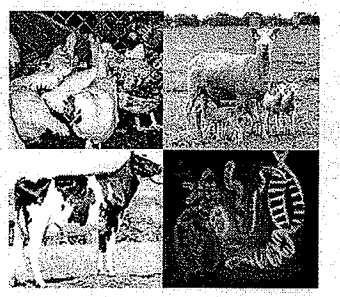
Response to selection II



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IAEA, Korea, April, 2006

Response will be examined for

Own phenotype $R = ih^2\sigma_P \quad R = ih\sigma_A$

Repeated measures

Correlated traits

Selection on BLUP EBVs / selection indices

Why do repeated measures differ?

Repeated measures differ due to *temporary environmental effects*

$$V_E = V_{EP} + V_{ET}$$

Environmental variance (V_E)=

environmental variance due to permanent effects (V_{EP}) + environmental variance due to temporary effects (V_{ET})

Errors with repeated measures

	E for measurement # 1 to 5; drawn from N(0,1) *					
Animal	**1**	**2**	**3**	**4**	**5**	**Mean**
1	-0.66	-1.01	-0.09	0.01	-1.44	-0.64
2	-1.40	2.11	0.64	1.53	1.46	0.87
3	0.67	0.66	-0.35	-0.80	-0.11	0.01
4	-0.94	0.48	0.32	-0.03	-1.75	-0.38
5	1.16	0.39	0.41	0.22	0.32	0.50
6	0.01	-1.73	1.85	1.22	0.09	0.29
7	-0.37	-0.97	0.75	0.76	2.65	0.56
8	-1.58	1.72	0.66	-0.83	-1.99	-0.40
9	-0.01	-0.81	-0.21	-2.11	-0.75	-0.78
10	-1.71	-0.43	-0.02	0.31	0.94	-0.18
11	0.62	-1.27	-0.45	-0.37	0.09	-0.28
12	0.15	-0.99	0.62	-0.74	0.25	-0.14
13	1.37	-1.04	-1.46	-0.24	0.38	-0.20
14	-1.42	-0.85	-0.14	0.97	1.83	0.08
15	-1.16	-1.36	-1.22	-1.06	0.43	-0.88
StdDev	**1.01**	**1.15**	**0.82**	**0.97**	**1.29**	**0.50**

** Environmental measurements were randomly drawn from a normal distribution with mean 0 and standard deviation of 1.*

Repeatability

Defined as

$$r = \frac{V_G + V_{EP}}{V_G + V_{EP} + V_{ET}}$$

ranges from 0 to 1

The larger the temporary environmental effects the lower the repeatability

Response using repeated measures

When the mean of repeated measures are used, temporary environmental effects tend to cancel out.

$$V_{P_n} = V_A + V_{PE} + \frac{V_{TE}}{n}$$

This results in a reduction in V_P (and σ_P)

$$V_{P_n} = \left(r + \frac{1-r}{n}\right)V_p \qquad \sigma_{P_n} = \sqrt{\left(r + \frac{1-r}{n}\right)}\sigma_p$$

Response using repeated measures

Response when selecting on one measure

$$R = ih^2\sigma_P = i\frac{V_A}{V_P}\sigma_P = i\frac{\sigma_A\sigma_A}{\sigma_P\sigma_P}\sigma_P = i\frac{\sigma_A}{\sigma_P}\sigma_A$$

Response when selecting on mean of n measures

$$R_n = ih^2\sigma_{Pn} = i\frac{V_A}{V_{Pn}}\sigma_{Pn} = i\frac{\sigma_A\sigma_A}{\sigma_{Pn}\sigma_{Pn}}\sigma_{Pn} = i\frac{\sigma_A}{\sigma_{Pn}}\sigma_A$$

Proportional decrease in phenotypic standard deviation equates to proportional increase in response

$$R_n = R\frac{\sigma_P}{\sigma_{Pn}}$$

Response to selection II

Additional response using repeated measures

Additional response depends on repeatability

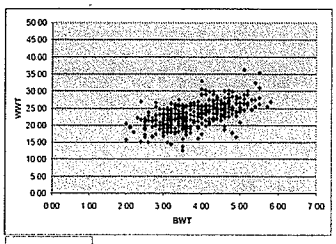
	n=2	n=5
r=0.10	35 %	89 %
r=0.50	16 %	29 %
r=0.90	2.6 %	4.3 %

Highly repeatable traits

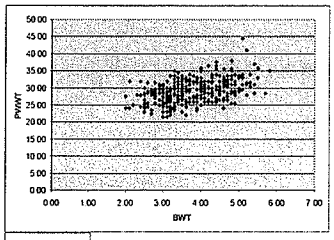
- measurements are similar
- additional measurements add little additional information repeated measures result in a small additional increase in response

Response to selection II

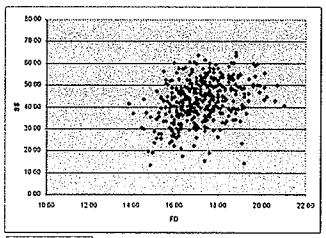
Trait correlations



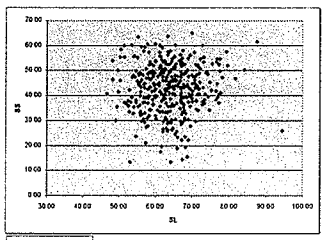
r=0.57



r=0.47



r=0.34



r=0.02

Correlations between traits

Genetic basis

- Genes are pleiotrophic
  - same genes influence the traits
  - e.g. weights over ages, response in two environments
- Genes for each trait are linked and thus inherited together

Environmental basis

- Environmental conditions affecting both traits
  - e.g. muscle and fertility both affected by nutrition

r_G and r_E do not need to be the same sign

Response using correlated traits

$$CR_y = b_A R_x \qquad R_x = i_x h_x^2 \sigma_{Px}$$

$$CR_y = i_x r_A h_x h_y \sigma_{Py}$$

correlated response in trait y when selecting on trait x

genetic correlation

phenotypic standard deviation for trait with correlated response

selection intensity (i) for trait you are selecting on

Response to selection II

CR_y/R_y

Response for indirect selection for a trait relative to response for direct selection for a trait

$$\frac{CR_Y}{R_Y} = \frac{i_x r_A h_x h_y \sigma_{Py} / L_x}{i_y h_y^2 \sigma_{Py} / L_y} = \frac{i_x h_x L_y}{i_y h_y L_x} r_A$$

Response to selection II

Use of correlated response

Indirect selection

- Select on trait X, but interested in response of correlated trait Y
- Useful if trait X is more heritable or can be measured earlier
- May be only option is trait Y is too difficult or expensive to measure

Example

- Objective is to increase weight in Atlantic Salmon
- Can either select on weight directly, or select on length with a correlated response in weight

  - h^2 weight = 0.09
  - h^2 length = 0.16
  - r_A =0.95

$$\frac{CR_Y}{R_Y} = \frac{i_x h_x L_y}{i_y h_y L_x} r_A = \frac{h_x}{h_y} r_A = \frac{\sqrt{0.16}}{\sqrt{0.09}} 0.95 = 1.27$$

selecting on length gives 27% more response in weight then selecting on weight directly (length is more heritable and correlation is strong)

Example

- If weight was the more heritable trait

  - h^2 weight = 0.39
  - h^2 length = 0.16
  - r_A =0.95

$$\frac{CR_Y}{R_Y} = \frac{i_x h_x L_y}{i_y h_y L_x} r_A = \frac{h_x}{h_y} r_A = \frac{\sqrt{0.16}}{\sqrt{0.39}} 0.95 = 0.608$$

selecting on length gives less response in (weight is more heritable)

Response to selection II

Example

- If the genetic correlation is weak

  - h^2 weight = 0.09
  - h^2 length = 0.16
  - r_A =0.15

$$\frac{CR_Y}{R_Y} = \frac{i_x h_x L_y}{i_y h_y L_x} r_A = \frac{h_x}{h_y} r_A = \frac{\sqrt{0.16}}{\sqrt{0.09}} 0.15 = 0.20$$

selecting on length gives less response in weight then selecting on weight directly

Response to selection II

Use of correlated response

To account for genotype x environment (G x E) interactions

For example, wish to compare

- Breed animals in environment A , with animals sold to commercial users in environment A (direct response)

$$R_x = i_x h_x^2 \sigma_{Px}$$

- Breed animals in the more favourable environment B with animals sold to commmercial users in environment A (correlated response)

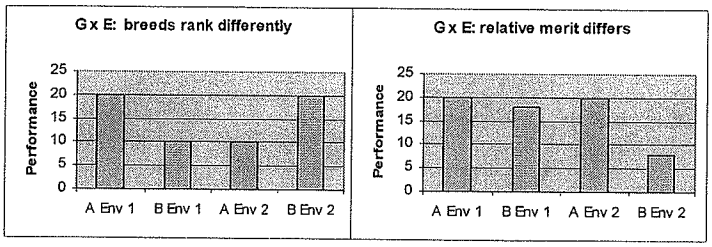
$$CR_y = i_x r_A h_x h_y \sigma_{Py}$$

Response to selection II

G x E interaction

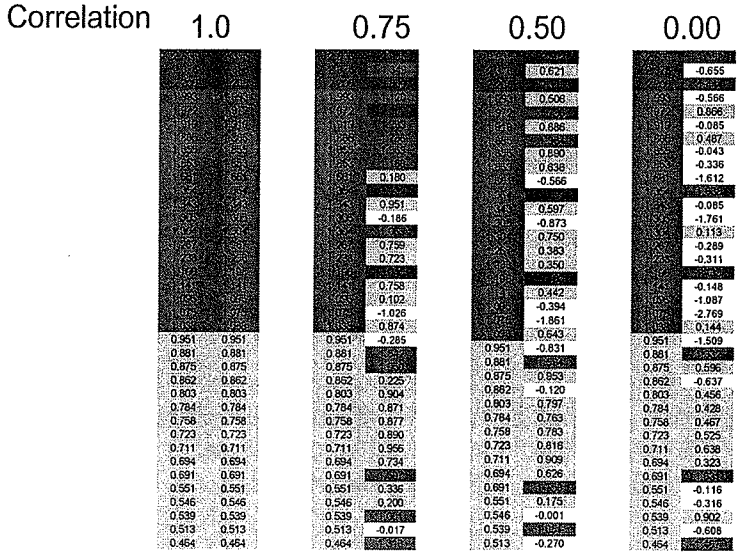
At breed / individuals level

- different breeds / individuals rank differently in different environments
- difference between breeds / individuals is smaller or larger in different environment



Response to selection II

G x E and re-ranking



Response to selection II

Response to selection for BLUP EBVs or selection indices

Selection on own phenotypes

- $R = i\,\sigma_P\,h^2$
- $R = i\,\sigma_A\,h$

Accuracy of MASS (own phenotype) selection

Selection on a selection index

- $R = i\,\sigma_A\,r_{IA}$
- $R = i\,\sigma_{EBV}$

Accuracy of EBV / index selection (correlation between estimated and true BV / index)

Response to selection II

Selection accuracy and response

Selection accuracy $R = i \sigma_A r_{I,A}$

- Range is 0 to 1
  - 0 is no information, 1 is full information
- Relates to heritability
  - low heritability → less accuracy
- Can be improved
  - use of repeated measures
  - information from correlated traits
  - information from relatives, especially progeny testing

More information → more accuracy → more response

Reaslised versus predicted response

These can differ due to

- Random drift
- Incorrect heritability estimates
- Inbreeding
- Non-random mating
- Natural selection
- Maternal effects
- Variance loss due to selection
- Environmental variation
- Selection limit reached

Additional reading on this topic

Falconer, D. S. (1989) Introduction to quantitative genetics, 3rd edition. Longman Scientific and Technical, Essex, England

- Chapter - *Selection; I The response and its prediction*

Cameron, N. D. (1997) Selection indices and prediction of genetic merit in animal breeding. CAB International, Oxon, UK.

- Chapter 4 – Identification of animals of high genetic merit