

# 421. Exploiting phenotypic plasticity in animal breeding

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## Abstract

Livestock populations can have different genetic backgrounds and may vary in their capacity to respond to environmental changes. Our findings suggest that improved chicken breeds differ in growth performance and phenotypic plasticity (yield stability) when they are introduced into new tropical environments. Dual consideration of productivity and phenotypic plasticity gives opportunities to select or recommend genotypes with optimal performance and wider adaptability for smallholder farmers raising livestock in different agroecologies.

## Introduction

Phenotypic plasticity refers to the variation in phenotype (e.g. morphological, physiological, behavioural) which results from complex relationships between a genotype and its environment (s). A genotype that shows high phenotypic variation across environments is termed 'phenotypically plastic' while the one that shows low variation is termed 'robust' or 'stable'. Plastic responses for a quantitative trait surfaces as genotype by environment interaction (G×E) during statistical analysis and can be explained through a 'reaction norm'.

Plasticity is thought to be under genetic control. Some genes control both plasticity and mean phenotype while many others are associated only with plasticity (Sieriebriennikov *et al.*, 2018; Lafuente and Beldade, 2019). Phenotypic plasticity can be incorporated as a selectable trait into an animal breeding programme to develop individuals or populations with wider environmental adaptation (De Jong and Bijma, 2002). Plasticity can also be harnessed to screen candidate breeds for introduction at scale to smallholder farmers in the tropics. The objective of the present study is to exploit the concept of plasticity to select and recommend improved chicken breeds with wider environmental adaptation and higher growth performance.

## Materials & methods

We distributed five different chicken breeds into three different agroecologies of Ethiopia. The agroecologies were defined following the approaches by Kebede *et al.* (2021) who applied species and phenotypic distribution models. Species Distribution Models (SDMs), implemented in MaxEnt (Phillips *et al.*, 2006) and similar software, predict distribution of a species based on presence-only data, estimate the contribution of environmental predictors, and help identify environmental predictors associated with habitat suitability and phenotypic differentiation in current and future environments. Agroecologies defined through distribution models give a better estimate of G×E compared to conventional agroecologies defined on agronomic attributes (e.g. length of cropping season) and are more appropriate to evaluate phenotypic plasticity in livestock.

A total of 21,562 improved chickens were raised by 2,547 smallholder households and average live body weight of each flock was recorded. The growth performance and plasticity (yield stability) of the five

chicken breeds until 150-days-of-age (LBW150) across three distribution-model-defined-agroecologies (AEI, AEII, and AEIII) was compared by Additive multiplicative interaction model (AMMI) and mixed-effects (REML)/LMM models.

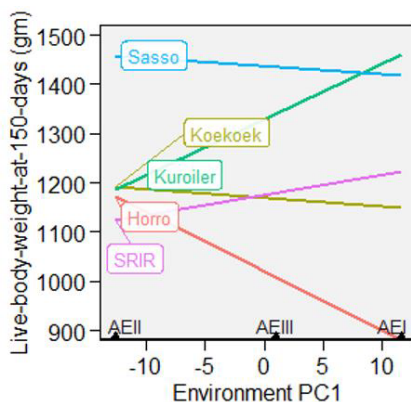
## Results

The phenotypic plasticity for LBW150 among different chicken breeds introduced into different environments based on AMMI model is presented in Figure 1. Performance of the five breeds in the different agroecologies is presented against the first environmental principal component (along the x-axis). The plastic responses of the breeds for LBW150 are characterized by changes in magnitude and rank, signifying the presence of G×E. Breeds with gentler slopes in the reaction norm plots (Sasso, SRIR and Potchefstroom Koekoek) indicate these breeds have wider adaptation (are less plastic). Kuroiler breed, shows a steeper slope (more plastic/less stable) and appears to be a better choice to be introduced specifically into agroecology-I (AEI). Differential growth performance of these breeds in conventionally defined agroecologies was shown by other statistical approaches (Lozano-Jaramillo *et al.*, 2019a,b; De Kinderen *et al.*, 2020; Alemu *et al.*,2021) supporting the presence of G×E.

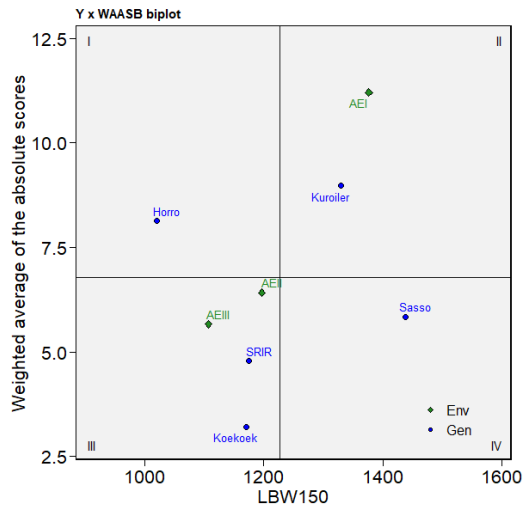
WAASB (Weighted Average of Absolute Scores) biplots on LMM/REML-based analysis for productivity and plasticity are presented in Figure 2. The breeds or agroecologies included in quadrant I are considered unstable breeds or agroecologies with high discrimination ability, and productivity level below the grand mean. We have Horro in quadrant I. Unstable breeds with productivity above the grand mean are included in quadrant II. The only breed which fell into this category is Kuroiler. Breeds withing quadrant III (SRIR and Koekoek) have close to average productivity but can be considered less plastic (stable) due to the lower value of WAASB. The lower the WAASB stability value, the more stable the breed can be considered. The agroecology included in the third quadrant are considered as unfavourable and having low discrimination ability. The breed within quadrant IV (Sasso) is considered highly productive and broadly adapted (less plastic/more stable).

## Discussion

The five chicken breeds showed different levels of growth performance and plasticity for LBW150 in three agroecologies defined by distribution models. That was probably due to differences in their genetic backgrounds (e.g. genes influencing plasticity, selection history, levels of inbreeding). AMMI and LMM



**Figure 1.** Performance plots showing phenotypic plasticity of five chicken strains for LBW150 against environmental principal component analysed by AMMI model. AEI, AEII, and AEIII, indicate the distance of agroecologies along PC1.



**Figure 2.** Biplot of LMM analysis for LBW150 showing mean growth performance (x-axis) and plasticity (four-quadrants) of five improved chicken breeds.

detected G×E differently but effectively. But LMM was more sensitive in identifying productive and stable breeds than AMMI. LMM-based models and indexes allowed fitting of random effects and helped generate biplots combining productivity and yield stability. Multi-environment comparison of breeds on productivity and plasticity is essential before new breeds are introduced to suboptimal environments of the tropics. Such comparisons may help identify breeds with high productivity and low plasticity for smallholders.

We recommend that phenotypic plasticity should be harnessed by animal breeders to deal with changes in production environment at present and future scenarios (e.g. climate, health, management levels). In depth studies should be conducted to understand molecular mechanisms controlling plasticity of QTLs. Multi-environment performance models incorporating diverse information (e.g. phenotypic, environmental, and genetic/genomic) should be also developed for comparison of livestock breeds on productivity and plasticity for smallholder systems.

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## References

- Alemu, S. W., Hanotte, O., Kebede, F. G., Esatu, W., Abegaz, S., *et al.* (2021). *Acta Agric. Scand. A Anim. Sci.* 70, 71-77. <https://doi.org/10.1080/09064702.2021.1891278>
- De Jong, G., and Bijma, P. (2002). *Livest. Prod. Sci.* 78, 195-214. [https://doi.org/10.1016/S0301-6226\(02\)00096-9](https://doi.org/10.1016/S0301-6226(02)00096-9)
- De Kinderen, M. A., Sölkner, J., Mészáros, G., Alemu, S. W., Esatu, W., *et al.* (2020). *Acta Fytotech. Zootech.* 23. <https://doi.org/10.15414/afz.2020.23.mi-fpap.205-213>
- Kebede *et al.*, K. H., Dessie T, Alemu SW, Hanotte O and Bastiaansen J (2021). *Front. Genet.* 12:723360. <https://doi.org/10.3389/fgene.2021.723360>
- Lafuente, E., and Beldade, P. (2019). *Front. Genet.* 10, 720. <https://doi.org/10.3389/fgene.2019.00720>

- Lozano-Jaramillo, a., Alemu, S., Dessie, T., Komen, H., and Bastiaansen, J. (2019a). *Sci. Rep.* 9, 1-11. <https://doi.org/10.1038/s41598-019-51910-6>
- Lozano-Jaramillo, M., Bastiaansen, J., Dessie, T., and Komen, H. (2019b). *Anim.* 13, 1536-1543. <https://doi.org/10.1017/S1751731118003002>
- Phillips, S. J., Anderson, R. P., and Schapire, R. E. (2006). *Ecol Modell* 190, 231-259. <https://doi.org/10.1016/j.ecolmodel.2005.03.026>
- Sieriebriennikov, B., Prabh, N., Dardiry, M., Witte, H., Röseler, W., *et al.* (2018). *Cell Rep.* 23, 2835-2843. <https://doi.org/10.1038/s41598-019-51910-6>