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NUTRITIONAL AND ECONOMIC BENEFITS OF LEUCAENA AND GLIRICIDIA AS FEED SUPPLEMENTS FOR SMALL FUMINANTS IN HUMID WEST AFRICA

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SUMMARY

Considering leguminous trees Leucauena and Gliricidia as good sources of quality food, on-station and on-farm studies were conducted in the humid zone of West Africa to establish animal responses to levels, times and forms of browse supplementation, to develop alternative feeding strategies for utilizing limited feed supply and to assess the economic benefits of feed supplements as against the use of tree foliage as mulch for crop production. Results indicate that at any level of supplement, sheep grew twice as fast as goats. The main benefits of supplementation came through increased growth and survival. Form and level of supplementation had significant effect on intake. Economic analyses showed that crop response to mulching was the principal competing determinant of whether the use of tree foliage as feed supplement was economic.

INTRODUCTION

There are 19 million small ruminants in the humid zone of West and Central Africa, 9 million in Nigeria alone (McIntire et al., 1992). Systems of management vary from free range in less populated areas to year round confinement and cut and carry feeding of grass and browse in densely populated areas. Long-term monitoring of village herds revealed disease and undernourishment as major problems particularly with confined animals. This indicated the importance of better quality foods for such animals (Mosi *et al*., 1982; Mack, 1983; Adeoye, 1985; Francis, 1988).

The International Institute of Tropical Agriculture (IITA) developed alley cropping to improve soil fertility, control soil erosion and increase crop yields, thus eliminating or reducing the need for long fallow periods for fertility restoration. In alley cropping, prunings of leguminous trees e.g. *Leucaena* and *Gliricidea* are applied as mulch during the crop season (Kang *et al*., 1990). The International Livestock Research Institute, formerly International Livestock Centre for Africa (ILCA), considered using the non-crop dry season prunings and a part of crop season prunings as protein-rich feed supplement to traditional village diets to increase small ruminant productivity. Small ruminants are a minor component of the crop dominated farm systems in the zone, so a technology beneficial to both crops and livestock was considered to have a better prospect for adoption. To this end, agronomic, nutritional and economic studies were conducted on alley farming over several years. This paper synthesizes the results of nutrition and related economic studies.

REVIEW OF RESULTS

Strategies for controlling the effects of mimosine in *Leucaena*

Experiences in south-east Asia showed mimosine toxicity was a potential constraint to the unrestricted use of *Leucaena* as a feed. If consumed at more than the safe level, sheep appear to be more susceptible to mimosine than goats, showing loss of heir around the face. Depressed appetite, low weight gains and alopecia are early signs of toxicity. Ulceration of the esophagus may also occur (Gray, 1968; NAS, 1977; Jones, 1979). At very high levels of toxicity animals may die and NAS (1977) recommended restricting intake of *Leucaena* to below 30% in ruminant diets. Initially restriction of intake was not considered practicable under African small-holder farm conditions, so 2 strategies to control the effects of mimosine were tried.

Rumen microbes degrade mimosine to 3 hydroxy 4 (IH) pyridone (DHP) which is then absorbed into the blood stream before eventually being excreted in urine. In Hawaii and Indonesia, goats fed high levels of *Leucaena* were found to excrete urine free of DHP due to the presence of rumen microbes able to degrade DHP (Jones, 1981). Rumen fluid from goats adapted to *Leucaena* diets was transferred to unadapted animal in Australia allowing the latter group to eat a diet comprising only *Leucaena*. It was also reported that the introduced bacteria could be passed from animal to animal, and would persist for at least 6 months after removal from *Leucaena* feeding (Jones et al., 1985).

Presence of DHP in the urine of West African Dwarf (WAD) goats and sheep in a trial on ad *libitum Leucaena* diet in southern Nigeria indicated the absence of detoxifying rumen microbes in those animals. So, WAD sheep and goats on *Leucaena* diet were inoculated with cultures of rumen microbes brought from Australia in 1985. The urine DHP of these animals, determined using high performance liquid chromatography, declined rapidly over the first 14 days following inoculation and levelled off to trace amounts after 25 days (ILCA, 1986). In another trial, no signs of toxicity were present in group fed sheep receiving the same level of supplementation, in which some animals were observed to consume more Leucaena than average. In early 1986, toxicity was also observed in a flock of sheep grazing in Leucaena alleys, and 2 animals eventually died. The rumens of the other animals on the trial were inoculated with bacteria that detoxify mimosine and DHP, and the signs of toxicity disappeared. Healthy lambs were born to these animals in the following season (ILCA, 1987).

Apart from mimosine toxicity, susceptibility of *Leucaena* to the Psyllid insect (*Heteropsylla cubana*) encouraged diversification of species with good food value. Gliricidia, originally from Central America, but well adapted to West Africa as a shade tree and live fence, was found to be a good option (Atta-Krah and Sumberg, 1988). The effect of combined *Leucaena* and *Gliricidia* supplement as a strategy to maintain high protein quality of the food while reducing the risk of mimosine toxicity were examined. When *Leucaena* and *Gliricidia* offered at 1:3 ratios, animals ate almost all the Leucaena but left some *Gliricidia*. With a 1:1 mixture, animals were not selective (Ademosun et al., 1985a). Growth rates of goats and sheep were higher with a 1:1 mixture of *Leucaena* and *Gliricidia* supplement compared to the same level of supplement with either sole or predominantly *Leucaena* or *Gliricidia* (Carew, 1982; Reynolds and Adeoye, 1985; Ademosun, et al., 1988).

Based on these experiences, 1:1 mixture of *Leucaena* and *Gliricidia* was adopted as a strategy to control the effect of mimosine toxicity and farmers participating in on-farm research were advised to grow *Leucaena* and *Gliricidia* in alternate rows and offer them to animals in equal quantities to avoid toxicity.

Role of energy in diet

Free roaming or confined village goats and sheep are not offered commercial protein supplements but are given farm by-products such as cassava peels, maize chaff and other household wastes. These energy rich feeds can be offered with or without protein rich browse. The benefits of such combination were studied.

Dry matter digestibility (DMD) of *Gliricidia* as a sole feed was found to be 54 to 57% while the addition of cassava tubers (Ademosun *et al*., 1985a) or cassava peel (Ifut, 1987) raised DMD to 70 to 74%. In a *Panicum maximum* plus *Gliricidia* diet, DMD fell as the proportion of *Panicu*m in the diet increased (Ademosun *et al*., 1985a; Ademosun et al., 1985b; Ifut, 1987). For a combination of *Panicum*, *Gliricidia* and cassava peel diet, DMD tended to increase as the level of consumption of cassava peel increased (Ifut, 1987).

These results indicated that the presence of a fermentable energy source in the diet allows high nitrogen feed such as *Gliricidia* and *Leucaena* to be utilized more efficiently (ABC, 1980). Based on this experience, a small amount of sun-dried cassava peel (about 50g/day) was used as a routine in most supplementation trials at ILCA.

Response to levels of supplementation with Leucaena and Gliricidia

Supplementation of WAD sheep

In group feeding trial on-station over 2 years (1983 to 85), all animals received adlibitum chopped P. maximum, water and a mineral lick. *Leucaena* and *Gliricidia* were offered in a 1:1 ratio at the rate of 0, 200, 400 or 800g DM/animal/day. Rams had continuous access to females. Animals were dipped and dewormed monthly and isometamedium was administered every 3 months as a prophylactic against trypanosomiasis (Reynolds and Adeoye, 1985).

Supplementation had a significant effect on all production parameters except litter size (Table I). The group without supplement performed either equally or slightly better than the group with the lowest level of supplementation on a number of parameters. However, the overall productivity index, measured as the weight of lamb surviving to 90 days per dam per year, shows that the highest level of supplementation gave 55% higher productivity than the group without supplementation.

Two other trials were conducted with weaned lambs, each lasting 6 months. In trial 1, all animals received a basal ration of ad *libitum* chopped *P. maximum* plus 50g/day of sun dried cassava peel, water and mineral block. In addition, one of 3 levels (200g, 400g, and 600g) of a 1:1 mixture of *Leucaena* and *Gliricidia* was offered as a supplement. In trial 2 conducted in a different year, all animals received a basal ration as in trial 1 and one of 3 levels (300, 600 and 900g) of 1:1 mixture of *Leucaena* and *Gliricidia* as a supplement.

Table 1: *The effect of browse supplementation on the productivity of West African Dwarf sheep*

Production parameter	Levels of supplement (g DMd^{-1})			
	0	200	400	800
Parturition interval (days)	262a	228b	226b	241c
Litter size	1.26a	1.27a	1.19a	1.17a
Birth weight (kg)	1.80a	1.61b	1.52b	1.72a
Survival to 90 days	0.65a	0.52b	0.65a	0.82c
Daily weight gain to 90 days (g)	64.4a	60.31a	73.4b	83.8c
Productivity index	8.67a	7.44a	10.15b	13.46c

Productivity index = kg offspring weaned at 90 days/dam/year.
Within a line, figures followed by different letter are significantly different (P<0.05)
Source: Reynolds and Adeyoye (1985)

In each trial, total feed intake significantly increased (P<0.05) as the level of supplement in the diet increased, but grass intake declined significantly (P<0.05). Growth rates tended to rise as intake increased but the rate of increase slowed down showing diminishing returns at the highest level of supplementation (Table 2).

Table 2: *Effects of supplementary browse on feed intake and growth rate of lambs offered Panicum maximum ad libitum.*

Level of supplement ($gDMD^{-1}$)	Browse intake gd^{-1}	Grass intake gd^{-1}	Cassava peel intake gd^{-1}	Total intake gd^{-1}	Growth rate gd^{-1}
Trial 1					
200	166	452a	47	665a	23.6a
400	362	397a	46	805a	35.0b
600	511	234b	48	793b	45.6b
Trial 2					
300	144	416a	48	608a	29.4a
600	298	331b	46	675b	38.7b
900	392	283c	46	721c	41.0b

Within a trial, values in a column with a different letter are significantly different (P<0.05)
Source: ILCA (1988), ILCA (1992).

Supplementation of WAD sheep and goats

Goats and sheep were studied over 2 reproductive cycles. All animals received a basal diet of ad *libitum* chopped *P. maximum* and 50g of sun-dried cassava peel for the last months of pregnancy and during lactation. Ewes were supplemented with *Leucaena* and *Gliricidia* (1:1) at the rates of 0, 200, 400, 800, or 1,200g DM/day. Does were offered the 4 rations containing supplement. Weaned kids and lambs from the treatments received *P. maximum ad libitum* plus supplements at a corresponding levels to their dams. The effects were measured in terms of growth rate and survival rate of offspring up to weaning and dam productivity, measured as kg offspring weaned per dam per year (ILCA, 1987; Reynolds and Adediran, 1988).

The result showed that as the level of supplementation increased, average growth rate per day to weaning increased from 25 to 50g in sheep and from 14 to 29g in goats ($P<0.05$). At any level of supplement, sheep were 1.7 to 2 times as responsive as goats. Survival of offspring to weaning increased from 50 to 100% in sheep and from 36 to 94% in goats ($P<0.05$). Selection of browse in preference to grass was more marked with goats than with sheep but the goats were unable to utilize the higher nutritive value of browse as effectively as sheep (ILCA, 1987; Reynolds and Adediran, 1988).

Having found sheep more responsive to supplementation, 6 months old weaned lambs were supplemented to slaughter at 18 months for males, and to first conception at 15 months for females. Animals received *ad libitum* chopped *P. maximum* plus 50g/day of cassava peel, water and mineral blocks supplemented with Leucaena and Gliricidia (1:1) as follows: from 6 to 12 months of age 300, 600 or 900g/day and from 12 to 18 months (12 to 15 months for females) of age 400, 800 or 1,200g/day. Females were removed from the experiment at 15 months for breeding (Reynolds, 1989).

Mean daily food intake was lowest at the lowest level of supplementation and highest at the medium level of supplementation. However, significant ($P<0.05$) substitution of browse for grass occurred with increased browse supplementation. Growth rates were significantly improved by increasing the level of browse on offer, rising from 30.0 to 48.9g/day in males and from 25.8 to 37.7g/day in females ($P<0.05$) but the rate of weight gain decreased with additional supplementation, indicating diminishing returns (Reynolds, 1989).

The trial was repeated the following year with WAD sheep and the same treatments except that at 15 months of age, females were put on a uniform diet, mated and the carry-over effects of the previous treatment assessed. Result showed that grass intake significantly decreased with increased supplementation. For the 6 to 15 month period, growth rate was 24, 35 and 44g/day at the low, medium and high levels of supplementation ($P<0.05$). Males supplemented from 15 to 18 months showed no benefit from higher levels of supplementation when the experiment period coincided with the on-set of the rainy season and an improvement in the quality of basal Panicum diet. For the females, previous nutritional treatment during growth up to 15 months of age had no effect on birth weight or growth of lambs up to 4 weeks (ILCA, 1990).

Effects of alternative feeding strategies

In alley farming systems the main use of tree foliage is expected to be for mulching so that tree forage availability is seasonal. Hence, continuous supplementation of animals may not be possible. In order to maximize the benefits from the limited quantities of available food from alley farms or feed gardens, types of animals should be fed at strategic times, in appropriate quantities and forms. Strategies considered to achieve this object are explained below:

Optimum period for supplementing adult sheep and goats

A study was conducted on-station separately with goats and sheep to compare the effects of giving extra supplements in late pregnancy, early lactation or late lactation in terms of growth and survival of offspring up to weaning. For each species, all animals received a basal diet of *ad libitum* chopped *P. maximum* plus 50g/day of sun dried cassava peel and a basic supplementation of 400g DM/day of 1:1 *Leucaena* and *Gliricidia* from late pregnancy to late lactation (control). In addition, group 2 had an extra supplementation of 400g DM/day during late pregnancy (12 weeks to lambing/kidding); group 3 received extra supplementation of 400g DM/day during early lactation (first 6 weeks after lambing/8 weeks after kidding) and group 4 received extra supplementation of 400 g/day during late lactation (7 to 12 weeks after lambing/9 to 16 weeks after kidding).

The treatments had no effect in goats on birth weight or growth rate of kids to weaning. In sheep, supplementation in late lactation significantly increased lamb growth rates up to weaning but supplementing at other times had no significant effect. Extra supplementation increased survival rate of both kids and lambs to weaning irrespective of time of supplementation. Survival rate of kids from all extra supplemented groups and control were respectively 87 and 58 percent. For lambs, the rates were respectively 92 and 70 percent. Both the differences were significant ($P<0.05$) (ILCA, 1989; ILCA, 1992).

Growth of sheep during continuous vs periodic supplementation

Experience from on-farm research (see below) indicated that farmers were using their limited browse either by supplementing for a few days each month or supplementing more frequently but with less material on offer for each occasion. A trial was performed on-station to determine the effect of periodic vs continuous extra supplementation with the same quantity of available browse. The null hypothesis was that a given amount of browse could be supplemented daily at a low rate or less frequently at a higher rate without any significant difference in results.

All animals received a basal ration of *ad libitum Panicum*, 50g of dry cassava peel and 400g DM *Leucaena* and *Gliricidia* browse (1:1) daily. In addition, Group 2 received a continuous supplementation of 80 g DM/day of the same browse every day; Group 3 had 280g DM browse/day on 2 days each week. The pregnant ewes were on trial for 24 weeks from 12 weeks prior to lambing to weaning of the lambs at 12 weeks of age. At weaning, the lambs were randomly reassigned to 3 groups for no supplementation, continuous and periodic supplements for 12 weeks with quantities 0, 50g, 100g for group 1, 2 and 3 (ILCA, 1989). The effect was measured in terms of growth rate of lambs.

From birth to 24 weeks, growth rates of lambs in no supplement, continuously and periodically supplemented groups averaged 43.7, 50.1, 44.0 g/day ($P<0.05$). No significant differences in growth rated of lambs between weaning at 12 weeks and the end of the trial at 24 weeks were observed. No significant correlation was observed between pre-and post weaning dietary regimes and growth rates. The non-significance of differences across treatments may indicate that the levels of supplementation considered were too low to make any significant impact through timing of supplementation (ILCA, 1989).

Supplementation of Leucaena in different forms

Agronomy trials have shown that *Leucaena* and *Gliricidia* foliage yields are higher in the wet season. A trial was conducted to assess the effect of sun-drying wet season output on intake and growth of lambs. Lambs aged about 10 months were offered 100 or 200g/day of fresh of sun-dried Leucaena with *ad libitum* chopped *P. maximum* and 50g/day or sun-dried cassava peel. The trial was run in the dry season, so the quality of *Panicum* was expected to be lower than in the wet season (ILCA, 1990).

Both forms of *Leucaena* were readily consumed though at higher levels of supplement, the intake rate of dry *Leucaena* was significantly lower ($P<0.05$). Over a 7 week period the animals on dried *Leucaena* grew at an average rate of 40g/day compared to 12g/day for those on fresh material ($P<0.05$), but there was no difference in growth rate between the 2 levels of supplementation on offer in either fresh or dry form. The sun drying process might have reduced mimosine levels in *Leucaena*, though no chemical analysis of the feeds was done to establish the effect of drying.

In order to understand the differences in performances of dry and fresh *Leucaena*, their digestibilities were investigated. Growing male sheep were penned individually in metabolism crates and offered a basal diet of chopped *P. maximum ad libitum* plus 50g/day of cassava peel, with either 1,100g/day of fresh or 400g/day of dry Leucaena. The 10 day adjustment period was followed by a 7 day trial period. At the end of the period those receiving fresh *Leucaena* were changed to dry *Leucaena*, and vice-versa (ILCA, 1990).

Panicum intake was unaffected by the form of supplement offered. Intake of fresh *Leucaena* was higher than that of the dry material, 389 v 359g DM/day, but total intake (about 1,690g) was unaffected by treatment. Nitrogen intake was higher in the fresh *Leucaena* group (22.0 v 19.6g/day) but faecal N and urinary N outputs were not different. Also digestibilities of DM and N were the same in the two groups, as was the N balance. Thus the utilization of fresh and dry *Leucaena* was similar (ILCA, 1990).

Palatability and voluntary intake of Gliricidia sepium in different forms

Gliricidia sepium is highly productive and well adapted to humid West Africa, but it is rarely used as feed for ruminants. Some farmers consider it 'poisonous' to sheep and goats (Atta-Krah and Sumberg, 1988) and it has been characterized as a plant having rodenticidal potential (Everard, 1966). *Gliricidia* was also found as the least preferred by goats when 8 indigenous browse species were compared with *Leucaena* and *Gliricidia* (Larbi et al., 1993a). However, small ruminants reared on the ILCA experimental farm ate *Gliricidia* once this was introduced to it as young-stock. Experimental animals purchased from the market ate *Gliricidia* after a period of adjustment. Farmers' animals on trial in the villages also ate *Gliricidia*. In all cases, *Leucaena* was preferred to *Gliricidia*.

Two experiments were conducted to explain the low acceptability of *Gliricidia* by village animals. In the first experiment, the cafeteria technique using three-year-old WAD sheep was employed to determine relative palatability differences within 28 collections of G. sepium from West Africa and Central America. Significant differences ($P<0.05$) in relative palatability were detected among the provenances considered and Mexican ecotypes appeared to be of low relative palatability compared to those from Costa Rica (Larbi *et al*., 1993b). This result indicated the possibility for selection on the basis of both yield and palatability, thus enhancing the adoptability of *Gliricidia* leaves as a feed resource in alley farming systems.

In the second experiment, separate trials were conducted with WAD sheep and goats –12 to 18 months old. *Gliricidia* was offered in fresh, wilted or dried form at 10, 20 or 30% of a daily DM allowance of the individually penned animals, with fresh *P. maximum*, harvested after 12 weeks re-growth, as the basal diet. The experimental period consisted of 7 days adaptation plus 7 days collection (ILCA, 1993).

Neither the form nor the level of supplementation of *Gliricidia* had any significant (P>0.05) effect on the intake of *Panicum* in the case of sheep, but both significantly (P<0.05) affected *Panicum* intake for goats. Form and level of supplementation and their interaction had very significant (P<0.01) effects on intake of the supplement *Gliricidia* by both sheep and goats. Intake in fresh and wilted form was significantly higher than in the dried form. Intake in fresh and wilted forms did not differ significantly (P>0.05). Intake increased linearly as the level of supplementation increased except in the case of sheep supplemented in dried form.

Effect of supplementary browse on the performance of free-roaming village flocks

In order to validate the results obtained on-station, on-farm studies were under taken for 2 years with free-roaming small ruminants in 2 villages in south west Nigeria (ILCA, 1992). Ten farmers who fed alley-browse and 12, who did not, were visited 10 days per month. Animals were tagged and all entries and exits to the herds were recorded. Animals roamed freely around the village scavenging, grazing and browsing on indigenous plants but intake during this period was not measured. At the end of the day, household wastes, cassava peels and tubers with or without browse were given. It was not possible to determine the DM content of the feeds offered and refused, and therefore values are shown on an as-fed basis.

Browse feeding households had nearly twice as many animals per household as non-browse feeders over the 2 year period, though initially the difference was not large (Table 3). Browse feeders fed browse intermittently for 6 to 8 days per month at the rate of about 300g fresh material per animal per day or 33kg per year. They offered cassava peels and household wastes less frequently than non-browse feeders. Browse feeders fed 85kg cassava peels and household wastes per animal compared to 141 kg by non-browse feeders.

Production parameters did not differ significantly between the 2 groups except in the case of adult survival rate and herd productivity. Overall performance of the herds was measured by 2 indices: Doe productivity = (kid weight at n months post partum x kid survival to n months x 365)/kidding intervals, and Herd productivity = Doe productivity x Doe survival rate.

Doe productivity did not differ significantly (P>0.05) but herd productivity did differ significantly (P<0.05) between browse feeders and non-browse feeders. Herd productivity was lower among non-browse feeders due to higher adult mortality.

Based on herd productivity, it was calculated that compared to non-browse feeders, browse feeding herds gave 53g of additional live-weight gain per kg of tree browse fed. This response rate was comparable to some of the on-station results described earlier. These significant weight gains were achieved by supplementing animals in small quantities on an irregular basis.

Table 3: Characteristics and performance of browse feeding and non-browse feeding village herds, southwest Nigeria, 1989-90

	Browse feeders	Non-browse feeders
Number of households	10	12
Animals per household-1989 beginning	9.7	7.3
- 1989 – 90 Average	12.2	6.5*
Adult females per household – 1989 beginning	4.5	3.4
- 1989 – 90 Average	6.1	3.5*
Frequency of feed offer (%days visited)		
Browse	29.6	1.4*
Cassava peels + tubers	50.2	57.2
Other household wasters	37.2	45.0
Feed consumed (kg/household/yr)("as fed" basis)		
Browse	398	7*
Cassava peel + tubers	627	433*
Household wastes	404	482*
Total	1429	922*
Feed consumed (kg/animal/yr)("as fed" basis)		
Browse	32.7	1.1*
Cassava peel + tuber	51.6	66.5*
Household wastes	33.2	74.0*
Total	117.0	141.6*
Production parameters		
Litter size	1.48	1.41
Parturition interval (days)	280.00	298.00
Weight at 12 months (kg)	9.50	10.10
Survival to 12 months	0.67	0.64
Survival of adults	0.92	0.70
Productivity indices to 12 months post partum(kg)		
Doe productivity	12.28	11.18
Herd productivity	11.29	7.82*

Only* marked items differ significantly (<0.05) between browse feeders and non-Browse feeders.

Source: ILCA unpublished data.

Economic benefits of browse supplementation

In an *ex ante* analysis of the economics of alley farming with small ruminants, Sumberg et al., (1987) used the following assumptions: (a) marginal productivity of mulch N (kg maize/kg mulch-N) is 5 for surface mulching and 10 for mulch incorporated under the soil, (b) daily feed intake of goats and sheep is equal to 5% of the animal's live-weight of which 25 or 50% is tree foliage, (c) animal productivity increases by 10 to 40% due to browse supplementation.

The outcome of this model indicated that using tree foliage as feed was uneconomic in relation to mulching for maize unless animal productivity increased 20 to

30% with 25% supplementary feeding. These were high targets for WAD goats and sheep. Agronomy trials on-station and on-farm have shown that the assumed crop response to mulching was significantly on the high side which required animal response to supplementation to be very high to be competitive with maize (ILCA, 1992).

By using a linear programming technique to model optimal enterprise combinations in a crop-livestock system in southern Nigeria, Ashraf (1990) has shown that feeding small ruminants with part of the tree foliage increased net farm income by 15 to 40% and the rate of increase was higher for smaller farms.

Using crop and animal response data from on-station and on-farm experiments in a partial budgeting procedure, Jabbar et al. (1992) have shown that when maize yield without mulch was 1.7t per ha and yield response to mulching was low, economic gains could be made by feeding small ruminants with part of the foliage. Using 50% of crop season pruning as mulch and the remainder of crop season and all of no-crop dry season pruning as fodder gave the highest returns. At low maize yield and low response to mulching, animal weight gain of 30g per kg browse supplement was enough to make browse feeding profitable. When base maize yield was about 2t per ha and yield response to mulching was medium to high, only half of dry season pruning could be profitably used as fodder. Animal live-weight gain of 60g or more per kg browse supplement would be required to make browse feeding competitive with mulching, and such high response rates were found to be rare with WAD sheep and goats.

In another study, Jabbar et al. (1994) used data from a 9 year experiment on-station in a capital budgeting procedure to compare the profitability of 3 production systems: traditional (non-alley) farming with a 2 year fallow after 4 years of cropping and no supplementary feeding for small ruminants, continuous alley farming where up to 50% of the tree foliage is used as feed supplement, and alley farming with a 2 year fallow period where up to 50% of foliage of both crop and fallow years are used as feed. The results indicated that the present values of gross margins from crop and livestock per hectare were Naira 16176, 18794 and 23749 respectively for traditional (non-alley) farming, alley farming with fallow and continuous alley farming. The last 2 systems generated 16 and 46% more returns compared to non-alley farming. The results also indicated that without livestock feeding, alley farming systems would yield 12 to 15 % less returns.

DISCUSSION AND CONCLUSION

The importance of browse in ruminant diets in Africa has been well documented (Le Houerou, 1980). Mimosine toxicity in *Leucaena* may be a potential constraint to its use at high level of supplementation. The chance of overfeeding with *Leucaena* causing mimosine toxicity appeared to be limited under farm conditions. Moreover, the risk of toxicity was reduced by producing *Leucaena* and *Gliricidia* together and offering them in a 1:1 mixture. This is a novel but easy technique.

Presence of a fermentable energy source e.g. cassava peel or tuber was found to increase the efficiency of utilization of protein rich *Leucaena* and *Gliricidia* leaves. Studies in the semi-arid region of Tanzania also showed that correlation between growth and intake of metabolisable energy was significantly higher than correlation between growth and protein intake. So, best effects on growth of weaned lambs and kids can be expected from supplements with high energy and moderate protein contents (Hai, 1988; Susuma, 1989; Mtenga and Madsen, 1992).

The potential of browse supplementation to improve animal resistance to trypanosomiasis was shown by Murray et al. (1982), ILCA (1987) and Reynolds and Ekwuruke (1988). Supplementation increased resistance in pregnant and lactating sheep, and increased offspring survival rates. Trypanosomes increase the nitrogen turnover rates of infected animals, raising maintenance requirements and hence reducing available N for the products of conception or milk production. Improved nutrition has also been shown to alleviate the consequences of *Haemonchus contortus* infection in sheep, which is a more widespread problem for small stock than trypanosomiasis (Blackburn et al., 1991).

Supplementation of a grass diet with mixed *Leucaena* and *Gliricidia* browse increased total DM intake, but substitution of browse for grass occurred particularly in the dry season when grass quality is low compared to the wet season, while browse quality remains relatively constant throughout the year. Browse intake of WAD does and kids were higher than for WAD ewes and lambs when offered the same levels of supplement, but the growth response of lambs was considerably higher. The effects on litter size and survival rates show little variation between sheep and goats but offspring growth rates differed significantly. This suggests a poor conversion of dietary nutrients to milk in the dams and/or poor food conversion efficiency in kids, as compared to ewes and lambs. No data are available from on-station trials to determine whether effects on parturition interval in goats are seen in sheep.

Periodic supplementation with limited supply of tree foliage at levels that farmers can provide, gave no significant improvement of growth performance. However, on-farm studies of farmer practice showed that herd productivity in animals receiving browse was significantly higher than for non-browse feeders because of differences in mortality rates of adult animals. On-station trials had not shown this effect on adults, probably because environmental differences on-farm includes greater disease stress. Hence, predictions of improved performance as a result of browse feeding were borne out on-farm, but not for the expected reasons. This emphasizes the need for controlled on-station trials to be confirmed by on-farm trials under farmer management. Bosman and Ayeni (1993) showed that the productivity of free roaming animals on-farm was more sensitive to disease control measures, than to measures targeted specifically at improving growth rates, whereas the reverse was true for confined animals. This confirms the observation of our own on-farm work.

Gliricidia has been used extensively as a fodder source in Central America and Asia, often from living fence lines, with significant effect on weight gains in sheep and goats (Devendra, 1993). In West Africa, *Gliricidia* accessions vary widely in palatability indicating the need for careful selection for on-farm planting. The form of feeding *Gliricidia* also appears to be important.

The benefits of browse feeding were confirmed in on-farm studies. Economic analyses have shown that in actual farm production situations, crop response to mulching is the most important determinant of whether the use of tree foliage as feed supplement is economic. Most nutritional studies with WAD goats and sheep have shown live-weight gains of 40 to 50g per kg browse (DM) supplement. At these response rates, feeding will be economic if crop yield and yield response to mulching are low. Low responses of WAD sheep and goats, particularly of goats to feed supplement remains a major limitation to the attractiveness of browse production for feeding small ruminants by smallholder farmers in West Africa (Reynolds and Jabbar, 1994). However, there may be specific market niches, such as sales of fattened animals at festival times when prices are generally high that provide the incentive to farmers to produce high quality browse feed.

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