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Effect of maize supplementation, seasonal temperature and humidity on the liveweight gain of steers grazing irrigated *Leucaena leucocephala/Digitaria eriantha* pastures in north-west Australia

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SUMMARY

Brahman Shorthorn steers (213 ± 4·6 kg initial weight) were grazed on a pangola (*Digitaria eriantha* cv. Steudel) pasture interplanted with leucaena (*Leucaena leucocephala* cv. Cunningham) in rows 1·8–2·7 m apart in the Ord River Irrigation Area (ORIA) in north-west Western Australia. The leucaena comprised a mean of 46% of the diet but ranged from 100% of the diet on day 1 to *c.* 18% on day 7 of a 7-day grazing period, within the rotational grazing system. It was suggested that the low herbage allowance of leucaena may have restricted the intake of the steers, reducing the quantity and quality of the herbage consumed.

The steers were also supplemented with maize during the dry and wet seasons (1992 and 1992/93). The maize supplement was offered at 0, 0·5, 1·0, 1·5 and 2·0 kg/head per day, over a 168-day period. Maize supplementation at 1·5 kg maize per head per day resulted in an increase in the liveweight gain of the steers grazing leucaena/pangola pastures in the dry season from 0·73 ± 0·05 kg/day (mean ± S.E.) for no supplementation to 1·1 ± 0·05 kg/day for 1·5 kg/head per day of maize. Maize supplementation up to 2·0 kg/day did not further increase the liveweight gain. A high rate of substitution of leucaena and pangola intake for the maize supplement occurred.

There was a large seasonal difference in liveweight gain (mean 0·89 *v.* 0·63 kg/day for the dry and wet seasons respectively; $P < 0{\cdot}001$) irrespective of the level of maize supplementation. This seasonal difference in liveweight gain was not primarily a function of the herbage on offer, but was most probably a direct function of the effect of the seasonal temperature and humidity influencing the feed intake and growth rate of these Brahman crossbred cattle.

This system produced some of the higher liveweight gains recorded per hectare for a grazing system (1570–2110 kg/ha per year), as a result of the very good individual liveweight gains (250–340 kg/head per year) and high stocking rate (6·25 head/ha).

INTRODUCTION

Leucaena (*Leucaena leucocephala* cv. Cunningham), a tropical tree legume, and pangola (*Digitaria eriantha* cv. Steudel), a tropical grass, have been utilized to develop an irrigated pasture system for beef production in the Ord River Irrigation Area (ORIA) of Australia. Leucaena has a crude protein content in the leaf of 260–300 g/kg and an *in vitro* dry matter (DM) digestibility of *c.* 700 g/kg (D. Pratchett, unpublished). Pangola has a crude protein (CP) content of *c.* 125 g/kg and a mean *in vitro* digestibility of *c.* 500 g/kg (D. Pratchett, unpublished). Leucaena has a similar chemical composition to that of temperate legumes such as lucerne (*Medicago sativa*) and white clover (*Trifolium repens*), although the availability of the protein in the leucaena may be modified by its tannin content (Norton 1994). Liveweight gains > 1·0 kg/day have been achieved with cattle grazing diets containing high proportions of these temperate legumes (Beever *et al.* 1986).

An intensive flood-irrigated system has been developed using rotationally grazed hedgerows of

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leucaena (1·8–2·7 m apart) with pangola in the inter-row area in the ORIA of north-west Western Australia. This system produces a large quantity of high-quality forage, yet cattle liveweight gains in the area do not reflect this quality. Mean liveweight gains of 0·78 kg/day, averaged over a year, have been achieved at a stocking rate of 6·25 head/ha and a herbage allowance of 288 kg DM/head per week (Pratchett & Triglone 1989). This equated to an annual liveweight gain of 1780 kg/ha per year. At a stocking rate of 2 cattle per hectare and a herbage allowance of 960 kg DM/head per week, the liveweight gain per animal increased to 0·9 kg/day during the dry season, although the liveweight gain per hectare declined to a mean of 657 kg/ha per year (Pratchett & Triglone 1989). Wilden (1985) and Quirk *et al*. (1988) reported that cattle grazing leucaena/pangola pastures in central Queensland have achieved liveweight gains as high as 1·11 and 1·03 kg/day, respectively, over shorter periods of 97 and 126 days.

Monthly liveweight gains from the leucaena/pangola pastures in the ORIA are lower (< 0·5 kg/head per day) during the cooler winter months (July–September) and the mid-late summer period (January and February) and higher (0·7–0·8 kg/head per day) during the early summer period (October–December; D. Pratchett, unpublished). The period of lower liveweight gain during the winter months coincides with a period of lower herbage availability, possibly due to the cooler seasonal conditions. The period of lower liveweight gain during the mid-late summer coincides with a period of high temperature (36–47 °C max.) and high humidity (75–95 %) which may be imposing a limitation on heat dissipation. It is possible, therefore, that seasonal conditions and herbage availability may be influencing the liveweight gain of the cattle in the ORIA.

Whilst the annual production per unit area is high, the individual cattle performance does not reflect the high quality of the leucaena in the system. This may be due to limitations in feed intake brought about by harvesting constraints imposed by a shrub or by limits to heat dissipation imposed by the high temperatures and humidities experienced in the ORIA. These aspects are examined by determining changes in herbage mass, responses of cattle to supplements of cracked maize grain and the response of cattle to seasonal effects.

MATERIALS AND METHODS

Location

The experiment was conducted at the Frank Wise Institute of Tropical Agricultural Research in the ORIA in the East Kimberley area of Western Australia (15° 39′ S 128° 43′ E). The mean rainfall at this site is 778 mm with 82 % of the rainfall falling between December and March. The mean maximum temperature in the hottest months of October and November is 39 °C and the mean minimum temperature in the coldest months of June and July is 14 °C. The relative humidity (measured at 09.00 h) is highest in February (70 %) and lowest in July (32 %). The soil of the experimental site is Cununurra Clay (Ug 5·29) with a mean pH of 7·0–7·9.

Pastures and paddock layout

The pastures were established in 1983 and consisted of paddocks of leucaena in continuous 50–100 m rows with both 1·8 and 2·7 m spacings between the rows and pangola grass planted in the inter-row area. Each paddock was 0·4 ha, with four paddocks constituting a treatment replicate (1·6 ha). In the 2 years prior to the experiment the paddocks were rotationally grazed in a 4-week rotation and stocked at 7·5 steers per hectare. In the 4 months prior to the beginning of this experiment, all the leucaena in the paddocks was slashed to 1 m in height and fertilized with 150 kg/ha of double zincated superphosphate.

During the experiment, the paddocks were rotationally grazed on a 4-week rotation, with each paddock being grazed for 1 week and rested for 3 weeks. The stocking rate was maintained at 6·25 steers per hectare. Each paddock was flood-irrigated once every fortnight with 1 000 000 litres water per ha.

Treatments

There were five treatments in this experiment, a control treatment and four rates of maize supplementation, 0·5, 1·0, 1·5 and 2·0 kg maize per steer per day. Each treatment was replicated three times and each replicate consisted of ten steers. A treatment consisted of a standard 4-paddock rotation. Both treatments and replicates were randomly allocated to paddocks. The experiment commenced on 12 August 1992 and finished on 27 January 1993. There was a dry season (August–October, 70 days) and a wet season (October–January, 98 days) component of the experiment.

Cracked maize was provided daily every morning in feed troughs adjacent to the water troughs in the laneway with 1 m of trough space per steer. All animals were offered 50 g/head per day of a vitamin mineral premix (Pfizer®) plus iodized salt (1 : 1).

Cattle management

In June 150 weaner steers (with a genotype of 3/4 Brahman 1/4 Shorthorn) weighing 213 ± 4·6 kg, were placed in a large paddock of leucaena/pangola pastures and were mixed with steers previously adapted to leucaena. The steers were grazed together for 1 month to allow the transfer of rumen bacteria (*Synergisi jonesii*) into the rumen of the introduced steers. These bacteria are capable of degrading the toxic by-product of mimosine, 3-hydroxy-4(1H)-pyridone (DHP) (Jones & Lowry 1984). The steers then grazed the treatment paddocks until the start of the experiment on 12 August, when they were weighed and allocated to the treatments and replicates using a stratified random allocation. At this stage, half the steers in each replicate were dosed with a slow-release rumen modifier. Within 3 weeks, some steers showed toxicity problems related to the release rate of the rumen modifier and all animals with the modifier were removed and replaced with other steers. They were not used in the statistical analysis. On 21 October, the end of the dry season period, 75 of the heavier steers were replaced with lighter steers to ensure that the mean steer weights in the wet and dry seasons were similar. These replacement steers had been grazing an adjacent paddock and had been adapted to leucaena in a similar fashion to that described above. At the time of allocation of steers to treatments, during both periods, their urine was checked for the presence of mimosine and DHP by the method of Allison *et al*. (1990). No mimosine or DHP was detected and hence it was assumed that all cattle had *S. jonesii* and could graze large amounts of leucaena safely.

When the steers were introduced to the experiment they were dosed with pour-on Bayticol (Bayer®) for external parasites and Systimex (Wellcome®) for internal parasites on arrival at the research station. A follow-up Bayticol and Systimex treatment was administered to the steers in January.

Measurements

The steers were weighed every 2 weeks unfasted, prior to their movement to a new paddock in the rotation. Once a month all the steers were mustered, faeces collected from the rectum and rumen fluid collected by stomach tubing. These samples were taken from five randomly chosen animals from each replicate. Samples of the faeces were also chilled and analysed for gastrointestinal parasites. The rumen samples were acidified with sulphuric acid, frozen and later analysed for rumen volatile fatty acids (VFAs).

Estimates of DM of leucaena and pangola herbage mass were made fortnightly before the steers were moved into two of the paddocks in the four paddock rotation and DM was also recorded when they were removed from the paddock. This allowed herbage data to be collected from two of the four paddocks in the rotation. These samples were collected to determine the herbage mass on offer as well as the residual herbage mass. The assessments were made using a visual estimate technique based on photographs and physical harvesting of quadrats of pangola and rows of leucaena to correlate with the visual assessments (a modification of the Botanal technique; Jones & Tothill (1985)). Fifty 1 m lengths of leucaena row and 50 areas of pasture (each 1 m^2) were visually assessed in each paddock by a trained assessor during each measurement period. These assessment values were averaged for each paddock. Fifteen 1 m lengths of leucaena of varying herbage mass and 15 areas of pangola (each 1 m^2) were plucked and cut respectively to develop correlations with the visual assessments each time the herbage mass was assessed. The aim of these assessments was to determine the herbage mass changes during the period of the experiment. The herbage mass of leucaena is green leaf and stem < 5 mm in diameter, whereas the herbage mass of pangola is total herbage mass.

Assessments of the growth of leucaena and pangola over a 1-week grazing period were also made at 20 randomly chosen sites in two of the three replicates in each treatment, once in the middle of the dry season and once in the middle of the wet season, by using pasture cages. These assessments of pasture growth provided an estimate of the pasture growth of the leucaena and pangola over the 7-day grazing period while the animals were in a particular paddock. The growth was determined by plucking 20 of the 1 m long rows of leucaena and by cutting 20 of the 1 m^2 areas of pangola immediately prior to the grazing period and plucking or cutting an adjacent exclosed area following the grazing period. The herbage growth was calculated as the herbage mass from the exclosed site minus the herbage mass prior to grazing (7 days earlier). There were no significant differences between the paddocks, treatments and the times, and therefore a mean figure of pasture growth was used in the herbage assessments.

Estimates of the daily intake of leucaena and pangola over a 7-day grazing cycle were also made in one randomly chosen replicate of each of the 0, 1·0 and 2·0 kg maize/head per day treatment paddocks in August and October during the dry season and also during November and January in the wet season. This was achieved by assessing the herbage mass of leucaena and pangola on a daily basis over the 7-day grazing period.

Pluck samples of leucaena and pangola were also collected monthly from one paddock of every replicate and treatment during the experiment (i.e. 15 samples of each species per month). These samples were bulked by paddock and season, dried and analysed for protein and neutral detergent fibre (NDF) contents and *in vitro* digestibility (Minson 1981).

Climatic data were gathered daily (at 09.00 h) at a weather station adjacent to the experimental area. Daily temperature and humidity were also estimated at 09.00 h in the centre of the leucaena paddocks. The temperature humidity index (THI) developed by Kibler (1964) was calculated from the temperature, wet bulb temperature and dew point data.

Statistical analysis

The animal and herbage data were analysed using an analysis of variance procedure with the GENSTAT 5 (Genstat 1993) package to compare the effects of the treatments and seasons. The steer weight data were analysed by fitting regressions to the individual steer weight data in the wet and the dry seasons and analysing the slope of the regression (150 animals), as the liveweight gain/head per day, in the analysis of variance. The dry season component was 70 days or 10 paddock rotations and the wet season was 98 days or 14 paddock rotations. The herbage data were analysed by replicate, treatment and season (30 values). The environmental data were analysed by season.

A correlation matrix and step-wise multiple regression were also developed to relate environmental, herbage and animal factors. The correlation matrix and step-wise multiple regression were based on animal and pasture data presented on a fortnightly, replicate and treatment basis (180 values) and the environmental data on a fortnightly basis (12 values). From this step-wise multiple regression, a formula was identified relating liveweight gain to the herbage and environmental factors in the wet and dry seasons.

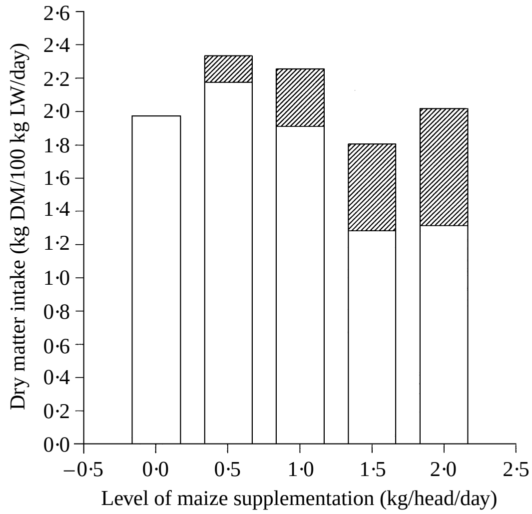

Fig. 1. Total herbage consumed (□, S.D. $\pm 0\cdot19$ kg DM/100 kg LW/day, D.F. = 29) as estimated by visual assessment and the maize consumed (▨) in the paddocks by the steers in each treatment.

RESULTS

Animal responses

There was a significant ($P < 0\cdot001$) seasonal difference in the mean liveweight gain with a mean dry season liveweight gain of $0\cdot89 \pm 0\cdot030$ kg/day (mean ± S.E.) and mean wet season liveweight gain of $0\cdot63 \pm 0\cdot030$ kg/day. There was also an interaction between the season and level of maize supplementation ($P < 0\cdot01$, Table 1). The annual liveweight gain in kg/head and kg/ha were calculated from the seasonal liveweight gain data as described in Table 1. The highest liveweight gain of $1\cdot10 \pm 0\cdot047$ kg/day ($P = 0\cdot004$) was achieved by the steers supplemented with 1·5 kg/day of maize in the dry season and can be compared with the control steers ($0\cdot73 \pm 0\cdot030$ kg/day, Table 1). Maize supplementation resulted in no significant effect on the liveweight gain of steers during the wet season. These results were constant irrespective of whether all the animals were used in the analysis or only the animals that were present throughout the whole experiment (five per replicate).

Rumen VFA concentrations were modified by the rate of maize supplementation, with maize-supplemented steers having higher ($P < 0\cdot05$) concentrations of acetic, propionic and butyric acid than the control steers (42·9, 9·7 and 5·8 mM/l *v.* 27·8, 6·83 and 3·86 mM/l respectively). There was no seasonal difference in VFA content. The molar proportion of each of the treatments was relatively

Table 1. *Mean dry and wet season liveweight gains and annual liveweight gain for the steers supplemented with five levels of maize supplementation on leucaena/pangola pastures in the ORIA, Australia*

	Level of maize supplementation (kg/head per day)					S.E. (D.F. = 149)
	0·0	0·5	1·0	1·5	2·0	
Dry season liveweight gain (kg/day)	0·73	0·78	0·99	1·10	0·85	0·044
Wet season liveweight gain (kg/day)	0·60	0·61	0·61	0·61	0·69	0·015
Annual liveweight gain (kg)	252	262	308	338	295	25·2
Annual liveweight gain per hectare (kg LWG/ha)	1575	1637	1925	2112	1844	160·0

Table 2. *Herbage mass, residual herbage mass, herbage allowance, intake and utilization/selection data for five levels of maize supplementation of steers grazing leucaena/pangola pastures as estimated by visual assessments* (D.F. *dry* = *11*, D.F. *wet* = *23*)

Herbage factor	Season	Level of supplementation (kg maize/day) 0	0·50	1·0	1·5	2·0	S.E.
Herbage mass data							
Herbage mass of leucaena (t/ha)	Dry	0·76	0·62	0·81	0·90	0·62	0·08
	Wet	0·60	0·54	0·86	0·90	0·71	0·06
Herbage mass pangola (t/ha)	Dry	2·29	3·36	1·62	1·34	2·09	0·45
	Wet	2·83	3·53	1·92	1·54	2·82	0·26
Total herbage mass (t/ha)	Dry	3·05	3·99	2·43	2·24	2·70	0·44
	Wet	3·43	4·07	2·79	2·45	3·53	0·25
Residual herbage mass							
Residual herbage mass leucaena (t/ha)	Dry	0·38	0·27	0·48	0·55	0·40	0·07
	Wet	0·27	0·26	0·41	0·48	0·43	0·06
Residual herbage mass pangola (t/ha)	Dry	1·79	2·74	1·12	1·20	1·74	0·45
	Wet	2·30	2·88	1·46	1·28	2·49	0·26
Total residual herbage mass (t/ha)	Dry	2·17	3·00	2·05	1·76	2·14	0·44
	Wet	2·57	3·13	1·86	1·76	2·92	0·25
Herbage allowance							
Herbage allowance leucaena	Dry	1·89	1·53	1·95	2·17	1·54	0·14
(kg DM/100 kg W/day)	Wet	1·23	1·11	1·71	1·82	1·43	0·12
Herbage allowance pangola	Dry	5·68	8·29	3·91	3·23	5·18	0·97
(kg DM/100 kg W/day)	Wet	5·81	7·27	3·81	3·12	5·68	0·65
Total herbage allowance	Dry	7·57	9·85	5·86	5·40	6·69	0·79
(kg DM/100 kg W/day)	Wet	7·05	8·38	5·53	4·97	7·11	0·51
Intake data							
Leucaena intake (kg DM/100 kg W/day)	Dry	1·03	0·94	0·85	0·89	0·59	0·07
	Wet	0·73	0·65	0·94	0·90	0·63	0·06
Pangola intake (kg DM/100 kg W/day)	Dry	1·27	1·61	1·26	0·39	0·89	0·21
	Wet	1·14	1·39	0·98	0·60	0·71	0·14
Total herbage intake (kg DM/100 kg W/day)	Dry	2·28	2·52	2·10	1·26	1·49	0·24
	Wet	1·87	2·03	1·92	1·50	1·33	0·13
Utilization/selection data							
Percentage of the leucaena on offer	Dry	54	61	44	41	38	4·2
consumed	Wet	59	58	55	49	44	2·6
Percentage of the pangola on offer	Dry	22	19	32	11	17	3·4
consumed	Wet	20	19	25	18	13	1·9
Percentage leucaena in the herbage	Dry	45	37	40	71	40	10·2
consumed	Wet	39	32	49	60	47	5·4
Percentage grain in the total dry matter	Dry	0	6	15	31	34	7·1
consumed	Wet	0	8	14	24	32	6·0

constant with acetic acid, propionic acid, butyric acid and the remaining VFAs comprising 0·69, 0·16, 0·09 and 0·06 molar proportion, respectively.

Fortnightly assessments of worm burden during the experiment indicated very low worm counts. The mean dry season parasite burden was $16{\cdot}8 \pm 6{\cdot}54$ eggs per gram and wet season burden was $34{\cdot}2 \pm 9{\cdot}56$ eggs per gram. There were no significant differences in the mean faecal egg counts between treatments, paddocks or times during the experiment. The mean monthly faecal egg count in the experiment was 27 eggs per gram of faeces and the maximum monthly count recorded was 45 eggs per gram of faeces recorded in January. The dominant worm species were *Cooperia* spp., *Oesophagostomum* spp. and *Haemonchus contortus*, constituting 81, 7 and 4% of the worms detected.

Herbage mass

There was no seasonal difference in the estimated herbage mass of leucaena, estimated herbage consumption of leucaena and pangola, or the proportion of leucaena in the total herbage mass and percentage leucaena in the herbage consumed. There was,

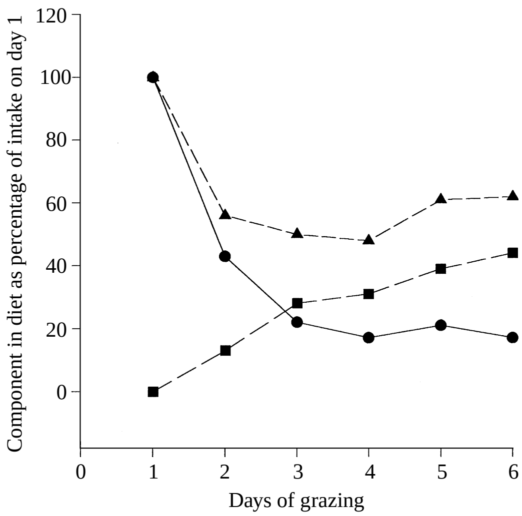

Fig. 2. Mean proportional intake of total herbage (▲, S.E. = 8·5, D.F. = 11), leucaena (●, S.E. = 8·0, D.F. = 11) and pangola (■, S.E. = 2·3, D.F. = 11) during a 7-day grazing period expressed as a percentage of intake on day 1 during a 7-day grazing period. Values are the mean of two replicates for three treatments in the wet and dry seasons.

however, an increase ($P < 0{\cdot}05$) in the herbage mass of pangola in the wet season, resulting in an increase in total herbage mass ($P < 0{\cdot}05$) over the wet season.

Although a seasonal difference was detected in the herbage mass of pangola and total herbage mass, these differences were constant between the treatments during the experiment. Therefore the data presented in Fig. 1 are the mean data over the whole experimental period with each figure representing the mean of three paddock replicates × 12 assessment periods. These data therefore allow the comparison of herbage mass and herbage consumption of the steers in each of the maize supplementation treatments. The steers consuming 1·0 and 1·5 kg/day of maize in the dry season were by chance offered the lowest amounts of total herbage mass (Table 2) and these steers also consumed the least herbage mass, compared to the steers supplemented with 0 and 0·5 kg/day (Table 2). Although these steers had the lowest total herbage mass and herbage mass consumed they did have the highest percentage of total herbage mass as leucaena, as well as the highest percentage of herbage mass consumed as leucaena (Table 2). The main factor affecting the total herbage mass of the paddocks was the amount of pangola present (Table 2).

The total DM consumption of the steers in each maize treatment was relatively constant, 2·30 ± 0·18 kg DM/100 kg LW/day (Fig. 1). The herbage mass consumed for the control treatment was 2·02 kg DM/100 kg LW/day. The herbage consumption of the steers offered 0·5 kg/day maize increased by 10 ± 0·93% above the control and then the intake declined relative to the control by 3 ± 0·3, 35 ± 3·3 and 34 ± 3·2% for the 1·0, 1·5 and 2·0 kg/day of maize supplement (Fig. 1). This trend in herbage intake does not appear to be a function of the total herbage mass or the herbage allowance (Table 2). The mean levels of supplement inclusion on a per liveweight basis during the experiment were 0·00, 0·19, 0·37, 0·57 and 0·76 kg/100 kg LW/day and no seasonal differences were recorded.

Steers preferentially grazed the leucaena, consuming a higher percentage ($P < 0{\cdot}05$) of the herbage mass of leucaena on offer than the herbage mass of pangola on offer (48 ± 0·1% compared with 18·6 ± 0·1%) (Table 2). Although steers consumed more of the leucaena on offer, the mean intake of leucaena and pangola over a 7-day grazing period was of a similar order of magnitude, 0·82 ± 0·14 *v.* 1·02 ± 0·35 kg DM/100 kg LW/day respectively. The percentage of the herbage mass of leucaena consumed declined linearly ($P < 0{\cdot}05$), from 55 to 40%, as maize supplementation increased from 0 to 2·0 kg/day (Table 2). There was a similar, although non-significant, trend with the percentage of the herbage mass of pangola consumed (Table 2).

The fortnightly pluck samples from each replicate and treatment were bulked and analysed. The leucaena and pangola had DM contents of 37 and 44%, organic matter 90·8 and 90·6%, NDF 20·6 and 66·7%, nitrogen 4·8 and 1·5% and *in vitro* DM digestibility 61·7 and 51·6%. There were no significant seasonal differences in the data.

Changes in herbage mass consumption over a 7-day grazing period

Measurements of herbage mass consumption over a grazing period were made in one replicate of each of the 0, 1·0 and 2·0 kg maize/head per day treatments in the dry season in September and October. These same paddocks were assessed in the wet season, with three being assessed in November and three in January. There were no significant seasonal differences, between the level or the rate of leucaena or pangola consumption. There were also no significant differences between the three treatments in either season. Given the lack of significant differences between the six paddocks and/or seasons, the data were combined and used to provide an indication of the rate of leucaena and pangola consumption over the grazing period (Fig. 2). Although the method of determination of these herbage consumption trends is not precise, the data should be sufficiently robust to provide an indication of the trend in herbage consumption.

Over the 7-day period there was a decline in the daily consumption of leucaena and an increase in the daily consumption of pangola (Fig. 2). The total

Table 3. *Wet season and dry season means and statistical differences for range of environmental indices measured at the Frank Wise Institute weather station, Australia* (D.F. = 175)

Weather index	Dry season	Wet season	S.E.
Maximum temperature (°C)	34·6	38·8	0·89
Minimum temperature (°C)	17·7	24·6	1·61
Humidity (%)	24·3	54·1	8·05
Rain (mm/d)	0·07	2·5	1·68
Evaporation (mm/d)	8·35	8·98	0·70
Wind (km/d)	14·40	14·80	0·82
Radiation (W/m^2/day)	18·40	18·78	1·14
Dew point (°C)	11·0	21·2	2·92
Wet bulb (°C)	18·7	25·0	1·48
Dry bulb (°C)	28·7	32·2	1·02
Temperature humidity index (THI)	73·9	81·0	1·60

herbage intake was relatively constant from day 2 to day 6, although on the first day of grazing it was 44·6% higher than the mean over days 2–6. The mean herbage consumption over the 7-day grazing period was $2{\cdot}9 \pm 0{\cdot}64$ kg DM/100 kg LW/day.

Weather data

The weather variables in the wet and dry seasons in this experiment were significantly different, with the wet season being hotter and more humid than the dry (Table 3). The Temperature Humidity Index (THI) for the two seasons was also significantly different ($P < 0{\cdot}001$, Table 3).

The mean liveweight gain of the steers in the dry season was positively correlated with leucaena on offer ($r = 0{\cdot}53 \pm 0{\cdot}21$, $P < 0{\cdot}01$), leucaena consumed ($r = 0{\cdot}51 \pm 0{\cdot}16$, $P < 0{\cdot}01$) and pangola on offer ($r = 0{\cdot}47 \pm 0{\cdot}24$, $P < 0{\cdot}05$) and negatively correlated with maximum temperature ($r = 0{\cdot}57 \pm 0{\cdot}12$, $P < 0{\cdot}001$), minimum temperature ($r = 0{\cdot}53 \pm 0{\cdot}21$, $P < 0{\cdot}01$), humidity ($r = 0{\cdot}62 \pm 0{\cdot}14$, $P < 0{\cdot}001$) and temperature humidity index ($r = 0{\cdot}57 \pm 0{\cdot}20$, $P < 0{\cdot}01$). The liveweight gain in the wet season was not correlated with any herbage factors but was negatively correlated with minimum temperature ($r = 0{\cdot}59 \pm 0{\cdot}22$, $P < 0{\cdot}01$), dew point ($r = 0{\cdot}53 \pm 0{\cdot}23$, $P < 0{\cdot}05$), wind speed ($r = 0{\cdot}54 \pm 0{\cdot}25$, $P < 0{\cdot}05$) and humidity ($r = 0{\cdot}61 \pm 0{\cdot}25$, $P < 0{\cdot}05$). Although the correlations were statistically significant, the correlation coefficients are still low.

A better indication of the impact of the environment on the liveweight gain was developed by using a range of environmental and herbage indices together. This was achieved by using a step-wise multiple regression analysis of the liveweight gain with the environmental and herbage data in the wet and dry seasons. From this analysis, a formula was developed for the dry and wet seasons. Additional factors were correlated with liveweight gain although they were not included in the formula as they accounted for < 1% of the remaining variation in the liveweight gain data. The optimal dry season formula was:

$$\text{LWG} = 1{\cdot}617 - 0{\cdot}017 * \text{Humidity} - 0{\cdot}0812 * \text{Pangola on offer} + 0{\cdot}646 * \text{Rainfall}$$
$$(r = 0{\cdot}69 \pm 0{\cdot}32,\ P < 0{\cdot}001)$$

with humidity as a percentage, pangola on offer in t/ha, rainfall in mm/day.

The optimal wet season formula was:

$$\text{LWG} = 4{\cdot}225 - 0{\cdot}2693 * \text{Minimum temperature} + 0{\cdot}1819 * \text{Dew point} - 0{\cdot}0182 * \text{Humidity} + 0{\cdot}0376 * \text{Pangola on offer}$$
$$(r = 0{\cdot}64 \pm 0{\cdot}28,\ P < 0{\cdot}001)$$

with temperature and dew point in °C.

Measurement of the mean humidity and temperature over 2 months, in both the wet and dry season, inside the leucaena paddocks and at the weather station at 09.00 h, were 33·9 *c*. 34·2 °C and 41·8 *v*. 46·3% respectively. The humidity inside the leucaena paddocks was 10% higher ($P < 0{\cdot}05$) than the humidity outside.

DISCUSSION

The liveweight gain response of the steers in this experiment was a function of the rate of maize supplementation, the season and the herbage mass on offer.

The effect of maize supplementation on liveweight gain

Maize supplementation of steers grazing leucaena substantially increased liveweight gain in the dry season, but had no effect on the liveweight gain of the steers in the wet season (Table 1). The effect of seasons is discussed below. Increasing the maize supplement from 0 to 1·5 kg maize/day in the dry season resulted in an increase in the liveweight gain of the steers from 0·73 to 1·10 kg/day. This response to maize supplementation resulted in an estimated annual liveweight gain of the control steers and steers consuming 1·5 kg maize/day of 252 and 338 kg per year (Table 1), which is a 34% increase in annual liveweight gain. The estimated annual liveweight gain per hectare for these two treatments was 1575 and 2112 kg/ha.

Table 4. *Calculation of the ME intake and ME requirements of steers supplemented with maize while grazing leucaena/pangola pastures in the ORIA, Australia (M/D of leucaena and pangola calculated from M/D = 0·156* DMD % −0·535, Ruminants (1990) and DMD % from an* in vitro *analysis*)

		Level of maize supplementation (kg maize/head/day)				
		0	0·5	1·0	1·5	2·0
Mean liveweight	(kg)	258	259	267	264	262
Total dry matter consumed	(kg DM/100 kg LW/d)	1·9	2·3	2·0	1·9	2·1
ME intake (MJ ME/head/day)	Maize (14·1 MJ ME/kg DM, NRC 1984)	0	6·4	12·9	19·3	25·8
	Leucaena (9·1 MJ ME/kg DM)	19·4	17·5	20·5	20·3	13·3
	Pangola (7·5 MJ ME/kg DM)	22·3	28·1	21·4	8·8	14·7
Total ME intake	(MJ/hd/day)	41·7	52	54·8	48·4	53·8
Mean dry season LWG	(kg/hd/day)	0·74	0·78	0·98	1·10	0·88
Calculation of ME requirements based on LWG data (MJ ME/hd/day)	NRC (1981) NRC (1984)	44	46	50	54	47
Ratio intake/requirement		0·95	1·13	1·10	0·90	1·14

Treatment differences in herbage mass may have also influenced the maize supplementation response. Differences in the mean herbage mass over the year were recorded between treatments (Table 2) although the treatments with 1·0 and 1·5 kg maize/day had the highest liveweight gain yet the lowest total herbage mass in the paddocks (Table 2). This suggests that variation in mean total herbage mass over the year observed in this experiment between treatment paddocks was not an important factor influencing the liveweight gain response of the treatments.

The liveweight gain response curve to maize supplementation is not linear, which suggests that some substitution of the herbage for the maize supplement may be occurring. If substitution occurred, the intake of herbage mass would be expected to decline as maize supplementation increased. The results indicate that, as maize supplementation increased, the herbage mass consumed (leucaena and pangola) did decline (Fig. 1) and the percentage of the herbage mass consumed also declined (Table 2). The total DM consumed, including the DM contribution of the maize, was relatively constant over the five supplementation rates (Fig. 1). These results suggest that the steers consuming the higher level of maize supplementation demonstrated some degree of substitution of herbage mass for the maize supplement. The method of intake assessment used here is not precise but should be able to detect the order of magnitude of treatment effects.

The degree of substitution of the herbage mass with the maize supplement appeared to be very high (Fig. 1) but, as indicated above, caution is required as the intake data were derived from visual assessments of only two of the four paddocks in the rotation and therefore the data could possibly have inherent errors. Substitution coefficients for energy supplements, with grazed forage, can vary from 0·25 to 1·67 with a mean of 0·69 (Minson 1981). The degree of substitution in this experiment was close to 1·0 for the 1·5 kg maize/day and 2·0 kg maize/day treatments and lower for the other maize treatments. The high levels of substitution may be a function of the daily timing of the provision of the supplement which was offered in the morning in this experiment. Adams (1985) suggested that substitution was greater when the supplement was fed in the morning than in the afternoon.

The liveweight gain response to maize supplementation would be expected to be a function of an increase in the total metabolizable energy (ME) intake as the total DM intake did not increase with increasing maize supplementation. Calculations of the ME intake (Table 4) for each of the rates of maize supplementation (NRC 1984) suggest that the ME intake did not increase in the steers consuming the higher rates of maize supplement. The lack of a trend in ME intake with increasing maize supplementation may be due to the inaccuracy in the herbage intake data or indicate that factors other than the ME intake were influencing the liveweight gain of the steers. It is also possible that the ME contributed from the maize may be used more efficiently than the ME from the herbage. Janes *et al.* (1985) reported an increase in liveweight gain with an energy supplement as a result of bypass glucose from the maize passing into the small intestine. Maize supplementation would also be expected to increase the protein supply because of the microbial crude protein produced in the rumen in response to the extra energy. The variability in the data was too great to confirm this hypothesis. No firm conclusions can be drawn except the maize supplementation of steers up to 2·0 kg maize/day while grazing leucaena/pangola pastures during the dry season increases liveweight gain and the greatest response occurred at 1·5 kg maize/day.

Another factor that may influence the higher annual liveweight gain of the 1·0 and 1·5 kg maize/day treatments in particular was the percentage of leucaena in the diet. This was 53% of the herbage consumed versus 39% for the other three treatments or 35 *v*. 18% in the total DM. Leucaena has a bypass protein content of 30% (Bamualim *et al*. 1980). Therefore the treatments with a higher leucaena content in the diet may have resulted in a higher protein:energy ratio of the absorbed nutrients, which would be expected to improve the efficiency of liveweight gain (MacRae & Lobley 1986).

Supplementing steers with 2·0 kg maize/day resulted in a lower annual liveweight gain response than in the steers receiving 1·5 kg maize/day. It is possible that the lower proportion of leucaena in the diet and lower herbage mass may have affected the liveweight gains, although no firm conclusions can be made from the data.

There were no treatment differences in rumen VFAs or parasite burdens. The VFA values and molar proportions in this experiment were similar to those for other tropical grass legume pastures (Poppi & Norton 1995). The parasite burdens of the steers in this experiment were very low and would not be expected to affect animal production.

Seasonal differences in liveweight gain

Past experiments from the ORIA suggested that liveweight gain was a function of the amount of herbage on offer during the year, and the herbage on offer was affected by seasonal differences in temperature, as described by Pratchett & Triglone (1989). The only seasonal difference in the herbage data was an increase in the total herbage mass ($P < 0{\cdot}05$) in the wet season as a result of an increase in the herbage mass of pangola ($P < 0{\cdot}05$). The herbage mass on offer increased over the wet season period and the liveweight gains decreased over the wet season, so a limitation in herbage factors such as harvesting or nutritional factors (physical, chemical) would not be likely to cause a low wet season liveweight gain. There was no seasonal difference in the proportion of leucaena in the diet so this is also unlikely to be a factor. The amount of heat which can be dissipated might be a limitation to intake and liveweight gain. Other factors such as parasites and weight class were relatively constant between the seasons and were not likely to have contributed to seasonal differences.

The results suggest that the environment may be an important factor affecting the liveweight gain of the steers in both the wet and the dry season (Bianca 1965). The fact that steers in the wet season did not show a liveweight gain response to maize supplementation also supports this. Temperature, humidity and THI all showed increases during the wet season (Table 3) and significant correlations between liveweight gain and environmental variables were found. These all suggest that, although animals were not showing overt signs of heat stress, they were adjusting intake in the wet season to enable them to dissipate heat easily. Other less quantifiable environmental factors may also have affected the liveweight gain of the steers. Following periods of rainfall, the paddocks and the entrances of the paddocks became very muddy (up to 1 m deep in the gateways). Regular observations indicated that the steers were less inclined to venture into the muddy paddocks to graze and, as a result, spent more time resting in the laneways compared to their behaviour in paddocks that were not as muddy during the wet season. Blackshaw (1992) also quoted reductions in grazing time as a result of muddy conditions in a grazing system. Thus muddy conditions may have contributed to the difference between seasons.

Herbage restrictions to feed intake

The influence of supplementation and environmental factors on liveweight gain have been discussed above. Herbage mass and herbage allowance may also be influencing the liveweight gain. Combellas & Hodgson (1979) suggested that a herbage allowance of twice the daily herbage intake is required for legumes to ensure that the herbage mass is not limiting intake. A value of 4–6 times is required for grasses. On entering the paddock, the control steers were offered approximately twice the leucaena they consumed and over five times the pangola they consumed. This would suggest that herbage mass and allowance did not restrict feed intake.

Although the herbage mass of the pasture appeared to be adequate, it is possible that the herbage mass of pasture per animal, or herbage allowance over the grazing period of 7 days on each paddock, may have limited the liveweight gain of the animals, given the high stocking rates used (6·25 head/ha). The feed intake requirements of the steers in each treatment and season were calculated using ARC (1980) recommendations, the mean seasonal weight of all the steers over the experiment and the mean seasonal liveweight gain of the steers over the experiment period. The calculated mean daily DM requirements were 2·02 kg DM/100 kg LW/day in the dry season and 1·91 kg DM/100 kg LW/day in the wet season, for steers averaging 228 and 277 kg, with a liveweight gain of 0·89 and 0·63 kg/day. The mean herbage allowance during the dry and wet season was 7·07 and 6·61 kg/100 kg LW/day, which was approximately three times the daily DM requirement as defined by the ARC (1980). This suggests that the mean herbage allowance may not have restricted the liveweight gain. However, over the course of the 7 days, the herbage allowance changed from 6·84 kg DM/100 kg LW/day to a residual herbage mass of 5·12 kg DM/100 kg LW/day and the leucaena changed from an allowance of 1·69 kg DM/100 kg LW/day to a residual herbage mass of 0·86 kg DM/100 kg LW/day. Over this period, the consumption of leucaena declined from 100 to 22% of the total herbage consumed (Fig. 2). It is therefore possible that on days 6 and 7 of the 7-day grazing period the herbage allowance, particularly of leucaena, may have restricted herbage consumption, even though the mean herbage allowance did not appear to be restricting feed intake.

It appears that the steers preferentially selected leucaena when they first entered the paddock and that over the 7-day grazing period the leucaena became progressively more difficult to graze. Hendricksen & Minson (1980) noted a similar decline in intake as defoliation of lablab (*Lablab purpureus*) progressed under a rotational grazing system. Chacon & Stobbs (1976) also noted high levels of selectivity in the early stages of defoliation with a *Setaria anceps* cv. Kazungula pasture. A reduction in the quantity of leucaena herbage harvested by the steers was associated with an increase in consumption of pangola, most probably in an attempt to maintain feed intake. Yet despite this attempt to compensate, intake still declined from day 1 to day 7 of the grazing period, suggesting that it was more difficult to harvest leucaena as the leucaena leaf disappeared. The progressive increase in the difficulty in harvesting the green leaf or leucaena was also noted when physically plucking rows of leucaena for the herbage assessments. As the leucaena leaf mass declined in the plucking site, the difficulty of harvesting the remaining leaf progressively increased.

The progressive increase in difficulty with harvesting the leucaena leaf may also be a function of the bulk density of the leucaena stand. The mean bulk density of the leucaena was $0·119 \pm 0·007$ kg/m^3 and pangola $1·180 \pm 0·072$ kg/m^3. These figures were calculated for leucaena from the mean measurements of the row height, width and length and herbage mass of leucaena in each paddock and for pangola from the mean height, by surface area and herbage mass of each paddock of pangola. The bulk density of leucaena is low compared with other tropical pastures (0·14–2·0 kg/m^3) and temperature pastures (1·6–4·1 kg/m^3) (Stobbs 1975). Chacon & Stobbs (1976) found that the grazing time, eating bites and bite size declined in the later stages of defoliation, reducing the intake of herbage on rotationally grazed *Setaria anceps* cv. Kazungula pastures. It is possible that these factors may have caused the decline in herbage consumed and the change in selection on the leucaena/pangola pastures. If the herbage allowance of leucaena had been increased (via a reduction in stocking rate), the consumption of leucaena may not have declined over the grazing period to the extent observed in this experiment. This would possibly have increased the quantity and quality of herbage consumed in a 7-day grazing period, possibly resulting in an increase in liveweight gain. The reason the stocking rate was not reduced on an annual basis to increase the herbage allowance is that with a low grazing pressure the leucaena shrubs grow taller and out of reach of the cattle. If the impact of increasing herbage allowance on liveweight gain is to be evaluated, a grazing system, such as a leader-follower system or a grazing/pruning system, needs to be adopted to maintain the height and herbage mass of the leucaena hedgerows.

It may be concluded that maize supplementation can significantly increase liveweight gain of steers grazing irrigated leucaena/pangola pastures in the dry season but not in the wet season. Leucaena was preferentially grazed in the early stages and comprised *c*. 46% of the diet on a weekly basis and, over a 7-day grazing cycle, its herbage mass declined to low residual levels. Increasing the herbage allowance of steers grazing leucaena/pangola pastures may increase the liveweight gain of steers, especially in the dry season. Seasonal factors such as temperature and humidity appear to limit the liveweight gain of steers in the wet season.

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