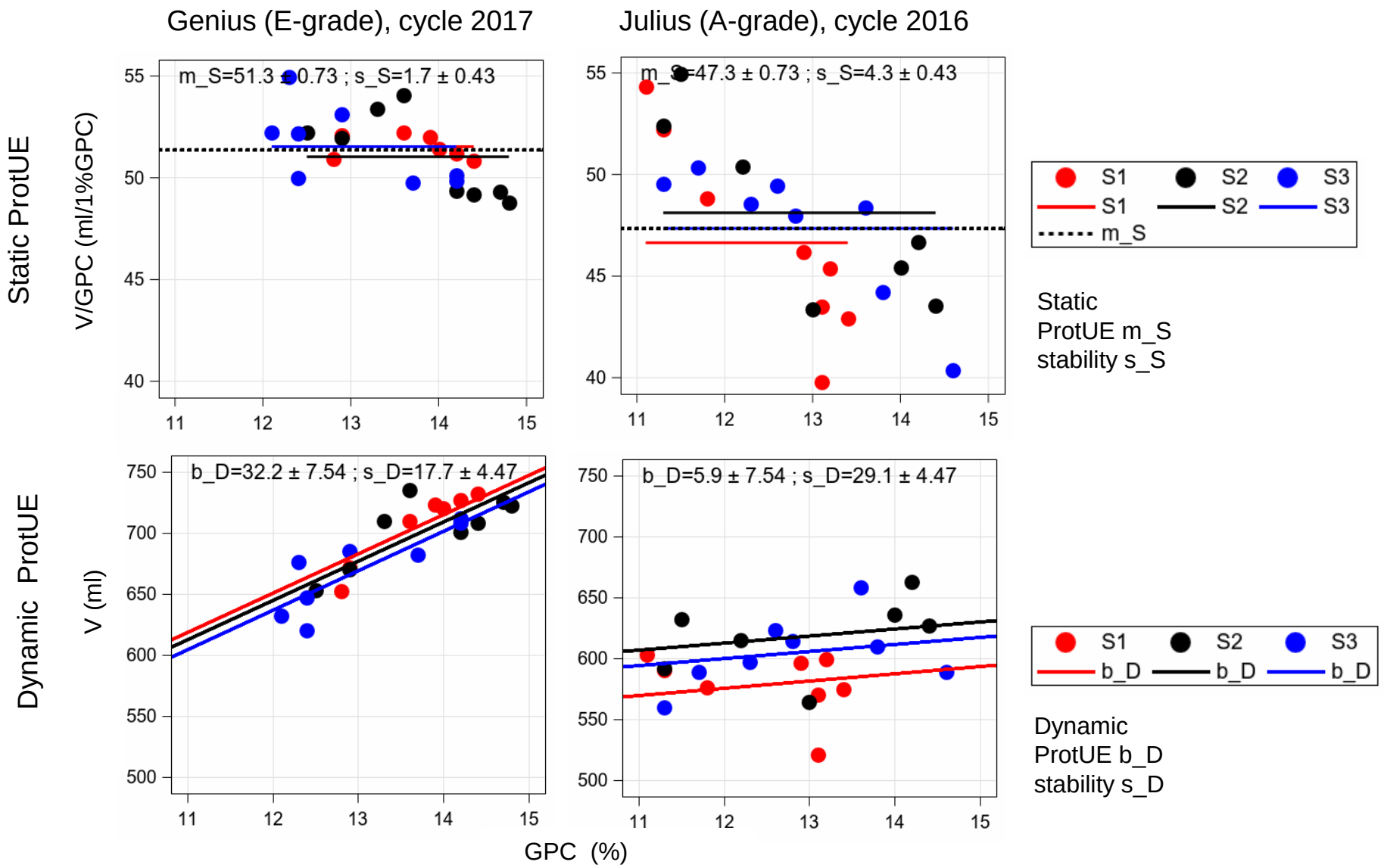
The regression model is

$$V_{jk} = \mu_{V,j} + \beta_D GPC_{jk} + e_{jk} \quad (3)$$

V_{jk}	V of a variety in the j* year and k* location
$\mu_{V,j}$	year-specific intercept
β_D	common slope
GPC_{jk}	covariate for GPC
e_{jk}	random deviation from the regression line with variance σ_D^2
β_D	dynamic ProtUE, indicated by the subscript *D*
σ_D	standard deviation is dynamic stability

Estimator of β_D (Eq. (3))	dynamic ProtUE b_D
Estimator of σ_D (Eq. (3))	dynamic stability s_D

4. Examples of ProtUE and stability



5. Heritability

Cycle based model

$$z_{ij} = \mu + \beta r_i + \gamma c_j + G_i + C_j + e_{ij} \quad (4)$$

z_{ij} measure of interest
(cycle means of V, m_V; of GPC, m_{GPC}; dynamic ProtUE, b_D; dynamic stability, s_D; static ProtUE, m_S; static stability, s_S)

z_{ij} measure i^{th} variety in the j^{th} cycle,

μ overall mean,

β fixed regression coefficient for the genetic trend,

r_i first year in trial of the i^{th} genotype,

γ fixed regression coefficient for the non-genetic trend,

c_j covariate for the j^{th} cycle year,

G_i effect of i^{th} variety,

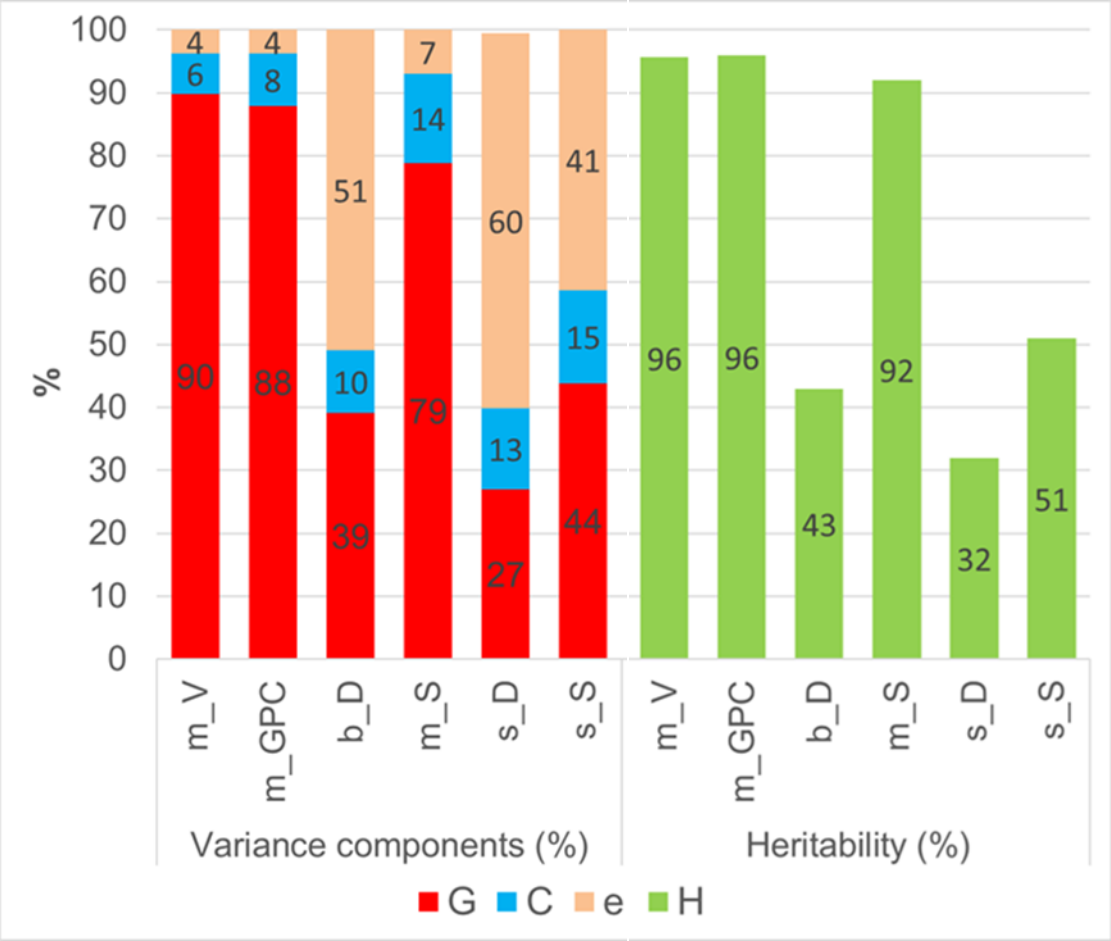
C_j effect of jth cycle year,

e_{ij} residual effect which comprises the residual error and the G × C interaction effect. the G_i, C_j and e_{ij} random effects with variance σ_G^2, σ_C^2 and σ_e^2

Heritability of cycle-based measures for comparison within cycles

$$h^2 = 100 \times \frac{\sigma_G^2}{(\sigma_G^2 + \sigma_e^2)} \quad (5)$$

5. Variance components and heritability



based on variety x cycle measures (Eq. (5))

Heritability
static ProtUE m_S > dynamic b_D
static stability s_S > dynamic s_D

m_V mean V; m_GPC mean GPC; b_D dynamic ProtUE (b_D); s_D dynamic stability (s_D);
m_S static ProtUE (m_S); s_S static stability (s_S);
G Genotype; *C* Cycle; e residual error;

6. Genotypic correlation

Correlation coefficients between genotypic effects G_i of cycle measures z_{ij} (Eq. (5))

m_V					
0.75	**m_GPC**				
0.49	0.40	**b_D**			
0.81	0.22	0.42	**m_S**		
-0.05	0.04	-0.48	-0.03	**s_D**	
-0.24	-0.28	-0.84	-0.07	0.65	**s_S**

m_V mean V; m_GPC mean GPC; b_D dynamic ProtUE (b_D); s_D dynamic stability (s_D);
m_S static ProtUE (m_S); s_S static stability (s_S);

No counter-action of static and dynamic ProtUE and stability on V and P>
Static ProtUE preferable to use as VCU criterion for baking quality

7. Conclusions

- New varieties with higher ProtUE and stability needed >
  very important to reduce N-use and cope with climate change
- Heritability of
  static ProtUE (92%) > dynamic ProtUE (43%)
  static (51%) stability > dynamic (32%)
- No counter-action of
  high dynamic and static ProtUE and stability,
  with V and P
- Static ProtUE and stability will be used as additional criterion for assessing baking quality

Literature

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