

## Selection strategies utilizing genetic resources to adapt livestock to climate change

B. A. Åby\* and T. Meuwissen\*

\*Norwegian University of Life Sciences, Department of Animal and Aquacultural Sciences, Norway

**ABSTRACT:** Climate change results in new challenges for livestock production and genetic adaptations are needed to avoid production losses. It is inadequate to merely store genes affecting adaptive traits in animal genetic resources. Adaptive traits must be implemented quickly within the commercial breeds or these breeds must be replaced with better adapted, possibly crossbred, populations. We performed a simulation study comparing different selection strategies applied to two subpopulations which were divergently selected for a production (PROD) or a fitness trait (FIT). The selection strategies were: 1) selection within PROD using BLUP; 2) selection within PROD using genomic selection; 3) crossbreeding between PROD and FIT using BLUP; 4) crossbreeding using genomic selection (GBLUP<sub>CB</sub>). The selection strategies resulted in different adaptive rates. GBLUP<sub>CB</sub> resulted in the quickest adaptation. However, further studies including other selection strategies and practical livestock breeding schemes are needed.

**Keywords:** climate change; genetic resources; genomic selection; selection strategies

### Introduction

Climate change will most likely introduce new challenges for animal production such as increased heat stress, reduced availability and increased prices of feeds and more disease pressure. A risk for future livestock production is the possibly too slow adaptive potential of current breeds to these new conditions, which in turn will lead to production losses (Nardone et al. (2010)). This is especially problematic in a world that needs more food to feed a fast growing human population. Next to management adaptations, the genetics of the animals needs to be adapted to, e.g., higher temperatures, lower quality diets and more disease pressures. This will require changes of breeding schemes and breeding goals (i.e., inclusions of new adaptive traits of economic importance). These changes need to be implemented rapidly into the commercial breeds or the commercial breeds needs to be replaced with better adapted, possibly crossbred, populations. For the latter Animal Genetic Resources (ANGR) may be used, in case the ANGR express the desired adaptive traits. Several breeding strategies may be considered to establish new adaptations in common, commercial breeds: 1) selection within the commercial breed for the adaptive trait; 2) select a new breed amongst the conserved breeds and select within that breed; 3) indentify the traits that the commercial breed is lacking; detect the genes underlying these traits and introgress these genes from another breed using a combined QTL detection and introgression scheme (Yazdi et. al

2010)); 4) perform crossbreeding to generate a new, synthetic breed and then select within the synthetic breed; 5) as in 1-4) but use genomic selection to speed up the genetic progress (Meuwissen et al., (2001)). The approach which results in the fastest adaptation to the new production circumstances will be favored.

The aim of this study was to compare alternative selection methods that adapt livestock to changing production conditions. To do this, a simulation study was performed and different selection strategies were compared based on their rate of genetic adaptation to new production circumstances.

### Materials and Methods

In this study, we used genetic resources from two divergently selected subpopulations: 1) the commercial breed selected for a production trait, PROD; and 2) an ANGR breed which has been mainly selected for a fitness related trait FIT (e.g. disease resistance). The simulations of the subpopulations and the applied selection strategies are described below.

**Simulation of populations.** A base population (N=200) was simulated for 2,000 generations of random mating before the population split into two equally sized subpopulations (N=100). The subpopulations were subsequently divergently selected for the two traits for 20 generations. One subpopulation was selected for PROD (per chromosome  $h^2=0.4/30$ ), whereas the other was selected for FIT (per chromosome  $h^2=0.2/30$ ).

To reduce computations, the genome consisted of a one Morgan chromosome. The mutation rate was 2 per chromosome and the probability that a mutation becomes a QTL was 0.025. The minimum frequency for a SNP to be included was 0.03. This resulted in a total of 3,990 SNPs and 100 QTL with effects on both traits. QTL effects were adaptive and sampled from a gamma distribution with a shape parameter of one. The traits were independent. Selection was based on estimated breeding values, and the top 40% males and 40% females were mated at random. The last generation of the PROD and FIT subpopulations (generation 2,020) was randomly mated to create base populations (generation 0). Different selection strategies were applied to the individuals in generation 0.

**Selection strategies.** Four alternative selection strategies were compared: 1) selection within PROD using conventional BLUP breeding values (PBLUP<sub>PROD</sub>); 2) se-

lection within PROD using genomic selection (GBLUP<sub>PROD</sub>); 3) crossbreeding between PROD and FIT using conventional BLUP (PBLUP<sub>CB</sub>); 4) crossbreeding using genomic selection (GBLUP<sub>CB</sub>).

Generations were discrete. In all schemes, 400 individuals were produced every generation and 40 sires and dams were selected. No preselection was assumed. The traits had equal economic weights. The strategies were evaluated on their genetic gain after 10 generations of selection. All results were averaged over 20 replicates.

**Breeding value estimation.** Two types of estimated breeding values (EBV) were used: PBLUP-EBV and GBLUP-EBV (GEBV). PBLUP-EBV were based on Henderson's (1984) mixed model equations. For GEBV, the individuals in generation 0-t were assumed genotyped and their phenotypes were used to estimate SNP effects using BLUP (Meuwissen et al., 2001). The estimates of the marker effects were used to calculate GEBV:

$$GEBV_i = \sum_{j=1}^{3,990} x_{ij} a_j$$

Where  $x_{ij}$  was the standardized marker genotype for animal  $i$  in position  $j$  ( $x_{ij}=(X_{ij}-2p_j)/\sqrt{2p_j(1-p_j)}$ ) with  $X_{ij}$  being the number of '1' alleles in the marker genotype and  $p_j$  being the frequency of the '1' allele); and  $a_j$  was the BLUP estimate for the  $j$ th SNP effect.

## Results and Discussion

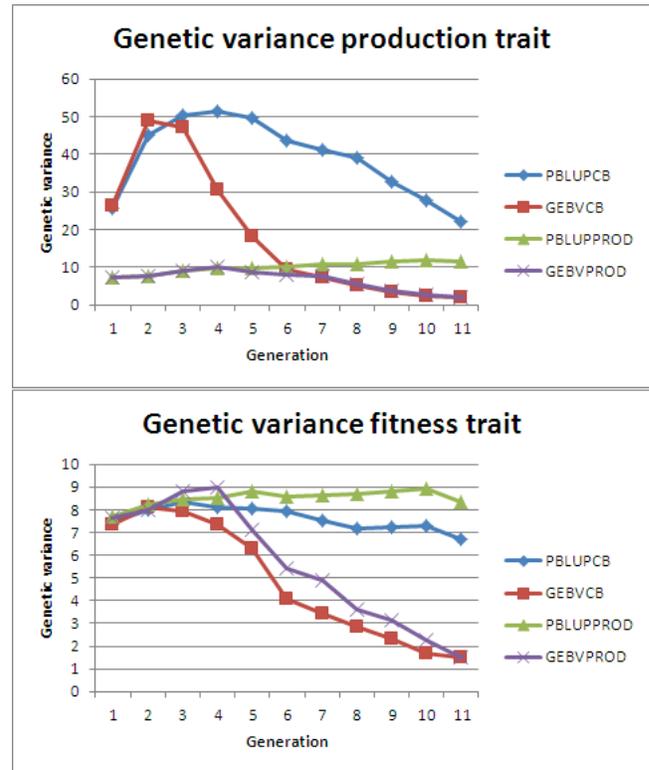
Average genetic progress per generation for the alternative selection strategies and rates of inbreeding are shown in Table 1. The differences in rate of genetic adaptation between the selection strategies may be explained by differences in genetic variances (Table 2) and selection accuracies (shown for males in Figure 2). The genetic gain was higher for the production trait compared to the fitness trait due to higher accuracies of the estimated breeding values, higher heritability and higher genetic variance (Figure 1). The rate of genetic gain for the production trait was largest for the GEBV<sub>CB</sub>-scheme. This was due to the substantial lower genetic variance within the PROD subpopulation (Figure 1). For the fitness trait, genetic gains using GEBV<sub>PROD</sub> and GEBV<sub>CB</sub> are similar, with a slightly higher progress using GEBV<sub>PROD</sub>. This is probably due to the slower reduction in genetic variance, as shown in Figure 1. PBLUP resulted in lower genetic progress than GEBV due to the lower selection accuracy (Figure 2). The GEBV schemes also resulted in lower rates of pedigree-based inbreeding compared to the selection strategies using PBLUP-EBV. This is due to the fact that selection on PBLUP-EBV results in the selection of more closely related individuals than when selecting for GBLUP-EBV. The selection strategy that resulted in the highest total genetic progress was selection on GEBV<sub>CB</sub>. However, the best se-

lection strategy also depends on the difference in genetic level between the PROD and CB populations in generation 0. Crossbreeding may result in a lower overall initial genetic level than the commercial purebred population (not including dominance effects). In such situations, the higher genetic gain may or may not compensate for this lower initial genetic level. This aspect was not investigated here, and in practice, depends on the choice of the crossbred populations.

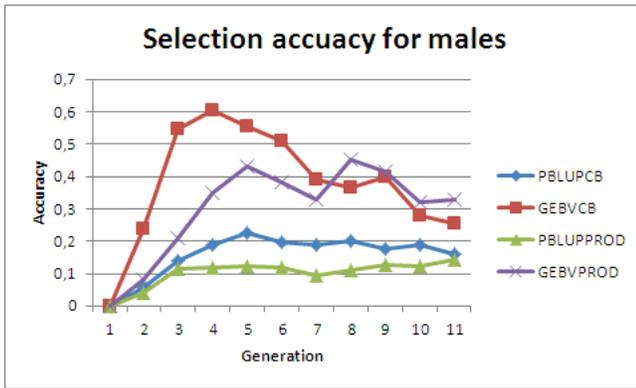
**Table 1. Estimates of genetic gain ( $\Delta_G$ ) for the production and fitness traits and rate of inbreeding ( $\Delta F$ ) for different selection strategies**

Selection strategy	$\Delta_G$ production	$\Delta_G$ fitness	$\Delta F$
PBLUP <sub>PROD</sub> <sup>1</sup>	0.656	0.412	0.025
GEBV <sub>PROD</sub> <sup>2</sup>	1.669	1.028	0.014
PBLUP <sub>CB</sub> <sup>3</sup>	2.064	0.398	0.028
GEBV <sub>CB</sub> <sup>4</sup>	3.190	0.901	0.013

<sup>1</sup>selection within PROD using conventional BLUP-EBV; <sup>2</sup>selection within PROD using genomic selection; <sup>3</sup>crossbreeding between PROD and FIT using conventional BLUP-EBV; <sup>4</sup>crossbreeding using genomic selection



**Figure 1: Genetic variance for the production and fitness traits during 10 generations of selection for PBLUP<sub>PROD</sub> (selection within PROD using conventional BLUP-EBV); GEBV<sub>PROD</sub> (selection within PROD using genomic selection); PBLUP<sub>CB</sub> (crossbreeding between PROD and FIT using conventional BLUP-EBV) and GEBV<sub>CB</sub> (crossbreeding using genomic selection)**



**Figure 2: Selection accuracy for males during 10 generations of selection for PBLUP<sub>PROD</sub> (selection within PROD using conventional BLUP-EBV); GEBV<sub>PROD</sub> (selection within PROD using genomic selection); PBLUP<sub>CB</sub> (crossbreeding between PROD and FIT using BLUP-EBV) and GEBV<sub>CB</sub> (crossbreeding using genomic selection)**

Introgression schemes using genomic selection were not included in this study. According to Ødegård et al. (2009), introgression has an advantage over genomic selection when a major QTL influences a lowly heritable fitness trait, such as disease resistance. More research in more practical and complex livestock breeding schemes, including introgression schemes, is needed.

## Conclusion

Genetic adaptation of livestock to new production conditions may be an important factor to meet the challenges of future climate changes. Different selection strategies will result in different adaptation rates to new production conditions. A combination of performing crossbreeding and genomic selection resulted in the highest genetic gain, but the adaptation potential also depends on the initial difference in genetic level between the cross- and purebred populations. More studies including other selection strategies (e.g., genomic selection introgression) and resembling practical livestock breeding schemes need to be performed.

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