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Pasture Management and Ruminants' Meat Production in Mascareignes Archipelago

[1]*Patrice Grimaud and* [2]*Patrick Thomas*

[1]Cirad Département Environnements et Sociétés, Pôle Elevage,
Ligne Paradis, F97410 Saint Pierre de la Réunion
[2]Union des Associations Foncières Pastorales, F97418 Plaine des Cafres

Abstract: Production of ruminants' meat in Mascareignes Archipelago-La Réunion (beef and venison), Mauritius (venison) and Rodrigues (beef)-mainly depends on pasture production. Tropical grasses are predominant on these islands, although many farmers of La Réunion Highlands can manage their pastures with improved temperate grasses owing to the altitude. Different studies were carried out to get a better knowledge on the farming systems in the three islands and to propose to the farmers some ways of pasture and animal production improvement. Observations were made on Rodrigues on the occasion of the visits on the island, while two independent 3-year surveys were carried out in both La Réunion and Mauritius with data collection on farmers' strategies and on both grass and animal production thanks to tools specifically conceived by the survey (SEBARUN database on La Réunion) or adapted to the tropical conditions (herbage nutrition indexes, functional analysis of feeding systems). On Rodrigues, stakeholders must think about new ways of farming after Republic of Mauritius decided to stop meat importations from Rodrigues to Mauritius. Animal performances were better in suckling cattle farms on La Réunion than in deer farms on both La Réunion and Mauritius, but can be significantly improved through a better pasture management in coherence with results of some simple indicators, like DM values and herbage nutrition indexes, which combine both plant mineral status and pasture biomass.

Key words: Beef and deer production • pasture management • tropical and temperate pasture • herbage mineral nutrition index • la réunion island • mauritius • rodrigues

INTRODUCTION

Mascareignes Archipelago: La Réunion, Mauritius and Rodrigues: Mascareignes Archipelago, located in the Indian Ocean on the eastern side of Madagascar, is made of the three islands of La Réunion, Mauritius and Rodrigues. La Réunion is a French overseas department, while Mauritius and Rodrigues are two components of the Republic of Mauritius. The area is classified as the oceanic tropical zone because of the influence of the trade winds, with two distinct seasons, namely a) winter, from mid-May to mid-November, a Cool Season (CS) with occasional high precipitations and b) summer, from mid-November to mid-May, a Hot Season (HS) with some possible hurricanes. The length of the day is shorter in winter, approximately 90 minutes, but the shining time is 1-hour longer during this season, due to overcast sky during the hot and wet season. The three islands are volcanic, with several mountains (higher than 2,000m on both La Réunion and Mauritius, culminating at 393 m on Rodrigues) and unequal superficies: 2512, 1865 and 109 km^2, for La Réunion, Mauritius and Rodrigues, respectively. The relief complexity and contrasting climates generate wide variations in the microclimates and native vegetation, e.g. on La Réunion where Cadet [1] defined four different ecological areas from the littoral to the top of mountains and these included (i) the urban areas, (ii) sugarcane plantations, (iii) orchards, market gardens and pastures and (iv) the forests. The central mountains on La Réunion cause increased precipitation on the eastern side of the island and the annual rainfall is irregular with an annual average of 1,000 mm in the South-West to more than 10,000 mm on the East coast. On Mauritius, mountains are scattered with a defined wetter inland area, where average rainfall ranges from 800 to 2,000 mm, which separates the dry south-western zone (with an average range of rainfall of 100-800 mm), from a more humid eastern coast (with an average range of rainfall of 500-1, 500 mm). On Rodrigues, high occurrence of hurricanes combined with a slope altitude often higher than 30% make the island very vulnerable to erosion. On these islands, average minimum and maximum

Corresponding Autor: Dr. Patrice Grimaud, Laboratoire de Recherches Vétérinaires et Zootechniques de Farcha, P.O. Box 433, N'Djaména, Chad

temperatures range from 17 to 20°C in CS and from 28 to 31°C in HS. Differences in daily temperatures never vary more than 10°C. They were not inhabited until the eighteenth century and population nowadays reaches more than 750,000 inhabitants on La Réunion, almost 1.1 million on Mauritius and about 35,000 on Rodrigues, whose repartition depends on the migration waves that affected these islands: Indian came to both La Réunion and Mauritius to work in sugarcane plantations and they now represent 40 and 70% of the population on these islands, respectively. Contrarily, no Asiatic migration occurred on Rodrigues where population is largely dominated by people of African origin, like other 40% of the population on La Réunion. These different origins influence the basic diet of the inhabitants, as cattle consumption is not allowed in Hinduism religion while Muslims refuse to eat pork. Cattle meat and venison value chains have been previously described on both La Réunion and Mauritius by different authors who reported that (i) La Réunion was not self-sufficient neither in beef nor in venison, as local farms provide the market with 30 and 20% of the demand, respectively [2, 3] and (ii) Mauritius was self-sufficient in venison, through both intensive and extensive ways of farming [4]. Until recently, Rodrigues was in charge of supplying Mauritius with beef, but meat trade liberalization led to a hard competition with African countries (Zimbabwe, Madagascar, Botswana ...) and people from Rodrigues are now struggling with the flow of their cattle to Mauritius.

A grass-dependant production: The different systems of production of beef or venison are dependant on pastures and rangelands on the three islands (photo 1, 2 and 3). From the littoral to the highlands, pastures on La Réunion cover up 10,250 ha and vary from tropical forages to temperate grasslands [5]. The nature and plant covers of these pastures differ according to the location. At the lowest altitudes, the grasses most often observed are tropical: *Chloris gayana* (Rhodes grass), *Pennisetum purpureum, Setaria anceps* and *Brachiaria decumbens*. Only one tropical grass, namely kikuyu (*P. clandestinum*), grows at altitude over 1,000 m. Pastures in the high altitudes are temperate and were recently improved with *Lolium perenne* and *Dactylis glomerata* as grams and *Trifolium repens* (white clover) as leguminous. On Mauritius and Rodrigues, swards are only made of tropical forages, where they represent more than 25,000 and 6,000 ha, respectively. On both these islands, *Stenotaphrum dimidiatum* (*bourrique* grass) and *Cynodon* spp. are present, *C. plectostachius* (star grass)

Photo 1: Exotic suckling cows on La Réunion

Photo 2: Tropical rusa deer has been fully acclimatized in both La Réunion and Mauritius

Photo 3: Sheep and cattle on eroded terraces on Rodrigues

on Mauritius and *C. dactylon* (lawn) on Rodrigues. Other nutritive species on Mauritius are *Bothriochloa pertusa* (sikin) in the coastal regions and *Ischaemum aristatum*, on the southern farms and the inland ranches, while on Rodrigues *Desmodium triflorum*, a small leguminous grass, frequently appears on the pastures. The divisions of Rodrigues from the littoral to the center of the island into (i) the cattle walk which belongs to the community and (ii) developed terraces on altitude where private property is allowed, influence the management of cattle which theoretically graze on the coast in HS and climb the hills in CS.

Pasture management is a major concern as the grass appears to be in excess in hot season with a drop in nutritive value, while there is a shortage in quantity the rest of the year [5, 6, 7]. Like in many tropical countries, farmers have to adapt their practices to that seasonal growth of the grass, in terms of stocking rate, methods of grass exploitation - grazing or mowing, field patterns surface, shape and number of paddocks - and fertilization. Controlled mineral fertilization practices are an important component for a sustainable management of grasslands. In northern countries, the assessment of available nutrients for the plants and the general recommendations on the level of phosphorus and potassium to apply on grasslands are classically based on soil analysis and average regional levels. The nitrogen is rapidly leaching in the soil and mid or long term recommendation cannot be easily derived from soil composition solely. Studies showed that sward management in these northern countries could lean on the use of nutrient combined indexes for nitrogen [8], phosphorous and potassium [9]. These indexes, IN, IP and IK, combine herbage mineral analysis and actual biomass measurement; when compared with a standard optimum, they indicate a limiting factor or an eventual excess in the mineral feeding of the grass that the farmers can easily correct [10].

Agronomic experiments have recently validated in tropical conditions the dilution process for N, P and K established in temperate climate [6] and the use of herbage mineral nutrition indexes as tools for better sward management have been encouraged in both La Réunion and Mauritius. Different surveys on pasture management, but also on farmers' strategies and on animal performances were carried out on both islands. Their results are presented in this paper beside some information collected on Rodrigues with the aim of describing the different systems of ruminants' meat production farming on Mascareignes Archipelago.

MATERIALS AND METHODS

Data collection on pastures: A first study concerned one-third of the inventoried farms of La Réunion, scattered in the whole island, which were surveyed and these included both Highlands (altitudes ranging from 800 to 2 000 m) and the littoral, over a period of 3 years. All the farms in Highlands-Midlands and West Highlands-were organized in paddocks made of either kikuyu grass or improved temperate grasses. They were all fenced and rotationally grazed. On the eastern littoral pastures are made of tropical forages for grazing cattle or deer. A similar second study was conducted on Mauritius, on seven intensive deer farms, where pastures were also fenced into several paddocks and rotationally grazed, and three extensive deer ranches, where the land consisted of pastures and natural forest. The pastures were largely unfenced, so that pasture management was minimal although some breeders used electric fencing to control pasture utilization. It was not possible to put in place this kind of survey on Rodrigues as the recent change in policy compromised the flow of cattle to Mauritius and modified the behavior of farmers who preferred to keep their animals rather than slaughter them at lower prices. Our study focused on the estimation of the potential of stocking rate through field observations.

In the farms on both La Réunion and Mauritius, the average size of paddocks was close to 1 ha. On each paddock, four to five times a year - 2 minimum per season- grass sampling was done 6-10 times depending on total area and sward homogeneity, using a metallic quadrat of 50 cm^2. The quadrats were located in areas of pure grass. The grass was cut at an average height of 5 cm representing the forage part eaten by the animals or cut for fodder conservation. The harvested fresh grass from each paddock was weighed using a Salter balance, England, 2000±20 g and a representative sample of approximately 1 kg of green forage was taken to the laboratory for further analysis.

The grass in La Réunion farms was categorized into three types and these included (i) improved temperate grasses consisting mainly of *L. perenne* and *D. glomerata*, (ii) kikuyu grass (*P. clandestinum*) and (iii) grazed tropical grasses. A total of 475 samples were collected of which, 57% was obtained in cold season and 43% in hot season. In Mauritian deer farms, pastures were categorized according to the predominant species and these included sikin (*B. pertusa*), star grass (*C. plectostachius*) and silver grass (*I. aristatum*). A total of 194 samples was collected, 61% in CS and 39% in HS. Dry matter contents of forage in the laboratory was determined by drying at 80° C for 48 h, while phosphorus and potassium were determined using both the atomic absorption spectrophotometry and continuous flow colorimetry. Nitrogen (N) was determined by the Kjeldahl

Table 1: Calculation of nitrogen (IN), phosphorus (IP), and potassium (IK) indexes, according to the nature and the productivity of the forage

Nitrogen (IN)	Forage in C3, with DM productivity >1 t/ha	100 x (4.8 - 4.8 x DM-0.32 + N) / 4.8
Nitrogen (IN)	Forage in C3, with DM productivity <1 t/ha	100 x (N / 4.8)
Nitrogen (IN)	Forage in C4, with DM productivity >1 t/ha	100 x (3.6 - 3.6 x DM-0.4 + N) / 3.6
Nitrogen (IN)	Forage in C4, with DM productivity <1 t/ha	100 x (N / 3.6)
Phosphorus (IP)	-	100 x 4.17 P x N-0.64
Potassium (IK)	-	100 x 0.62 K x N-0.48

DM: dry matter

method on dry samples [11]. The dilution indexes for N, P and K mineral elements in forage were calculated following procedures previously described in Europe [12, 14], validated on La Réunion [6, 14] and based on equations described in Table 1.

Statistical procedure on data related to grass production was performed with the GLM procedure of SAS [15]. The data (i) collected on the fields (dry biomass), (ii) obtained in laboratory (dry matter contents) and (iii) calculated (IN, IP and IK), were subjected to analysis of variance (ANOVA) according to the model $X_{ijk} = \mu + N_i + Y_j + S_k + NY_{ij} + NS_{ik} + e_{ijk}$, where X is the dependent variable, μ the overall mean, N_i the effect of the nature of the grass (i = 1 to 3), Y_j the effect of the year (j = 1 to 3), S_k the effect of the season (k = 1 or 2), NY_{ij}, NS_{ik} the interactions and e_{ijk} the error. L_l was added as complementary factor for Mauritian data, representing the location (l = 1 to 3).

Data collection on cattle (La Réunion): Ten suckling cattle farms were surveyed meanwhile the pasture survey. The average pasture surface per farm was 51.7 +/- 18.1 ha and the farms housed a total livestock of 541 adult females, mainly of European breed (predominantly *Limousine* and *Blonde d'Aquitaine*). The survey was conducted in each farm every three months. The inventory of the herd was renewed on each visit, according to the age, to the sex and to the physiological stage of the animals. All the calves born about two months before the start of the survey and less than 6 months of age, were weighted using a field balance (Salter balance, England, 500 kg, ±5 kg) until the end of the survey. All the data were recorded on a database software that was developed for monitoring of suckling cattle on La Réunion, SEBARUN (*Suivi des élevages bovins allaitants de la Réunion*) where four domains were created, namely: farmers' practices, complementary feeding strategy, pasture and animal. This software allows the user to check the data coherence and performs statistical analysis by importing data files into statistical software SAS. The data entered in SEBARUN are presented Table 2. For this current study, we particularized some parameters related to performance directly due to grass production: (i) the Age at First Calving (AFC) and the Calving-calving Interval (CCI), representative to the reproductive performance of heifers and lactating cows, respectively and (ii) the calf's live weight at 210 d of age (LW_{210}) representation of the calf's growth. Both annual fecundity rate and 0-1 year calf mortality rate were calculated for each farm and were used to determine the numeric productivity index (NPI), according to the formula:

Table 2: SEBARUN (Suivi des Elevages Bovins Allaitants sur l'île de la Réunion) data collection

Domain	Data
Farmers' practices	· Particulars · Farm characteristics · Number and quality of herds · Herds movements
Complementary feeding strategy	· Raw material analysis · Composition of complementary feed · Calculation of rational feeding
Pasture	· Paddock description · Rotational strategy · Paddock fertilization · Harvest · Pasture height · Grass bio-volume · Number of utilization in a given time · Rest period · Time of utilization
Animal	· Census · Stocking rate · Renewing rate · Calves' weight · Daily growth rate · Calving-calving interval · Adult females' body condition scoring (BCS) · Change in BCS related to calving · Parasite load · Grade of slaughtered animals · Age of females when slaughtered

$$NPI = \frac{\text{No. of 1-year alive calves}}{\text{No. of adult reproductive cows}}$$

NPI comprises between 0 and 1.

Data on La Réunion animal production were first graphically approached to support statistical analysis [16]. To randomly include some effects, the Proc Mixed procedure of SAS [15] was used. Data on adult females performance were subjected to ANOVA, with a random effect of the farmer, according to the model $X_{ijk} = \mu + B_i + Y_j + S_k + Z_l + BS_{ik} + BZ_{il} + YB_{ij} + e_{ijkl}$, where X is the dependent variable, μ the overall mean, B_i the effect of the nature of the breed (i = 1 to 3), Y_j the effect of the year (j = 1 to 3), S_k the effect of the season of the birth (k = 1 or 2), Z_l the effect of the zone (l = 1 to 3), BS_{ik}, BZ_{il}, YB_{ij} the interactions and e_{ijkl} the error. After having graphically identified the breed *Limousine* as different from the others, data on calves' weights were subjected to ANOVA, with random effects of both the farmer and the calf, according to the model $X_{ijk} = \mu + B_i + S_j + R_k + e_{ijk}$, where X is the dependent variable, μ the overall mean, B_i the effect of the nature of the breed (i = 1 if *Limousine* or 2), S_j the effect of the sex (j = 1 or 2), R_k the effect of the rank of calving ((k = 1 to 3; the value of 3 corresponding to more than 2 parturitions); previously tested and non significant interactions were removed from the model, which accepted the age as the intercept.

Data collected on deer (Mauritius): In the absence of survey on live animals, animal performances were studied through carcass weights that were compiled by the deer cooperative from 1995 to 2000. A total of 10,270 weights have been collected, corresponding to 1998 slaughtered lots. Statistical procedure on data related to weight carcasses on Mauritius was performed with the GLM procedure of SAS [15] according to the model $X_{ijk} = \mu + L_i + Y_j + S_k + LY_{ij} + LS_{ik} + YS_{jk} + e_{ijk}$, where X is the dependent variable, μ the overall mean, L_i the effect of the location of the farm (i = 1 or 2, carcass weights of inland ranches not being registered), Y_j the effect of the year (j = 1 to 6), S_k the effect of the season (k = 1 or 2), LY_{ij}, LS_{ik} the interactions and e_{ijk} the error.

Identification of constraints in the three islands: Farmers' practices were studied through a two-hour thought process with the farmers on La Réunion and Mauritius, according to a functional analysis of the farming systems' methodology [17]. A discussion with the farmer allowed the facilitator to know the farmer's habits, which took into account all the alimentary resources ingested by the animals, either grazed or distributed. Some more information were obtained, related to the past events occurring in the farm, aimed at describing the farming system and at defining homogeneous sequences of feeding events for every animal group. These sequences are both characterized (i) by elements related to animal performances, as reproduction cycles or body condition scoring and (ii) by information on sward management, as grass availability in terms of quantity or quality, period of harvesting or paddock accessibility. The bounds of each sequence are determined by changes in the level of animal feed requirements and / or by changes in the nature of the consumed alimentary resource. The superimposition of the year's calendar on seasonal natural resources, physiological cycles or periods of specific requirements of the animals and herds' movements reveals the critical periods ("key periods") which the farmer had to cope up with.

On Rodrigues, two 2-week visits in the aim at studying the balance between fodder resources and cattle have been made in the frame of a Europe and Mauritius co-funded Project to fight against dramatic erosion on the island. To make a diagnosis on this issue needs to assess the grass potential related to agro-ecological zones and the census of cattle on the island, which have been both evaluated through a scarce bibliography and within the 5 months between the visits thanks to a facilitator who closely worked with the local agricultural services.

RESULTS

Pastures: Data on dry matter contents and dry biomass are presented in Figure 1. We observed higher DM contents on Mauritius than on La Réunion, where pastures are made of both temperate and tropical grasses. DM contents were significantly influenced by the nature of the grass ($P<0.01$ on La Réunion and $P<0.001$ on Mauritius; Table 3) and the year ($P<0.05$ on La Réunion and $P<0.01$ on Mauritius; Table 3), while we evidenced a significant effect of season only on Mauritius ($P<0.001$, Table 3). The availability of swards made of tropical and temperate grasses in terms of dry biomass were different on La Réunion between seasons at the beginning of the survey, with a lower value in cold season while plant dry matter was observed to increase. DM contents were not significantly different between CS and HS for all the

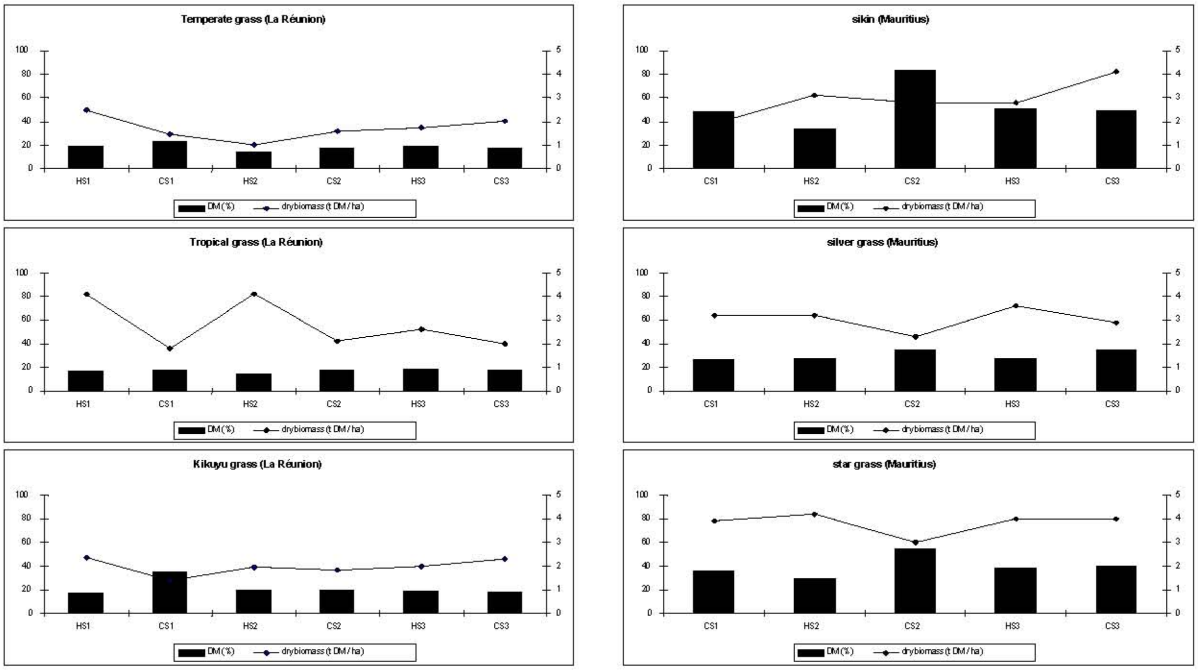

Fig. 1: Dry biomass (t DM/ha) and DM (%) of temperate grass, tropical grass and kikuyu grass on La Runion, and sikin, star grass and silver grass on Mauritius. *CS: cold season; HS: hot season*

Table 3: Statistical significance of values related to grass production

	SE1	location	nature	season	year	N x S2	N x Y
La Réunion							
DM3 (%)	4.50	ND	**	NS	*	NS	*
DM / ha (t)	0.03	ND	**	**	*	*	NS
IN	8.40	ND	***	**	***	*	***
IP	11.2	ND	***	***	***	NS	***
IK	16.8	ND	***	***	***	NS	NS
Mauritius							
DM (%)	7.30	***	***	***	**	***	NS
DM / ha (t)	0.04	NS	*	NS	NS	NS	NS
IN	5.30	***	*	***	NS	NS	NS
IP	4.50	***	*	NS	***	NS	NS
IK	9.60	*	NS	***	***	NS	NS

1 Standard error

2 N x S: nature of the grass - season interaction; N x Y: nature of the grass - year interaction

3 DM: Dry matter; IN: index of nitrogen; IP: index of phosphorous; IK: index of potassium

*: P < 0.05; **: P < 0.01; ***: P < 0.001

ND: not determined; NS: not significant

grasses year-2 and year-3 of the survey. On Mauritius, the significant interaction (P<0.001) between the nature of the grass and the season was mainly due to very high DM contents in CS on the littoral.

Calculated dilution indexes of N, P and K over the surveys are presented in Table 4 and must be compared to the ideal values of 80 (IN) and 100 (IP and IK) for a good herbage growth. A rapid overlook on the symbols representing the values evidenced a better control of phosphorous on La Réunion and of nitrogen on Mauritius, while potassium appeared in excess on both islands. Season (P < 0.01, Table 3), nature of the grass (P < 0.001) and year (P < 0.001), significantly influenced nutrition indexes on La Réunion, with a significant interaction between the nature of the grass and the year for IN and IP (P < 0.001). A significant interaction (P < 0.05) between the season and the nature of the grass also occurred for IN. On Mauritius, the effect of location was highly significant for nutrition indexes (P < 0.001 for IN and IP; P < 0.05 for IK, Table 3), with lowest IN and highest IK on West coast and lowest IP on the inland ranches (results not shown). We observed no interaction in the data, while IN and IP were affected by the nature of the grass (P < 0.05, Table 3), IN and IK by the season (P < 0.001) and IP and IK by the year (P < 0.001).

Table 5 presents the estimated surfaces and corresponding grass DM potential production according to the different agro-ecological zones observed on Rodrigues. The low potential of both cattle walk and terraces does not allow maintaining a high number of

Table 4: Values of nutrition indexes: (-): deficit; (=): fair; (+): excess

	HS1	CS1	HS2	CS2	HS3	CS3	HS1	CS1	HS2	CS2	HS3	CS3	HS1	CS1	HS2	CS2	HS3	CS3
La Réunion	Temperate grass						Kikuyu grass						Tropical grass					
IN	-	-	=	=	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IP	=	=	=	=	=	=	=	-	=	=	=	=	=	=	=	=	=	-
IK	=	=	+	=	+	=	+	-	+	+	+	+	+	=	+	+	+	=
Mauritius	Sikin						Star grass						Silver grass					
IN	ND	-	=	-	-	=	ND	=	=	-	=	=	ND	=	=	-	=	-
IP	ND	-	-	-	-	-	ND	-	-	-	-	-	ND	-	-	-	-	-
IK	ND	+	+	-	=	=	ND	+	+	=	+	+	ND	+	+	-	+	-

ND: not determined; HS: hot season, CS: cold season

IN, IP and IK: nutrition indexes of nitrogen, phosphorous and potassium, respectively.

Table 5: Geographical distribution of pastures and rangelands on Rodrigues

Altitude	Designation	Potential Yield (t DM / ha)	Main species	Utilization by animals	Surface(ha)	Property
< 100 m	Cattle walk	From 0.5 to 1	Cynodon dactylonPaspalum spp.Alysicarpus ovalifolius	Stray animals	2760	State
> 100 m	Terraces	From 3 to 6	Cynodon dactylon Paspalum dilatatumPennisetum purpureumStenotaphrum dimidiatumDesmodium trifolium	Tied up animals	2640	State for 90%
> 200 m	Calderas	From 10 to 12	Stenotaphrum dimidiatumPanicum maximumArachis pintoi	Surveyed animals	720	Community
< 50 m	Protected areas in valleys	From 12 to 15	Panicum maximumNeotonia wightiiCentrosema pubescens	Cut and carry	825	Community

sheep and cattle, so they are often overgrazed. Protected perimeters with high DM production of improved grasses, legumes and shrubs could provide high quality forage to the animals, but experience showed an under-utilization of these surfaces by farmers who are not used to cut and carry the grass towards animals, except for a few of them who breed dairy cows but generally own a perimeter with improved grass close to the farm. Forests (1600 ha) on Rodrigues could also provide some grass to cattle; however farmers are not allowed to enter them.

Animal performance: The frequency of calving in suckling cattle on La Réunion was significantly higher in CS ($P < 0.01$, results not shown); the graphic distribution of AFC and CCI is presented in Figure 2: 50% of the females have calved before 36 m of age and 80% of the calving-calving intervals were less than 405 d. We observed a significant effect of the year ($P < 0.05$; results not shown) and of the zone ($P < 0.05$; results not shown): both AFC and CCI decreased from the first to the third year of the survey and the lowest performance was observed on the East coast. A significant effect of the season of the birth was observed only for CCI (348.6 d in CS *vs.* 363.5 in HS, $P < 0.05$). LW_{210} was significantly affected by race ($P < 0.05$), sex ($P < 0.01$), rank of calving ($P < 0.01$) and zone ($P < 0.01$), e.g. 260.2; 201.5 and 172.0 kg for males in the Midlands, in the West Highlands and on the East coast, respectively and 244.6; 185.8 and 159.2 kg for females in these zones. Corresponding NPI were 0.66; 0.82 and 0.54, respectively.

Average deer carcass weights on Mauritius were significantly higher in HS (30.45±4.51 vs. 29.42±3.54, $P < 0.001$; Table 6) with no significant effect of the location. We observed a significant effect of the year (highest values on year 1; lowest on years 3 and 4, $P < 0.001$, Table 6) with an interaction between the year and the season ($P < 0.05$, Table 6).

Farmers' strategies and identification of constraints: On La Réunion, 3 groups of suckling cattle farms have been identified according to farmers' practices and are related to the geographical zone: (i) in the Midlands, farmers are used to managing their herd according to the grass availability in HS. Paddocks are rotationally used along the whole year by several physiological groups of animals with high stocking rates and complementary feed is distributed in CS with grass silage; (ii) in the West Highlands, the way of farming is more extensive and continuous grazing is adopted in CS; (iii) on the East coast where rainfall is higher, rhythm of rotational grazing

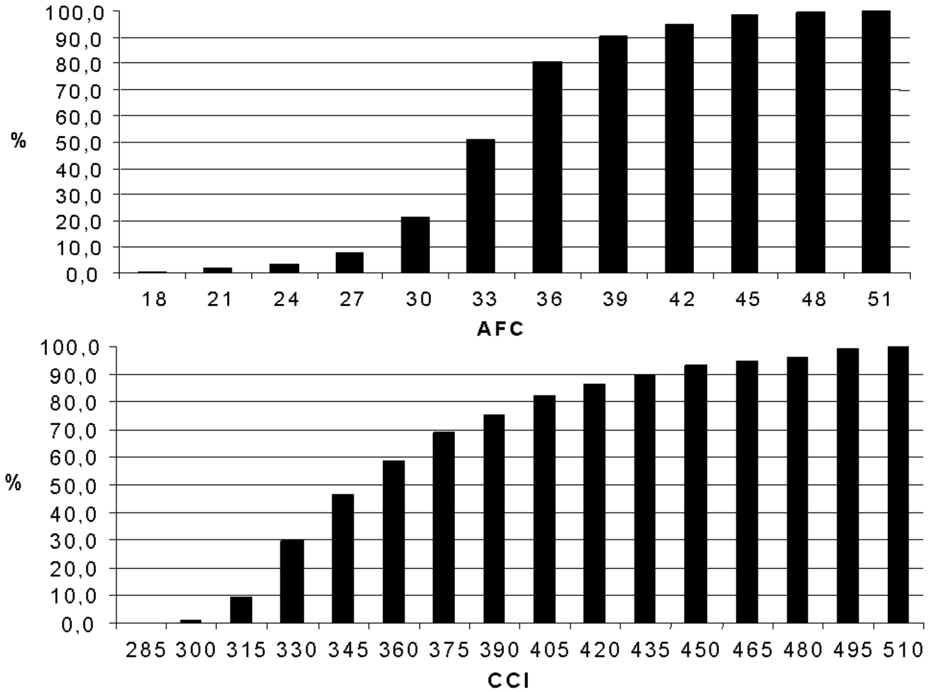

Fig. 2: Age at the first calving (AFC, in months) and calving-calving intervals (CCI, in days), in meat farms on La Réunion

Table 6: Deer carcass weights on Mauritius (kg)

Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		SE1	SS2
CS	HS	CS	HS	CS	HS	CS	HS	CS	HS	CS	HS	1.29	Y***; S***YxS*
30.4	32.6	29.1	31.2	28.5	28.9	28.4	28.2	29.6	30.6	29.5	30.6		

1SE: standard error

2SS: Y, effect of the year; S, effect of the season; YxS: year-season interaction. *: $P < 0.05$; ***: $P < 0.001$.

HS: hot season; CS: cold season

is high and animals are offered a regular complementary feed of DM to cope with high pasture humidity. Whatever the zone, key-periods are dictated by climatic conditions (decrease in grass availability, protection against hurricanes, DM balance in the diet...), animals' physiological requirements (good genetics of cattle, high reproductive performance...) and the objectives of the farmers (good body scoring conditions at calving, heavy animals to be slaughtered...).

Analysis of constraints in deer farming reveals two key periods in both La Réunion and Mauritius, namely: (i) the nesting period of the fawn which makes it difficult for the farmer to maintain rotational grazing and (ii) the lactating period, characterized by lack of grass making it difficult for the hinds to meet their nutritional requirements. Another key-period appears in Mauritius at the end of the cold season, which is the time when the cooperative must provide the venison on the market, as farmers cannot present deer with a sufficient carcass weight.

On Rodrigues, the bottleneck for meat producers is to find a market since the recent trade liberalization of meat in the Republic of Mauritius has limited exportations from Rodrigues to Mauritius. Due to a dramatic increase in the cattle population as farmers refused to sell their animals at a loss, local authorities put in place a cattle regulation with the aim to slaughter the oldest cows and to reduce the load on the pastures of the island. High stocking rates, close to 4 heads per ha, have been observed despite this regulation (photo 3), although the low potential of DM production.

DISCUSSION

A grass production unequally spread out over the year: Our observations on grazed pastures are in accordance with the situation in tropical countries: the cold and dry season corresponds to a decrease in forage production, despite a dramatic increase in DM contents [18-20] and farmers have to cope with an excess of forage at certain periods of the year, while a lack of grass could occur the rest of the year. Dry biomass increased during the hot season, a period corresponding to high rainfall intensities and these first rains result in high productivity of pastures that can not be eaten or managed by the only cattle. Consequently, farmers begin the hot season with a high plant cover in quantity but of lower quality [5-7]. They meet difficulties in making it totally ingested by their herd: swards are consequently often under-grazed, whose consequences could be as critical as overgrazing. Thomas and Grimaud [21] observed that such management practices generally lead to development of invasive species, such as *Sporobolus fertilis*, a non-palatable grass which can disappear with more rational farmers' practices that must combine adequate fertilization with intensive exploitation. *Acacia mearnsii*, an exotic shrub introduced from Australia to regenerate the fallow lands, appears to be the ultimate and non reversible stage of this degradation on La Réunion [22]. However, at the lowest altitudes of Highlands on La Réunion, swards comprise of both kikuyu grass and temperate grass and thus farmers can manage it differently while taking advantage of both forages [21]: during CS, temperate grasses are the most dominant pastures with small kikuyu cover remaining under *D. glomerata* or *L. perenne* and kikuyu grass dramatically grows on the onset of the first rains and dominates the sward. We concomitantly observed an increase in DM content in CS, dramatically higher for tropical grasses compared to temperate grasses. DM contents greater than 30 % lead to roughage utilization at too old stages so as to guarantee an optimal nutritive value of forage although this does not interfere with palatability [20]; in addition, tropical forages are known to have a lower nutritional value than temperate forages [18]. Nevertheless, these high DM contents were not evidenced for *C. gayana*, another tropical grass but managed on La Réunion by regular cuttings [5]. Grazed temperate forages, with a lower increase in DM content in CS, showed better resistance to cold and dry periods, as previously observed [23].

Farmers' strategies for high animal production: On La Réunion and Mauritius, all the farmers have adopted rotational grazing although their strategies differed on seasonal stocking rates, calculated either on HS grass potential with complementary feeding in CS, or on CS grass potential with unused paddocks for grazing in HS. However, on both islands, deer farmers have to cope with the nesting period which forces them not to close some paddocks when fawns are hidden. Such policies are possible due to fences which separate private farms into paddocks; they are unfortunately unrealizable on Rodrigues without any regulation on cattle walk and where a too high number of animals leads to a high degradation of the soils and to a conflict with maize producers who have to fight against stray animals [24]. Transfer of HS forage surpluses as silage (both temperate and tropical grasses) or hay (Rhodes grass), like the use of round bales made of sugarcane plant residues, are nowadays common farmers' practices on La Réunion, as they prevent the risk of pasture degradation due to swards under-exploitation, secure the animal nutritional requirements during CS when pasture productivity is lower and avoid overgrazing of the remaining forage [5]. Mauritian farmers are keen on transferring these technologies on Mauritius, as majority of them manage sugarcane plantations and also encounter the same forage excess in HS and could make silage from their pastures, although silage with tropical grasses is unfortunately not so easy to conserve [25]. This kind of practices led beef farmers on La Réunion to reach high performance with their cattle, close to those observed in temperate countries [26, 27], or to those registered with European breeds under tropical climates when feeds are not limiting [28]. At this time, deer farming on Mauritius is not as performing as expected [29], even if carcass weights on this island are higher than on La Réunion where deer farmers suffer satisfying the venison market demand [3]. Farmers progressively adapted the fertilizer quantities applied on pastures both to the season and to the animals' withdrawal, with the objective of not reaching the climatic potential of the sward but rather maintain its quality high. The low IN values on La Réunion suggested low availability of N, which inhibited pasture growth potential especially in CS, while high IK values revealed by this study were attributed to the rapid absorption of K by the plant roots, despite all the soil analysis evidenced K deficiencies in tropical conditions [6]. On Mauritius, acidic littoral soils brought about phosphorous unavailability which was confirmed by low IP values. This prevents good utilization of ternary mineral fertilizers that are in addition not generally adapted to pastures, as farmers use commercial formulas calculated for sugarcane plantations like on La Réunion some decades before [5]. The values obtained in our studies can be considered as the climatic potential of the forage growth that can be valorized by animals. However, lower indexes could meet the animals' requirements with a lower withdrawal from the sward. This phenomenon points out the need to combine the index values with the height of the grass and to provide an adapted fertilization to improve pasture management and thus to take a higher financial advantage from suckling cattle or deer exploitation.

Tools for farm management: Our studies focused on both grass and animal surveys, with the aim of proposing to farmers the tools to reach the best balance between pasture availability and animal requirements. These surveys lean on experiences carried out in other geographic zones and adapted to the environment of these Indian Ocean islands, like functional analysis of feeding systems [17] and herbage mineral nutrition indexes [13] in Europe, or specifically conceived for them (SEBARUN database on La Réunion). These tools have both purposes to assist the farmers and to participate to applied research aimed at the best knowledge of farming systems in particular environments. On La Réunion, experts' principles were gathered in a technical guide distributed to the farmers [30] and throughout the survey, these recommendations led to an increase in dry biomass during CS, combined with a decrease in DM contents. Some of the results collected on Mauritius were presented in this guide, which can easily bring useful information to deer farmers, who now have to accept a survey on live animals performances. The assistance of laboratory was helpful to analyze our samples and recent studies showed that Near Infra Red Spectroscopy - NIRS - could favorably be used in order for farmers and pasture experts to get relevant information at lower prices and shorter delays than classical mineral analysis [31]. This rapid diagnosis towards pasture management is an area that could need more attention by forage scientists in tropical countries and particularly in Africa, in order to improve on animal productivity and reduce on costs associated with the classical pasture feed analysis. Those tools unfortunately cannot be used on Rodrigues, where cattle regulation needs to be applied and where farmers have to "think in another way" to get profit from their animals. A few positive experiences related to milk production, with exotic cattle and private pastures, are encouraging.

CONCLUSION

Cattle and deer farming for meat production differ on Mascareignes Archipelago according to the islands: the profession is well organized on both La Réunion and Mauritius, while on Rodrigues beef farmers are confronted with a crisis they do not understand since the Republic of Mauritius has stopped importing meat to the main island from Rodrigues. This led to an overpopulation of cattle which now threatens the island with erosion and compromises relations between breeders and cultivators. Some surveys were conducted on cattle farming on La Réunion and on cattle and deer farmers on both La Réunion and Mauritius, using tools that were either specific to the context or adopted from experiments carried out in other climatic environment. Assessment of available nutrients to plants and general recommendations on the level of minerals to apply on pastures is classically based on soil analysis. Our study indicates that the dilution process for N, P and K can be associated with biomass measurement to calculate nutritional indexes of herbage in a tropical environment. Controlled mineral fertilization is thus an important practice of a sustainable management of grasslands and recommendations adapted for various seasons and types of pastures can be made based on these indicators. Farmers can progressively adapt fertilizer quantities to the pasture growth, in the same way as stocking rate, to get a better profit from their animals, particularly in deer farming as performances in cattle meat production on La Réunion are good.

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