Onderstepoort J. Vet. Res., 54, 337–340 (1987)

GENETIC RESISTANCE OF GUADELOUPE NATIVE GOATS TO HEARTWATER

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ABSTRACT

MATHERON, G., BARRÉ, N., CAMUS, E. & GOGUE, J., 1987. Genetic resistance of Guadeloupe native goats to heartwater. *Onderstepoort Journal of Veterinary Research*, 54, 337–340 (1987)

The resistance rate of different populations of the same breed of creole Guadeloupean goats to *Cowdria ruiminatium* infection varied greatly depending on the previous heartwater history of each population. After experimental infection of goats removed decades ago from endemic areas, the observed resistance rate was 25 %, while it was 54 % in a population that had been isolated from the disease for 10 years and reached 78 % in a flock actually exposed to heartwater.

This resistance seems to be under genetic control as sex and paternity were the most important factors which could explain resistance in a group of 90 kids of the same flock, tested under controlled conditions. Resistance rate varied greatly (20–83 %) depending on the sire, with a heritability estimate of 0,49 for half sibs and 0,85 for full sibs. A recessive sex-linked gene could be involved in the genetic determination of this resistance.

From these observations, it can be stated that in endemic heartwater areas, each population, i.e. each flock, will have developed resistance at a definite rate according to population, age and the extent of past and present exposure to the disease, through a natural selection of resistant lines. Populations removed from exposure to heartwater will progressively lose their ability to resist infection through an increase in the frequency of susceptible stock.

If our hypothesis of a recessive sex-linked gene is proved correct, it should be easy to select for improved resistance of the Guadeloupe breed of goat to heartwater.

INTRODUCTION

Research work, particularly during the last decades, has focused attention on the resistance of animals to diseases and has, in some instances shown much promise for improved selection of livestock.

In the case of ruminants, a genetic determinant appears to occur in diseases induced by viruses, (Schade, 1983) bacteria, (Anon., 1983; Stewart, Emery, Clark, Peterson, Iyer & Jarrett, 1985; Dumas, Lhoste, Chabeuf & Blancou, 1971) protozoa, (Murray & Trail, 1984; Chabeuf, 1983; Toure, Seye, Mbengue & Dieye, 1983; Bradley, 1980) and helminths, (Wakelin, 1980, Courtney, Parker, McClure & Herd, 1985) as well as for arthropod infestations (Seifert, 1984; Ponzoni, 1984).

A review of our current knowledge on resistance to heartwater was recently made by Uilenberg (1983). Differences in the resistance of cattle to the disease have been well documented, the general opinion being that local breeds, i.e. breeds developed in endemic areas, are more resistant than exotic breeds. A 5 % mortality rate has been observed in Africanders compared with 60 % in European calves introduced into South Africa (Bonsma, 1944), while an annual report (Anon., 1983) documents 2,3–2,6 % mortality in Africanders, Bonsmara and crossbreds and 6 % in Simmental and Hereford cattle. Uilenberg (1971) observed 0,4 % mortality in Malagasy zebu and 2,2 % in Renitelo, Brahman, Friesian and crossbreds with exotic taurin and zebu also being susceptible. Barré & Camus (1984) showed 0,8 % mortality in creole zebu and 13 % in half-bred Limousin × zebu cattle.

The same observations have been made on goats and sheep, although the resistance of indigenous small ruminants is more controversial. Theiler (1905) quoted by Uilenberg (1983), Curasson & Delpy (1928), Alexander (1931), Hornby (1935) quoted by Uilenberg (1983), Neitz (1939), Henning (1956), Uilenberg (1971), Erasmus (1976) and Du Plessis, Jansen & Prozesky (1983) noted a higher resistance on the part of local breeds, while other authors denied this or observed heavy losses among them (Cilli & Corazzi, 1954; Evans, 1963; Karrar, 1960, 1968; Ilemobade, 1977; Aklaku, 1980). The controversial nature of these opinions may be due to different interpretations. In the case of Guadeloupe creole goats, for instance, we would agree with the first group of authors, for we observed a higher resistance in this breed compared with the Dutch goat (69 deaths out of 109 infected creole goats in contrast to 12 out of 12 Dutch goats) (Uilenberg, Camus & Barré, 1985). On the other hand, if we take into account the heavy losses (about 10 % mortality annually) attributable to heartwater in Guadeloupean goat flocks (Barré & Camus, 1984) then the opinion of the second group of authors may be regarded as more correct.

In fact, as stated by Uilenberg (1983), it might not be a question of breed but of population. This author estimates that "differences in susceptibility do not appear to be linked to any particular breed or species but probably depend mainly or exclusively on inherited resistance acquired by local livestock through long, natural selection." The author further proposes a genetic determinant induced by selective pressure in the resistance of ruminants to the disease, and recommends that only different groups of animals which had the same previous history, be compared in order to distinguish innate resistance from acquired immunity.

Based on this hypothesis, we gathered the results of the infection of creole goats carried out in Guadeloupe and conducted an experiment in a controlled flock, in an attempt to confirm the influence of a genetic determinant in the resistance of goats to heartwater.

MATERIALS AND METHODS

Goats

All the goats used were of the creole breed except for 12 Dutch goats (Table 1, Uilenberg *et al.*, 1985). The creole goat has been established in Guadeloupe and on neighbouring islands (Les Saintes, La Désirade) for 2 or 3 centuries. It is a small breed resembling the East African dwarf goat and the Asian Kambling Katjang (Chemineau, Cognié, Xandé, Péroux, Alexandre, Lévy, Shitalou, Beche, Sergent, Camus, Barré & Thimonier, 1984).

Because the most important sailing routes established during and after the slave trade period were to and from Africa, we assumed that this breed originated in that continent. It is a very popular animal in Guadeloupe where 35 000 are raised for meat production, usually in small flocks.

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Received 24 June 1987—Editor

TABLE 1 Resistance of goat populations, with different previous heartwater histories, to experimental infection with Gardel strain (Results on Dutch goats from Uilenberg *et al.*, 1985)

	Breed originating from area free of heartwater (Dutch goat; Holland)	Breed originating from endemic area of heartwater (creole goat; Africa and Guadeloupe)		
Contact with heartwater	No contact (raised in Holland)	No contact for 100 years (Saintes/Désirade)	No contact for 10 years (Duclos farm)	Heartwater present (Gardel farm)
Rate of resistance (survived/infected)	0 % (0/12)	25 % (21/85)	54 % (49/90)	78 % (28/36)

Cowdria ruminatium *stock*

The *Cowdria ruminantium* stock used in all the experiments was isolated in December 1982 from adult *Amblyomma variegatum* collected on cattle at the INRA farm of Gardel in Guadeloupe ('Gardel strain'). Infection of goats was carried out with virulent blood, fresh or cryopreserved, or with infected ticks (usually nymphs fed at the larval stage on a reacting goat).

Monitoring the reaction

From the day of infection and for at least three weeks thereafter, rectal temperatures were recorded daily and a serum sample collected every week. Infected animals did not receive antibiotic treatment at any time and the disease followed its normal course without (human) intervention.

Animals which died with colonies of *C. ruminantium* in their brains were considered susceptible. Resistant animals were those survivors which experienced a temperature reaction (usually without pronounced symptoms), sero converted to the IFAT (Du Plessis, 1981) and resisted a challenge with a homologous strain.

Experimental procedures

1. *Incidence of selective pressure on the innate resistance of goats with different previous heartwater histories*

Four different populations of goats were infected during our four-year survey and our experiments on heartwater in Guadeloupe. We compared the resistance rate of the following populations:

— Dutch goats: raised and experimentally infected in Holland (Uilenberg *et al.*, 1985). This breed has never had any contact with heartwater.

— Creole goats from populations removed from heartwater areas for some time and from populations raised in an endemic area. Three groups of goats were compared in this category:

- Creole goats from Les Saintes and La Désirade islands, supposedly originating from Guadeloupe but established for decades or even centuries on these islands, free of exposure to heartwater.
- Creole goats from Duclos in Guadeloupe raised on a heartwater-free farm but whose dams and sires had been introduced 10 years previously from the infected Gardel farm.
- Creole goats from the Gardel farm in Guadeloupe where heartwater is endemic. Some animals of this group may have acquired an immunity prior to the experimental infection by natural contact with heartwater. To estimate the resistance of this population and to allow comparison with the others, we took into account deaths after experimental infection as well as those induced by natural heartwater in the flock concerned during the preceding year. With these corrections, it was possible to approach a resistance rate (animals naturally immunized prior to the experimental infection plus animals resistant to the experimental infection) in this particular epidemiological situation.

2. *Genetic determinants of resistance*

The experiment was carried out on the creole goats from the Duclos farm (see above) which was free from heartwater and ticks. Ninety kids of both sexes, aged 2–8 months (average 3,5 months) were infected. Birth mass and daily gain were recorded for all kids, while other zootechnical parameters (kidding season, litter size) and especially the identification of parents were recorded for 77 of the kids.

The kids tested were from 19 sires and our sample contained 10 full-sib couples.

Estimation of effects and correlation between parameters were calculated by the least square analysis of data (Harvey, 1975), using χ^2 and F tests for significance.

Heritability of resistance (h^2) was estimated by calculating the correlation between relatives (full-sibs and paternal half-sibs).

RESULTS

Reaction to experimental infection

Except for some goats from Gardel, propably naturally immunized before experimental infection, each of the 187 goats in the three other groups, which had no previous contact with heartwater, showed at least a temperature reaction after experimental infection.

This observation seems to confirm Uilenberg's opinion (1983) that resistance is a 'resistance against severe reaction' and, consequently, not an absence of susceptibility. After infection, a rickettsaemia occurs in all non-immunized animals irrespective of their resistant or susceptible status.

Incidence of selective pressure

The influence of selective pressure is illustrated in Table 1. The Dutch breed, which never had contact with heartwater, was fully susceptible to the disease, while the creole breed showed marked differences in resistance, depending on the population concerned.

The population maintained in the infected area expressed a high level of resistance (78 % at Gardel) whereas those removed from the endemic areas lost their

TABLE 2 Effect of birth mass and growth on the resistance of goats to heartwater

	Resistant	Susceptible	Level of significance (F)
No. of animals and (%)	49 (54,4)	41 (45,6)	—
Birth mass (g)	1 500	1 400	P 10 %
Daily mass gain (g)	58,5	54	P 18 %

TABLE 3 Effect of sire, kidding season, litter size and sex on the resistance of goats to heartwater

	Paternal effect	Kidding season			Litter size			Sex	
		March April	Aug. Sept.	Dec. Jan.	1	2	3	Males	Females
No. of animals tested	77	27	39	11	10	58	9	20	57
Resistance rate		44 %	69 %	53 %	70 %	56 %	67 %	75 %	53 %
Level of significance χ^2	P 10 %	P 20 %			NS			P 6 %	

TABLE 4 Resistance rate of offspring produced by different sires and estimated heritability of resistance to heartwater

Sire No.	3164	01	2625	3521	15	08	02
Number of off spring tested	5	9	12	5	9	5	6
Resistance rate	20 %	22 %	58 %	60 %	67 %	80 %	83 %

h^2 estimate (paternal half-sibs) 0,49 ± 0,50
h^2 estimate (paternal full-sibs) 0,85 ± 0,60

resistant status, even more so since they had been raised in a protected area for a long period of time.

In our opinion, these results indicate the probable existence of a natural selection among goat populations raised in endemic areas. The resistance rate acquired in such epidemiological conditions depends on the intensity of infectious contacts experienced by the population.

Genetic determinants of resistance

Only the results obtained at the Duclos farm, which is free from heartwater and where we controlled and recorded most of the zootechnical parameters, were analyzed from the viewpoint of the determinants of resistance. After experimental infection, we observed a rate of resistance of 54,4 % (49 out of 90) in our sample (Table 1).

Different adjustments were taken into account to evaluate the significance of the effect of the sire. They included kidding season, size of litter, sex, birth mass and daily growth (Tables 2 & 3).

Kidding season had a significant effect with a higher resistance in animals born in August/September, which corresponds with the period of highest grass production, compared with those born in March/April, at the end of the dry season. Young born in single litters showed a slightly higher resistance than twins or triplets, but the difference was not significant. Birth mass, as well as daily mass gains, were significantly greater in resistant than in susceptible kids. We also observed a marked difference between sexes with males being more resistant than females (75 % *vs* 53 %).

After adjustment for all these factors, we detected a significant paternal effect leading us to accept the existence, at least partially, of a genetic determinant in the resistance of individuals to heartwater infection (Table 3).

When we looked at the mean resistance rate of the offspring of the seven sires having more than 4 offspring tested (Table 4), we observed a wide variation among them. Resistance of offspring ranges from 20–83 %, depending on the sire. Considering all factors the heritability of the resistance character was significantly greater than zero. When considering half-sibs, the heritability estimate was 0,49 and reached the very high value of 0,85 for full-sibs. This last value was due to the fact that of the 10 full-sib couples, 9 reacted in the same way, either both died or both survived.

Because the number of goats studied was small, our results showed a large confidence interval in the estimate of heritability that did not allow for a definite conclusion. Nevertheless, we presume that genetic determinants play a marked role in resistance to heartwater. More data are necessary to confirm this opinion and to understand the genetic process of resistance. When considering only the results presented here, we can state that several factors concerning the animal itself including mass, kidding season, sex and lineage, have an influence on the resistance of Guadeloupean goats to heartwater. Calculations based on data obtained on the resistance of both sexes indicate that resistance could be controlled by a recessive sex-linked gene. A simple genetic determinant has also been involved in resistance of mice to *Rickettsia tsutsugamushi* (Groves, Rosenstreich & Osterman, 1980).

Du Plessis & Bezuidenhout (1979) found a relationship between the levels of conglutinin in sera of ruminants and their resistance to heartwater. We did not look for this serum protein in our experiments, but if the observation of these authors is confirmed, the level of conglutinin could be used as an indicator of resistance in a programme of selection (Du Plessis, Bezuidenhout & Lüdemann, 1984).

CONCLUSION

From the experiments conducted on the goats of Guadeloupe it can be stated that resistance to heartwater is manifested as a resistance to severe disease but not to mild reactions, such as a rise in temperature. Resistant as well as susceptible animals are prone to infection.

Populations of the same breed having different previous heartwater histories respond differently to infection. In the epidemiological conditions of Guadeloupe, we believe that each goat flock constitutes an isolated population. The resistance rate in each of these flocks depends on age and the intensity of tick infestation and consequently of exposure to *C. ruminantium,* resulting in a more or less intense and rapid natural selection. Since selective pressure is long standing and permanent in endemic areas, more animals have acquired an inherited resistance to the disease. The resistance rate declines progressively when populations are removed from infected areas and are reared in a protected environment, or when exposure decreases, probably because of the survival of susceptible breeding stock which subsequently transmit their susceptible character to the population.

In addition to the concept of the population, as suggested by Uilenberg (1983), replacing the breed, the effect of lineage or family must be taken into consideration in an attempt to explain the resistance of goats and perhaps other ruminants to heartwater.

Several factors are involved in individual resistance, among which genetic effect appears to be one of the most important. A recessive sex-linked gene could be involved in the control of resistance. The high level of heritability, although with a large confidence interval due to the small size of our sample, gives us reasonable hope that the resistance of goats in Guadeloupe may be improved by selecting for this character. If our hypothesis of a sex-linked determinant is confirmed by further data obtained from males (only 20 inoculated per 57 females) and by challenge of offspring born from resistant parents, the next step in our experiment based on the selection of a heartwater resistant population of Guadeloupe goats, could be very easy.

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Printed by the Government Printer, Private Bag X85, Pretoria, 0001