CLIMATE AND PRODUCTION FROM GRAZING ANIMALS IN AUSTRALIA

INTRODUCTION

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Most of the domestic breeds of grazing animals in Australia, and many of the introduced pasture species, originate in climates which differ from those experienced here (Williams 1973). The large size of this continent means that there are several very diverse climatic zones, few of which provide an ideal environment for grazing animals or for the pastures they use. The resulting penalties to animal production are greatest where periodic climatic extremes are most pronounced.

Animal production may be affected directly, through physiological effects on the animal of heat or cold, and indirectly through effects on the pasture.

In this contract we review some of the direct effects of cold (mainly in sheep) and heat (mainly in cattle) on the physiological responses and the production of these animals. , The final paper examines the effects of climate, particularly of cold and water shortage on the feed resource, In each case the contributors discuss ways of alleviating adverse effects of climate.

DIRECT EFFECTS OF COLD ON GRAZING ANIMALS

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BACKGROUND

Under cold conditions, homeothermic animals must expend energy to maintain body temperature. As the rate of heat loss increases under the influence of the additive effects of decreasing ambient temperature, increasing wind and evaporation, the animal makes use of energy from extra food or catabolism of tissue reserves to balance that being lost (Alexander 1973; Webster 1973). Increased insulation and behavioural patterns that reduce heat loss make these processes more efficient.' However, if heat loss exceeds the animal's capacity for generating heat, hypothermia occurs resulting in a decline in metabolic rate and ultimately death. Sudden severe cold exposure can cause death before significant depletion of tissue reserves has occurred (Alexander et al. 1980).

Animals with a high ratio of surface area to mass are particularly prone to rapid heat loss. The newborngrazing animal is in this category and, in addition, its coat is saturated with fluid, the evaporation of which requires energy both from the animal and the environment. Energy demands at this time are probably greater than at any other stage of life.

The lower limits to homeothermy can 'be defined by an animal's summit metabolism i.e. its maximum metabolic response under, controlled conditions designed to keep it on the brink of hypothermia. This maximum effort can only

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be sustained for a limited time (20 min for lambs, 1-2 h for adult sheep) and is therefore only useful to define a physiological limit, not conditions under which animals can be kept for extended periods. Lesser effort can be maintained for longer, e.g. 80-90% of summit for 4-8 hours in adult sheep (Bennett 1972).

Prolonged cold exposure also causes reduction in productive processes such as growth and lactation (McBride & Christopherson 1984a,b) due to diversion of energy towards the maintenance of homeothermy.

PHYSIOLOGICAL RESPONSES TO COLD STRESS

Animals have two thermogenic mechanisms for responding to cold (Alexander 1979). Shivering in skeletal muscles increases metabolic rate 2-3 times in newborn lambs and 8-10 times in adult sheep and accounts for almost all the extra heat that can be generated in adult grazing animals. Newborns possess, in addition, an equivalent capacity for non-shivering thermogenesis from catabolism in mitachondria-rich brown fat, a tissue which is replaced by non-thermogenic white fat within a few days or weeks of birth.

Other physiological adaptations occur during prolonged exposure to cold conditions. Resting metabolic rate increases by 20-40% (Young 1975), appetite is stimulated (Moose et al. 1969) although feed digestibility is reduced (Kelly & Christopherson 1986) and there is altered perception of cold by the central nervous system (Webster 1973). Resistance to cold also has a genetic component as shown in sheep by breed differences and heritability estimates (Slee 1985).

MECHANISMS TO REDUCE HEAT LOSS

Physiological and behavioural. adaptations which act to reduce heat loss in cold conditions complement thermogenic capacity in animals. Growth of hair and wool and piloerection increase external thermal insulation; sheep and goats are therefore particularly vulnerable to the effects of cold after shearing. Cold also induces increases in 'insulation of the body shell by peripheral vaso-constriction (Webster 1974) and increased skin thickness (Wodicka-Tomaszewska 1960).

Behaviour changes that effectively reduces heat loss includes changing posture and angle of the body with respect to wind direction, huddling and the seeking of 'shelter, especially from. wind (Bird et al. 1984; Obst and Ellis 1977). Provision of shelter reduces sheep deaths off-shears in bad weather and improves neonatal lamb survival (Alexander et al. 1980).

COMPUTER PACKAGES TO PREDICT THE DIRECT EFFECTS OF COLD ON GRAZING ANIMALS

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BACKGROUND

Two management options that a grazier can exercise without committing any extra capital resources are the choices of a lambing date and a shearing date. A shift inlambing date may have profound effects on profits, both directly and also through 'interaction with other management variables. The conventional time for lambing on the tablelands of south-eastern Australia is late winter or early

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spring, primarily because lambs are assured of an abundant feed supply and their growth rate will be high throughout spring. Moreover , joining in late summer or autumn increases the likelihood of multiple ovulations in the ewe flock, so that the proportion of twins is also likely to be high. However, research at Canberra has shown that a June lambing is more profitable for prime lamb flocks than an August lambing even though fewer twins may be born. This is mainly because the period between birth and the end of spring is much longer. The lambs do not grow as fast as their August-born counterparts but they are heavier at the end of the season and a greater proportion is sold as prime. For wool-growing enterprises there may be advantages from heavier weaning weights and better survival over summer when the only grazing available is low quality dry residue s. Flock management is simplified since the larger lambs can be shorn with the ewe flock at weaning, giving added protection from fly-strike and eliminating the need for a separate crutching.

PREDICTION OF COLD STRESS

Lambing date

A grazier contemplating the possibility of a shift in lambing date from August to June needs to be able to assess the likely losses of new-born lambs from cold weather. We have developed the LAMBALIVE package (Donnelly et al. 1987) to examine the probability of their death from exposure based on known physiological responses to cold stress. These responses are formulated in an experimentally established relationship between lamb mortality and the level of chill prevailing at the proposed times of lambing (Donnelly, 1984). Negotiations have commenced to make the package available commercially. The package will be supplied with the appropriate database of daily meteorological records for the district in question. Output includes the expected distribution of losses predicted from meteorological records for the specified lambing periods. Options are provided to specify the breed and frame size of the ewes, and weight or body condition at lambing. The relative contributions of wind, rain and temperature. to the chill factor and lamb mortality can be assessed.

Shearing date

Similarly, altering the shearing date for a flock can markedly influence of f-shears losses. Heavy rain and wind can place newly shorn sheep at risk from exposure even when the temperature is relatively high. The OFFSHEARS package provides the grazier with a graphical display of the probability of dangerously chilling conditions calculated' from local meteorological records for shearing dates at any time of the year.

Effects on production

The economic impact of chilling is not only, through the death of sheep. . The growth of young lambs and calves may be markedly reduced because of the diversion of energy from growth to maintenance under cold conditions. The grazier who wants to assess the overall effects of a change in mating policy can obtain estimates of the effects of specified weather conditions on young animals using the GRAZFEED package. . The main aim of this package 'is to provide the grazier with a rapid assessment of the animal production that can be obtained from a specified pasture and the calculations include estimates of the effect of chilling on their off spring.

CONCLUSION

These three packages, LAMBALIVE, OFFSHEARS and GRAZFEED use known information on the physiology of cold stress in farm animals and match it to local farming conditions. GRAZFEED can be used to assess the short-term feed requirements of grazing animals. LAMBALIVE and OFFSHEARS provide information for making the best long-term decisions, but they are not designed to predict the outcome of a specific lambing or shearing. LAMBALIVE and GRAZFEED are based on the results of experiments and are now being tested in the field. They are user-friendly and operate on a wide range of microcomputers. OFFSHEARS is at an earlier stage of development.

EFFECTS OF HEAT ON CATTLE

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BACKGROUND

Bos taurus cattle taken from temperate climates to tropical or subtropical areas generally show impaired growth rate, reduced fertility and milk production. As well as these readily observable effects, measurements on cattle exposed to high environmental temperatures have shown changes in metabolism with increasing body temperature (O'Kelly 1973).

METABOLIC EFFECTS OF HYPERTHERMIA

The onset of disturbed metabolism due to hyperthermia occurs at similar body temperatures whether the cattle are heat adapted or not.

Heat stress affects an animal's metabolism by causing a reduction in food intake (the anorectic effect) and changes. that result from increased body temperature alone (the specific effect). Depressed appetite is linked with many physiological and endocrinological adjustments to reduce heat generated during ruminal fermentation and body metabolism and is probably not readily reversible. Reduced food consumption during heat stress may also be associated with deficiencies of essential nutrients. For instance, at high environmental temperatures large amounts of potassium are lost in sweat (Schneider et al. 1986).

A fine balance exists be'tween the daily intake of essential fatty acids from the dam's milk and the metabolic requirements of the calf in the first seven days after birth (Noble et al. 1981). During this critical period calves may suffer a deficiency of essential fatty. acids due to exposure to high environmental temperatures.

Heat-susceptible Hereford steers exposed to environmental temperatures of about 32°C increase their body temperature by more than 1°C. Metabolic derangements associated with this degree of hyperthermia include an increased urinary nitrogen loss, an increase in fat excretion in the faeces, and endocrine imbalances, such as a decrease in thyroid activity (O'Kelly 1973). At the same environmental temperature heat-tolerant Brahman steers , increase body temperature by only about 0.4°C. They show disturbances in metabolism similar to' those observed in Hereford steers, though of a smaller magnitude (O'Kelly 1986).

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REDUCING HYPERTHERMIA AND ITS EFFECTS

Using genetic differences

From studies of the responses of temperate and tropical breeds of cattle it is apparent that animals differ in their general tolerance of heat. This large genetic diversity offers ample scope for selection, within as well as between breeds of animals for effective thermoregulation.

Since basal metabolism may contribute 4O-50% of the total heat to be dissipated, a low inherent metabolic rate could be considered a desirable attribute of cattle in tropical areas. However, although Bos taurus breeds possess an inherent metabolism 12-15% higher than Bos indicus cattle, the evidence indicates that heat tolerance derives from efficient mechanisms of heat loss rather than low metabolic rates. The advantages of a low fasting metabolic rate lies in a lower maintenance requirement serving to defend the body against weight loss under conditions of feed shortage (Finch 1986).

Heat tolerance is governed by various characters such as skin structure and coat type (Finch 1986). Cattle coats form a barrier between the body and the environment and the thermal properties of coat have a major influence on the level of heat stress. Woolly coats are associated with high body temperatures while sleek coats favour thermal balance. Clipping woolly coats lowers body temperature but does not make the animal grow nearly as well as a naturally sleek animal. Coat type and colour also interact to affect tolerance to solar radiation. Heritabilities of rectal temperature (an index of heat tolerance) of 0.25 and genetic correlations with female fertility of -0.76 and with growth of -0.86 have been reported (Turner 1982). Summarizing the extensive research in heat physiology, it may be concluded that there are techniques available to the producer to be able to selectively breed cattle which have superior thermo-regulatory mechanisms. Nevertheless a significant loss of production still occurs even in genetically adjusted animals during hot summer conditions. Manipulation of the environment% is then the other option for ameliorating the effects of heat stress. However, the information available to producers. to aid in the management of livestock in such adverse conditions is limited.

Manipulation of the environment

Shade During daylight hours almost all of the heat gained from the environment comes directly or indirectly from solar radiation. The main function of shade is to reduce the heat load of animals by reducing. the incident solar radiation. This is rarely considered an economic proposition for beef cattle managed under extensive systems ‘in Australia. Nevertheless, studies with grazing beef cattle have shown that the dam’s body temperature and use of shade during lactation were significantly correlated with calf birth weight (Bennett and’ Holmes 1987). The dam’s use of’ shade was also correlated with calf growth rate to weaning. Through management the increment of metabolic heat associated with exercise can be reduced by strategic positioning of shade and watering facilities. With lactating dairy cows a shade management system has lowered body temperature, increased milk yield and improved reproductive, performance (Igono et al. 1987). Repeated cycles of wetting,, the coat and forced ventilation has proved successful in preventing increases in the body temperature of high yielding dairy cows.

Hormonal manipulation It may be possible to correct hormone imbalances due to hyperthermia. Studies with Brahman steers fed a restricted intake of lucerne hay implied that the impaired growth rates due to heat exposure are not likely to be greatly improved by the use of thyroid hormone replacement therapy nor by the use of anabolic compounds which mediate their effects predominantly through increased thyroid activity (O'Kelly 1986). There is some evidence that daily subcutaneous injections of growth hormone may offer a means of counteracting the heat induced decline in milk production in dairy cows (Mohammed and Johnson 1985).

Feeding strategies It is possible to counter the urinary nitrogen and faecal fat losses caused by the specific effect of heat exposure. Studies with steers fed diets which were isonitrogenous and isocaloric have shown that when fat constitutes an increased proportion of food supplied for maintenance, urinary nitrogen loss is reduced at thermoneutral temperature and during heat exposure (O'Kelly 1987). In addition animals on the high fat diet showed lowered body temperature coupled with a higher evaporative water loss during heat exposure. Adding fat to the diet has also increased the comfort of lactating cows exposed to heat. The newborn ruminant has an improved ability to withstand heat through a simple enhancement of its essential fatty acid status during the early neonatal period by means of dietary supplementation with linoleic acid (Noble et al. 1981). The definite changes in the composition of milk fat caused by heat exposure would undoubtedly also be countered by dietary fat supplementation. Increased production responses in hot conditions to dietary sodium and potassium intakes have been demonstrated in lactating dairy cows (Schneider et al. 1986).

Improved production should therefore be possible using diets supplemented with essential nutrients and fats to ameliorate the biochemical and physiological stresses suffered by ruminants at high environmental temperatures.

INDIRECT EFFECTS OF CLIMATE THROUGH INFLUENCES ON THE FEED RESOURCE

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Extremes of temperature, and moisture deficits or excesses have obvious effects on growth of herbage and thus feed availability for grazing animals. Although less obvious, changes in botanical composition, sward composition and nutritive quality may also 'occur and 'affect animal production.

EFFECTS OF CLIMATE ON THE' FEED RESOURCE

High temperatures

Pasture plants have optimum temperatures for growth and as temperature increases above this Level, growth rate progressively slows. Beat stressed plants show reduced levels of storage carbohydrate as a result of increased respiration (McWilliam 1978).

Temperature stress also affects the nutritive quality of pastures. Grasses grown in tropical and sub tropical regions have lower digestibility than grasses grown in temperate areas. This is partly due to an inherent difference between digestibility of tropical and temperate grasses (Wilson and Ford 1971) but also to a specific effect of temperature (Wilson 1982). Digestibility declines with increasing temperature in both tropical and temperate grasses because of both an increase in structural carbohydrates and a reduced' digestibility of these components. The difference' in digestibility between tropical and temperate legumes is less than with the grasses (Minson and Wilson 1980) and the decline in digestibility with increasing temperature is less with legumes than with grasses (Wilson'and Minson 1983). Increasing temperature hastens ageing of plant tissue

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leading to a faster decline in digestibility of senescing leaf and to a more rapid decline in plant digestibility because of a hastened maturity.

Low temperatures

Low temperatures retard growth of temperate species due to a decline in leaf appearance and expansion. Leaf appearance interval in perennial ryegrass is approximately 20 to 30 days in winter compared to 7 to 10 days in summer (Davies 1977). Senescence rate however also declines and leaf lifespan in winter is 60 to 90 days compared to 20 to 30 days in summer (Davies 1977). White clover growth slows more than the grasses because of its higher optimum temperature, and a reduced clover content may decrease animal production (Reed 1981). Tropical species are particularly sensitive to low temperatures; night temperatures of 10°C reduce growth of pangolagrass (West 197.0). Tropical species also have a low tolerance to frost (Wilson 1982); frost damage causes tropical legumes to shed leaves, and digestibility of any killed leaves remaining on plants declines rapidly.

Many grazing and indoor feeding trials have shown reduced animal production on autumn-winter temperate pastures compared with spring-summer pasture (Reed 1978) and this has been attributed to both a reduced voluntary intake and a reduced efficiency of utilisation of digested energy. Autumn-winter pastures have lower soluble carbohydrates and thus a higher structural to non structural carbohydrate ratio than spring-summer pastures and this may slow breakdown in the rumen. Winter pastures would also have lower clover contents.

Water stress

The ef fect of water deficit on pasture growth has been reviewed by Turner and Begg (1978). Water deficit reduces pasture growth by slowing leaf appearance and expansion. The first factor limiting growth is a reduction in cell size but decreased photosynthesis as a result of stomata1 closure . and reduced leaf area becomes increasingly important. Tiller production declines and there is a hastened death of tillers and older leaves. Leaf shedding occurs in tropical legumes (Fisher and Ludlow 1981) and in extreme cases the plant may die back to the crown. Temperate species may allow complete senescence of green leaf and depend for survival on dormant axillary buds. In dry conditions, white clover is less competitive than grass because of its shallow rooting. Nitrogen-fixing ability of nodules is diminished because of a reduced nutrient supply resulting from the reduced photosynthesis.

Limited degrees of water stress may, actually increase nutritive quality of pastures (Wilson 1982) because of a slower plant maturation rate, a higher digestibility and higher levels of soluble carbohydrates, nitrogen and minerals. This effect appears particularly important with tropical grasses.

In situations of water excess,, the major factor is reduced oxygen supply to plant roots and again legumes are more sensitive because. of reduced rhizobial activity. Excess water reduces root penetration through. the soil and this. may make plants more sensitive to future drought. .

METHODS OF OVERCOMING LIMITATIONS

Use of genetic resources

The sudden and severe grazing of native pastures at the beginning of European settlement in Australia resulted in a rapid change in pasture composition and stability (Tothill 1978). The familiar European species were not adapted to most areas of pastoral Australia and pasture workers had to concentrate on introducing plants from other areas of the world. Successful use of plant genetic resources in overcoming climatic limitations initially involves introduction of plants selected from similar environments. Subsequently, more emphasis is needed on adapting plants for specific environments and this involves a fuller understanding of the physiological and morphological characteristics which contribute to a plant's ability to persist and yield consistently (Wilson 1981) and which contribute to high levels of animal production. Selection of plants able to survive in a stressful environment may not always contribute to a higher growth rate in that environment. Nosberger et al. (1981) selected white clover from a range of altitudes and found that the high altitude ecotypes had higher photosynthesis rates when grown at cold temperatures but the extra reserves were partitioned to the stolons at the expense of leaf growth. Plants may be stress avoiders or stress tolerators and selection of plants able to grow in stressful environments may compromise persistence. Italian ryegrass continues to grow in dry conditions and appears drought tolerant, however this use of reserves to maintain growth compromises plant survival if the dry, conditions persists. In contrast, perennial ryegrass becomes almost dormant in dry conditions (Norris 1982).

Management aspects

Feed shortage in periods of environmental stress may be alleviated by management inputs such as irrigation, pasture conservation and feed purchase. However, in many cases the economic benefit of these is doubtful. Improved understanding of the interactions between pastures and animals often suggests alternative ways of overcoming environmental limitations.

Reduced pasture leaf growth in dry conditions causes a shortage of feed and a decline in quality of standing herbage because of, a reduced green to dead ratio. In some cases, animal production is reduced in dry conditions because the presence of the dead herbage residues reduces availability of green herbage, and in southern Australia where there is summer rainfall and growth does occur, higher levels of animal production are found in summer when the spring surplus is removed before it senesces (Birrell and Bishop' 1980; Michell and Fulkerson 1987). Removal of the spring surplus before dry conditions arrive may also increase plant density and pasture growth in dry summers (Korte 1981). In Mediterranean type environments with little summer rainfall the situation is different.. There, animals depend on the spring residues carried into the summer, and rainfall, if it does occur, is likely to reduce the quantity and quality of the standing feed (Allden 1981).

Pasture growth may be increased in dry conditions by prevention of over-grazing because once all green leaf is removed, transpiration and water absorption by the plants ceases. If green leaf can be protected by the presence of a stubble then plants will continue to grow into dry conditions (Jantti and Heinonen 1957). In the perennial pasture areas of southern Australia this involves the three aspects: (i) prevention of patch grazing by animals in the spring (where areas of the sward are consistently overgrazed or undergrazed), (ii) timing pasture-conservation so that harvested paddocks return to the grazing area while pastures are still growing, and (iii) --progressively raising the cutting height of harvesting equipment when dry conditions occur.

In southern Australia, cold winters restrict pasture growth resulting in a feed shortage in late winter and early spring. Slow winter grazing rotations of 60 to 90 days have been found useful in transferring pasture grown in autumn' and early winter into late winter (Smeaton and Rattray 1984). These grazing systems increase the total quantity of utilized pasture and this appears to result more from an increased harvesting efficiency due to the higher intensity of grazing than from an increased pasture growth (Fulkerson and Michell 1987).

CONCLUSIONS

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Due to limitations of space this review has not addressed the effects of water shortage on animals or discussed the direct effects of hot climates on sheep. There is a considerable body of work on the deleterious effect of heat exposure on all phases of the reproductive cycle in sheep. This was reviewed by Brown and Hutchison (1973), who also state that "Assessment of the severity of climatic stress on animals in difficult pastoral conditions is a most neglected field of study". This is still true.

The overall economic impact of climatic extremes on the Australian grazing industry is huge, but is difficult to quantify. At one extreme there are deaths, at the other chronic losses of production; the latter may well be the most important economically. Deaths usually occur when vulnerable animals are suddenly exposed to cold. Onset of such bad weather can be difficult to predict but the probability of it occurring at lambing or shearing can be assessed as described by Donnelly and Freer, and management decisions can be based on these probabilities.

The chronic losses of production resulting from climatic stresses may be due to inadequate feed intake (lack of available feed or lack of appetite) or to the diversion of large proportions of the feed eaten to non-productive processes for maintenance of homeothermy. Various approaches to overcoming these problems have been discussed.

All methods of alleviating climatic stress or its effects have costs attached. Much further information is needed both on the extent of the penalties and on the costs of alleviating them before the economic impact of climate on the grazing industry can be adequately assessed.

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