Sheep and Goat Production in Hot Climates

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خلاصة : تناقش هذه الورقة أسباب تربية المجترات الصغيرة وتبحث في المجالات المتاحة لتطوير التقنيات لإحداث الآثار القصوى لزيادة الإنتاج من مشاريع الضأن والماعز في المناطق الحارة. أهم المجالات التي يمكن فيها استخدام المعالجة الحيوية لرفع الإنتاج هي التغذية المحسنة، ورفع معدل حياة المواليد الجدد. من المحتمل أن لا تعكس دراسات التغذية التي تجرى على الحيوانات التي تتغذى على حشائش المراعي في المناطق الحارة والشجيرات حقيقة العلائق التي تم تناولها، ويرجع ذلك إلى مقدرة الحيوانات على اختيار أنواع الغذاء ذي النوعية الجيدة مما يتدم إليها من غذاء. وهناك اقتراح لاستغلال هذه المقدرة على الاختيار لرفع إنتاجية القطيع ككل. يوفر خيار تحسين صحة الحيوان المجال الأوسع لزيادة الإنتاجية بتخفيض معدل الوفيات في الحيوانات الصغيرة السن، كما هو مشاهد في العديد من مشاريع الإنتاج في المناطق الحارة. وأصل هذه المشكلة في الغالب هو الإصابة بالطفيليات. وقد أثبتت الأدوية طاردة الديدان فعاليتها للمعالجة على المدى القصير لكن السرعة التي تتمكن بها الطفيليات من اكتساب المناعة ضد هذه الأدوية تشير إلى خيار مهم آخر هو استيلاد حيوانات ذات مناعة ضد الطفيليات لتوفير حل على المدى الطويل.

ABSTRACT: This paper discusses the reasons for keeping small ruminants and investigates the areas in which technological improvements are likely to have most impact in increasing the output from sheep and goat enterprises in hot climates. The most important areas in which biological manipulation can raise productivity lie in the areas of improved nutrition and increased survival of young animals. Nutritional studies of animals receiving diets of natural tropical grazing and browse may not reflect the rations actually consumed due to the ability of animals to select high quality forage from what is on offer. One suggestion is made as to how this selection can be exploited to increase the productivity of the herd as a whole. Improved health care offers the largest potential for increases in productivity by reducing the large mortality of young animals seen in many tropical production schemes. Much of this mortality has its roots in parasite infection. Anthelmatics have proved valuable for short term therapy but the speed at which parasites become resistant to drugs indicates that selective breeding of animals with resistance to parasites is a more valuable long term solution.

There are many ways that sheep and goat producers can improve output - through their own ingenuity, the work of researchers, advice from extension agents and as a result of Government policy. However, farmers have often been slow to adopt technology options that require changes in production systems. This paper discusses the reasons that farmers keep sheep and goats and outlines the constraints to production, identifying issues that farmers believe are important. A number of technology options are considered, as well as their potential for adoption.

Reasons for Keeping Sheep and Goats

Biological research is designed to increase the output of meat, milk, or wool from small ruminants based on the unspoken assumption that these outputs, for home consumption or sale are the reasons why the animals are kept. Such assumptions are partially correct but do not tell the full story.

In mixed farming systems in high rainfall areas (1200mm), with 4-6 sheep or goats per household and 2 ha under cultivation, smallstock provide less than 5% of farm income and less than 2-3% of household income. As sales of smallstock or smallstock products appear of marginal importance, why do half the households in the mixed farming sector keep sheep and goats? Slaughtering for home consumption does not appear to be a significant factor, supplying annually around 10 kg/household (Reynolds and Adediran, 1994). However, the income from sales of smallstock is meeting specific needs, such as school fees and medical bills. Smallstock act as a readily encashed form of savings - the current account in banking parlance - and are a hedge against risk. As human population density rises, less grazing land is available and farmers must rely on their own feed resources. Two distinctly separate trends are observable. In one direction, cattle disappear leaving only smallstock as a savings reserve (eg Rwanda), while in the other direction, specialisation and intensification driven by market demand for milk has led to the replacement of indigenous cattle by dairy breeds, and a decline in the number of smallstock (eg Kenyan highlands).

At the other extreme in mixed farming areas with 600-800 mm rainfall herd size is larger and more variable. Livestock provide an increasing proportion of household income as cropping becomes less reliable. Agropastoral households in the millet system in Mali keep around 20 cattle and 35 small ruminants, and cultivate 14 ha. Livestock provide 10 - 40% of household income, out of which smallstock sales alone contribute about one third. Goats milk is a further but minor source of earnings (ILCA, 1990). Manure is an important source of nutrients for maintaining soil fertility and crop yields. Smallstock contribute less than cattle, but manure from confined or tethered fattening sheep is valued for vegetable gardens. Animal numbers fluctuate greatly depending upon rainfall and the success or failure of cropping. When the crops fail, livestock are sold to buy grain, but after a good harvest surplus income is invested in animals. In an average year, 3 sheep and goats are slaughtered and 5 are sold (Wilson, 1986). Around a quarter of households confine or tether 1-2 intact males to fatten for festivals. Hence smallstock provide meat and milk, and are a significant source of income.

In pastoral areas with lower rainfall and little potential for cropping, income from livestock and livestock products, plus remittances together contribute to household income. Herd size and species composition is variable, depending upon family wealth and the stage in the rainfall-derived cycle between boom and bust. More affluent families have larger herds and a higher proportion of large ruminants; poorer households depend more upon smallstock. Smallstock provide meat, milk, skins as well providing income. As pastoralists become more closely connected with a consumer society, an increasing proportion of human food intake is derived from cereals which are purchased through sales of livestock and livestock products (Bekure et al, 1991). Under non-equilibrium environmental conditions with high inter-annual variations in rainfall, animal numbers are largely determined by drought induced crashes. When the rains fail, livestock are sold to purchase cereal food for the household. When the rains return, smallstock, which are more likely than cattle to survive serious drought are purchased first and are the basis for herd rebuilding, rapidly reproducing on the understocked pasture allowing herd growth and sales to generate resources to buy large ruminants. Alienation of higher potential areas reserved for dry season grazing, by cultivators places more pressure on rangelands and may cause degradation in the long term unless animal numbers fall or other sources of dry season feed are developed.

Priorities vary across production systems. In high rainfall mixed farming, smallstock are very low in the pecking order - effectively scavenging adjuncts to the farming systems. In drier mixed farming systems, livestock are given more attention but priority is given to draught animals, cows and then other cattle before smallstock. In pastoral areas large ruminants, especially lactating animals are considered more important than smallstock.

National level priorities also need to be considered, particularly where food self sufficiency or self reliance are emphasised. The former requires within-country production of staple foods sufficient to meet internal demands; the latter requires that the country can afford to meet food needs from a combination of internal production and from imports funded from export earnings. Demands for self-sufficiency may lead to production in inclement environments where farming would be uneconomic without subsidy. Where micro-environmental modifications are needed, primary production (i.e. crops of any description) will be expensive, but secondary production (eg. of livestock products) based on the use of primary products will be even more expensive in comparison to world market prices. Agriculture and livestock production are an important source of rural employment, and this can justify subsidy in areas with difficult climates.

Biological Options for improving Productivity

Overall animal performance is determined from lambing/kidding interval, conception and birth rates, litter size, milk production, growth rates, and survival. Technological improvements can be targeted on one or more of these parameters, but for maximal impact is important to know which is the most critical. For example, short term supplementary feeding to young stock after weaning improves growth rate but is there any long term effect on reproductive performance of females or mature/market weight of males? Could the same amount of feed be more effectively used with pregnant or lactating females? What would be the effect of allocating the same resources to provision of drugs/vaccines rather than feed, to large ruminants rather than smallstock, or to crops rather than livestock? Simple biological trials that answer a single question are useful, but the value of the information rises exponentially when multiple answers are obtained contemporaneously within the trial. Economic analysis requires careful physical measurement and interpretation, only after which can financial calculations be made. Morris and Meek (1980), for example, describing the biological components needed to assess the economic effects of disease and the benefits of treatment, include reproductive performance, mortality, reduction in yield of a product, age and sex structure of a herd (which will have a feedback effect on productivity), and product quality.

In practical terms, changes in feeding, health treatments and management systems are the main options open to producers, but these may need to accompanied by institutional support organised by Government or private enterprise to provide inputs, advice or marketing opportunities.

A) IMPROVED FEEDING: Sheep and goats rely largely on natural pasture, the quality of which varies widely with season. Young vegetative growth has a relatively high nutritive content, but mature foliage is low in protein, high in fibre and indigestible. However, grazing animals have a remarkable capacity to select the more nutritive portions from the feed on offer. Oesophageal fistulated animals reveal that green material is found and consumed from a grazing Sahelian landscape that looks totally desiccated to the human eye (S. Fernadez-Rivera, personal communication). Hence, sampling by hand to determine feed quality of natural pasture is very difficult.

Equally, animals grazing crop residues are very selective while sufficient feed is on offer. With sorghum stover, higher quality material from panicles and upper leaves is consumed before lower leaves and upper stem, and much of the unpalatable residue remaining in the field will be lower stem (Powell, 1986). Indeed, Owen and Aboud (1988) suggested that high levels of offered crop residues would improve the performance of stall fed ruminants. This suggestion was further investigated with pearl millet stover leaves (*Pennisetum glaucum*) by Fernandez-Rivera et al (1994), who found that as leftovers rose from 10% to 50% of the amount offered, organic matter digestibility *in vivo* rose by a quarter (Table 1). Dry matter intake (DMI) by sheep struck a plateau when the food allowance reached 3.2% of body weight.

Farmers would probably be cautious about such a strategy in semi-arid areas in the absence of surplus dry season feed since the left-overs might be regarded as wasted. However, as the amount of food on offer rose animals were able to be more selective in their consumption so that the quality of the refusals increased. When the left-over food from the high-refusal treatments was re-offered to sheep on an *ad-libitum* basis digestible organic matter intake was depressed by less than 10%. Fernandez-Rivera et al (1994) concluded that farmers would benefit by offering high levels millet stover (so that left-overs were twice the traditionally recommended 15% of intake) to animals of particular economic value, and that the left-overs could then be offered to less valuable or selective stock without adversely affecting their performance.

TABLE 1

Feeding value of pearl millet leaves at a high level of offer, and the re-fed leftovers.

	Original offer	Re-fed leftovers	Significance
Offered			
ADF (g/kg DM)	394	429	**
Ingested			
ADF (g/kg DM)	377	421	**
in vivo OMD (g/kg)	505	489	NS
DOMI (g/kg MBW)	22	20	*
Food uneaten			
% of offered	29	37	**
in sacco OMD (g/kg)	406	369	NS

ADF = acid detergent fibre
in vivo OMD = organic matter digestibility
DOMI = digestible organic matter intake
MBW = metabolic body weight
in sacco OMD = organic matter degradability

Many research trials have demonstrated the addition of protein rich feed to a low quality roughage diet increases total intake, and sometimes may result in a higher level of consumption of the basal roughage. Increases in dry matter intake are taken to be desirable objective in their own right, but this may not be a realistic aim for semi-arid and arid areas where limited feed is available. Raising the rate of extraction of nutrients from a limited intake level may be a more suitable objective given the situation faced by producers.

In many production systems sheep and goats obtain protein-rich feed from browse and herbaceous legumes rather than from concentrate. Much of the research activity has dealt with browse leaves, but for some species, such as *Acacia tortilis* and *Prosopis juliflora*, seeds are also a valuable livestock feed. During the breeding season for Maasai smallstock pods from *Acacia tortilis* comprise up to 50% of total daily intake, resulting in higher conception rates for animals with access to the pods (de Leeuw et al, 1986).

Many browse species contain anti-nutritive factors, such as saponins, alkaloids and tannins that can significantly reduce nutritive value, and may affect palatability. Condensed tannins have a significant effect on fermentability in the rumen, but have little effect on palatability. Drying and wilting sometimes reduces total phenolics and condensed tannin levels, but depresses palatability, degradability and digestibility in some species (eg. *Calliandra calothyrsus,* Palmer and Schink, 1992; Ahn et al 1989), while with other species palatability increases (eg. *Gliricidia sepium*, Ash, 1989). Although the palatability of cultivated browse is dependant on the provenance from which it was derived, many widely used exotic browses are often derived from a narrow genetic base, selected for biomass production rather than palatability (Larbi et al, 1993). Anti-nutritional factors in leguminous browse can form indigestible complexes with dietary protein in the rumen, or can bind with endogenous enzymes secreted into the small intestine for post-ruminal digestion. However, rumen microbes are capable of degrading many anti-nutritional compounds so limiting their impact on nitrogen metabolism, although the effect on microbial growth rate can be severe (eg *Acacia* *nilotica*, Muller-Harvey et al, 1988). Soluble phenolics have little effect on rumen degradation but at the lower pH levels found post-rumen, irreversible complexes may be formed with protein (Nsahlai et al, 1994); the resulting protein-phenolic complex remains intact during its passage through the rest of the digestive tract and will be excreted in faeces. In-vitro studies must be interpreted with care because soluble phenolics are unable to escape from the fermentation vessel, in contrast to the situation *in-vivo*.

There is wide variation in the site and extent of breakdown of protein from browse, as indicated in Table 2. Much of the data available refers to browse species that are more suitable to humid and sub-humid zones, there is a need for researchers to look more closely at degradation and digestion characteristics of (for example) *Acacia* and *Prosopis* species which are widely used in dry areas (Fagg and Stewart, 1994). Drying increases the rumen degradability of protein, and the proportion of undegradable protein that is catabolized in the small intestine from *Albizzia*, *Erythrina* and *Leucaena*, but decreases it in *Gliricidia* and *Calliandra*. Time spent in the rumen is affected by the level of food intake, and the rate of breakdown of particles in the rumen. Increasing the time spent in the rumen raises the level of degradability and decreases the level of subsequent catabolism in the small intestine. It also affects heat production, a factor to consider under extreme climatic conditions. The proportions of dietary N excreted in dung or lost in urine from livestock on a forage diet will depend upon the site of catabolism in the digestive tract (Reynolds and de Leeuw, 1994). This will be of significance where manure is collected for use on arable land, or where animals graze crop residues in situ.

TABLE 2

Rumen degradation and post-rumen digestion coefficients of browse species, as affected by forage preparation, forage regrowth period, and length of time the material remains in the rumen.

Species	Condition	CP %	RDP %	IDP %	ExDP %
a) Forage preparation					
Erythrina variegata	Fresh	25.3	64	25	11
	Sun-dried	25.3	74	20	5
Gliricidia sepium	Fresh	26.1	69	25	6
	Sun-dried	26.1	70	19	11
Leucaena leucocephala	Fresh	24.6	39	37	24
	Sun-dried	24.6	48	34	18
b) Forage regrowth time before harvesting					
Callianda calothyrsus	12 weeks	28.2	59	32	9
	24 weeks	25.3	58	26	16
	48 weeks	23.1	51	23	26
c) Time in the rumen					
Sesbania sesban	24 h	26.7	77	10	13
	48 h	26.7	84	6	10
Leucaena leucocephala	24 h	25.7	44	32	24
	48 h	25.7	57	21	22

RDP = Rumen degradable protein
IDP = Intestinal digestible protein
ExDP = Excreted dietary protein (undegraded and undigested)

A highly significant browse by animals species interaction for the rate and extent of degradation of the slowly degradable DM fraction in browse has been observed (J A Smith, personal communication). Since there is no difference in the ability of sheep and goats to digest most conventional diets except when dietary protein levels are very low (Tolkamp and Brouwer, 1993), this suggests specific adaptation by different animal species to browse. It also suggests that the source of rumen microbes used for in-vitro studies will affect observed degradability, and that care must be taken in extrapolating nutritive values for browse from one animal species to another.

Under difficult environmental conditions, smallstock exhibit low twinning rates. It is possible to increase twinning rate through selection, improved feeding and management, but a crucial question is the subsequent survivability of twins under farming conditions. Unless there is adequate nutrition for the dams during late pregnancy and lactation, increased prolificacy will be accompanied by higher mortality rates in the offspring. The net result will be no advance in numbers of offspring reaching market weight, and increased pressure on dams, shortening their productive life.

Supplementation can be targeted on pregnant and lactating females. Birth weight will increase when pregnant females are supplemented, and weaning weight goes for the offspring of females receiving supplementation during lactation. However, by the time the offspring reach 12 months of age there may be little difference in weight between those whose dams were supplemented and those that were not because of periods of undernutrition on poor quality natural grazing may be followed by compensatory growth when feed quality and quantity improves. Short term supplementation in early or late lactation has no long term effect on weight of the offspring, even though short term benefits to liveweight are observed (Reynolds and Adediran, 1988; ILCA, 1990). However, while the effects on liveweight are short lived, very significant effects are observed on survival rates up to 6 months of age, which can rise from 45% on a grass- only ration to 98% when leguminous browse comprises 40% of the intake. Improved survival translates into very significant improvements in overall herd productivity, and is particularly attractive to producers who raise smallstock as a risk-avoidance strategy.

Interactions between nutrition and health may allow improvements in production even where the veterinary infrastructure remains to be developed. Blackburn et al (1991), for example, reported that the addition of legume hay to a ration allowed young goats to counteract the consequences of *Haemonchus contortus* infection by controlling PCV, worm numbers and faecal egg counts. Improved nutrition was ineffective however, in preventing establishment of the infection. Raising below-maintenance intake levels, as may occur in the dry season, to maintenance level sharply reduced mortality rates in sheep and their lambs from trypanosomiasis (Reynolds and Ekurukwe, 1988).

In semi-arid Kenya stratification of production, encouraged by donor support from development agencies, has been tried with beef animals. Young stock born in pastoral areas, were purchased and supplemented with grain up to market weight in feedlots. The advantages are reduced mortality rates of young stock, reduced pressure on grazing areas, and a higher quality meat product. Although biological successful, the programme eventually folded because it was economically unsustainable. The key economic variables were the relative prices of meat and grain, and the availability (and cost) of young stock to enter the feedlots. The equivalent fattening system for smallstock has focused on-farm, with selected animals receiving cut and carry forage and concentrates. This has advantages in that capital intensive infrastructure is unnecessary, and individual producers can easily modify their production strategy to meet changes in their socio-economic and environmental circumstances.

B) Improved Health Care: Control of epidemic diseases has had a major effect on animal production globally, and vaccination campaigns, such as against cattle Rinderpest in Africa have been supported by major donors. Less dramatic diseases with more localised impact on small ruminants receive less attention at international, national or district level. On mixed smallholder farms conventional veterinary treatment for smallstock is the exception rather than the rule. Expenditure on drugs is focused on the most valuable of the livestock - which usually means cattle. Smallstock may be treated with indigenous remedies but the market value of an individual animal usually does not warrants a visit from a veterinarian or the purchase of imported drugs. Nevertheless, many studies have demonstrated the potential impact on sheep and goat production of improved health care. Examples include control of Peste des Petits Ruminants (Hill, 1983; Ata and Al-Sumry, 1995), and gastro-intestinal parasites (Blackburn et al, 1991).

It has often been demonstrated that anthelmintics improve small ruminant performance on-station, but their effectiveness on-farm is much reduced if there is no uncontaminated pasture on which cleaned animals can graze. Most grazing animals are infected with internal parasites (eg. Tawfik and Al-Sumry (1991) in Oman). In many hot, humid environments uptake of parasites from pasture is almost continuous, so that re-infection will be rapid, negating the effect of treatment. Under semi-arid conditions the environment is only intermittently favourable to nematodes. A long dry season of at least 4 consecutive months with no rain allows the distributive forms on pasture to drop to low numbers, and the wet season with at least 4 months with more than 50 mm rainfall is enough for the development of a significant challenge to the host.

Drug treatment can control parasite levels and reduce the effects on animal performance, However, parasites are capable of developing resistance, as has already happened for many of the most widely used drugs against *Haemonchus contortus* because of frequent use, under-dosing and continuous use of the same drug family (Waller, 1991). Worms that survive treatment pass their genes onto the next generation with consequent accumulation of resistance. Initially the development of resistance is slow, but once the proportion of worms with resistance reaches 25%, there is a rapid increase and drug treatment ceases to be effective. Resistant parasites to the major drug groups such as levamisole, the benzimidazole group of compounds and more recently to avermectin have emerged in Australia, New Zealand, Europe and America (Waller, 1991). Resistance has also been found in Tanzania, Kenya, and South Africa, (Bjorn et al 1991; Mwamachi et al, 1993; van Wyk et al 1989).

To prevent resistance developing, animals should be drenched according to the weight of the heaviest animal in the flock, rather than on average weights, since this leads to many animals receiving less than the required dose. Annual rotation across drug families is another best-bet strategy. An alternative approach is the use of strategic drenching, focusing on the most susceptible animals at the periods when they are at most risk. The immune system in lambs is not fully developed until around 12 months of age, and therefore regular drenching is helpful up to that age. The immune system needs priming with an initial challenge, and thereafter needs some exposure to maintain an effective defence. Adult sheep are therefore relatively unaffected by worms, but hormonal changes in ewes around lambing time and during lactation suppresses the immune response system and worms can take a serious toll. Strategically timed treatments in sheep in Australia generated gains in animal productivity that are similar to that of sheep drenched every three weeks (Brown et al, 1985). The most susceptible 15% of a flock produce around half the worm eggs returning to pasture, and hence culling of a small number of individuals can lead to a major reduction in both larval pasture contamination and the worm burdens in lambs (Windon, 1990). Losses in productivity attributable to internal parasites are between 14% to 79% for weight gain and between 9% and 30% for wool production. Mortality rates of up to 66% can occur in young stock in the absence of control measures. Even where control of grazing is possible, such as in Australia, the total cost of helminthiasis was estimated to be the equivalent to be A$ 350 million, 15% of the total Australian wool returns (Beck, 1985).

Within any group of animals there is a natural variation in susceptibility to parasites, and an alternative approach for nematode control is to select and breed from animals that exhibit high levels of natural resistance. Within breed genetic variation for resistance to internal parasites in the developed world shows heritabilities of around 0.35 (Baker et al, 1992a). Successful divergent selection for resistance or susceptibility to internal parasites in Merino sheep in Australia (Woolaston,1990) and Romney sheep in New Zealand (Baker et al, 1991) have been demonstrated. Woolaston found that after 11 years of selection, worm egg counts in the resistant line were 80% lower than in susceptible Merinos. Computer simulation models indicate that over a 20 year period, depending on management used, the peak larval numbers on pasture from resistant sheep would be 2-6 times lower than with unselected sheep. Not only would animals be more resistant to worm infection but there would be fewer larvae on pasture for them to pick up.

Some breeds are more resistant than others, but from a commercial point of view it is unfortunate that resistant breeds, such as Florida Native in America and Red Maasai in Kenya, tend to be smaller and slower growing than commercial breeds. In Kenya the indigenous Red Maasai breed is more resistant to *Haemonchus* than is the exotic Dorper breed (Baker et al, 1992b), as expressed in terms of lower faecal egg counts (FEC), better maintenance of packed cell volume (PVC) levels in blood and lower mortality rates. Post mortem analysis showed that 75% of the mortalities post weaning could be ascribed to helminthiasis. Analysis of data from 10 months old animals indicated a negative correlation FEC and liveweight, and a positive correlation between PCV and liveweight, both of which are desirable associations of these measures of resistance with growth. Growth rates or liveweight are often used as proxies for productivity, but when measures of ewe reproduction and mortality are included from the coastal Kenyan study, the Red Maasai and its crosses are more productive than the imported Dorpers (Table 3). The periparturient rise in FEC between lambing and weaning was more marked in Dorper than in Red Maasai ewes, confirming that the Red Maasai is more resistant. Heritability estimates showed that genetic improvement for resistance to helminths is achievable for African sheep through selection (Table 4), just as has been achieved in Australasia. For all liveweights from birth to 10 months of age the maternal component of heritability was significant, while the direct additive component steadily increased from weaning. No significant maternal effects were found for FEC or PCV at any age, but direct additive heritability increased with age for both traits.

TABLE 3

Total Productivity for flocks of Dorper, F1 (Red Maasai X Dorper) and the backcross (Red Maasai X [RM X D]) sheep in coastal Kenya.

	Dorper	RM x D	RM x (RMxD)
Ewes lambing/ewes mated %	70	70	81
Lambs born/ewes lambing %	103	103	101
Lamb mortality to weaning %	24	18	18
Lambs weaned/ewes mated %	55	70	76
Lamb mortality to 1 yr %	45	30	24
Lambs reared (1yr)/ewe mated %	40	51	63
Surplus sheep for sale[a]	20	31	43
Lamb liveweight at 1 yr (kg)	22.0	21.5	21.0

a Assuming a 100 ewe flock with a 20% replacement rate

TABLE 4

Heritability estimates (with SE) for liveweight, packed cell volume, faecal egg count for lambs in coastal Kenya at 3 months and 10 months of age.

	N	h_D^2	h_M^2
Birthweight	648	0.09 (0.07)	0.38 (0.06)
Weaning weight (3m)	529	0.00 (0.09)	0.29 (0.08)
Liveweight (10 m)	448	0.12 (0.10)	0.34 (0.09)
PCV (3 m)	529	0.00 (0.07)	0.04 (0.09)
PCV (10 m)	448	0.11 (0.12)	0.28 (0.11)
FEC (3 m)	356	0.20 (0.13)	0.12 (0.33)
FEC (10 m)	407	0.42 (0.21)	0.00 (0.13)

h_D^2 direct heritability
h_M^2 maternal heritability

Adoption Potential for Improved Technology

Reproductive performance, growth rates and survival rates in traditional systems compare poorly with those obtainable from more intensive production. Increasing the quality and quantity of feed on offer will improve all the above parameters, as demonstrated in many research projects, but very few have successfully transferred from research station to farm. The provision of improved feed at farm level is often difficult. Legumes have a poor track record beyond the short term in strengthening natural pasture on communal land, and even on privately controlled land, it is difficult to manage grazing to sustain legumes in tropical pasture. Cut and carry feeding systems are rather easier to manage, but it is only when there is an economically valuable product that farmers will consider cultivating forages. In Yemen, alfalfa is grown on irrigated plots to be fed to draught animals and lactating cows. Smallstock may occasionally receive alfalfa supplements in the dry season, but the main use is reserved for large ruminants (Hendy, 1994). Irrigation is dependant upon remittances from migrant workers to buy and maintain the pumps.

In grazing systems, establishment of palatable fodder species is difficult unless animals can be excluded. In semi-arid areas, deep rooting browse species may prove more hardy than introduced herbaceous forages, and they will have a greater effect on the microclimate, providing conditions that will encourage understorey plants. Prosopis woodland in parts of Oman contains a high proportion of unpalatable understorey plants (Munton, 1988), which may be indicative of overuse.

Sensitivity analysis of components of productivity will indicate where to place emphasis. In high rainfall areas for example, animal health interventions were found to be more effective than improved feeding for free-roaming animals, but improved feeding is more critical when animals are confined (Bosman and Ayeni, 1993). Although tree legumes are more resilient than herbaceous legumes on small-scale mixed farms, adoption has been slow. The most promising scenario for adoption of cultivated forages is where livestock production is driven by market demand (eg. milk production from dairy cattle).

An encouraging example of herbaceous legumes offered to smallstock comes from Nigeria. Fodder banks of *Stylothantes hamata* were originally designed to provide dry season feed to lactating cattle owned by pastoralists, but the concept was adapted by settled farmers to improve soil fertility regeneration on fallow land. This had multiple benefits of providing high quality wet season feed for tethered smallstock, reducing the need for herding at time when labour was required for cropping, while also raising soil fertility through direct return of excreta to arable land. Higher crop yields were obtained when the land returned to cultivation. This approach was in keeping with farmer priorities since it addressed the primary concern of farmers - raising crop yields (ILCA, 1992; G Tarawali, personal communication).

Selection for resistance to internal parasites is already featuring in Australasia, and can be expected to spread to other large scale commercial sheep areas. The potential for impact of this approach depends upon controlled breeding, controlled access to grazing areas and infrastructural support from extension/ veterinary services. The medium term prospects for adoption and impact in the developing world are slim. Introduction of improved sires, a development approach that sometimes attracts donor support, should proceed with caution in mixed smallholder farming systems since the fastest growing males may be sold or slaughtered first to meet short term cash needs (Reynolds and Adediran, 1994). The potential for sustained adoption of improved sires is higher in pastoral systems with large herds and flocks that practice controlled breeding (eg Maasai).

Conclusion

A holistic view of farming systems is required so that research activities address critical constraints. Proposed solutions to livestock problems should be compatible with other farm objectives and activities. Priority issues, and hence solutions to the problems of smallstock producers will vary across locations depending on the biophysical and socio-economic environment, and hence no single solution will be universally applicable. Applied researchers and development workers need to be flexible in their approach, and must listen to problems as identified at farm level. Farmers seek to optimise rather than maximise resource use, so that improvements to a priority area of a farming system, can raise opportunities in another part of the system. This approach may be more successful in raising performance of smallstock mixed farming systems where they considered of low priority by the producer. Improved animal survival has greater impact on overall performance under small-farm conditions than increases in growth rate. In addition to veterinary approaches, to which smallstock have limited exposure, survival can be increased by improved nutrition. Selection for increased resistance to internal parasites is a further option for producers who can operate controlled breeding strategies.

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