DOI: http://dx.doi.org/10.14334/Proc.Intsem.LPVT-2018-p.357-364

Genetic and Environmental Interaction for Small Ruminant Development to Improve the Economic Value

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ABSTRACT

Small ruminants contribute very significantly to farmers' income in Indonesia. The productivity of small ruminants is affected by breed or genotype and by the environment. This paper discussed the effects of genetic factors and their interaction on the economic value of goat and sheep production. Research results have shown that livestock productivity is influenced by the management system (intensive and semi-intensive) as well as by season of birth. Level of infestation by internal parasites varies according to breed, sex, a group of birth and type of birth, and rearing. Generally, worm infestation in small ruminants fed on native pasture in the rainy season is higher than in the dry season. Choosing livestock suitable and adaptable with the environment is a recommended strategy to optimize livestock productivity, hence, increase farmers' income and welfare.

Key Words: Small Ruminants, Genetic, Environment

INTRODUCTION

An objective of the Government of Indonesia is to support community welfare and increase the consumption of animal protein in line with increase in household income. Meat resources from poultry, small ruminants (goats and sheep) and fish are considered relatively affordable and are targeted in this effort. Small ruminants are found in many communities in almost all regions of Indonesia. Generally, goats and sheep raised by farmers are for meat production purposes, although there are some farmers who keep goats for milk production.

Small ruminant production makes a positive contribution to the family's economy. Many farmers find it helpful to keep goats or sheep which can be used as family savings and can be sold when money is needed for diverse purposes such as school fees or house repairs. However, there are also a growing number of farmers who keep goats and sheep for commercial purposes, either as breeding stock or for slaughter.

The nationwide populations of small ruminants in 2016 were approximately 20 million goats and 18 million sheep. In 1996 the corresponding figures were 14 million goats and 8 million sheep (FAO 2018). Thus there has been a 40% increase in the goat population and a massive 130% increase in the sheep population in the last 20 years. The highest goat population is in Central Java (23%), while the highest sheep population is in West Java (64%) (DGLH 2017).

Livestock performance is closely related to environmental conditions, particularly the availability of feed and other environmental factors. Generally, livestock in the tropics face many challenges from various diseases and parasites, in addition to heat stress. The warm wet conditions of the humid tropics favour the development of internal parasites such as the *Haemonchus* species of gastrointestinal worms, which reduce livestock performance by living on some of the nutrients consumed by livestock. Besides that, seasonal changes can affect the availability of animal feed; generally, in the rainy season more feed is available than in the dry season, but in the rainy season internal parasites are a more serious problem than in the dry season.

Environmental stress significantly affects the performance of small ruminants. Different genotypes respond in different ways to a particular environment (Finocchiaro *et al.* 2005; Marai *et al.* 2008), and this is known as the genotype-environment interaction or GEI. It is important to select livestock that are both productive and adaptable in the tropical environment, with a good level of resilience or tolerance to potential problems.

There are several native breeds of goats and sheep in Indonesia, all of which have the advantage of being well adapted to a specific environment. Even within a breed of goats or sheep, productivity varies depending on location. This results from the existence of different environmental conditions, namely climatic conditions, feed, management systems and animal health. Differences in productivity are also seen with differences in livestock breeds raised in certain areas. The variation in performance in some breeds or genotypes of livestock is one reason for choosing livestock breeds or genotypes that are best suited to specific environments. Livestock performance is influenced by genetic and environmental factors, but what also needs to be considered is the effect of genetic and environment interactions (GEI) which are an important factor in determining the efficiency of livestock production.

This paper discusses the influence of genetic and environmental factors and their interaction, in an effort to increase the economic value of goats and sheep.

GENOTYPE BY ENVIRONMENT INTERACTION

Based on a simple genetic model for quantitative effects, appearance (phenotype) is the sum of the effects of genetic and environmental traits. However, there are genetic and environmental interactions (GEI). Thus when analysing phenotypes GEI is included in the statistical model. The effect of GEI is very important because these influences cannot be considered as the sum of genetic and environmental influences, and the influence of GEI can determine the most efficient level of livestock production (Falconer 1996; Dickerson 1962).

Genetic-environmental interactions can affect the efficiency of a genetic selection program by reducing performance (i.e. growth, milk production) in animals raised in some environmental conditions. This reduction may affect reproduction and survival rates of genotypes that are raised in certain locations. The effect of GEI resulting from a lack of adaptation of certain genotypes to certain conditions can reduce economic performance when environmental conditions of selected animals differ from commercial populations. Genetic interaction with the environment can be described as the presence of different genotypes that will have different responses to different environments.

Genetic-environmental interactions must be taken into account when planning genetic improvement programs for livestock, including genetic livestock selection programs. This is alongside information about existing and potential climatic conditions, availability of feed, housing, disease threats, and market potential.

Some livestock breeds have a very good response to improved environmental conditions such as feeding and better management. Likewise, a number of livestock breeds do not show significant changes, even with improved quality and quantity of feed and rearing management. However, there are also a number of well-known breeds that still show good production and reproduction despite the existence of a number of environmental constraints, such as local tropical livestock that are able to convert low-quality feed and show good reproduction compared to exotic livestock breeds. Therefore, any selection program to improve livestock production should consider the GEI before deciding on the best animals to choose.

SMALL RUMINANT PRODUCTION, ENVIRONMENT AND SUSTAINABILITY

Adaptability of an animal can be defined as the ability to survive and reproduce within a defined environment (Prayaga & Henshall 2005) or the degree to which an organism, population or species can remain/become adapted to a wide range of environments by physiological or genetic means. In certain environments there are differences in livestock resilience in diseases and adaptability to the availability of certain feeds, so that important traits should be included in the breeding program. These are disease resistance and the ability to cope with poor quality nutrition (Verbeek *et al.* 2007). In Soay sheep, for example, which have evolved to live on Scottish islands with very little human intervention, it is clear that producing larger litters is increasingly favoured as environmental conditions become more conducive to offspring survival (Wilson *et al.* 2009).

A study of Black Bengal goats in different rearing systems undertaken in Bangladesh (Table 1), showed that productive and reproductive performance (birth weight, litter size, weight at first heat, age at first kidding, and weight at first kidding) in goats kept intensively was significantly better than in semi-intensive systems (Faruque *et al.* 2010). Also, weight at first heat and weight at first kidding was significantly affected by season of birth.

Table 1. Goat production and reproduction parameters in different rearing systems and groups of births

Effect	Significance		Source
	Rearing system	Group of birth (season)	
Birth weight (kg)	*		Faruque *et al.* (2010)
Litter size	*		
Weight at first heat (kg)	*	*	
Age at first kidding (d)	*		
Weight at first kidding (kg)	*	*	

* = Significant ($P<0.05$); ** = Significant ($P<0.01$)

In a study of Buchi sheep in Pakistan (Table 2), all preweaning traits were significantly ($P<0.05$) affected by year, sex, the interaction between year and season, and the interaction between year and sex of lamb. A significant interaction ($P<0.05$) between season and sex existed for weight at weaning and 120 days. In addition, weaning weight adjusted to 120 days was also significantly affected by the interaction between sex and litter size. Birth weight was affected (P<0.05) by season, birth type and parity.

Working with indigenous Sabi, Mutton Merino and Dorper sheep in Zimbabwe, Assan & Makuza (2005) observed several non-genetic influences that had significant effects including sire, year of lambing, litter size, and the interactions with sire*year, year*sex and sex*litter size and year*sex*litter size on birth weight and weaning weight. Therefore, to increase the accuracy of the selection for birth weight and weaning weight in sheep, it is essential to make a correction for sex of lamb, year of mating and type of birth.

Table 2. Factors affecting the weight of Buchi sheep

Effect	Significance			Source
	Birth	Weaning	120 Days	
Year of birth (yob)	**	**	**	Akhtar *et al.* (2012)
Season of birth (sob)	**	Ns	Ns	
Sex of lamb (sex)	**	Ns	*	
Type of birth (tob) or litter size	**	Ns	Ns	
Parity	*	Ns	Ns	
yob*sob	**	Ns	**	
yob*sex	**	**	**	
sob*sex	Ns	**	**	
sob*tob	Ns	**	*	
sex*tob	Ns	Ns	Ns	

* = Significant (P<0.05); ** = Significant (P<0.01); Ns = not significant

Environmental factors such as year of birth were a significant source of variation for growth traits (body weight and average daily gain) of Ghezel sheep (Baneh & Hafezian 2009). Taking account of genotype-environment interactions can help during the selection process and improve the efficiency of genetic evaluation, using parents placed in different environments. Post-weaning characteristics are economically important and are more influenced by the effects of genotype-environment interaction than are pre-weaning characteristics. Some observations show that genotype-environment interactions tend to increase when weight measurements are carried out in old age. Therefore, environmental factors should be taken into the account when estimating best linear unbiased predicted values (BLUP) (Guidolin *et al.* 2012).

Environmental influences, especially climate, have been widely reported to have an impact on the abundance of parasites that adversely affect livestock production. The level of productivity of small ruminants raised in humid tropical environments such as Indonesia has been widely reported. The response of livestock to an environment that has a high level of worm infestation can be categorized as tolerant and also resistant. Resistant animals are those that have the ability to exert control over the parasite or pathogen lifecycle. The level of parasite burden is often considered to an indicator of resistance. Measures used include faecal egg count, viraemia, or bacterial load in animals infected with nematodes, viruses, or bacteria, respectively. Tolerance is the net impact on performance at a given level of infection. Resilience is often measured simply as performance in a challenging environment; however indirect measures such as treatment requirements are sometimes used as a proxy. Prevalence is the proportion of the host population that is infected at a specific point in time. Incidence is the number of new cases that arise in a population over a specific time period (Bishop 2012; Doeschl-Wilson *et al.* 2012a; 2012b).

Not all environmental components can be modified, especially in low-input tropical production systems, and it is necessary to determine which genotypes can be used under a particular set of environmental conditions. Generally, exotic breeds will struggle in harsh tropical environments, and there will be a need for adjustments in several environmental factors, such as availability of feed, veterinary services and the development of new production systems. Only where environmental constraints can be alleviated, are exotic or “improved” breeds likely to be relevant and valuable.

Livestock genotype significantly affects worm infestation, as some genotypes are more resistant and some are less resistant. Thus, there is a strong case for the use of locally available resistant genotypes in combination with environmental improvements that are biologically and economically feasible, while also considering the development of appropriate breeding programs for further development of the genotype

Climate affects the prevalence of diseases and has an impact on animal health. Studies have shown that endemic parasites such as worms are strongly influenced by short-term weather and climate through effects on larval growth in grasslands. Climate change and increasing environmental temperatures have resulted in greater abundance and spread of endemic worms in Europe (Van Dijk *et al.* 2010; Philipsson *et al.* 2011).

Research by Odoi *et al.* (2007) on the burden level and risk factors of gastrointestinal nematode infections in sheep and goats kept by smallholders in the Central Highlands in Kenya, indicate that faecal egg counts (FEC) were relatively low during the months with low rainfall and rose approximately two months after the onset of ain. The genera of nematodes identified were: Trichostrongylus (42.0%), Haemonchus (35.8%), Strongyloides (12.0%), Cooperia (5.5%), and Oesophagostomum (4.7%).

A study of local and crossbred sheep with natural infections of gastro-intestinal nematodes was undertaken in North Sumatra by Romjali *et al.* (1997). The factors considered were genotype, season, a number of lambs born and number of lambs reared, age, sex and effect of worm burden, and packed cell volume (PCV) on weaning weight. Results show that genotype, sex, type of birth and rearing and birth group all affected faecal egg count or “eggs per gram” (EPG) of faeces and packed cell volume (PCV) levels in sheep at the age of 3 months (Table 3).

Table 3. Effect of the genotype, sex, type of birth and rearing and birth group on EPG and PCV levels in sheep of the age of three months

Parameter criteria	EPG	PCV
Lamb genotype	*	**
Sex	**	**
Type of birth and rearing (litter size)	**	**
Birth group (born in)	*	**

* = (P<0.05); ** = (P<0.01)

Source: Romjali *et al.* (1997)

The lowest EPG was found in Sumatra x Barbados Blackbelly and the highest in Sumatra x Java Fat Tail lambs. Season of birth had a significant effect on faecal egg count of lambs at three months of age. Faecal egg counts of lambs were lower for those born in dry months than born during higher rainfall ($P<0.05$). This shows that the level of rainfall affects the abundance of worm larvae on grass consumed by sheep. Type of birth and rearing (litter size) had a significant effect on faecal egg count at three months of age ($P<0.001$). The mean EPG for single lambs was lower than that for twins reared as singles, twins reared as twins and triplets and quadruplets reared as twins ($P<0.001$). Linear regression coefficients of weaning weight on EPG were negative, indicating that weaning weight decreased with increasing EPG. All linear regression coefficients of weaning weight on PCV were positive, indicating that weaning weight increased with increasing PCV. Generally in the rainy season with high humidity, the abundance of internal parasites is very high. Worm larvae will be on the grass consumed by livestock so that the larvae will develop in the host's body and corrupt the food ingredients from the host (Baker & Gray 2004).

CONCLUSION

Different small ruminant genotypes show varying responses to several aspects of the environment. In an effort to improve economic value, genetic-environmental interactions need to be considered when determining which small ruminants will be developed in accordance with specific environmental conditions.

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