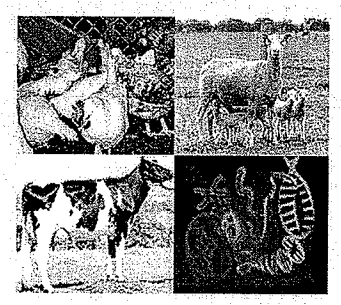
Multiple trait selection



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IAEA, Korea, April, 2006

Multiple trait breeding objectives

- Breeding objectives = "where you want to go"
- Should include all traits of economic importance
- Select on an index where index weights are derived taking into account
  - Relationships between traits
  - Economic value of each trait

Range of possible responses in two traits

r_A=1 or -1

r_A=1 (-1) both traits will always change in same (oppsite) direction

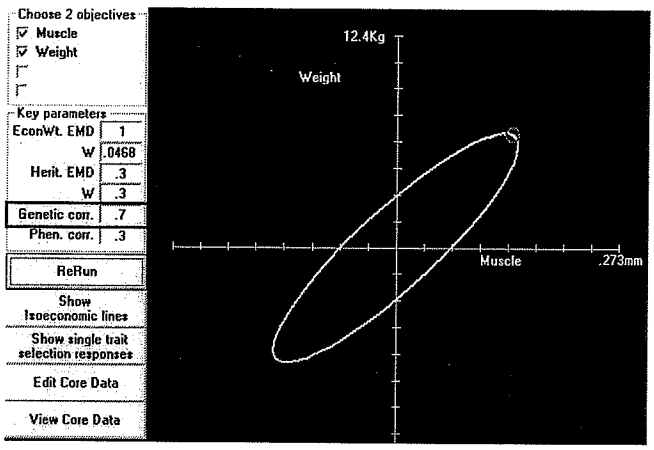
r_A between 0 and 1

easy to change traits in same direction
possible to change traits in opposite direction
- harder if r_A is closer to 1
- compromise is that maximal response is not obtained for either trait

r_A between 0 and -1

easy to change traits in opposite direction
possible to change traits in same direction
- harder if r_A is closer to -1
- compromise that that maximal response is not obtained for either trait

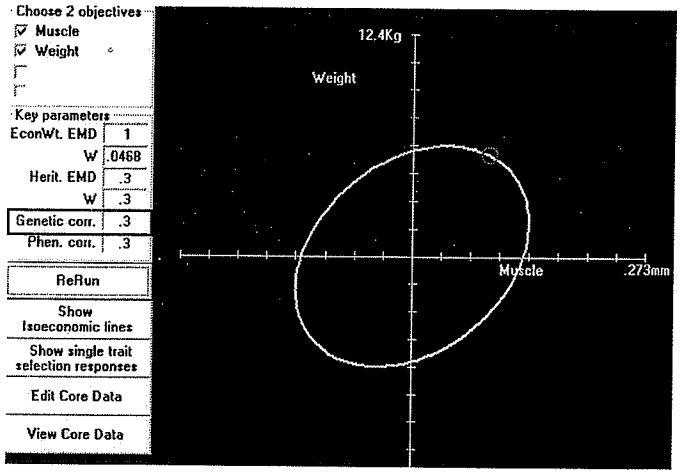
Multiple trait selection



The 'ellipse' is the range of possible outcomes, in one generation

As association is positive
- most possible outcomes lie in quadrants for high PWWT and high EMD, or low PWWT and low EMD
- some possible outcomes lie in the other quadrants

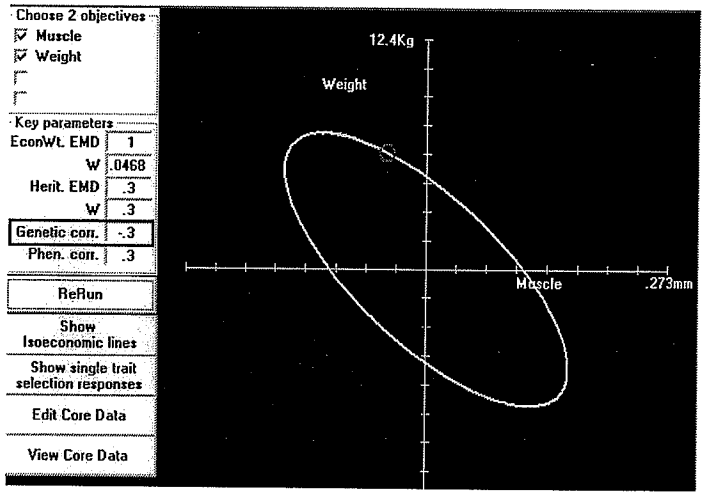
Multiple trait selection



Association is positive but less strong

- Lower maximal response for increased PWWT and EMD
- More outcomes in undesirable quadrants

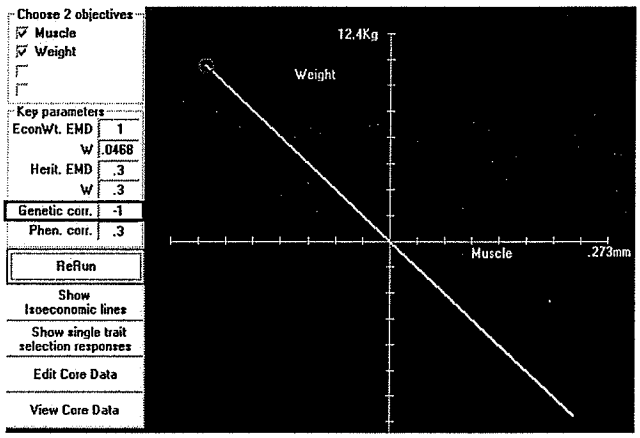
Multiple trait selection



If the association was negative

- More difficult but not impossible to increase both PWWT and EMD

Multiple trait selection



If the genetic correlation was -1

- Could not increase both PWWT and EMD

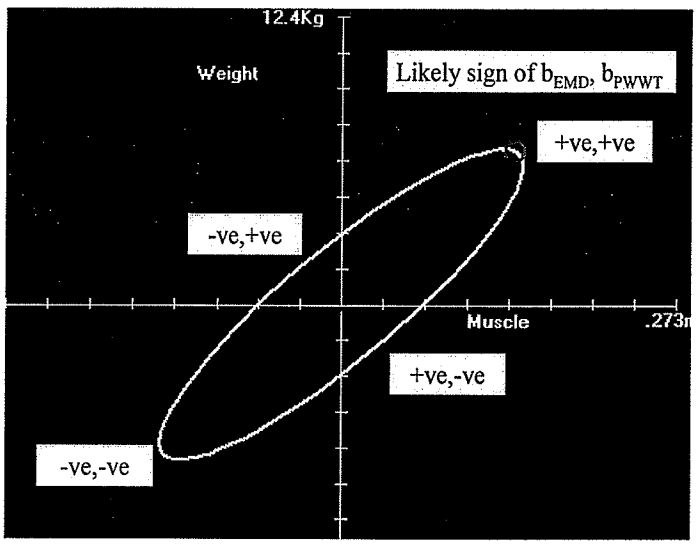
Calculation of weights (b)

$$\text{Index} = b_1X_1 + b_2X_2 + b_3X_3 + \ldots.$$

Weights on each information source take into account

- relationships between traits (set)
- economic values of breeding objective traits (variable)
- *$b=P^{-1}Ga$ (see later)*

The relative response in each trait can be changed by altering the economic values and thus index weights of the traits



Multiple trait selection

Calculation of weights (b)

H (breeding objective) = $b_1X_1 + b_2X_2 + b_3X_3 + \ldots$

$b=P^{-1}Ga$

- **b** is a vector of selection index weights for traits in the selection criteria,
- **P** is the phenotypic variance-covariance matrix for traits in the selection criteria, Var(X)=P
- **G** is the genetic covariance matrix between traits in the breeding objective and the traits in the selection criteria, Cov(X,H)=G
- **a** is a vector of the economic values of traits in the breeding objective

Multiple trait selection

Example

Objective
- GR fat depth (GR)
- eye muscle area (EA)

Criteria
- C fat depth (CF)
- Eye muscle area (EA)
- Liveweight (LW)

$$\begin{bmatrix} b_{LW} \\ b_{CF} \\ b_{EA} \end{bmatrix} = \begin{bmatrix} CovP_{LW,LW} & CovP_{LW,CF} & CovP_{LW,EA} \\ CovP_{CF,LW} & CovP_{CF,CF} & CovP_{CF,EA} \\ CovP_{EA,LW} & CovP_{EA,CF} & CovP_{EA,EA} \end{bmatrix}^{-1} \begin{bmatrix} CovA_{LW,EA} & CovA_{LW,GR} \\ CovA_{CF,EA} & CovA_{CF,GR} \\ CovA_{EA,EA} & CovA_{EA,GR} \end{bmatrix} \begin{bmatrix} a_{EA} \\ a_{GR} \end{bmatrix}$$

Index weights

Phenotypic VCV matrix of traits in the selection criteria

Genetic covariance matrix between traits in the selection criteria and objective

Economic values of breeding objective traits

Multiple trait selection

Index selection

Variance of the index $V_{Index} = V_{(b'X)} = b'V_X b = b'Pb$

$ response per generation $\$R = i\sigma_{Index} = i\sqrt{b'Pb}$

Component trait response $\Delta G = \frac{b'G}{\sigma_{Index}}$

Case study

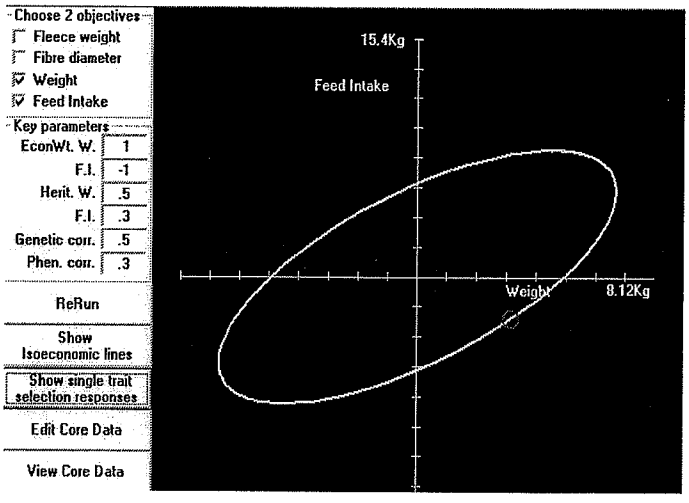
Weight (W) & Feed Intake (FI)

- Traits have a positive genetic and phenotypic correlation
- Typical industry objective is to increase weight and decrease feed intake

	h^2	σ_P
W	0.5	17kg
FI	0.3	25kg
r_A	0.5	
r_P	0.3	

Multiple trait selection

Ellipse of possible responses



Multiple trait selection

Breeding objective & selection criteria | Economic values | Index weights | Response

BO	SC	ev_W assumed	ev_{FI} assumed	b_W	b_{FI}	R_W	R_{FI}
W	W	1	0	0.5	*na*	8.50	4.84
W	W&FI	1	0	0.49	0.03	8.53	5.40
W&FI	W&FI	1	-1	0.32	-0.23	4.02	-2.64
W&FI	W&FI	1	-3	-0.97	-7.65	-3.40	-7.54

Multiple trait selection

Relationship between economic values and breeding objectives

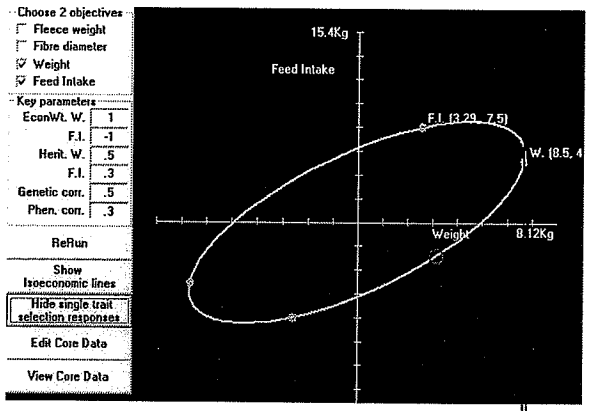
BO	SC	ev_W assumed	ev_{FI} assumed	b_W	b_{FI}	R_W	R_{FI}
W	W	1	0	0.5	*na*	8.50	4.84
W	W&FI	1	0	0.49	0.03	8.53	5.40
W&FI	W&FI	1	-1	0.32	-0.23	4.02	-2.64
W&FI	W&FI	1	-3	-0.97	-7.65	-3.40	-7.54

Multiple trait selection

Single trait breeding objective

BO	SC	ev_W assumed	ev_{FI} assumed	b_W	b_{FI}	R_W	R_{FI}
W	W	1	0	0.5	*na*	8.50	4.84
W	W&FI	1	0	0.49	0.03	8.53	5.40
W&FI	W&FI	1	-1	0.32	-0.23	4.02	-2.64
W&FI	W&FI	1	-3	-0.97	-7.65	-3.40	-7.54

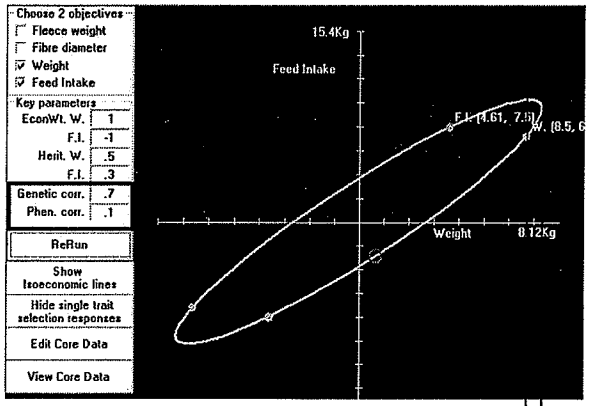
Multiple trait selection



BO = W
SC = W

BO = W
SC = W + FI

Multiple trait selection



BO = W	BO = W
SC = W	SC = W + FI

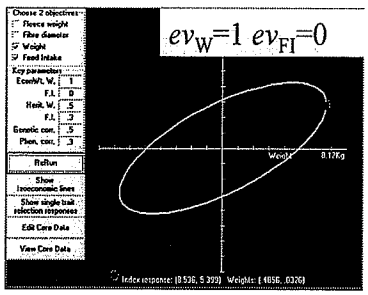
Multiple trait breeding objective

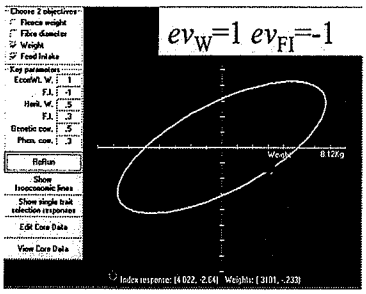
BO	SC	ev_W assumed	ev_{FI} assumed	b_W	b_{FI}	R_W	R_{FI}
W	W	1	0	0.5	*na*	8.50	4.84
W	W&FI	1	0	0.49	0.03	8.53	5.40
W&FI	W&FI	1	-1	0.32	-0.23	4.02	-2.64
W&FI	W&FI	1	-3	-0.97	-7.65	-3.40	-7.54

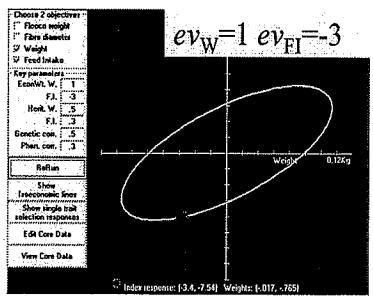
Note the relationship between economic values, index weights, and subsequent response

BO	SC	ev_W assumed	ev_{FI} assumed	b_W	b_{FI}	R_W	R_{FI}
W	W	1	0	0.5	*na*	8.50	4.84
W	W&FI	1	0	0.49	0.03	8.53	5.40
W&FI	W&FI	1	-1	0.32	-0.23	4.02	-2.64
W&FI	W&FI	1	-3	-0.97	-7.65	-3.40	-7.54

Multiple trait selection







Multiple trait selection

Note compromise in trait response

BO	SC	ev_W assumed	ev_{FI} assumed	b_W	b_{FI}	R_W	R_{FI}
W	W	1	0	0.5	*na*	8.50	4.84
W	W&FI	1	0	0.49	0.03	8.53	5.40
W&FI	W&FI	1	-1	0.32	-0.23	4.02	-2.64
W&FI	W&FI	1	-3	-0.97	-7.65	-3.40	-7.54

Correct economic values → correct index weights → most $ returns

BO	SC	ev_W assumed	ev_{FI} assumed	b_W	b_{FI}	R_W	R_{FI}	$
W	W	1	0	0.5	*na*	8.50	4.84	3.66
W	W&FI	1	0	0.49	0.03	8.53	5.40	3.13
W&FI	W&FI	1	-1	0.32	-0.23	4.02	-2.64	6.66
W&FI	W&FI	1	-3	-0.97	-7.65	-3.40	-7.54	4.14

*$ return was calculated using **real** economic values of +1 for weight and -1 for feed intake*

Correct economic values → correct index weights → most $ returns

BO	SC	ev_W assumed	ev_{FI} assumed	b_W	b_{FI}	R_W	R_{FI}	$
W	W	1	0	0.5	*na*	8.50	4.84	-6.02
W	W&FI	1	0	0.49	0.03	8.53	5.40	-7.67
W&FI	W&FI	1	-1	0.32	-0.23	4.02	-2.64	11.94
W&FI	W&FI	1	-3	-0.97	-7.65	-3.40	-7.54	19.22

$ return was calculated using real economic values of +1 for weight and -3 for feed intake

Multiple trait selection

Points to note

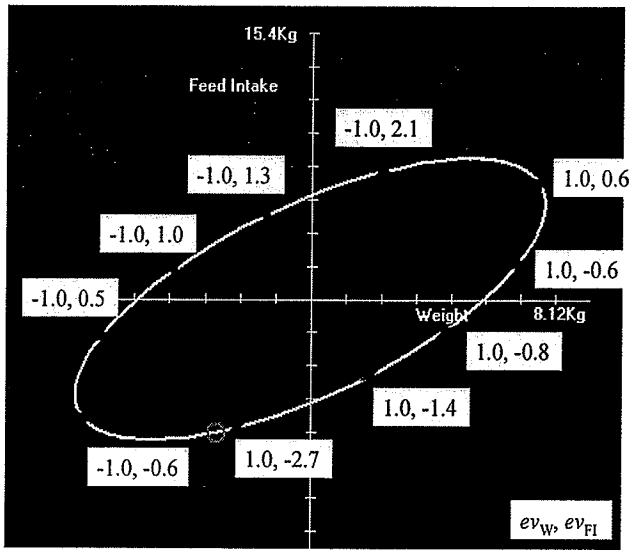
Changing the economic value of traits, alters the index weights, and thus response

The highest $ return is achieved when the index weights are calculated using the true economic values

Definition of an economic value – is $ return for a one unit trait increase (all other traits held constant)

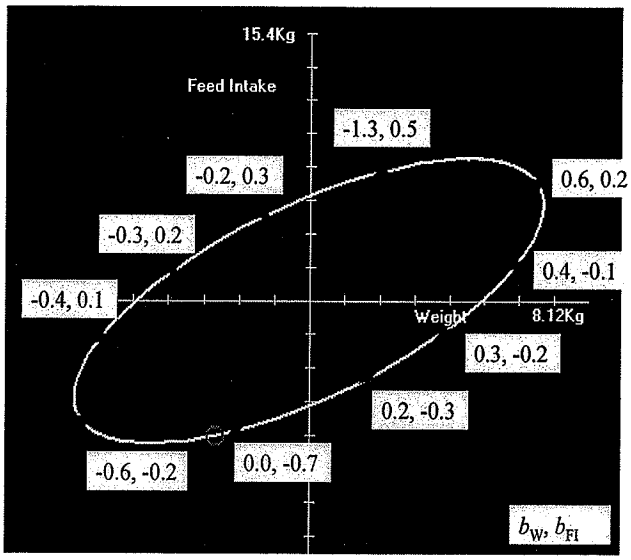
Multiple trait selection

Obtaining different responses by altering the economic value

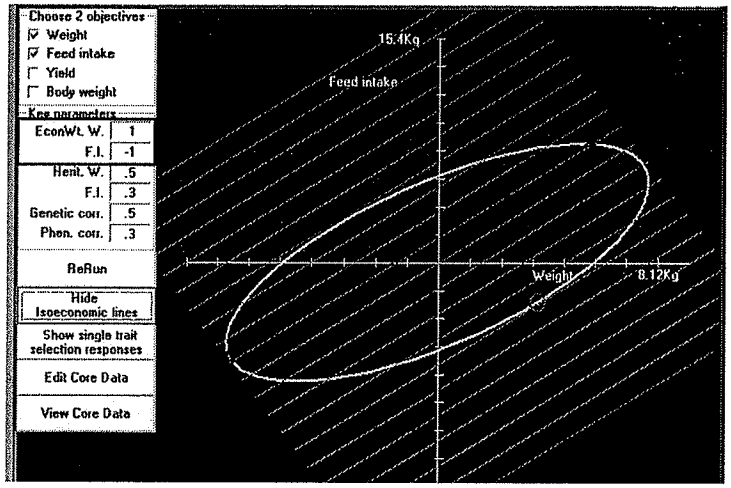


Multiple trait selection

Corresponding index weights



Multiple trait selection



Isoeconomic lines are lines of equal economic value

- * gives an example of the same economic return achieved through different trait response
- red circle is the most economic place to be

Multiple trait selection

Could we decrease feed intake with no change in weight?

BO	SC	ev_W assumed	ev_{FI} assumed	b_W	b_{FI}	R_W	R_{FI}
W&FI	W&FI	1	-1	0.32	-0.23	4.02	-2.64
W&FI	W&FI	1	-3.2	0.26	-0.92	0.00	-7.12
W&FI	W&FI	1	-3	-0.97	-7.65	-3.40	-7.54

Multiple trait selection

A final note

EBVs calculated via multi-trait BLUP already account for relationship between the traits

To combine into an index, simply weight by the economic value

$$\$index = ev_{trait1} \times EBV_{trait1} + ev_{trait2} \times EBV_{trait2} \cdots$$