Effect of Low Levels of Leucaena Foliage Supplementation on Intake, Nutrient Digestibility and Microbial N Yield in Cattle Fed Rice Straw Alone

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ABSTRACT: The minimum amounts of leucaena (Leucaena leucocephala) required to improve the performance of cattle on a straw diet has been studied. Four levels of leucaena, namely 0 (0%), 2 kg (10%), 4 kg (18%) and 6 kg (27% of dietary dry matter intake) were supplied to 4 adult indigenous bulls (355±21.5 kg weight) fed rice straw alone, in a 4×4 latin square design. Measurements were made on intake, digestibility, N balance and microbial N yield. Up to 10% level of leucaena supplementation, there were no significant improvement on intake, digestibility, microbial N yeild and N balance. Both straw and total dry matter intake showed diminishing return to increasing levels of leucaena supplementation and the maximum intake was observed at around 20% level. However, dietary N and digestible organic matter intake, the microbial N yield and the N balance increased linearly to the increasing levels of leucaena supplementation. On a rice straw based diet, the minimum level of leucaena required to improve the animal performance would probably be at around 20% of the dietary intake.
(**Key Words:** Leucaena Supplement, Straw Diet, N Balance, Microbial N Yield)

INTRODUCTION

Rice straw as such is deficient in readily fermentable energy, N, minerals and vitamins. So, it can not provide necessary ATP, ammonia, amino acids, minerals and vitamins for optimum microbial growth in the rumen or tissue development of the host. As a result, growth rates or milk production of the animal consuming rice straw alone are generally low and often only about 10% of the genetic potentiality of the animal (Leng, 1995).

However research has shown that large increase in animal productivity and efficiency of feed utilization from such low quality forages can be brought about by appropriate supplementation which bring essential changes in the balance of nutrients in the basal feed (preston and Leng, 1987; Leng, 1990). On a straw diet, supplementation of small amount of green grasses is often recommended for optimization of rumen environment (Preston and Leng, 1987) or even to meet the maintenance requirement of animal (Ranjhan and Singh, 1993). However, work in this laboratory has shown that on a rice straw diet, native unimproved green grasses (having 40-46% ADF, 1.4-3.4% N and 48 h DM degradability in the rumen of 42%) supplemented from 0 up to 26% of the diet had no positive effect on straw intake, ruminal fermentation, whole gut digestibilities of nutrients, microbial N yield and growth rate of cattle (Chowdhury and Huque, unpublished). It was concluded that such supplementation was unable to meet the critical nutrient deficiencies of the basal diet. In the context of ever decreasing land availability for forage production and the large supply of low quality basal feed resources, leguminous plants (which can be tree, small tree, shrubs or undershrubs) can be effective supplement for ruminants. Generally, legumes are rich in N, digestible energy and elements such as S (Minson, 1982) and sometimes P, Na, Ca, Zn, Cu and Co (Elliott and McMeniman, 1987) and can be grown as homestead forestry, or in wood or fellow land (Leng, 1995) without using the cultivable land. Of different legumes, *leucaena* grows most extensively throughout the tropics including Bangladesh (FAO, 1995) and yields highest edible biomass (36 Ton/hac) and protein (2.11 Ton/hac) annually (Huque et al., 1995). Leucaena foliage supplemented at the level of 40 to 50% of ration DM to rice straw (Devendra, 1983), or 50 to 60% of DM to maize stover (Banda and Ayoade, 1986) diet was found to increase the voluntary intake in goat and sheep respectively. Similarly, on a sorghum straw diet, supplementation of leucaena foliage between 0 to 34% of dietary DM, increased dietary digestible organic matter

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intake and rumen NH_3-N level (Goodchild and McMeniman, 1994). The present trial describes the response of cattle consuming rice straw supplemented with different levels of *Leucaena leucocephala* (leucaena) foliage. It was hypothesized that leucaena foliage would increase the intake, digestibility, N balance and microbial N yield.

MATERIALS AND METHODS

Experimental design, animals and diet : The experi - ment was conducted from August, 1995 to November, 1995, with 4 adult indigenous bulls of 42 months old and 355±21.5 kg liveweight. They were allocated to 4 treatments in 4 different periods in a 4×4 latin square design. The four treatments were *ad libitum* chopped (15 cm) rice straw supplemented with 0, 2, 4 or 6 kg fresh leucaena foliage. Besides fresh clean water was available throughout the day. Leucaena foliage was collected from a well-established stand at the Bangladesh Livestock Research Institute, Savar, Dhaka, Bangladesh. The diets were offered in equal portion twice daily (08:00 and 17:00 h) and straw was given 15% in excess of intake. Each period consists of 28 days, having 21 days adjustment and 7 days collection of faeces and urine. Animals were housed individually in a face-out-stanchion barn during the first 21 days and in the metabolic stall (having facilities for separate collection of faeces and urine) during the collection of faeces and urine.

Chemical analysis : Samples of feeds, faeces, urine and leftover were analyzed for dry matter, organic matter and N accoring to AOAC (1984). Acid detergent fibre (ADF) was determined according to Goering and Van Soest (1970). Microbial N yield were quantified by measuring the purine derivatives (allontoin + 15% correction for uric acid contained in urinary excretion) according to Chen and Gomes (1992).

Energy estimation : Dietary energy contribution was estimated from the digestible organic matter intake as DOMI × 15.8 = MJ ME (Kearl, 1982).

Statistical analysis : The data were analyzed by an ANOVA of 4×4 latin square design with appropriate standard error of mean differences. Simple linear regression of the from $y = a + bx$ was used where appropriate. Statistical method of Snedecor and Cochran (1967) was used for the analysis.

RESULTS

Chemical composition : The chemical composition of straw and leucaena are shown in table 1. Over duration of the experimental periods (90 d), there were little changes in the chemical composition of straw or leucaena. The mean OM, N and ADF content of straw were 80, 0.75 and 43%, respectively and the corresponding values for leucaena were 93, 3.95 and 26%, respectively.

Table 1. Chemical composition of feed ingredients used in four different periods of the trial

	g DM[1] per 100 g fresh sample		g per 100 g of DM					
	$\bar{X}$	SD	OM	SD	N	SD	ADF	SD
Period I								
Straw	88.8	3.23	79.7	0.31	0.68	0.059	43.7	0.69
Leucaena	29.9	0.36	91.2	1.03	3.98	0.631	25.12	3.21
Period II								
Straw	95.8	0.58	81.00	0.13	0.71	0.021	53.0	0.57
Leucaena	24.9	1.57	91.2	0.62	4.22	0.567	28.0	0.75
Period III								
Straw	88.1	0.71	79.9	1.79	0.80	0.011	39.4	3.45
Leucaena	24.89	0.85	98.0	0.59	4.07	0.507	24.9	2.14
Period IV								
Straw	89.3	0.19	79.9	0.02	0.80	0.071	37.08	0.68
Leucaena	35.3	0.37	91.3	0.48	3.51	0.862	27.3	0.74
Mean								
Straw	90.5	3.57	80.2	0.57	0.75	0.062	43.31	7.04
Leucaena	28.7	4.96	92.9	3.67	3.95	0.306	26.34	1.546

DM = Dry matter; OM = Organic matter, N = Nitrogen, ADF = Acid detergent fibre, SD = Standard deviation.

Intake: Intake from straw and leucaena is shown in table 2. Both straw and total dry matter intake showed diminishing return to increasing levels of leucaena supplementation and the maximum intake was observed at around 18% level (figures 1 a,b). The straw DM intake were 62, 62, 63 and 55 g/kg $W^{0.75}$ /d and the total DM intake were 62, 69, 77 and 75 g/kg $W^{0.75}$/d respectively for 0, 2 (10% of total DMI), 4 (18% of total DMI) and 6 (27% of total DMI) kg leucaena foliage supplementation. Increasing levels of leucaena supplementation linearly increased ($p < 0.05$) the total organic matter intake (OMI, Eqn. 1), but linearly reduced (not significant) the OMI from straw (Eqn. 2) as follows (also see figure 1c):

$Y = 49 + 0.65 \pm X$ ($r^2 = 0.986$; $p < 0.05$)... Eqn. 1

$Y = 50 - 0.299 \pm X$; ($r^2 = 0.83$; $p < 0.10$)...Eqn. 2

Here, X = levels (% of total DM intake) of leucaena supplementation and Y is the OMI g/kg $W^{0.75}$/d from total diet (Eqn. 1) or from straw (Eqn. 2). The substitution rate, which is the reduction (%) in straw DMI due to supplementation, were very negligible at 10 (−0.2%) or 18 (−0.2%) percent level, but largely increased (9.94%) at 27% level of leucaena (table 3).

Table 2. Dry matter intake (DMI) from straw and/or leucaena by the indigenous bulls fed either straw alone (T1); or with 2 kg (T2), 4 kg (T3) or 6 kg (T4) leucaena foliage daily

Parameters	level of leucaena foliage, kg/d				SEM
	0	2	4	6	
Straw DMI (kg/d)	5.03	5.04	5.04	4.53	0.404
Leucaena DMI (kg/d)	0	0.56	1.11	1.67	–
Total DMI (kg/d)	5.03	5.60	6.15	6.20	0.463
Total DMI (g/kg $W^{0.75}$/d)	62	69	77	75	–
Total OMI (g/kg $W^{0.75}$/d)	49^{b}	55^{ab}	62^{ab}	66^{a}	5.82
Straw DMI % of Lwt (kg/d)	1.48	1.43	1.45	1.36	0.057
Straw DMI (g/kg $W^{0.75}$/d)	62	62	63	55	4.76
Straw OMI (g/kg $W^{0.75}$/d)	49^{a}	49^{a}	46^{ab}	41^{b}	3.5
Leuaena as % of total DMI	0	10	18	27	–
Substitution Rate (%)	0	−0.2	−0.2	9.94	–

[ab]Means with different superscripts differ significantly ($p < 0.05$). SEM = Standard error of mean differences.

Table 3. Nutrient digestibilities (%) of diets based on rice straw supplemented with either 0, 2, 4 or 6 kg leucaena foliage

Nutrients	Level of leucaena foliage(kg/d)				SEM
	0	2	4	6	
Dry matter	44	39	41	49	4.3
Organic Matter	47^{ab}	42^{b}	44^{b}	54^{a}	4.0
Nitrogen	16^{a}	13^{b}	35^{ab}	52^{a}	12.3
ADF	42	42	35	42	5.4

[ab]Means with different superscripts differ significantly ($p < 0.05$). SEM = Standard error of mean differences.

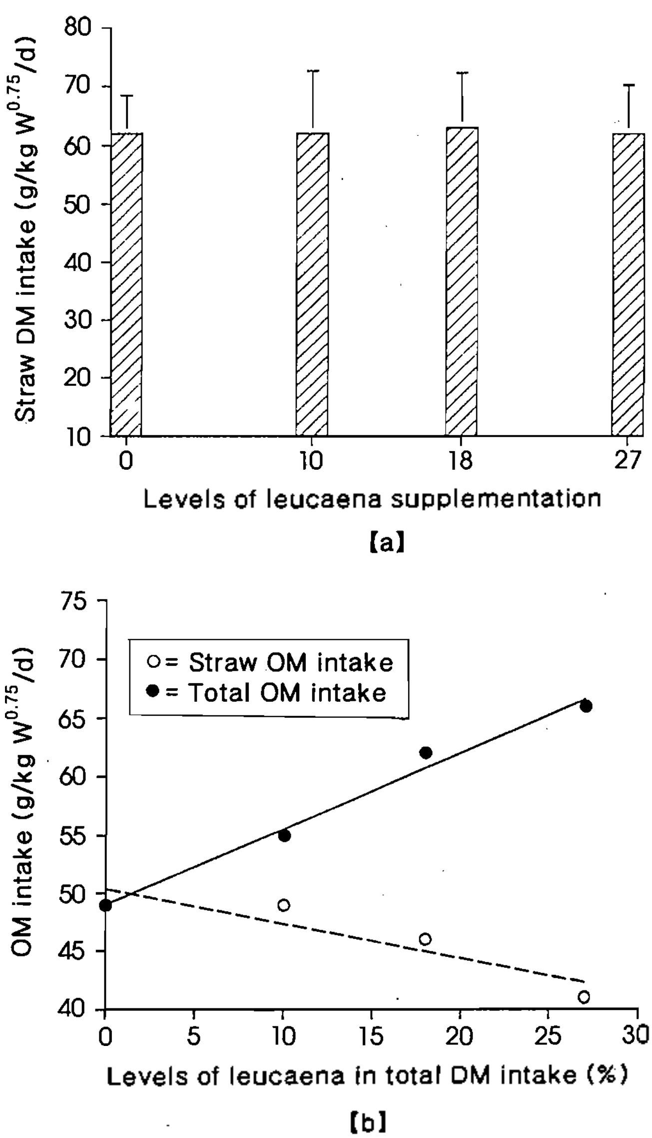


Figure 1. Response of different levels of leucaena foliage supplementation of a straw diet on straw DM intake (figure a) and organic matter intake (figure b) in native adult bulls. Each point represents mean of four observations.

Digestibilities of nutrients : Digestibilites of different nutrients are shown in table 3. Compared to that of the 0, 10 or 18 percent levels of leucaena inclusion, DM digestibility was nonsignificantly higher at the 27% level of leucaena supplementation. Also, OM and N digestibilities were significantly ($p < 0.05$) higher at 27% level of leucaena supplementation. ADF digestibilities, on the other hand, were not effected by the level of supplementation. Except for the ADF, the diet with 10% leucaena had the lowest digestibilities of DM, OM and N (table 3).

Nitrogen utilization : Nitrogen utilization in different groups of animals are shown in table 4. The obvious effect of increasing levels of leucaena supplementation was to linearly increase ($p < 0.05$) the N intake, which were 426, 731, 889 and 1,044 mg/kg $W^{0.75}$/d for 0, 10, 18 and 27% level of leucaena supplementation, respectively. The fitted regression between the level of leucaena (X, % of total DMI) and the N intake (Y, mg/kg $W^{0.75}$/d) shows (see figure 2a) that for 1% increase in dietary leucaena level, N intake increased by 22.72 (±2.337) mg/kg $W^{0.75}$/d. However, except the initial rise at 10% leucaena supplementation, neither the faecal N nor the urinary N excretion increased with the subsequent levels of leucaena. Consequently, starting from negative N balances at 0 (−94 mg/kg $W^{0.75}$/d) and 10 (−171 mg/kg $W^{0.75}$/d) percent level, animals attained positive N balances at 18 (96 mg/kg $W^{0.75}$/d) and 27 (314 mg/kg $W^{0.75}$/d) percent of leucaena supplementation. The fitted regression (Eqn. 3 and figure 2b) between the N intake (X, mg/kg $W^{0.75}$/d) and the N balance (Y, mg/kg $W^{0.75}$/d) shows that the minimum N loss of indigenous bulls at zero N intake would be 467 mg/kg $W^{0.75}$/d and the efficiency of N utilization was about 65 (±35.3)%.

$Y = 0.65(\pm 0.353)X - 467$ ($r^2 = 0.63$; $p = 0.206$)......Eqn. 3.

Microbial N yield : Microbial N (MN) yield are shown in table 4. Compared to that of the control (9.19 g/d), the microbial N yield increased significantly ($p < 0.05$) with 10 (16.93 g/d), 18 (20.29 g/d) and 27 (24.48 g/d) percent of leucaena inclusion. The fitted regression between the levels of leucaena (X, % of total DMI) and MN yield (Y, g/d) was as follows (see figure 3a):

$Y = 10.07 + 0.556(\pm)X$ ($r^2 = 0.98$, $p = 0.011$)... Eqn. 4.

However, the efficiency of MN yield, i.e., g MN/kg digestible OM apparently fermented in the rumen (0.65 DOMR, ARC, 1980), showed curvilinear response which were 7.95, 13.76, 14.16 and 13.51 g/kg DOMR for 0, 10, 18 and 27 percent leucaena supplementation respectively (see figure 3b).

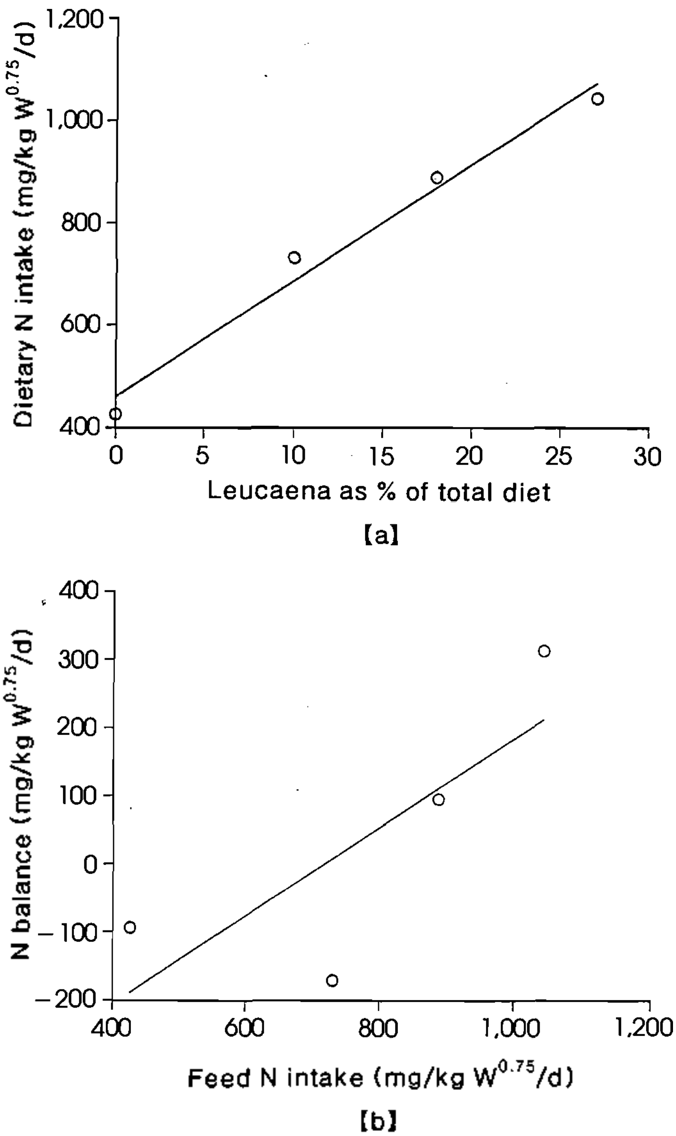


Figure 2. Response of different levels of leucaena foliage supplementation of a straw diet on dietary N intake (figure a) and N balance (figure b) in native adult bulls. Each point represents mean of four observations.

Estimated energy utilization : Dietary energy contribution estimated from the digestible organic matter intake (DOMI × 15.8 = MJ ME; Kearl, 1982) are presented in table 5. Although increasing levels of leucaena supplementation curvilinearly increase the DOMI (see figure 4a) and total ME intake (MEI), but the response was significant ($p < 0.05$) only at 27% level of leucaena. The energy intake expressed as ME/kg $W^{0.75}$/d showed almost similar responses as DOMI, which were 360, 371, 430 and 536 (kJ/kg $W^{0.75}$/d) respectively for 0, 10, 18 and 27% level of leucaena supplementation (figure 4b).

Table 4. Nitrogen status of animals fed diets based on rice straw supplemented with either 0, 2, 4 or 6 kg leucaena foliage

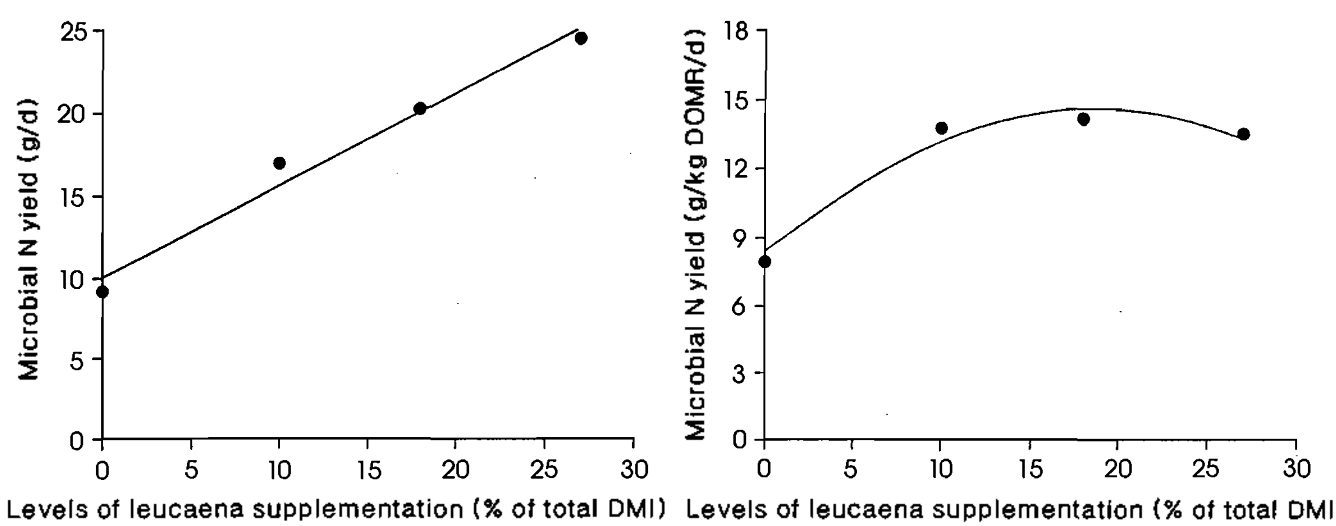
Parameters	Level of leucaena foliage (kg/d)				SEM
	0	2	4	6	
Feed N intake (g/d)	34.63^{c}	59.66^{b}	78.59^{ab}	85.19^{a}	8.114
N intake (mg/kg $W^{0.75}$/d)	426^{b}	731^{ab}	889^{ab}	1,044^{a}	133.2
Faecal N excretion (g/d)	31.11^{b}	50.77^{a}	52.83^{a}	47.75^{ab}	7.091
Urinary N excretion (g/d)	13.67	21.58	19.97	26.82	5.55
N balance (g/d)	−7.63^{bc}	−13.61^{c}	7.90^{ab}	25.41^{a}	7.62
N balance (mg/kg $W^{0.75}$/d)	−94^{b}	−171^{c}	96^{b}	314^{a}	82.1
Microbial N yield (g/d)	9.19^{c}	16.93^{b}	20.29^{ab}	24.48^{a}	2.915
Microbial N g/kg DOMR	7.95^{b}	13.76^{a}	14.16^{a}	13.51^{a}	1.443

^{abc}Values with different superscripts differ significantly ($p < 0.05$).
DOMI × 0.65 (Fermentability of DOM in the rumen, ARC, 1980).
SEM = Standard error of mean differences.

Table 5. Estimated energy status of animals fed diets based on rice straw supplemented with either 0, 2, 4 or 6 kg leucaena foliage

Parameters	Level of leucaena foliage kg/d				SEM
	0	2	4	6	
Dig. OM intake(kg/d)	1.870^{b}	1.896^{b}	2.232^{ab}	2.772^{a}	0.2885
Est. total ME intake (MJ/d)	29.55^{b}	29.96^{b}	35.27^{ab}	43.80^{a}	3.598
Est. ME intake(kJ/kg $W^{0.75}$/d)	360^{b}	371^{b}	430^{ab}	536^{a}	36.1
MJ ME/kg DM	5.87	5.35	5.73	7.07	−

^{ab}Means with different superscripts differ significantly ($p < 0.05$).
ME = Metabolizable energy, estimated as DOMI × 15.8 = MJ ME (Kearl, 1982).
SEM = Standard error of mean differences.



[a] [b]

Figure 3. Response of different levels of leucaena foliage supplementation of a straw diet on the total microbial N yield (figure a) and the efficiency of microbial N production (figure b) in native adult bulls. Each point represents mean of four observations.

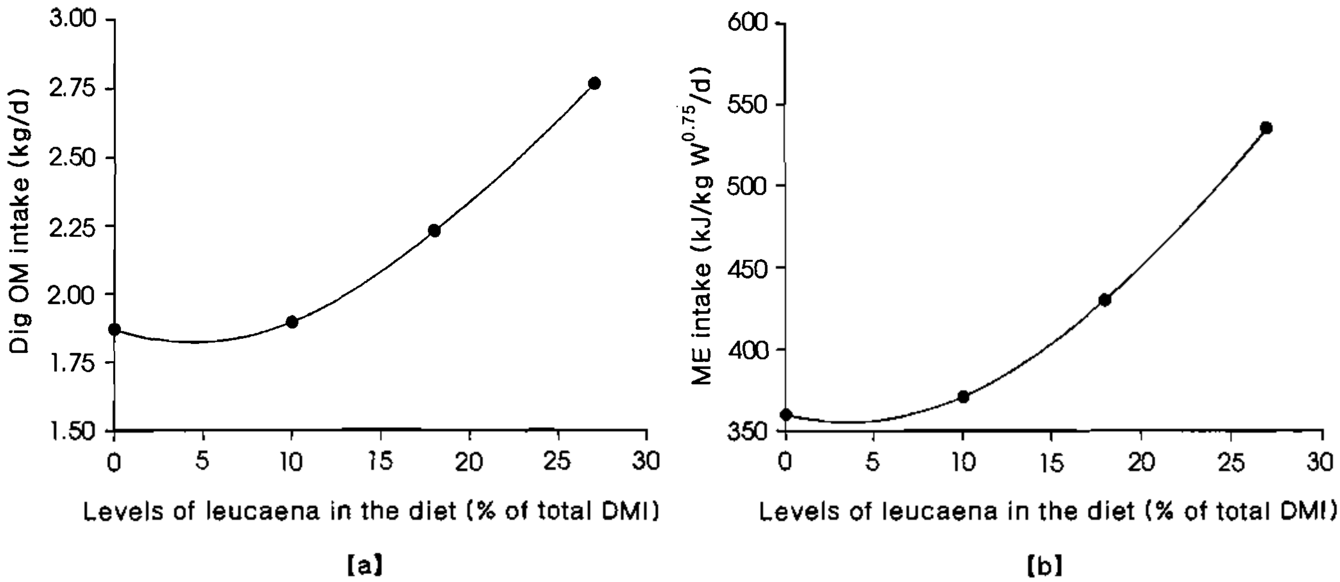


Figure 4. Response of different levels of leucaena foliage supplementation of a straw diet on the digestible organic matter (figure a) and metabolizable energy (figure b) intake in native adult bulls. Each point represents mean of four observations.

DISCUSSION

Inclusion of tree foliage in the diets for ruminants given low quality forages generally improves production by increasing the intake, digestibility and N balance. In this trial, the minimum amount of foliage necessary to improve the productivity of cattle on a straw diet has been studied at levels between 0 to 27% of total DMI, although it is less than the suggested 38% level for optimum balancing of poor quality forages (Leng, 1995).

Effect on intake : Voluntary intake of total OM did not show diminishing return, rather, increased linearly to increasing levels of leucaena inclusion. Similar linear increase in OM intake to increasing levels (0 to 34% of total DMI) of leucaena on a sorghum straw diet has been observed in sheep (Goodchild and McMeniman, 1994). The increase in total OM intake due to leucaena supplemention may be caused by an upturn in host energy demand (Goodchild and McMeniman, 1994) resulting from an improved supply of rumen undegraded protein (Egan and Moir, 1965; Bamualim et al., 1984), which, for fresh foliage can be up to 30-40% of the total N (Bamualim, 1986). Another possibility is that leucaena increased the OM intake by acting on rumen kinetics (Leng, 1984) or by increasing the packing density of the digesta (Thornton and Minson, 1973). However, high level (27%) of leucaena resulted in the depression of total DM and the straw DM, probably due to the availability of more palatable forage than the straw. Similar reduction in DM intake from sorghum straw (Goodchild and McMeniman, 1994) or rice straw (Moran et al., 1983) has also been observed when leucaena constituted > 20% of total DM intake. So, when increase in the straw intake is the main concern, the supplementation level should be at or below 20%. Similar conclusion was also drawn by Bamualim (1986).

Effect on digestibility : As the ratio of dietary straw: leucaena N increased, N digestibility increased linearly. This can be expected because 52% of the straw N are present as neutral detergent insoluble N with a true digestibility of 54% (Walli et al., 1993), while 65% of leucaena N is degraded in the rumen and the rest is being digested and absorbed in the lower tract (Bamualim, 1986). However, the initial decrease of DM and OM digestibilities at 10% and 18% level and subsequent increase at the 27% level or no change in ADF digestibility at any level of leucaena supplementation, is quite different from the expected linear response. In this laboratory, a similar response has also been observed when straw diet was supplemented with green grass at 0 to 18% level (Chowdhury and Huque, unpublished). One possibility is that increasing levels leucaena increased the DMI (table 2) which in turn increased the fractional outflow rate (Leng, 1984; Faichney, 1986; Osuji et al., 1995) of rumen digesta. On such a straw diet with low levels of supplementation, increase outflow rate may decrease the digestibility of the diet. However, as the ratio of straw: leucaena OM increases, the digestibility will rise due to the inherent higher digestibility of the later. This condition will probably be achieved at leucaena level of > 20% of the total DMI. Therefore, on a straw diet, when higher digestibility is the main concern, the leucaena level should be > 20%.

Effect on N economy : Linear increase in N balance with increased level of leucaena supplementation agrees with other observations (Bonsi et al., 1994; Topps, 1995). Obvious effect of increased N balance would be to increase circulating plasma amino acid concentration, with the consequent increase in growth hormone (Pell and Bates, 1990), insulin like growth factor (IGF) and insulin (Istasse et al., 1987) concentration which in turn increases growth rate or milk production. In the present trial, at 27% level of leucaena inclusion, the N balance was 314 mg/kg $W^{0.75}$/d. For a 350 kg cattle, the lean tissue equivalent of 314 g N balance is 667 g (assuming, lean tissue contain 20% protein, ARC, 1984) or at least 476 g (considering the fact that N balance over estimate the body N status by up to 40%, Riis, 1983). Worked carried out in Kenya showed that up to 24% levels supplementation leucaena foliage linearly ($p < 0.01$) increases the milk yield and some curtailment in liveweight loss in Jersey cows fed low quality Napier grass (Toops, 1995). In the present trial the levels of supplementation used, N balance was still increasing linearly. This means that levels of supplementation that would optimize N balance (> 20%) may be different from those that maximizes intake (< 20%).

Effect on microbial N yield : With the levels of supplementation used in the trial, microbial N yield showed linear response. Similarly, supplementation of teff straw with graded levels of cowpea or lablab linearly increased the microbial N yield in calves (Osuji et al., 1995). Enhanced microbial yield due to the supplementation of legume foliages is probably due to the increased supply of N (Goodchild and McMeniman, 1994; Leng, 1995), readily fermentable energy (Osuji et al., 1995), branched chain fatty acids (Ndlovu and Buchanan-Smith, 1987), readily fermentable beta glucans (Silva and Ørskov, 1985), peptides (Cotta and Hespell, 1986: Hume, 1970), sulphur (Elliott and Armstrong, 1982) and also by improving the fractional outflow rate from the rumen (Bonsi et al., 1994). Although extracts of *Leucaena leucocephala* found to prolonged the lag phase of cellulolytic bacteria (Osuji et al., 1995), but no sign of decrease in the microbial N yield was observed in the present trial even at the highest (27%) level of leucaena supplementation. Therefore, on a rice straw diet, for maximum microbial N yield, the level of leucaena would probably be greater than 27% of the dietary intake.

Effect on energy status : Leucaena supplementation at 10% of the diet had no effect on the energy intake. Any substantial improvement in the digestible organic matter or in the estimated metabolizable energy (ME) intake was observed from 18% level of leucaena supplementation. While, the corresponding value for green grass (non-legume) supplementation on a straw diet (Chowdhury and Huque, unpublished) was 25%. This improvement was suggested to be due to the increased rate of passage of digesta (Leng, 1984; Goodchild and McMeniman, 1994; Toops, 1995) and packing density (Thronton and Minson, 1973) of the rumen resulting from leucaena supplementation. The estimated ME intake reaches close to the maintenance requirement (450 kJ/kg $W^{0.75}$/d, ARC, 1980) from 18% level of leucaena supplementation. Therefore, as far as energy intake is concern, optimum level of leucaena supplementation would probably be at or above 20% of the rice straw diet.

General conclusion : The inclusion of leucaena at 10% level had no beneficiary effect on the animal performance. However, inclusion at the rate of 18 or 27% of the diet, consistently improved the intake of ME and N, microbial N yield and N balance of cattle. Both leucaena production and availability in many tropical countries including Bangladesh is limited, therefore, feeding strategies should be at maximizing the low quality roughage utilization. On a rice straw based diet, the minimum level of leucaena required to improve animal performance would probably be at around 20% of the dietary intake.

REFERENCES

AOAC. 1984. Official Methods of Analysis, Centennial Edition. Association of Official Analytical Chemist, Wasington DC.

ARC. 1980. The Nutrient Requirements of Ruminant Livestock. Commonwealth Agricultural Bureaux. Slough England.

ARC. 1984. The Nutrient Requirements of Ruminant Livestock. Supplement No. 1 Commonwealth Agricultural Bureaux. Slough England.

Bamualim, A. 1986. Effect of *Leucaena* as a supplement to ruminants on a low quality roughage diet. In: Ruminant Feeding Systems Utilizing Fibrous Agricultural Residues (Editor. R. M. Dixon). International Development Programme of Australian Universities and College Ltd., Canbara, Australia. pp. 107-112.

Bamualim, A., S. Stachiw, R. J. Jones, and R, M. Murray. 1984. The effect of fresh *Leucaena leucocephala* as a supplement on the utilization of pasture hay by goats. Proceeding of the Australian Society of Animal Production, 15, 259-262

Banda, J. L. L. and J. A. Ayoade. 1986. Leucaena leaf hay (*Leucaena leucocephala* cv. Peru) as a protein supplement for Malawain goats fed chopped maize stover. In: Towards Optimal Feeding of Agricultural By-Products to Livestock in Africa (Editors. T. R. Preston and N. Y. Nuwanyakpa). Proceedings of a Workshop held at the University of Alexandria, Egypt, Octobor 1985. Addis Ababa, Ethiopia: ARNAB, International Livestock Research Centre for Africa. pp. 124-128.

Bonsi, M. L. K., P. O. Osuji, I. V. Nsahlai, and A. K. Tuah. 1994. Graded levels of *Sesbania sesban* and *Leucaena leucocephala* as supplement to teff straw given to Ethiopian Menz sheep. Animal Production, 59, 235-244.

Chen, X. B. and M. J. Gomes, 1992. Estimation of microbial protein supply to sheep and cattle based on urinary excretion of purine derivatives-an overview of the technical details. An occasional publication of the Rowett Research Institute, Greenburn Road, Bucksburn Aberdeen AB2 9SB, UK.

Chowdhury, S. A. and K. S. Huque. Graded levels of green grass supplementation on nutrient digestibility, rumen fermentation and microbial nitrogen production in cattle fed rice straw alone. (Unpublished).

Cotta, M. A. and R. B. Hespell. 1986. Protein and amino acid metabolism of rumen bacteria. In: Control of Digestion and Metabolism in the Rumen. (Editors, L. P. Milligan, W. L. Grovum and A. Dobson). A Reston Book, Prentice-Hall, New Jersey. pp. 122-136.

Devendra, C. 1983. Physical treatment to rice straw for goats and sheep and the response to substitution with variable levels of cassava (*Manihot esculenta* Grantz), Leucaena (*Leucaena leucocephela*) and gliricidia (*Glaricidia maculata*) forages. Malaysian Agricultural Research and Development Institute Research Bulletin, 11. 272-280.

Egan, A. R. and R. J. Moir, 1965, Nutritional status and intake regulation in sheep. I. Effects of duodenally infused single doses of casein, urea and propionate upon intake of low quality roughages by sheep. Australian Journal of Agricultural Research, 16. 437-449.

Elliott, R. and D. G. Armstrong, 1982. The effect of urea and urea plus sodium sulphate on microbial protein production in the rumens of sheep given diets high in alkali treated barley straw. Journal of Agricultural Science Cambridge, 99. 51-60.

Elliott, R. and N. P. McMeniman, 1987. Supplementation of ruminant diets with forage. In the Nutrition of Herbivors (Eds. J. B Hackerand J. H. Ternouth). Sydney: Academic Press. pp. 409-428.

FAO. 1995. Feed resources for ruminants. In: Tropical Animal Feeding-A manual for research workers. By T. R. Preston. FAO Animal Production and Health Paper 126. Rome. pp. 109-154.

Faichney, G. J. 1986. The kinetics of particulate matter in the rumen. In: Control of Digestion and Metabolism in the Rumen. (Editors, L. P. Milligan, W. L. Grovum and A. Dobson). A Reston Book, Prentice-Hall, New Jersey. pp. 173-195.

Goerging, H. K. and van P. J. Soest. 1970. Forage Fibre Analysis. United States Department of Agriculture Handbook No. 379.

Goodchild, A. V., N. P. McMeniman, 1994. Intake and digestibility of low quality roughage when supplemented with leguminous browse. Journal of Agricultural Science, Cambridge, 122-160.

Hume, I. D. 1970. Synthesis of microbial protein in the rumen III. The effect of dietary protein. Australian Journal of Agricultural Research. 21. 305-314.

Huque, K. S., S. A. Chowdhury and E. Haque. 1995. Study on the productive and nutritional characteristics of maize intercropped with different varieties of legumes. Research Report, Animal Production Research Division, Bangladesh Livestock Research Institute, Savar, Dhaka 1341, Bangladesh.

Istasse, L., N. A. MacLeod, E. Goodal and E. R. Ørskov.sh 1987. Effect of plasma insulin of intermittent infusion of propionic acid, glucose or casein into alimentary tract of non-lactating cows maintaining on a liquid diet. British Journal of Nutrition, 58.139-148.

Kearl, L. C. 1982. Nutrient requirements of ruminants in developing countries. International Feed Stuffs Institute, Utah Agricultural Experiment Station. Utah State University, Logan, Utah, USA.

Leng, R. A. 1984. Supplementation of tropical and sub-tropical pastures for ruminant production. In: Herbivore Nutrition in the Subtropics and tropics. (Editors, F. M. C. Gilchirst and R. I. Mackie). Craig-hall, Science Press. pp. 129-144.

Leng, R. A. 1990. Factors affecting the utilization of poor quality forages by ruminants under tropical condition. Nutrition Research Reviews. 3. 277-303.

Leng, R. A. 1995. Trees-Their Role in Animal Nutrition in Developing Countries in the Humid Tropics. University of New England, Armidale, N. S. W 2351. Australia

Minson, D. J. 1982. Effects of chemical and physical composition of herbage eaten upon intake. In: Nutritional Limits to Animal Production from Pasture (Editor. J. B. Hacker). Commonwealth Agricultural Bureaux, Slough, England. pp. 167-182.

Moran, J. B., K. B. Satoto and J. E. Dawson. 1983. The utilization of rice straw fed to Zebu cattle and Swamp buffalo as influenced by alkali treatment and leucaena supplementation. Australian Journal of Agricultural Research, 34, 73-84.

Ndlovu, L. R. and J. G. Buchanan-Smith, 1987. The effect of supplementing corn cobs with lucerne hay, lucerne cell wall, a soyabean protein isolate or high fatty acids on intake, ruminal degradation and rate of passage in sheep. In: Herbivore Nutrition Research (Editor, M. Rose). International Symposium of Herbivores held at the University of Queensland, Brisbane, Australia, July 6-10, 1987. pp. 189-190.

Osuji, P. O., S. Fernandez-Rivera, and A. Odenyo. 1995. Improving fibre utilization and protein supply in animals fed poor quality roughages: ILRI nutrition research and plans. In: Rumen Echology Research Planning. Proceedings of a Workshop held at ILRI, Addis Ababa, Ethiopia, 13-18 March, 1995. (Editors: R. J. Wallace and A. Lahlou-Kassi). International Livestock Research Institute, Nairobi, Kenya. pp. 1-24.

Pell, J. M. and P. C. Bates, 1990. The nutritional regulation of growth hormone action. Nutrition Research Review, 3. 163-192.

Preston, T. R. and R. A. Leng, 1987. Matching Ruminant production Systems with Available Resources in the Tropics and Sub-tropics. Panambul Books, Armdale, N. S. W., Australia.

Ranjhan, S. K. and K. Singh, 1993. Nutrient requirements feeding standards and feeding of ruminants and their relevance to Indian condition. In: Feeding of ruminants on Fibrous Crop Residues. (Editors, Kiran Singh and J. B. Schere.) Indian Council of Agricultural Research, Krishi Bhavan, New Delhi, India. pp. 117-130.

Riis, P. M. 1983. Nutritional and other environmental condition. In: Dynamic Biochemistry of Animal Production. Basic Information 3. Elseveir Scientific Publishers. pp. 319-353.

Silva, A. T. and E. R. Ørskov.rs 1985. Effect of unmolassed sugar beet pulp on the rate of straw degradation in the rumen of sheep given barley straw. Proceeding of the Nutrition Society 44. 50A.

Snedecor, G. W. and S. J. Cocharn, 1967. Statistical Methods. (The Iowa State University Press, Ames, Iowa, USA.

Thornton, R. F. and D. J. Minson, 1973. The relationship between apparent retention time in the rumen, voluntary intake, and apparent digestibility of legume and grass diets in sheep. Australian Journal of Agricultural Research, 24. 889-898.

Topps, J. H. 1995. Forage legumes as protein supplements to poor quality diets in the semi-arid tropics. In: Rumen Ecology Research Planning. Proceedings of a Workshop held at ILRI, Addis Ababa, Ethiopia, 13-18 March, 1995 (Editors: R. J. Wallace and A. Lahlou-Kassi). International Livestock Research Institute, Nairobi, Kenya. pp. 183-190.

Walli, T. K., K. T. Sampath, S. N. Rai and S. Tamminga, 1993. Relevance of the RDP/DUP system for feeding ruminants in the tropics with emphasis on straw based diet. In: Feeding of Ruminants on Fibrous Crop Residues. (Editors: Kiran Singh and J. B. Schere) Indian Council of Agricultural Research, Krishi Bhavan, New Delhi, India. pp. 157-170.