Development and on-farm evaluation of agroforestry livestock feeding systems

FINAL TECHNICAL REPORT

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R5999 Livestock Production Programme (LPP) and

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LIST of ACRONYMS and ABBREVIATIONS

ACS	Agronomy Cropping Systems
APO	Associate Professional Officer (ODA)
ASAL	Arid and Semi-Arid Lands
CP	Crude Protein
DM	Dry Matter
EU	European Union
FRP	Forestry Research Programme
ICRAF	International Centre for Research in Agroforestry
KARI	Kenya Agricultural Research Institute
KBC	Kenya Broadcasting Corporation
KEFRI	Kenya Forestry Research Institute
LPP	Livestock Production Programme
NAFRP	National Agroforestry Research Project
NFTA	Nitrogen Fixing Tree Association (now part of Winrock International)
NRI	Natural Resources Institute
ODA	Overseas Development Administration
OFI	Oxford Forestry Institute
RRC	Regional Research Centre (KARI)
SIDA (Sida)	Swedish International Development Agency
TCO	Technical Cooperation Officer (ODA)
WREN	World Radio for Environment and Natural Resources

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R5732 FINAL TECHNICAL REPORT

Executive Summary

Project objectives

The project was designed to address Purpose 1 of the Semi-Arid System of the FRP, 'the use of trees within farming systems, including community and farm woodlots, optimised', and Output 1.1. 'improved understanding of the biological, social and economic interactions between people, animals, trees and crops incorporated into land-use strategies and promoted'.

In the original project proposal, prepared in 1992, it was planned to work in two contrasting environments, one in Kenya and the other in Malawi. The objectives were stated as follows:

- To describe existing livestock feeding systems in two contrasting agroecological zones; To determine constraints as perceived by both farmers and technicians;
- To test, with farmer participation, interventions in fodder production and livestock feeding systems in approaches ranging from on-farm, farmer-managed to on-station, researcher-controlled trials;
- To evaluate animal performance in relation to existing and improved feeding strategies.

By the time of project inception in 1994, in conjunction with ICRAF, slight modifications were made to the objectives, to take into account the changing conditions within the project area and the research results that had become available over the previous 15 months. The major change was to concentrate the research efforts in Kenya, finding the desired agroecological contrasts across the climatic and altitudinal gradients within the Embu district. The efficiency of the project could then be improved by a reduction of the involvement in Southern Africa to the provision of occasional technical support to on-going ICRAF programmes in the region. The modified objectives can then be summarized as follows:

1. To study the effects of both indigenous and exotic tree fodders on the on-farm productivity of cattle, small ruminants and poultry in both the higher potential and the arid and semi-arid lands (ASAL) of the East African Highlands.

2. To estimate the replacement value of selected tree fodders in terms of commercially available-concentrates.

3. To facilitate the availability of tree seedlings to interested farmers through collaboration with both government and non-government nurseries.

4. To disseminate results through the establishment of an efficient zero-grazing demonstration unit at the KARI station, and through farmer participation in on-farm experiments, field days and meetings.

Project Administration and Staffing

In the period from February 1994 to July 1996, a project was conducted in Embu, Kenya, to study the utilization of tree fodders by livestock within agroforestry systems. It was fully funded by the UK Overseas Development Administration (ODA), with the bulk of the money coming from the Forestry Research Programme (FRP) managed by Oxford Forestry Institute (OFI), but with additional funding from the Livestock Production Programme (LPP) and the former Agronomy and Cropping Systems (ACS) sub-programme. The project was executed by the Natural Resources Institute (NM) in collaboration with the Kenya Agricultural Research Institute (KART) and the International Centre for Research in Agroforestry (ICRAF).

Within Kenya, the project was based at the KART Regional Research Centre (RRC) in Embu, where it worked as an integral part of the wider National Agroforestry Research Programme (NAFRP), itself a collaborative programme between KARI, KEFRI and ICRAF. This allowed it to build on the farm survey and agronomic data regarding tree fodders that had been accumulated by NAFRP in the previous five years. At the start of the project, activities were restricted to the higher potential areas of the coffee-based land-use system where NAFRP operated. In the final year, work started in the areas of lower agricultural potential. This was intended to lead into an extension of the project in time and space, to address stated priorities of both ICRAF and KARL to spread agroforestry work into the drier regions down slope from Embu. This work will be the subject of a follow-on project now in preparation.

A staff member from NRI was in post from the start of the project in February 1994 until he went on terminal leave in mid-June 1996. He was supported by a Dutch associate animal nutritionist assigned by ICRAF and a counterpart KARL research officer. From November 1995, ODA provided the services of an Associate Professional Officer (APO). KARL assigned technical officers as required and ICRAF provided professional support, particularly in biometrics and social sciences. All activities were fully integrated with the extension services in the field and emphasis was placed on on-farm research. Priority animals were dairy cattle, but work was also conducted with goats and poultry.

A number of post-graduate students worked within the project and their studies were supervised or assisted by project staff. In some instances, limited funds were provided from the project to facilitate the field work of the thesis studies conducted in Embu. The programmes included four at MSc level and two at PhD level. Four of the students were from either KARL or KEFRI, while the other two came from Austria and Ireland, assigned to the project through ICRAF.

Research Activities

A series of feeding trials was conducted to test the value of *Calliandra calothyrsus* as a supplement to typical local diets of cattle, based on Napier and other fodder grasses or on grazing. In acceptability trials, a daily ration of Calliandra was fed to growing heifers at pasture for a period of 10 months. During that time, the animals averaged better than normal liveweight gains of 0.55 kg/day and showed no adverse effects that could be ascribed to the tree fodder. In on-station and on-farm feeding trials with milking dairy cattle, 3 kg of fresh *C. calothyrsus* foliage (about 1 kg DM) had the same effect on milk

yields as 1 kg of additional concentrate with 16% CP. The tree fodder increased the content of butterfat in the milk. Preliminary observations were made with other tree fodders such as *Morus alba* and *Manihot glaziovii*. These were well accepted by cattle and could make a significant contribution to daily intakes of minerals and protein. These fodder species were not present on the farms in sufficient quantities to measure their effects on animal performance. A cautious approach was adopted with the latter species because it has the potential to cause cyanic acid poisoning unless it is sun-dried before feeding. Steps were taken to introduce *Malba* onto a number of farms in the area, but detailed experiments could not be done within the time-scale of the project.

Goats are popular with farmers in the study area, apparently because of their convenient size and the ease with which they can be sold to generate cash for household needs. They are also traditionally important in the fulfillment of social obligations, but little is recorded about management practices used or the levels of production obtained. A case study was conducted over a full year on eight farms to determine these parameters. Some of the farmers were members of goat improvement groups or schemes, while others operated more-or-less independently. Some farms had local small East African breed animals while others had crosses of this breed with exotic breeds such as Alpine and Toggenburg. There was little difference between farms in the types of feed given to the goats, although the amounts on offer were more than adequate. The independent farmers generally gave more feed, so that goats therefore had a greater chance for improved diet selection than the scheme farmers. Almost all farmers gave some concentrate (either dairy meal or bran). Tree fodders were little used and there would appear to be an opportunity to study the effect on animal productivity of replacement of concentrate with cheaper tree foliage. Within the zero-grazing production system in the area, the effect of management on animal production was much more important than the effect of breed. It would appear that within the higher potential areas, either the production potential of the local animals has been under-estimated, or alternatively, the positive effects of crossing have been exaggerated. Research to clarify the position would be of great practical importance before costly mistakes are made in the promotion of improved breeding.

C. calothyrsus and *M. alba* were studied to define their possible roles as diet extenders for commercial egg production. While there was a suggestion that inclusion of the dry leaf meals at levels of 5% in the `as-fed' diets could be possible, higher inclusion levels resulted in reduction of both egg production and feed efficiency, possibly because diets could not be formulated to provide the necessary balance of nutrients. It was concluded that the use of these tree fodders for laying hens fed on commercial rations would be restricted to the provision of pigmentation to make the yolks more attractive. Leaf meals may find a place in rations based on readily available energy sources at the farm level and this could be a fruitful avenue for further research.

Farmer knowledge and use of indigenous fodder trees was surveyed across the altitudinal gradient in both Maseno (Western Kenya) and Embu. In both areas, a range of trees is fed to livestock and in Embu, seedlings and cuttings of farmers favourite species were produced. These will be offered to collaborating farmers for diagnostic plantings in the proposed further project, to confirm the species chosen, planting niches and management practices that were identified in the survey work. This will be of practical importance since some of the species which were identified from the survey are somewhat controversial (eg. *Lantana camara* which is regarded as a poisonous weed in some countries).

Agronomic work was conducted on a range of species and provenances of both exotic and indigenous fodder trees. The local landrace of C. *calothyrsus* was almost as productive as the best of a number of provenances and had the highest CP content. *Acacia angustissima* was the most productive tree in the year after establishment, but nothing is yet known about its animal production potential. While it is important to promote genetic diversity as an insurance against devastation by the arrival of new pests and diseases, it is pleasing to note that the locally available tree fodder compares well with a range of newly introduced lines.

Dissemination Activities

Since the project involved extension agents and farmers at all stages of the work, there was a large amount of spontaneous dissemination to these collaborators through constant contact. In addition to this, about 1000 visitors were received by NAFRP during the course of the project and the vast majority of these were exposed to project activities through visits to the agroforestry zero-grazing demonstration unit, which was renovated for this purpose. Project staff participated in 16 major farmer meetings, local seminars, local training attachments and international courses, and workshops and conferences to bring project activities to the widest possible audience. Excluding periodic reports, a total of 23 written contributions were prepared in a number of formats ranging from hand-outs for meetings to course notes, internal discussion documents for both ICRAF and NRI and formal papers for presentation at international workshops and for submission to journals. An interview about fodder trees for WREN radio was broadcast in Kenya by KBC. This led to a visit to the station by journalists from the local media, which resulted in a number of items in the press and on radio, citing aspects of project activities. The results have therefore been widely disseminated both in Kenya and elsewhere.

Achievements

This relatively short-term project has shown the potential for systematic incorporation of tree fodders into the diets of ruminant livestock, particularly in the higher potential areas of East Africa. The work on C. *calothyrsus* for dairy production is unique, since there are few published data available from other areas of the world. The project has contributed to knowledge regarding the efficient utilization of tree fodders and demonstrated effective techniques for on-farm experimentation with dairy cattle. It has provided several simple and effective extension messages for the improved use of tree fodders (especially C *calothyrsus)* in the diets of livestock. It has also assisted in the training of professional and technical staff from ICRAF's collaborating institutes in a number of developing countries, particularly in sub-Saharan Africa.

While it would benefit from additional research to define appropriate utilization techniques for other tree species such as the naturalized *M alba* and the indigenous *Trema orientalis,* in order to broaden the range of species, the results generated by the project in the areas of higher potential can and are being employed by extension agents and an increasing number of farmers. As a result of the way the project was planned, the work in the areas of lower potential is at a less developed stage. Further research on propagation methodologies and

management techniques would be required in order to utilize the results that have so far been obtained. It is hoped that this will be undertaken over the next three years by KARL/ ICRAF under a NAFRP proposal which has been submitted to Sida for possible funding. Further research on nutritive values and feeding systems for these fodders as proposed under the new NRI/KARI/ICRAF project is also required to complement these activities.

BACKGROUND

Farming systems

In the coffee-based land use systems of the East African Highlands, farms are small (frequently less than 2 ha) and located on steeply sloping land. The farming systems are extremely complex and intensive. Indigenous trees are commonly preserved on or near farms for a variety of purposes. In addition to this, exotic species are planted for the production of fruits, fuelwood and timber. In the Embu district of Kenya, there is an average density of about 103 trees/ha (Thijssen *et al.,* 1993) and the farms constitute examples of spontaneously developed agroforestry systems. In this area, some 30-40% of the farm is devoted to the main cash crop, coffee. Tea first appears at altitudes above about 1700 m. and above 1900 m, it totally replaces coffee as the major commercial crop. About 25-30% of the farm area is devoted to a range of food crops, including maize, beans, sweet and Irish potatoes, vegetables and fruits. These are primarily for home use, although the surplus produce finds its way into the market (Murithi *et al.,* 1993).

The remainder of the farm is usually planted to Napier or similar grasses *(Pennisetum purpureum* or hybrids of this species with P. *glaucum,* formerly known as P. *typhoides)* for feeding to both dairy cattle and small ruminants kept largely under zero grazing systems. Almost all farms have one, or up to four dairy cows, usually grade Friesian, Ayrshire or Guernsey, with some crosses between these breeds. Goats, often crosses between the local breed (small East African) with a range of exotic breeds such as Alpine, Saanen and Toggenburg, are found on most farms, while sheep are less common. The zero-grazing unit for both cattle and small ruminants is perceived by many farmers as the hub around which the farm revolves, since sale of milk provides a reliable cash flow and the manure is of vital importance in the maintenance of soil fertility for crop production. The provision of an adequate diet for the cows is of prime importance to the production system. Previous work by government and para-statal scientists (NDDP, 1980) showed that well-managed Napier grass could support milk yields of up to 7 kg/cow/day but that for higher yields, it would be necessary to supplement the animals in some way.

Previous research

Research efforts have been expended to demonstrate that herbaceous legumes, mainly *Desmodium intortum* and *D. uncinatum,* would grow well in the area and could provide the additional protein required for increased milk production. Adoption of these species by farmers has, however, been limited (Snyders *et al.,* 1992). It is believed that small land areas, scarcity and high cost of seed, establishment failures and the difficulty of managing these species when grown together with the highly aggressive Napier grass, have all contributed to limited farmer adoption of the technology. Commercial concentrates are available in the area, but moving bulky products to the farm presents a logistical problem for farmers without their own transport. Furthermore, farmers perceive concentrates to be expensive. While in international terms this is not so since 1 kg of concentrate costs less than the income from the sale of 1 litre of milk, this concept may be a reflection of the undoubted variation in feed quality that occurs from one batch to another, even from the same manufacturer.

With these considerations in mind, it was reasoned that tree fodders could provide a useful source of protein supplementation for livestock. This could be particularly attractive to farmers if the trees also served a secondary purpose such as boundary demarcation, erosion control on the steeply sloping lands, or fertility maintenance or improvement, either through nitrogen fixation by leguminous trees, or by recycling of nutrients from lower soil horizons by deep-rooted species (Minae and Nyamae, 1988).

The National Agroforestry Research Project (NAFRP) is a collaborative activity of the Kenya Agricultural Research Institute (KARI), the Kenya Forestry Research Institute (KEFRI) and the International Centre for Research in Agroforestry (ICRAF), which has largely been funded by the Swedish International Development Agency (SIDA until 1995, and Sida thereafter). It started work in the coffee-based land use system at the KARL Regional Research Centre (RRC) in Embu in 1991, where early farm surveys had shown that lack of both fodder quantity and quality, particularly in the dry seasons, were major limitations to farm productivity in the area (Minae and Nyamae, 1988).

Agronomic studies were initiated both on-farm and on-station, to identify potential tree fodder species. Three species showed initial promise, these being *Leucaena leucocephala, Sesbania sesban* and *Calliandra calothyrsus.* The first species was attracting considerable farmer attention until it was severely affected by the arrival of the Leucaena psyllid *(Heteropsylla cubana)* at the end of 1992. The pest has since also caused severe damage to *L. diversifolia,* a species which has been reported to show resistance in some areas (eg Dzowela *et al.,* 1995). Sesbania established well and was highly productive in the early stages, but did not survive frequent cutting under an intensive fodder management system. It is probably better suited for use to improve short term fallows where this is a feasible technology. The third species, *Calliandra calothyrsus,* was very productive and appeared to be resistant to most of the endemic pests and diseases (Paterson *et al.,* in press). This rapidly became the favourite with the farmers (Franzel *et al.,* in press), many of whom visited the RRC, forestry departments and other potential sources, in search of seedlings. It was therefore thought necessary to study animal utilization aspects of this and other exotic and indigenous species in order to produce recommendations regarding optimum use of tree fodders for animal production.

ICRAF as an institute is well staffed in a range of agricultural and socio-economic disciplines but has little in-house expertise in research into animal production and fodder utilization. In 1992, in recognition of the increasing importance of work on the utilization of tree fodders within the framework of the generation of appropriate agroforestry technologies for small farmers, an approach was made to the Overseas Development Administration (ODA) of the British Government, through the Forestry Research Programme (FRP) managed by the Oxford Forestry Institute (OFI). OFI in turn contacted the Natural Resources Institute (NRI) and in late 1992 an NRI consultant and an officer of OFI traveled to Kenya to assist ICRAF in the preparation of a project proposal for submission to FRP and KART. The proposed project was to be fully integrated with extension services and was to include farmer participation at all stages, to ensure that the research was appropriate for the client farmers.

The work described in this report was largely funded by FRP, but with additional funds from the Livestock Production Programme (LPP) and the Agronomy and Cropping Systems (ACS) sub-programme of the Resource Assessment and Farming Systems

Programme of ODA. The project started with the arrival in post of an NRI forage agronomist/animal scientist on 5 February 1994 and it concluded at the end of July 1996, a period of 30 months. ICRAF provided professional support, particularly in the fields of biometrics and soci-economics, while assigning a Dutch associate to work with project. KARL provided the physical base with existing office and farm infrastructure, together with counterpart and technical staff. Post-graduate students were also attached to the project, through either ICRAF or the national institutes.

PROJECT PURPOSE

The project was designed to address Purpose 1 of the Semi-Arid System of the FRP, 'the use of trees within farming systems, including community and farm woodlots, optimised', and Output 1.1. 'improved understanding of the biological, social and economic interactions between people, animals, trees and crops incorporated into land-use strategies and promoted'.

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- To describe existing livestock feeding systems in two contrasting agroecological zones; To determine constraints as perceived by both farmers and technicians;
- To test, with farmer participation, interventions in fodder production and livestock feeding systems in approaches ranging from on-farm, farmer-managed to on-station, researcher-controlled trials;
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With these objectives in mind and in full consultation with the participating institutes of NAFRP, a draft work plan was prepared for the 30 months of the project. This was the subject of a start-up workshop held on 16 and 17 June 1994, at which Provincial and District officers from government and non-government bodies involved in agriculture, livestock and forestry expressed their views. The work-plan was then finalized at the beginning of July 1994 with the help of the Head, Livestock Section of NRI, who visited Kenya for that purpose. Planned activities were based on full-time involvement of the staff member from NRI, together with most of the time of the Dutch associate expert assigned to the programme through ICRAF (all of his activities were part of NAFRP, but some were not directly related to fodder utilization) and most of the time of a KART counterpart research officer (subject to time available, considering his other RRC duties). With effect from the end of October 1995, the team was augmented by the arrival in post of an Associate Professional Officer (APO) on attachment from ODA. Technical assistants were provided by KARI for all activities, as required, for the full period of the project.

The emphasis of the work during the first 18 months was in the higher potential areas as there was a solid base of agronomic research into the production aspects of tree fodders on which to build. With the arrival in post of the APO, work in the drier, lower potential areas assumed increased importance, in accordance with the stated priorities of both ICRAF and KARI. This work will be continued under the new KARI/NRI/ICRAF project proposal.

RESEARCH ACTIVITIES

The project workplan was based on a number of assumptions, some of which proved to be false. This led to the following constraints to project activities:

- The field work for the IDRC survey of 1350 households across the region was completed during 1994, but ICRAF was unable to arrange for the analysis of the results. The crude data are available, but they have not been processed in any way. Similarly, the results of the DAREP surveys conducted in 1993 and 1994 did not become available until mid-1995. This lack of survey data delayed some project activities, particularly in the areas of lower agricultural potential.

- It was assumed that the laboratory facilities at the KARI RRC in Embu would be commissioned by the end of 1994. Despite diverse attempts by many people, no progress had been made up to June 1996, either in completing the building or in setting up alternative local facilities for feed evaluation work.

- During 1993 and 1994, many farmers in the area had difficulty in obtaining artificial insemination services for their dairy animals. This reduced the number of farms with young calves at particular times of the year. It proved to be impossible to conduct the planned evaluations of the effects of feeding of *Calliandra calothyrsus on* milk production during the wet seasons of 1995, because sufficient farms with cows at a

suitable stage of lactation could not be identified. On-farm assessments were therefore carried out only in the dry seasons of 1994 and 1995.

Each series of on-farm experiments was started with a meeting of farmers and front-line extension agents, in order to explain the objectives and to solicit the opinions of the participants regarding the proposed work. Where the farmer had a spouse, both members of the couple were invited to the meeting and occasionally where a spouse was absent, the farmer came with an adult son or daughter. Attendance was generally in excess of 70% of all invitees. In most cases, the farmers' own current practice was determined and incorporated into the experiment as the control against which to measure the efficiency of the agroforestry interventions. In a similar way, each series of experiments was ended by a further meeting of the same group, to explain the results obtained and to determine the opinions of both farmers and extensionists regarding the intervention. In this way, the farmers experienced a degree of ownership over the experiments and the extension staff were fully involved in all phases of the work. All parties were keen to cooperate and neighbouring farmers who were not involved in a particular experiment often volunteered to participate in subsequent activities. The willingness of the participants contributed greatly to the achievements of the project.

The activities and results of the project will be described under sub-headings that correspond to the modified objectives noted above.

1. Animal Production

Cattle: Because of the limited amounts of fodder available in the area, previous evaluations of feeding of *Calliandra calothyrsus* to animals, both on-farm and on-station, had been carried out for periods of just a few weeks. This led to concern that little was known about potential long-term problems that could occur due to the presence of anti-nutritive factors, particularly condensed tannins, known to occur in the foliage. It was therefore planned to conduct a formal experiment on dairy heifers to determine the effect of long-term feeding of calliandra on growth rate, conception, birthweight of calves and milk yield. Unfortunately, RRC had insufficient heifers of a comparable age to provide for a control group and efforts to borrow additional, comparable animals proved fruitless. An informal, observational trial was therefore initiated.

In July 1995, five grade Ayrshire heifers that were used to eating tree fodders, were selected at the RRC. They were kept at pasture with the dairy herd and each afternoon, they were separated into individual pens for a period of about one hour, while they were offered, as their only supplement, a ration of freshly-cut calliandra leaves and small sterns. The amount given was calculated to provide 25% of their daily dry matter (DM) intake. The refusals were weighed on a daily basis and samples were periodically taken of both the offered and the refused fodder, in order to calculate actual DM intake of the supplement. The animals were weighed every Wednesday at the same time of day (08:00 hrs) and they were observed daily to detect any health problems. The weights during each calendar month were averaged to give a mean monthly weight. These are shown in Figure 1. From December 1995, the heifers were served using semen from the same Ayrshire bull. They are expected to calve in late 1996 and KART has agreed to continue the trial, giving a daily

calliandra ration until after the animals reach the peak of lactation. This will allow assessment of the health of the calves as well as an estimation of milk yields.

Goats: As noted above, most farmers in the higher potential areas keep goats but there is little published information available on either management practices or the contribution of these animals to the farm economy. In March 1995, a case-study was initiated with a view to documenting some of these aspects of goat production. From informal, on-farm interviews, it was hypothesized that two basic dichotomies could be identified amongst goat producers: the farmers were either members of self-help, or producer-groups or they operated independently; and goats were either local breeds or they were crosses with a range of exotic breeds. In conjunction with front-line extension officers, attempts were made to identify two collaborating farmers from each of the four possible combinations of these two characteristics. This proved to be impossible because no farmers could be found who were not members of a group but had improved, crossbred goats. This might suggest that group activities seek to emphasize the desirability of breed improvement, despite the absence of concrete evidence to indicate the inferiority of local animals when kept under good management. Eight farmers were therefore chosen who fell into the categories noted below:

- group members with cross-bred goats (2 farmers)
- group members with local goats (3 farmers)
- independent with local goats (3 farmers)

At the start-up meeting, all farmers agreed to maintain full records of inputs used and outputs received from their goat enterprise for a period of a complete year. They were initially visited every few days by a technical officer who helped them to keep the records. With the passage of time, such intensive assistance was no longer necessary and the frequency of visits was gradually reduced to two per month.

At the completion of the year, the results were processed to define the resources devoted to goat production, together with the returns in terms of meat, milk and manure. This information, summarised in Table 1, was intended to be used to design research activities that would realistically address the real problems of the producer and constraints to productivity.

Poultry: There has been a reduction in the profitability of egg production in recent years as prices of commercial feeds have increased faster than the purchasing power of the consumers. Further, although there is no premium price for eggs with a good yolk colour, there appears to be general consumer dissatisfaction with the pale yolks that result from feeds based on white maize. It was reasoned that if poultry diets could be extended by the inclusion of high protein tree leaf meals, feed costs would be reduced, vitamin supplies improved, and the yolk colour of eggs improved.

A series of experiments was conducted in a small-scale, commercial battery operation to study this aspect of the feeding of laying hens. Birds were kept, two to a cage, with a bank of five adjacent cages feeding from a communal trough. A bank of 10 birds therefore made a convenient experimental unit. All banks had permanent access to fresh water. The birds were Rhode Island Red hybrids. For the first two experiments, 120 birds were used (3 replications of 4 treatments) while in the second half of their laying cycle. For the final

experiment, a replacement batch of 160 birds (4 replications of 4 treatments) was used, the work starting soon after they had reached full lay. No artificial lighting was available during the first experiments but before the start of the final one, light was supplied at night by a single, low-powered incandescent bulb, fitted at ceiling height.

In the first experiment, dried calliandra leaf meal was thoroughly mixed with commercial layers meal at inclusion levels of up to 15% (as fed). In the second week of feeding, egg production and feed efficiency (eggs/kg of feed) at the highest inclusion level declined notably and the experiment was terminated to prevent excessive losses to the commercial producer (Table 2). After a period to allow the birds to adjust again to their normal diets, the second experiment was imposed, using a different randomization to prevent any carry-over or cumulative effects from the highest calliandra inclusion. Inclusions levels of calliandra were 0, 5, 7.5 and 10% of the diet (as fed). The experiment continued for 10 weeks and during that time feed consumed and eggs produced were measured daily, average egg weights from each bank were recorded weekly and one egg was taken at random from each bank for assessment of yolk colour using a Roche colour fan. The birds were weighed fortnightly. The results are summarized in Table 3.

The first two experiments had been conducted with birds nearing the end of their productive cycles. When the producer replaced these birds with a new batch of the same breed, the opportunity was taken to confirm the results with birds in the early stages of their cycle. All available cages were full at this time and this allowed the use of four complete replicates of the same four treatments as had been used before. All other aspects of the work remained unchanged.

After a feeding period of five weeks, it became clear that the results with young birds were similar to those obtained previously. The birds were then returned to their normal diet without tree leaf meal for a period of three weeks to achieve standardization. They then returned to experimental diets where dried leaves of the common mulberry *(Morns alba)* replaced the calliandra at the same rates as before (0, 5, 7.5 and 10% as fed). The feeding period again lasted for five weeks. The results are shown in Table 4.

2. **Replacement Value**

Feed intake by heifers

Five Ayrshire heifers were used in a latin-square design to evaluate acceptance of a range of tree fodders when the animals were kept in individual pens and fed a basal diet of Napier grass. Commercial dairy meal (16% crude protein, CP) was used as the control. The trees used were the exotic species *Calliandra calothyrsus* and *Leucaena diversifolia,* together with the naturalized species *Morus alba* (mulberry) and *Manihot glaziovii* (tree cassava). Of these, soft stems and leaves of the first three were cut daily and fed fresh, while to reduce the danger of cyanic acid poisoning, the last species was sun-dried for two days before feeding only the leaves. In each case, sufficient supplement was offered to provide an estimated 25% of daily DM intake (estimated assuming total feed DM intakes of 2.5% of liveweight). Each feeding period lasted for three weeks and in the final week, the amount refused was recorded daily and weekly samples were taken for chemical analysis. All heifers were exposed to each supplementary feed. Detailed measurements

were made on the refusals in order to identify the plant parts actually consumed. Although the work was not designed to measure growth rates, animals were weighed weekly at the same time of day (08:00) to determine the amount of supplement to offer for the following week. The results are summarized in Table 5.

Milk production by cows

Two on-farm experiments and an on-station observation trial were conducted to study the replacement value of calliandra for milk production. During the dry season from August to October 1994, 12 farms (15 cows total) were involved in an experiment to estimate the replacement value of the tree fodder in terms of commercial concentrate with grade Ayrshire and Friesian cows. The farms were uniformly small, in the region of about 2 ha, with one or two cows per farm, all kept within a zero-grazed system. The basal diet consisted of Napier grass, together with an assortment of other feeds, including maize stover, banana stems and leaves, sweet potato vines, weed grasses, etc. The cows were milked twice per day, to produce an average of about 10 kg/day.

The farms were selected because of the presence of relatively large amounts of calliandra and the presence of at least one cow which had calved 3-4 months prior to the start of the experiment. Milk yield of a cow at this stage of its lactation will respond rapidly to changes in the nutritional value of the diet. Three treatments were used on all cows in a cross-over design. The feeding period was three weeks with one week of standardization followed by two weeks of measurements:

1. Control; the farmers own feeding regime, including both 1.25 kg of fresh calliandra and 2 kg of commercial dairy meal (16% CP)
2. Dairy Meal; the calliandra from treatment 1 was replaced by 0.6 kg of additional concentrate
3. Calliandra; a total of 2.5 kg of fresh tree fodder (as for treatment 1, but with an additional 1.25 kg/day of the tree foliage).

The first two treatments were designed to provide the same amount of digestible protein while the third treatment supplied more of this component. Measurements were made of daily milk yield and butterfat contents. The results are summarised in Table 6.

In an on-station trial to follow-up this work, three mature Ayrshire cows at pasture and one in the demonstration zero-grazing unit were selected. All were in their fifth, or sixth month of lactation. They were fed a daily supplement of 2 kg of commercial dairy meal for a period of four weeks, during which the daily milk yield was recorded. Following this, the concentrate was completely replaced for a further four weeks with a daily ration of 6 kg of fresh calliandra leaves, fed twice per day at the time of milking. The lack of a statistical design was regrettable but could not be avoided due to the lack of sufficient suitable animals. The results are shown in Table 7. This observational trial supported the calculated replacement value of calliandra from the first on-farm experiment.

A second on-farm, cross-over experiment was carried out on 12 farms (12 cows) in the 1995 dry season to look at the additive effects of dairy meal and calliandra on milk production. Again, all cows were subjected to all treatments but in different orders over the four periods of two weeks each (4 days standardization and 10 days assessment). Four

of the farmers who participated in the first experiment also took part in the second one, but the others could not be included because they did not have a cow in the right stage of lactation at the time. The treatments were as follows:

1. Control; farmers own feeding regime including the normal ration of from 2 to 4 kg of concentrate (16% CP) but with no calliandra
2. Calliandra; as for 1, together with 3 kg of fresh tree fodder
3. Dairy Meal; as for 1, together with an additional 1 kg of concentrate
4. Dairy Meal and Calliandra; as for 1, together with both 3 kg fresh calliandra and and additional 1 kg concentrate.

The treatment effects were small, but while the animals are genetically capable of producing higher yields, it may be that they were yielding at close to the maximum possible within the limitations of the existing management system. The results are summarised in Table 8.

3. Availability of Planting Material

Calliandra provenance trial

The locally-used landrace of calliandra was shown by isozyme analysis at OFI to have originated from Patulul in Guatemala (Joanne Chamberlain, pers. comm). While it was productive and extremely popular with farmers, at the time of selection for on-farm testing, few provenances were available from which to choose. There was no guarantee that the Patulul provenance was amongst the best for the region. An OFI regional trial was therefore established in 1994 (funded under the ODA FRP) to compare the local landrace with a range of provenances of three *Calliandra* spp. *Acacia angustissima* and some popular indigenous fodder trees were also included in the evaluation. The planting pattern simulated an agroforestry production system, with four replications in a randomized complete-block design. The trees were established from seedlings as hedgerows at an inter-row spacing of 6 m and dual-purpose sweet potatoes (tubers for human consumption and vines for fodder) were grown between the rows. After a uniformity cut some six months after planting out, the trees have been cut over two growing seasons and the harvested material separated into woody and edible (leaves and soft stems) fractions. While the work is not yet complete, preliminary data are shown in Table 9. It is being written up as the MSc thesis of a KEFRI officer, for presentation through Sokoine Agricultural University in Tanzania (Paul Tuwei, unpublished).

Surveys of fodder tree utilization

In 1995, a survey was conducted amongst farmers in three agroecological zones across the altitudinal gradient in Embu District to determine their current practices regarding the feeding of tree fodders to livestock and their favourite fodder tree species. This partially overlapped with a similar survey which was supervised by the project and conducted in Maseno (Western Kenya) as an MSc study through the University of Vienna (Anette Mayr, unpublished). Both studies were intended to identify local fodder species which were known and appreciated by farmers and which would be suitable targets for further,

detailed propagation and utilization work. Maseno is ecologically similar to Embu, but socio-economic factors vary widely between the two regions.

In the Maseno survey, 20 farms with livestock were selected in each of three agroecological zones; UM1, tea-coffee zone at altitudes between 1500 and 1800 m and with an annual rainfall of 1700 to 2400 mm; LM2, marginal sugar cane zone between 1200 and 1500 m with 1200 to 1600 mm annual rainfall; and LM4, marginal cotton zone between 1135 and 1200 m and about 1050 mm annual rainfall. On each farm, a formal questionnaire was completed, samples of preferred fodder trees were collected for identification and species were ranked by the farmers for palatability and nutritive value for cattle and goats, drought resistance and regrowth after browsing, and compatibility with crops (Anette Mayr, unpublished). The favoured species are shown in Table 10.

In the Embu work, the altitudes were slightly lower and the agroecological zones chosen were; UM2, main coffee zone, located at about 1600 m altitude and 1300 mm annual rainfall; LM3, cotton zone at about 1100 m and with rainfall of about 1000 mm; and LM5, livestock-millet zone, at 800 m altitude and about 800 mm annual rainfall. A total of 30 farms were surveyed in each zone (Roothaert and Kidundo, 1996). Most fodder trees and shrubs are periodically coppiced, although species that are used for timber are normally only pruned or pollarded in order to preserve the trunks for future use. The preferred species are summarized in Table 10.

Propagation of indigenous species for dry lowland areas

With the arrival in post of the ODA-funded APO late in 1995, the opportunity was taken to expand this work with activities designed to feed into the proposed extension of the project. A new nursery was established for the LM3 and LM5 regions at the KARI sub-station at Machang'a and the existing nursery at Embu was expanded for the UM2 region. Seeds and cuttings of the indigenous species which the Embu survey had shown to be the most popular were collected from the wild and planted in the nurseries. The data generated by this activity are summarized in Table 11. When they are ready to be transplanted into the field, the seedlings and cuttings will be offered to collaborating farmers who will select their own species, plant them wherever they like on their farms and manage them according to their own criteria. Such diagnostic plantings should provide hard information to confirm survey data on favourite species, likely planting niches and management practices. This information will be taken into account in the design of future agroforestry interventions in the area.

At the end of the period under review, a KEFRI staff member attached to RRC Ernbu, returned to Kenya from the Centre for Arid Zone Studies, University of Wales (Bangor), to conduct the field work for his MPhil study. His interest lies in the development of shrub and tree propagation techniques for use on farms in the drier areas. In consultation with project staff, he has chosen to concentrate his efforts on *Melia volkensii* and an *Indigofera* sp., species which are favoured as fodder sources and which have proven to be hard to propagate in the project nurseries. The results will start to become available from September 1996, although the thesis will not be completed until 1997, and will feed into the work of the new KARI/NRUICRAF project proposal.

4. Dissemination

The present project has carried out dissemination in a number of ways, including the use of a zero-grazing demonstration unit, meetings for farmers and extension agents, participation in ICRAF training courses and local and international meetings.

Zero-grazing demonstration unit

An existing zero-grazing demonstration unit at RRC was renovated and agroforestry technologies installed, including fodder tree hedgerows and a range of upper-storey species for fuelwood and timber. It has a total area of 1.2 ha but only about 40% of this is used to feed the animals, the remainder being used for pasture experiments. It houses two Guernsey/Ayrshire crossbred cows that are fed exclusively from the produce of the enclosed area, without purchased feeds. The diet is based on Napier grass produced from 0.35 ha, and sweet potato vines from 590 square metres, supplemented with a range of tree fodders including calliandra, *Gliricidia sepium, Leucaena* spp. and *Sesbania sesban,* together with the herbaceous legumes greenleaf desmodium *(Desmodium intortum),* silverleaf desmodium *(D.* uncinatum)and tropical kudzu *(Pueraria phaseoloides).* Slurry from the unit feeds a low-cost biogas installation and the wastes from this, together with surplus slurry are recycled to the fodder production area.

Detailed records were kept of all inputs and outputs on the unit, for a period of 18 months from October 1994 when cows were assigned, including feed consumption and the labour requirement of the various components of fodder and animal management. The data are summarized in Table 12. KARL has agreed to maintain this unit after the closure of the project. The unit is frequently visited as part of farmer and extension agent training programmes, and research meetings.

Workshops and training

As noted above, the project as a whole, and each series of experiments within it, started and ended with a meeting of farmers and extensionists, in order to discuss proposals for the work and to decide treatments and management of the individual experiments. In addition to these meetings which kept the local community fully abreast of activities, project personnel were involved in discussions with numerous visitors to the agroforestry work on the station. Interviews were given to journalists representing both print and broadcast media. Training attachments and short visits to Embu were arranged by ICRAF for a number of their national collaborators from neighbouring countries and also some further afield such as Zambia and Zimbabwe, while project scientists took part as resource persons in formal ICRAF international training courses. Post-graduate thesis programmes were supervised and papers were prepared for presentation at national and international conferences. In this way, the methodology and findings of the project were widely disseminated.

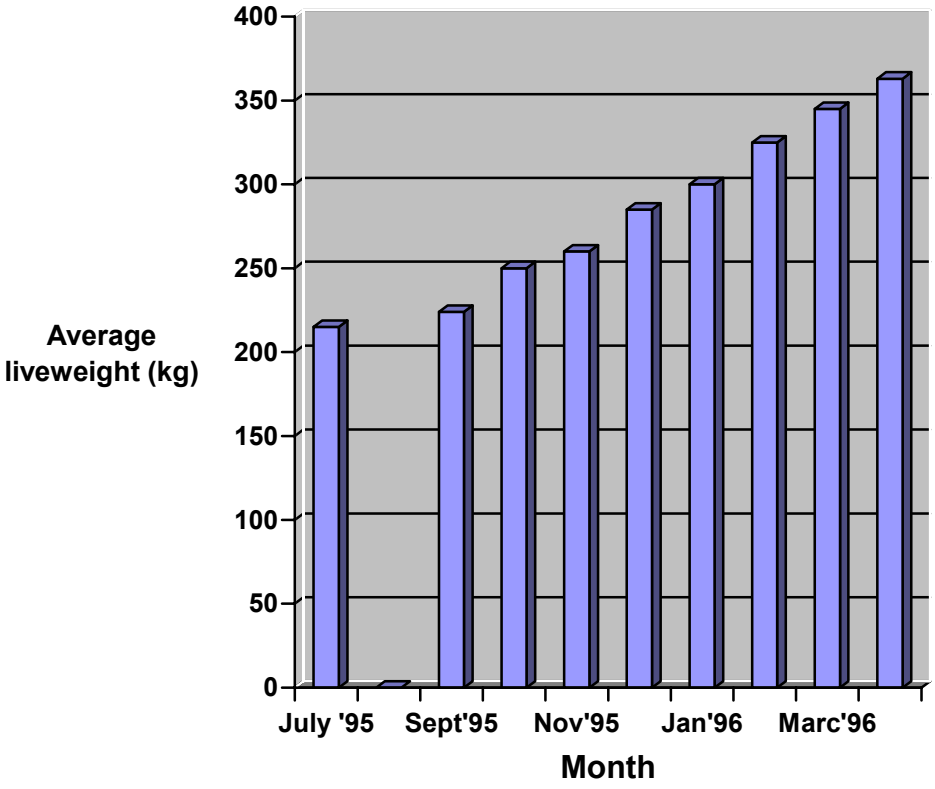
A list of published and unpublished reports produced by the project is included in Table 13.

OUTPUTS

1. Animal Production

Cattle: In the observational trial of long-term feeding of calliandra to dairy heifers, over a period of 10 months from July 1995 to April 1996, intake averaged 2.9 kg/day of fresh calliandra fodder. This provided about 1.0kg/day DM, which at an assumed daily requirement of the heifers. Monthly averages of liveweights are shown in Figure 1. the average daily gain over the 10 months of observations was 0.55 kg/day (range of individual animals 0.52 to 0.59 kg/day) and the monthly average liveweight for April 1996 was 363 kg. Two heifers were confirmed pregnant after one service, one after two and one after the third insemination. The final animal suffered what appeared to be a false heat two weeks after the first service. Her pregnancy has yet to be confirmed. No serious health problems have been noted that could in any way beattributed to the daily ration of calliandra.

Figure 1. Group mean monthly weights of five heifers fed a daily supplement of Calliandra calothyrsus



Note: weights for August 1995 are not presented because of problems with the cattle scale

Goats: The monitoring work showed that there were general similarities across farms in the sources of the fodder provided for goats. Common forages include Napier and Kikuyu grass, a range of weed grasses *(Cynodon* spp. etc.), sweet potato vines, banana leaves and pseodostems, field weeds *(Commelina benghalensis,* etc), crop residues (maize stover, bean haulms, etc.), together with household wastes. Some tree foliage was offered from avocado *(Persea americana), Lantana camara* and *Triumfetta* spp. but there was little use of exotic trees such as calliandra, or commonly cited indigenous fodder species such as *Tithonia diversifolia, Trema orientalis* or *Vernonia lasiopus,* which had been identified in earlier surveys as important fodder sources. In general, the quantities on offer appeared to be more than adequate, with luxury amounts provided by the independent (non-scheme) farmers. Most farmers supplemented these rations with dairy meal or bran. Concentrate usage did not correlate well with either breed or scheme activities, although there was a tendency for non-scheme farmers to feed less concentrate to local animals. Mineral licks were generally available and all farmers gave water *ad libitum.*

Production parameters for the goats are summarized in Table 1. These show that improved animals kept by group members were bred later at first breeding than local animals and this would influence their lifetime production, particularly as they also had long kidding intervals. Does belonging to scheme farmers had 66% twins compared to 20% on non-scheme farms. Although milk yields of non-group, local animals was lower than in the other categories, these animals suckled their kids while being milked and so the yields quoted do not fully reflect their milking potential. There was considerable variability in the yields of the individual local animals, suggesting that selection for milk yields could lead to rapid and significant improvements.

Table 1. Goat production parameters in the high potential region of Embu.

	Type of farm/breed of goat		
Parameter	group*/crossbred	group/local	non group/local
Reproduction			
age at first service (m)	21.8	17.0	12.0
gestation (d)	146	146	147
kidding interval (d)	315	270	nd
birthwt twins (kg)	2.4	2.0	1.75
singles (kg)	2.75	2.75	2.4
Milk Production			
amount (kg/d)	0.9	0.6	0.3
lactation (d)	125	128	107
Growthrate of kids (g/d)	93	nd	nd

* group members of a scheme or goat improvement group
nd not determined

In general, membership of an improvement group appeared to have a greater bearing on goat productivity than did the breed of the animals, since the production levels of the improved animals were not high. Unless reasons for this can be identified and rectified, there would seem to be little advantage to the use of cross-breeding. The results suggest that local animals are capable of relatively good production parameters when well managed.

Poultry:

First experiment: At the start of the first experiment, birds were maintained on their normal diets for a period of two weeks to determine differences between the banks of battery cages. While feed intake, egg production and feed efficiency (eggs/unit of feed) all improved in the second week, there were no significant differences between the banks and so it was not felt necessary to utilize these results as covariates in subsequent analyses. In the second week of feeding of the experimental rations, egg production from the high calliandra diet (15% inclusion) fell rapidly, even though the feed intake remained steady (Table 2). The experiment was terminated to prevent financial losses to the producer.

Second experiment: In the second experiment, levels of inclusion of calliandra were limited to a maximum of 10% of the diet as fed. Feed intake increased at the two highest inclusion levels, but this did not result in an increase in egg production (Table 3). The net result was a reduction in feed efficiency, accompanied by a small loss of weight of the birds. It was concluded that calliandra showed little potential as a diet extender for use with commercial poultry rations, even though, in view of its apparent palatability, it may still be possible to use it as the protein fraction of diets based on locally available energy sources. Further investigation of its role as an extender of commercial rations may be warranted, however, with attempts made to ensure diets fully balanced for energy and protein (noting though that this would require manipulation of some other ration ingredients). The observations that feed intakes increased in the higher calliandra diets suggest that birds might have been trying to compensate for nutrient imbalances.

Table 2. **Poultry feeding; short term observation trial: daily feed intake (kg), egg production (nos.), feed efficiency (eggs/kg of feed) and average egg weight (g). Means over 3 banks of 10 chickens fed varying levels of dried Calliandra leaf meal.**

	Uniformity Period[1]		Experiment Period		sed (+)
Week Number	1	2	3	4	
Feed Consumed (kg/10 birds/day)					
Commercial Meal	1.30	1.43	1.40	1.46	)
5% Calliandra	1.38	1.43	1.40	1.51	) 0.039
10% Calliandra	1.36	**1.48**	1.43	1.46	)
15% Calliandra	1.39	1.45	1.40	1.47	)
Eggs Produced (total from 10 birds/dav)					
Commercial Meal	6.5	6.7	6.4	6.8	)
5% Calliandra	6.9	7.5	7.4	7.7	) 0.35
10%Calliandra	7.0	7.1	6.4	6.1	)
15%Calliandra	6.4	7.4	6.8	5.9	)
Eggs per kg of feed					
Commercial Meal	4.97	4.94	5.10	4.62	)
5% Calliandra	4.69	5.23	4.75	5.11	) 0.347
10% Calliandra	4.57	5.31	4.47	4.85	)
15% Calliandra	4.66	5.08	4.17	4.04	)
Average Egg Weight (g)					
Commercial Meal		62		66	)
5% Calliandra		70		67	) 3.1
10% Calliandra		65		71	)
15% Calliandra		67		67	)

[1] For a uniformity period of two weeks, the birds were fed on their normal rations to determine existing background differences between banks. In weeks 3 and 4, the experimental rations were fed.

sed standard error of the difference between means

Calliandra showed itself to be an efficient source of pigmentation for egg yolks. Even at the lowest level of inclusion, there was a significant deepening of the yolk colour within three days of commencement of feeding. At 5% inclusion, this colour persisted for about three days after withdrawal of the calliandra, while persistence extended to 10 days at 7.5% and to 14 days at 10% inclusion. Roche colour ratings improved from 3 - 4 (pale

creamy yellow) in the control up to a very acceptable 9 (deep, orange-yellow) with the low level of calliandra. At the highest inclusion level, the rating was 11 - 12, a colour that some people find too violently orange to be attractive.

Table 3. Second poultry feeding experiment: daily feed intake (kg), egg production (nos.), feed efficiency (eggs/kg of feed), average egg weight (g) and overall average bird weight changes (g). Means over 67 days from 3 banks of 10 chickens fed varying levels of dried Calliandra leaf meal.

Treatment	Feed Intake/day, 10birds	Eggs/day, 10birds	Eggs/kg of feed	Average Egg Weight (g)	Average Bird Weight Changes (g)
Control	1.29	5.5	4.24	69.8	143
5% Call.	1.27	4.1	3.20	70.3	53
7.5% Call.	1.39	4.2	3.01	69.4	23
10% Call	1.51	5.2	3.51	69.8	-37
sed (f)	0.025	0.19	0.141	1.67	*55.2*
cv (%)	7.2	15.6	16.0	8.3	

sed standard error of the difference between means
cv coefficient of variation

Third experiment: The final poultry experiment took place with young birds over three periods, feeding, respectively, diets with calliandra (five weeks), control diets (commercial poultry feed, three weeks) in an intermediate uniformity period, and diets with *Morus alba* (mulberry, five weeks). This trial largely confirmed the results from the previous work with older birds, in that feed intake remained satisfactory and statistically similar with increasing inclusion levels, but feed efficiency fell as a result of falling egg yields (Table 4). There was no effect on egg weight and all birds, including the controls, lost a similar amount of weight during the feeding period, so this could not be attributed to the calliandra. Again the tree fodder had a marked effect on yolk colour, with Roche colour fan ratings of 10 or 11, even though this time, with a different batch of basal feed from the same manufacturer, the colour of the control was a quite acceptable 7.

Table 4. Third poultry feeding experiment: daily feed intake (kg), feed efficiency (eggs/kg of feed) and average bird weight changes per period (g). Means over 4 banks of 10 chickens fed varying levels of dried meal of *Calliandra calothyrsus* and *Mortis alba.*

Treatment period	Feed Consumed kg/10 birds/day	Eggs Produced No/10 birds/day	Feed Efficiency eggs/kg of feed	Egg Weight (g)	Yolk Colour (Roche score)	Bird Weight Changes g/period
Calliandra Period						
control	1.45	7.2	4.98	72	7.1	-125
5% calliandra	1.53	7.2	4.73	70	10.5	-123
7.5% calliandra	1.46	7.0	4.82	70	**10.8**	-90
10% calliandra	1.46	6.4	4.42	69	11.1	-128
sed	0.033	0.23	**0.168**	2.1	0.43	28.5
cv (%)	3.1	4.6	5.0	4.1	6.1	*
Uniformity Period (commercial feed only)						
control	1.25	7.6	7.57	62	4.8	-52
5%	1.35	7.9	7.85	61	5.0	-10
7.5%	1.31	7.5	7.50	61	4.8	-12
10%	1.30	7.4	7.35	62	4.8	-12
sed	0.025	0.26	0.21	1.5	0.34	18.6
cv (%)	2.7	4.9	1.7	3.4	9.9	*
Mulberry Period						
control	1.45	6.9	4.62	61	5.1	+125
5% mulberry	1.56	6.8	4.36	60	7.2	+58
7.5% mulberry	1.47	6.3	4.28	61	7.5	+100
10% mulberry	1.39	5.8	4.19	64	7.5	+60
sed	0.056	0.32	0.32	1.5	0.30	20.9
cv (%)	*3.2*	*6.7*	6.1	3.3	6.2	*

sed standard error of diftcrence
cv coefficient of variation
* cv not valid where changes can he either positive or negative

During the mulberry period, the net effects were similar, although the high inclusion level resulted in a significant reduction in egg production. Differences in feed intake and feed efficiency were not statistically significant (Table 4). Birds on all treatments gained a small amount of weight, but again, this could not be attributed to the tree fodder, since the effect

on the control was similar to that of the mulberry treatments. The tree fodder improved egg yolk colour, but the response was smaller than with the calliandra, being limited to an increase of about two units on the Roche fan.

2. **Replacement Value**

Feed intake by heifers

The tree fodders were all well accepted by the heifers. Greatest intake was measured from the mulberry, where in addition to eating the leaves, the animals also stripped the bark from the stems. Clearly this species is highly palatable and this observation has been confirmed on farm with cattle, small ruminants and pigs. While dry matter intake of the tree cassava *(Manihot glaziovii)* was lower than for the other species, the CP was both plentiful and highly digestible. Supplementation with this species resulted in the highest intake of digestible crude protein (Table *5)*.

The experiment showed that from a nutritional point of view, a number of tree fodders are capable of providing significant amounts of protein to livestock. Even though calliandra is well adapted to the region, has been well accepted by farmers and is capable of providing significant amounts of digestible protein to livestock, it is not the only candidate for this role. It may not necessarily be the best, from the point of view of the dairy cow, of the several alternative tree fodders which are presently available for use as dietary supplements.

Table 5. Dry matter and crude protein intake of dairy heifers offered a daily supplement of tree fodders, KARI RRC, Embu

Supplement	Total DMI (g/kg $LW^{0.75}$)	Estimated CP (%)	Digestibility of CP (%)	Supplement DMI (g/d at *200* kg LW)	DCP intake (g/d at 200 kg LW)
C. calothyrsus	114.2	*28*	*65*	*934*	170
L. diversifolia	116.1	*23*	*75*	884	*152*
M.*alha*	115.7	15	*85*	1184	151
M. glaziovii	114.4	*35*	*80*	771	216
dairy meal	116.9	16	*80*	1201	154
p				0.002	

DMI	Dry Matter Intake	$LW^{0.75}$	Metabolic liveweight
CP	Crude Protein	DCP	Digestible Crude Protein
p	probability of a significant difference		

Milk production by cows

First on-farm trial: Results of the first on-farm dairy experiment are shown in Table 6. Only small differences in milk yields were seen between treatments ($p>0.05$). This was expected since the nutritional differences between the rations were also small. They did, however, follow expected trends since the ration with the highest CP content (treatment 3) gave both the highest milk yield and the highest butterfat content. The results were used to calculate a theoretical replacement value of 3 kg of fresh calliandra (about 1 kg DM) equivalent to 1 kg of additional dairy meal. This relationship was tested in subsequent work both on-station and on-farm.

Table 6. Daily milk yields (kg) and average butterfat contents (%) of milk from cows in on-farm trials in Manyatta and Runyenjes, August to October 1994

Feed treatments*	Milk Yield (kg)	Butterfat Content (%)
1. Control (farmer diets)	10.1	4.0
2. Dairy Meal	10.3	4.3
3. Calliandra	10.5	4.5
sed	0.25	0.12

* treatments as defined on page 8

sed standard error of difference

On-station trial: The results of the on-station trial are shown in Table 7. Mean weekly milk yields were similar on the diets supplemented with commercial dairy meal concentrates or with fresh calliandra, which confirmed the replacement value calculated above. The trial may not, however, accurately represent the value of calliandra due to possible changes in weekly milk yields through the lactation over the course of the trial. Possible period differences could not be analysed due to the design of the trial (necessitated by the availability of animals). Period effects were small, though; as the 95% confidence limits of the difference between the two periods, calculated as 0.2 ± 0.59 kg/day, suggests. The small reduction in yield from one month to the next was consistent with cows moving into the third trimestre of their lactation curves.

Considering the results individually, one cow showed a slight reduction in milk yield, probably because she was reluctant to eat all of the calliandra on offer in the time available in the milking shed. Two other cows produced almost constant milk yields, while the last one showed a modest increase in the second period.

Table 7. Average weekly milk yields (kg) of cows fed either 2 kg commercial dairy meal or 6 kg of fresh calliandra, KARL RRC, Embu, March to May, 1995

Treatment/Week	cow 87	cow 76	cow 99	cow 111	Mean
Dairy Meal					
1	7.2	7.3	4.3	4.4	5.8
2	8.4	7.3	4.5	4.6	6.2
3	9.1	6.9	4.3	4.3	6.2
4	9.3	6.2	3.5	4,3	5.8
Mean	8.5	6.9	4.2	4.4	6.0
Calliandra					
5	8.3	6.6	4.2	4.6	5.9
6	8.4	6.3	5.5	4.8	6.3
7	7.9	4.6	5.3	4.3	5.5
8	8.1	4.2	5.2	4.3	5.5
Mean	*8.2*	*5.4*	5.1	4.5	5.8

standard error of differences between means	
between week or cow means within periods (margins)	±0.57
between overall period means	10.28
overall coefficient of variation	13.7%

Second on-farm trial: In the final experiment in this series, treatments were arranged factorially within a fully balanced cross-over design with plus and minus both calliandra and extra dairy meal. Twelve cows on twelve farms were used, with treatments as described on page 9 to test the estimated replacement value of 3 kg fresh calliandra equivalent to 1 kg of dairy meal. Results are shown in Table 8.

Treatment differences were again small, and narrowly failed to reach conventional levels of statistical significance. Nevertheless, all three trials gave similar results and this adds greatly to the level of confidence that can be felt in the making of recommendations regarding this feed resource. The calculated replacement value was again confirmed in the field. The results also showed that the effects of calliandra and dairy meal on milk production were fully additive, with no sign of an interaction. This is an important practical consideration since it shows that calliandra can be used with equal efficiency to either lower costs by replacing commercial concentrate, or to increase milk yields if used as an additional source of nutrients. Furthermore, the positive effect of calliandra on butterfat content was also confirmed. While the parastatal dairy enterprise in Kenya does not yet pay producers on milk quality, private dairies in Nairobi have recently started to offer to

the public three grades of milk, with the price scaled according to butterfat content. It therefore appears that farmers could soon be paid according to the fat content of the milk that they produce. This will provide an additional incentive to the use of calliandra on dairy farms.

Table 8. Main effects of feeding calliandra and additional dairy meal on milk yield (kg) and butterfat (%) on farms in Manyatta and Runyenjes, August to September 1995

Treatment *	Milk yield (kg)	Butterfat content (%)
Dairy meal		
no extra	10.72	3.9
1 kg extra	11.15	3.9
Calliandra		
none	10.70	3.7
3 kg	11.17	4.0
sed	0.22	0.11
cv	7.1	10.0

*	treatments as defined on page 9
sed	standard error of difference
cv	coefficient of variation

3. Availability of Planting Material

Calliandra provenance trial: The preliminary results of the provenance trial are shown in Table 9. In general, the highest yields came from the two lines of *Acacia anguslissima,* and this species clearly merits further attention in the future. *Calliandra calothyrsus* and C. *houstoniana* both performed well, but *C. juzepezukii* and the local species were less productive.

While the local landrace of calliandra was not the highest yielder of fodder in the first year of growth following the establishment period, it was third amongst the eight lines of C. *calothyrsus,* being superceded only by the provenances from San Ramon (Nicaragua) and Santa Maria de Jesus (Guatemala). It also had a higher average CP content than any other *Calliandra* provenance in the trial. While a strong case can be made for growing other provenances to widen the genetic base in the region, it is pleasing to note that the local landrace is amongst the most productive provenances in the present work.

Table 9. Total woody and leafy biomass (kg/ha) and average fodder crude protein (%) content of tree species in provenance trials over one year of two growing seasons (P. Tuwei, unpublished).

Species and Provenance	Woody biomass (kg/ha)	Leafy biomass (kg/ha)	CP of fodder (%)
Trema orientalis (Embu)	973	2254	22.7
Sapium ellipticum (Embu)	257	663	14.2
Mimosa scabrella (Rwanda)	1528	3461	**18.2**
Calliandra calothyrsus (Embu)	2136	4192	21.5
C. calothyrsus (Flores, (Guatemala)	1770	3450	18.7
C. calothyrsus (San Ramon, Nicaragua)	2357	4732	17.3
C. *calothyrsus* (Madium, Indonesia)	2051	3500	20.7
C. calothyrsus (La Ceiba, Honduras)	1828	2984	19.8
C. calothyrsus (Santa Maria de Jesus Guatemala)	2610	4631	21.1
C. calothyrsus Fortuna, Costa Rica)	1745	3579	20.6
C. calothyrsus (Coban, Guatemala)	1808	3692	20.7
Calliandra houstoniana (Rio Hondo, Mexico)	2051	4509	16.7
C *houstoniana* (La Esmeralda, Mexico)	1281	3202	17.4
C. houstoniana (Minattlan, Mexico)	1607	3440	17.2
C. houstoniana (Palenque, Mexico)	1 872	4433	16.2
C. houstoniana (Tuxtepec, Mexico)	1721	4271	16.6
Calliandra juzepezukii (Pijipan, Mexico)	1035	2210	14.4
C. juzepezukii (Pochutla, Mexico)	909	2187	14.2
C. juzepezukii (Cintalapa, Mexico)	1980	3649	15.2
Acacia angustissima (San Marcos, Guatemala)	3488	5809	20.8
A. angustissima (Volcan Salvador, El Salvador)	2993	5312	22.3

Surveys of fodder tree utilization: Results on farmer knowledge and opinions on the utilization of tree fodders derived from surveys in Maseno (W Kenya) and Embu are outlined below. A large number of indigenous fodder species were commonly utilized, usually in an opportunistic way, by farmers in both surveyed areas of Kenya. The most popular species as identified by farmers in Embu (Ralph Roothaert, unpublished) and Maseno (Anette Mayr, unpublished) are shown in Table 10.

Table 10. Farmer ranking of best fodder trees in agro-ecological zones* of Maseno and Embu

Region/ ranking	Agro-ecological zone* UM1	LM2	LM4
Maseno			
1	*Sesbania sesban*	*Lantana camara*	*Grewia trichocarpa*
2	*Lantana camara*	*Harrisonia abyssinica (for cows), Carissa edulis (for* goats)	*Lantana camara*
3	*Bridelia micrantha*	*Tithonia diversifolia*	*Rhus natalensis*
4			*Harrisonia abyssinica (for* goats only)

Region/ ranking	UM2	LM3	LM5
Embu			
1	*Triumfetta*	*Aspilia mossambicensis*	*Melia volkensii*
2	*tomentosa*	*Lantana camara*	*Crotalaria goodiiformis*
3	*Commiphora zimmermanii*	*Grewia tembensis*	*Aspilia mossambicensis*
4	*Tithonia diversifolia*	*Indigofera* sp.	*Grewia tembensis*
5	*Bridelia micrantha* *Vernonia lasiopus*	*Crotalaria goodiiformis*	*Acalypha fruit icosa*

* agro-ecological zones as defined on page 10

Note: In LM4 (Maseno), *Harrisonia abyssinica* was only reported as being good for goats. In LM2, it was rated for cows but not for goats. The reasons for this contradiction are not known.

The consistent naming of *Lantana camara* amongst the top three species in LM2-4 was surprising since this species is widely considered to be toxic, particularly to cattle. It has been suggested that the indigenous shrub may be less toxic than exotic varieties imported from India (Munyua *et al.,* 1990), although the project was unable to study this aspect within the available time-scale. The planned diagnostic plantings will indicate whether or not farmers have sufficient confidence in this species to select it for planting on their properties.

Propagation of indigenous species for dry lowland areas: Seeds of the species identified in the Embu survey were collected from the wild population during the period from January to March 1996. Some chosen species (eg. *Acacia* spp except for A. *ataxacanthe)* did not carry seeds at that time and even for those collected, this may not necessarily have been the most favourable period for seed production. The seeds were dried, treated according to farmer practice and planted in the nurseries prepared for the purpose (at Embu for upland species (agro-ecological zone UM2) and Machang'a for lowlands (zones LM3 and

LM5). The seed treatment practices and germination results are summarized in Table 11 a and b.

Table U. Summary of nursery data

11a. Provenance performance for species at Machang'a nursery

Species	Origin	Pretreatment	Germination rate (%)	Number surviving
Acacia alaxacanthe	UN site	None	72	197
	UN site	None	54	415
	Maringa's house, Kamarugu	None	50	334
	Maringa's house, Kamarugu	None	78	368
	Maringa's house, Kamarugu	None	50	180
Acalypha fruticosa	Kirima		64	531
Asp/ha mossambicensis	Kirima	None	<1	0
	Kirima	None	<1	5
	Kirima	None	<1	14
Balanites peddicellaris	Kirima	Pulp removed	14	42
	Farm by UN site	Burnt	38	164
	Farm by UN site	Boma, goat	52	292
	Farm by UN site	Chewed	46	281
	Farm by UN site	None	50	300
Crotalaria goodiiformis.	Gachoka	none	71	356
	Gachoka	none	32	139
	Gachoka	none	64	472
	Gachoka	none	25	112
Grewia bicolor	UN site	none	*	*
Herman is exappendiculata	Kirima		18	51
Indigofera sp. (mugiti)	UN site	soaked	<1	62
	Mbete South	plant in sand	3	11
	Kiamaringa	soak 24 hours	5	35
	B. Muthanje, Gachoka	scarify	<1	23
Melia volkensii	Farm by UN site	boma	*	*
	Farm by UN site	chewed		*
	Farm by UN site		*	*

UN University of Nairobi site, Machang'a
* Seeds planted but yet to germinate

Table 1 lb. Provenance performance for species at Embu nursery

Species	Origin	Pre-treatment	Germination rate (%)	Number surviving
Achryanthes aspera	Stella Gatuiri - Kivinga	remove from stem	n/a	591
Bridelia micrantha	Kiare, Njuranio, Gatanduri	none	15	*78*
Commiphora zimmermani	several locations	cuttings	42	*445*
Cordia africana	Murithi - Gatanduri (1)	none	*32*	16
		soaked	34	17
	Murithi - Gatanduri *(2)*	none	*64*	*32*
		soak *24* hrs	*22*	11
		soak 6 hrs	*40*	*20*
		soak 6 hrs and nip	*44*	*22*
	Kiringa	none	1	*2*
	Adreni Nyagah		*	*
	Stella Gatuiri	scarification - animal digestion	*	*
Ficus glumosa	Ndubai, Kiangima	cuttings	24	*37*
Lantana camara	Kangaru	cuttings	*92*	***138***
Milletia dura	several	none	*78*	954
Ocimum suave	Njeru Njagi - Mageca, Gatanduri.	none	2	11
Tithonia diversifolia	Terresio Njiru - Gatanduri	cuttings	34	*85*
Triumfetta rhomboidea		seeds removed from capsule	n/a	127
Triumfetta tomentosa	Gatanduri	seeds removed from capsule	3	9
Vernonia lasiopus	Kimithu Thabui, Kiringa. Gaturi S.	none	n/a	57

n/a not available (seed too small to count readily)
* seeds planted , germination data not yet available

There was great variability in the germination rates of some species *(eg. Milletia dura, Cord/./a africana),* while the germination rate of some species was uniformly poor *(Aspilia mossambicensis, Indigofera sp.).* However, this work was set up as a multiplication exercise rather than as a germination experiment; it is difficult to draw definite conclusions from the existing variation between seed treatments, since planting dates varied between different seed lots. Germination could therefore be influenced by seed quality and growing conditions while in the nurseries. Nevertheless, the primary purpose was achieved, since appreciable numbers of seedlings were produced from several popular tree fodder species. These will be made available to farmers for diagnostic plantings at a later stage, in order to confirm in the field, the information on preferred species, planting niches and farmer management which had been collected during the survey stage of the research continuum.

4. **Dissemination**

Zero-grazing demonstration unit: Preliminary results of the recording of performance and inputs for the two cow zero-grazing unit are outlined below. One of the cows developed an unidentified skin complaint about half way through her lactation and she was replaced in 1995. No other health problems were noted, although it proved difficult to get the other original cow into calf a second time. She was served four times before she held. This could possibly have been due to a mineral inbalance, since no salt or minerals were provided at this time. She was not dried off, however, until she was pregnant and this resulted in a lactation period of 451 days. If milking had been terminated after the usual period of 305 days, this may have led to improving body condition during the early inseminations, a state which is known to predispose towards improved fertility.

The milk production of the only cow to complete a lactation in the unit averaged 6.5 kg/day over the very extended period of 451 days. This was achieved without concentrates. It compares rather poorly with the area average of 8.3 kg/day with about 2 kg/day of commercial concentrate at 16% CP (NDDP, 1992) but this is to be expected from the calculated feed intake. The estimated daily DM intake per cow in the unit ranged between 9 and 12 kg/day. Only at the highest extreme is this likely to be adequate for a lactating cow of some 400 kg liveweight and so it is likely that the yield was limited by the amount of feed on offer.

The average time taken to perform various feed-related tasks in the unit are shown in Table 12. The data show that on a per kilogramme basis, calliandra is the most time consuming of the common fodder species, due to the need to individually cut many small branches. Even so, the difference between calliandra and other leguminous supplementary species such as desmodium is not really great. The significant effect that it has on milk production clearly outweighs the time element in the minds of the farmers, since almost all those who have planted it have taken steps to obtain more seedlings (Franzel *et al.,* in press).

Table 12. Mean time spent (hours) in routine activities involving fodder utilization on the zero-grazing demonstration unit (per stated quantities of fodder)

Time per operation (hours)	Napier Grass 120 kg	Calliandra 10 kg	Sweet Potato vines 20 kg	Desmodium 10 kg
Harvest	0.60	0.25	0.18	0.18
Transport	0.28	0.08	0.07	0.03
Chop	0.82	0.15	0.15	0.12
Total	1.70	0.48	0.40	0.33
Minutes per kg fresh fodder	0.85	**2.88**	1.20	2.00

In addition to the times shown in Table 12. feeding took, on average, 0.42 hours per day and shed cleaning a further 0.95 hours. The time spent on milking ranged from 0.47 hours when yields were 11-16 kg/d to 0.17 hours when only 3-5 kg/d were obtained. The calculated average over the whole period was 0.31 hours.

In the unit, when calves were also present, the whole operation of caring for two cows required some 5-6 hours per day. On a typical small-scale mixed farm, this is a significant demand on the available labour of the farm family. The fact that almost every farm in the area keeps dairy cows attests to the universal importance placed upon them by the local community.

Workshops and training: The major formal meetings and training events at which project staff have played a dissemination role are noted below:

- June 1994: Project start-up workshop
- August 1994: Dairy experiment start-up workshop
- August 1994: Training visit to Embu by an ICRAF collaborator from Zambia
- October 1994: ICRAF international training course
+ December 1994: Training visit by an ICRAF collaborator from Zimbabwe
- February 1995: Goat case study start-up workshop
- March 1995: Dairy experiment final workshop
- May 1995: ICRAF international training course
- June 1995: Radio interview (WREN Radio)
- July 1995: Dairy experiment start-up workshop
- October 1995: ILRI technical visit to Embu
- November 1995: Dairy experiment final workshop
- April 1996: Training visit by an ICRAF officer from Zimbabwe
- April 1996: Visit by journalists to NAFRP, Embu
- May 1996: Training meeting for divisional extensionists and subject matter specialists in fodder and animal production
- June 1996: Project concluding workshop

In addition to this list, project activities have been publicised by presentations made at the following major workshops:

- March 1995: NFTA international workshop on nitrogen fixing trees for fodder, Pune, India
- September 1995: EU-sponsored International workshop on fodder trees, Harare, Zimbabwe
- January 1996: NFTA international workshop on the genus *Calliandra,* Bogor, Indonesia
- February 1996: ICRAF international workshop on tree domestication, Nairobi, Kenya
- March 1996: First National Agroforestry Conference, Nairobi, Kenya

Publications: During the course of the project, quarterly, calendar year and annual reports were made available to the collaborating agencies in Kenya and to the management and funding agencies in UK. In addition to this, the following publications were written and distributed to interested parties. They have been listed in chronological order of preparation, as most of those submitted to journals and conference proceedings have not yet appeared in printed form.

Table 13 List of published and unpublished reports of the project

Paterson, R.T. 1994. Proposed work plan, Development and on-farm evaluation of agroforestry livestock feeding systems. Final, agreed work plans for limited circulation within both recipient and donor agencies involved in the project.

Paterson, R.T. 1994. Case study: fodder production in Embu. Lecture prepared for an ICRAF training course on Agroforestry for Development, Nairobi, Oct-Nov 1994.

Paterson, R.T. 1994. *Animal Production and Utilization Research.* ICRAF Training Notes Series, Field experimental methods and data collection in agroforestry research. Nairobi: ICRAF.

Paterson, R.T. and Mwangi, L.M. 1996. Honey fungus in agroforestry. *Agroforestry Today, 8(1):* 19-20.

Paterson, R.T. 1994. Fodder research within ICRAF: it's role and an implementation strategy. Internal ICRAF discussion document.

Roothaert, R. and Paterson, R. 1994. Standardization for the screening of new tree species (indigenous and exotic) for fodder in ICRAF projects. Internal ICRAF discussion document.

Paterson, R.T., Dzowela, B.H., Akyeampong, E., Niang, A.I. and Otsyina, R.M. 1994. A review of ICRAF work with fodder trees in Africa. To be published in *Proceedings, NFTA international workshop on multipurpose trees for fodder, Pune, India, March 1995*. Morrilton, USA: Winrock International

Paterson, R.T. 1995. The use of supplements for goat production in Eastern and Southern Africa. NRI Discussion Paper.

Paterson, R.T. 1995. Animal production activities in the drylands of Embu and Tharaka-Nithi. NRI Discussion Paper.

Paterson, R.T. 1995. Trees for livestock production in the Kenya highlands. Radio interview, World Radio for Environment and Natural Resources (WREN), broadcast in two parts, in July and August 1995.

Roothaert, R.L. and Paterson, R.T. 1995. Recent work on the production and utilisation of tree fodder in East Africa. Presented at Regional Workshop, Harare,

Zimbabwe, August 1995. To be published in a special issue of *Animal Feed Science and Technology*.

Paterson R T. 1995. Calliandra for milk production in the Embu region. For presentation at a meeting of farmers and extensionists, Embu, November 1995.

Paterson, R.T., Roothaert, R.L., Nyaata, O.Z., Akyeampong, E. and Hove, L. 1996. African experience with *Callianda calothyrsus* as a feed for livestock. To be published in *Proceedings, NFTA international workshop on Calliandra, Bogor, Indonesia, January 1996.* Morrilton, USA: Winrock International.

Roothaert, R. and Kidundo, M. 1996. Screening of indigenous fodder trees. Abstract to be published in *Proceedings, ICRAF international conference on domestication and commercialization of non-timber forest products in agroforestry systems, Nairobi, February 1996.* (Poster presentation). Nairobi: ICRAF.

Paterson, R.T., Roothaert, R.L. and Kariuki, I. 1996. Utilization of fodder trees under small-holder systems in Kenya. To be published in *Proceedings, First National Agroforestry Conference, Nairobi, Kenya, March 1996.* Nairobi: KEFRI.

Paterson, R.T., Roothaert, R.L. and Kiruiro, E. (draft) The feeding of ealliandra leaf meal to laying hens. For submission to *Animal Feed Science and Technology*.

Paterson, R.T., Kiruiro, E. and Arimi, H.K. (draft) The use of *Calliandra calothyrsus* for milk production. For submission to *Animal Feed Science and Technology*.

Paterson, R.T., Roothaert, R.L. and Kariuki, I. (draft) *Calliandra calothyrsus* and *Morus alha* as extenders in rations for poultry. For submission to *Animal Feed Science and Technology*.

Paterson, R.T., Kariuki, LW. and Roothaert, R.L. 1996. The long-term feeding of *Calliandra calothyrsus* to dairy cows. To be published in *Agroforestry Today,* **8(4)**

Mason, V. 1996. Indigenous fodder species collection and propagation. Handing-over report at the end of the project. This is being rewritten under the provisional title "Propagation of indigenous trees in Embu district-initial observations" and is expected to be published in 1997 in *Agroforestry Today,* 9(1)

Kariuki, I.W., Kiruiro, E.M. and Paterson, R.T. 1996. Goat monitoring in the high potential areas of Embu District. Research report, which the senior author intends to refine for submission, possibly to *East African Agriculture and Forestry Journal.*

Kiruiro, E.M., Kariuki, LW., Murithi, F.M. and Paterson, R.T. 1996. Input and output data monitoring at the zero-grazing model farm unit at RRC Embu: the case for dairy cattle performance on agroforestry based feeding system. Research report.

Paterson, R.T. and Kariuki, I.W. (eds). 1996. *End-of-project workshop for the ODA-funded project number R5732, ref 237. Embu,* Kenya: National Agroforestry Research Project (NAFRP).

CONTRIBUTION of OUTPUTS

1. Animal Production

The project has clearly shown that tree fodders have potential for the improvement of productivity of ruminant livestock, even though their usefulness for non-ruminants is less well defined. ICRAF work in Kenya has suggested that the true economic cost of production of calliandra fodder, including seedling production, establishment, harvesting and possible loss of crops due to competition with the trees, is of the order of KSh 4/kg DM if a productive life of eight years is assumed (Franzel *et al.,* in press). At this time, the oldest trees in Embu are about eight years and as yet show no signs of falling productivity. The effective life-span is not yet known, but could be well in excess of 10 years. The cost of production of calliandra fodder is therefore less than half the price of commercial dairy meal in the market, even ignoring the true cost of transporting bulky feeds (including the opportunity cost of the time taken to make the purchase) to the farm. In this context, if the efficiency of utilization of the tree fodder even approaches that of the purchased feeds, it will represent a highly economic practice for small farmers.

Cattle: After feeding calliandra to breeding heifers for a period of 10 months, no adverse effects on animal health or fertility were detected. Although this work is not complete, the results so far available are most promising. It was shown that for mature dairy cows, calliandra could be fed either as a replacement, or as an addition to commercial concentrate, since there was no interaction between the two feed sources in terms of milk production. Calliandra was more efficient than concentrates in terms of promoting high contents of butterfat in the milk. Thus it appears that calliandra is safe, nutritionally useful and cost-effective for use in the dairy enterprise that is of prime importance to the small scale farmers of East Africa. Together with the results on feeding values for replacement of dairy concentrates, the project has generated several important and easily communicated extension messages which are already being more widely disseminated.

Work with other tree species started later than that with calliandra and is therefore less well advanced. Nevertheless, it appears that for the high potential areas of Kenya, naturalized species such as *Morus alba* and *Manihot glaziovii* are also both productive and well accepted by cattle. They should therefore be useful alternatives which may also be employed to extend the range of genetic diversity of tree fodders in the region. It remains to study cutting management and animal utilization of these species to be able to recommend them with confidence to farmers. These activities will form part of the proposed follow-on project.

The extension services are well informed of the work that has been done to date and their enthusiasm is beyond question. The farming community suffered an obvious disappointment with *Leucaena leucocephala,* which has been uprooted from a number of farms as a result of the appearance of the leucaena psyllid in late 1992. Recent introductions of biological control measures into the Embu area by non-ICRAF activities may effect control to a sufficient level to demand a re-evaluation of this fodder species in the future, but at the moment, this is a matter for conjecture. Nevertheless, the farming community is keen to continue its collaboration in experiments with tree fodders for dairy and other animals. Further on-farm work along these lines will be easy to organize, provided that funding, personnel and transport are made available to lead the work.

Goats: Because of the general dearth of information related to the role of goats in the farming system, it was felt necessary to undertake both a literature review and a case-study to attempt to identify where research could play a part in this enterprise. Both exercises suggested that when kept under good management, the small East African goat may be more productive than hitherto recognized. It emerged that so-called `upgrading' with exotic blood had less apparent effect than improved management on a range of production parameters including birthweights and milk yields. It seems likely that selection within the existing population could have a rapid effect on milking potential of the local animals and, in view of their obviously good adaptation to the environment, selection should be encouraged at the expense of cross-breeding.

While it has been observed that some farmers feed calliandra and other selected tree fodders to goats, this was not reflected in the case-study. Athough it is recognized that goats are browsers by nature, rather than grazers, grass and crop residues formed the bulk of the rations provided to animals kept in full confinement during the year of the study. It appears that future work should establish feeding priorities and objectives with goats, before evaluating the effects on both local and crossbred animals of a range of tree fodders, including calliandra, mulberry, tree cassava and some of the preferred indigenous tree species such as *Trema orientalis* and *Vernonia lasiopus*. It should be aimed at the definition of optimum inclusion levels and combinations of tree fodders for both milk production and growth rates.

Poultry: The work so far has indicated that fodders from calliandra and mulberry may have little potential, except as sources of vitamins and pigmentation for egg yolks, for inclusion as extenders in conventional, commercial rations. This observation says nothing, of course, about the possibility of including tree fodders as the protein component of rations based on locally available energy sources. Further studies are required of the nutritive values of these feeds for poultry (more difficult to estimate than for ruminants), and of the appropriate inclusion rates and additional supplements needed to ensure balanced diets. In view of the ready acceptance of tree leaf meals by laying hens, it is believed that further studies along these lines should be conducted. There is, however, limited interest in this work from the local scientific community and it will probably be given a very low priority within the wide range of proposals for further NAFRP activities

2. **Replacement Value**

The replacement value of calliandra in milk production has been established at 3 kg of fresh foliage equivalent to 1 kg of commercial concentrate. The fodder can be fed with equal efficiency either in place of dairy meal to reduce the cost of milk production, or in addition to concentrate in order to increase the yield. Indications are that, at present, about *67%* of those farmers using calliandra are adding it to the usual ration, while the rest are using it to substitute for concentrate. Most farmers are therefore aiming to increase income, rather than to cut costs.

Mature, lactating cows in Embu readily consumed a daily ration of at least 6 kg of fresh calliandra (equivalent to 2 kg of dairy meal) in addition to the normal feeding regime based on Napier grass and crop residues, while intake levels of 8-9 kg were reported from

Western Kenya (van der Veen and Swinkels, 1993). At levels of intake of 2-3 kg per day, butterfat content is increased, while there is no sign of tainting of the milk, even at the higher levels. There is considerable flexibility in the use of the tree fodder as it is well accepted by livestock and there appears to be no need for an adaptation period.

Future work with calliandra should be aimed at defining the effect of drying of the fodder on utilization and digestibility of the fodder. Laboratory tests have shown that *in vitro* digestibility decreases rapidly on drying (Palmer and Schlink, 1992). It is necessary to confirm this effect *in vivo,* in order to determine the feasibility of storing calliandra leaf meal produced in the growing season for use in times of feed shortages, particularly in the months of July and August when the growth of calliandra is greatly reduced by low temperatures. It was not possible to address this issue during the present project, since the expected completion and commissioning of the laboratories at RRC did not take place. These were constructed during 1992 as part of a World Bank project but work stalled when they were 80% complete. Without on-site laboratory facilities, it was impossible to characterise fresh calliandra material in order to measure changes during the drying process.

No other tree fodder was tested at the same level of detail as calliandra, as this was the only species found on farms in sufficient quantity to conduct experiments on animal production. Steps were taken to introduce hedges of mulberry onto farms in the Manyatta area and it had been planned to study the effect of this fodder on the productivity of a range of small animals in the second half of 1996. This work will now be conducted as part of the follow-up project.

3. Availability of Planting Material

Taken in its widest sense, availability of planting material refers not only to quantity of seed or cuttings, but also to the appropriateness of the material on offer. This section will therefore consider the selection of species and provenances of known, characterized and recommended fodder trees.

The local landrace of *Calliandra calothyrsus* is now established on a cross-section of farms in the area and seedlings are becoming available in greater numbers as both farmers and non-government organizations join in with more traditional sources of seedlings. One or two newer provenances of this species (San Ramon, Santa Maria de Jesus) appear to be more productive that the local landrace, at least in the early stages, while there are also highly productive lines of C. *houstoniana (Rio* Hondo, Palenque) and *Acacia angustissima* (San Marcos), which could possibly thrive in areas which are too dry for C. *calothyrsus.* They may, therefore, widen the area where exotic trees could become the legumes of choice. As yet, however, nothing is known about animal acceptance and production from these alternative species. This is work that needs to be tackled as a matter of urgency, in view of their agronomic promise.

It has been shown that naturalized species such as *Morus alba* and *Manihot glaziovii* are highly productive in the region. Both of these species are easily propagated vegetatively and canes of the first have been distributed to visiting groups of farmers and also spread by extensionists, with a view to having sufficient material on farms to conduct animal

evaluations in the near future. Mulberry is one of a number of tree species which could contribute to species diversification and which could possibly complement calliandra during the period of the year when production of the latter is limited by low ambient temperatures. The project has demonstrated its potential feeding value, and the justification of further detailed feeding trials. In view of its palatability, trials with supplementary feeds for weaning calves may be justified.

Al. *glaziovii* has not yet been distributed because of fears that the known content of cyanic acid could cause stock losses. Before it is generally released to farmers, it is believed that more work should be done on-station to establish beyond doubt that sun-drying reduces the HCN content to below the toxic threshold.

Work with indigenous species will probably be of importance in the drier areas, rather than for the areas of high potential, since there are relatively few naturally-occurring trees left in the wetter parts of the region. The activities with these species are also of more recent origin and therefore are not as well developed. Consequently, apart from the establishment of seedlings that will be used for experimental purposes, nothing has yet been done to provide planting material for the areas of lower potential. It will require some years of research to define production levels and suitable management practices before recommendations can be made for the commercial-scale production of planting material for these areas.

4. Dissemination

During the course of the project, over 1000 people, including farmers, extensionists, journalists, course participants and local and international scientists, have visited NAFRP in Embu. This figure does not take into account visitors to RRC who had no interest in agroforestry. Although separate records have not been kept, the vast majority of the NAFRP guests have taken the time to see the demonstration unit, which has stimulated much interest and discussion.

In July 1995, an interview was recorded by World Radio for Environment and Natural Resources (WREN), in which tree fodders and the work of the project were discussed. This was broadcast in a number of countries in sub-Saharan Africa, including Kenya, in the latter part of that year. This led to interest by the local media in the activities at RRC, culminating in April 1996 in a visit by print and radio journalists to the centre. Further interviews, recorded by RRC staff at that time (in Swahili), have subsequently been broadcast and several items on calliandra have appeared in the local press. This publicity has generated telephonic requests for further information on tree fodders from farmers and technical staff in several parts of the country.

Within the Embu area, a recent survey (Franzel *et al.,* in press) showed the following main points with regard to calliandra:

- while first planting (1989-93) averaged 84 trees, the average in 1995 was 216 trees per farm. In many instances, this is enough to provide a significant daily supplement to one dairy cow for about half her lactation.

- after the initial planting, 82% of farmers had expanded once, 38% twice and 13% three or four times.
- the first expansion averaged 85 trees, the second 108 and subsequent expansions 156 trees. Growth is therefore exponential at this time.
- only half of the farmers obtained seedlings for expansion from projects. Others obtained seed from their own, or neighbouring farms or from commercial nurseries.
- 31% of farmers already have their own nurseries, of which two-thirds used seed from their own trees.
- 67% of farmers are currently leaving some trees for seed production
- 44% have harvested seed and each seed producer has distributed seed or seedlings to an average of 10 other farmers.

Before data were available, fears had been expressed that the extra time involved in harvesting and feeding calliandra could prevent its widespread adoption. The zero-grazing unit has shown that while it takes considerably more time to cut a quantity of calliandra than it does for the same amount of basal ration such as Napier grass, the difference between calliandra and other common leguminous supplements such as *Desmodium* spp. *is* not great (Table 12). While all the calliandra fed in the unit was chopped together with the other feeds, other work with growing heifers at RRC has shown that chopping is not necessary, since the animals will readily consume the leaves and the edible stems from the woody material if young branches are offered. Chopping of desmodium is advisable, since without it, utilization in feeding troughs can be inhibited by the presence of sticky hairs on the sterns. If chopping of calliandra is omitted, then the total time would be equal between calliandra and desmodium.

In the higher potential areas, farmers are clearly taking steps to expand their calliandra plantings for use with dairy animals and extensionists are well aware of the potential benefits of the tree. NAFRP recognizes the great potential for impact in the farming system and ICRAF is attempting to identify sources of funds for a major extension thrust to carry the story to other parts of the region. At this point in time, the greatest constraint to wider usage of the tree is the shortage of seed and its very high cost in the international market. As noted above, farmers are starting to save their own seed and ICRAF is also taking steps to produce basic seed of a few newer provenances, in order to supply small scale village nurseries. It is therefore likely that the problem of seed supply will be short-lived. Once planting sources are assured, the next problem will be to persuade farmers to plant other tree fodder species as well as calliandra, in order to prevent excessive reliance on a restricted genetic base. This would imply the need to continue the research started by the current project on alternative species such as *Morus alba, Manihot glaziovii* and a range of indigenous fodder trees including *Trema orientalis* and *Vernonia lasiopus.* Studies are particularly required on aspects of utilization by animals in order to justify the promotion of alternative fodder species.

Work in the lower potential areas is less advanced than in the region of higher rainfall. The Dutch associate to the project intends to continue with this work for a further two years, but his activities will be dependant upon the provision of adequate funding to NAFRP. It is hoped that he will be able to provide seedlings of farmer-selected fodder species for on-farm diagnostic plantings, in order to determine the niches chosen and the management

practices used. He also plans to study cutting management techniques and fodder utilization by goats, in conjunction with the University of Nairobi. The university is already active in agricultural extension in the drier areas and it is expected that this will allow a ready flow of information to the farmers in the recommendation domain, once the research results become available.

In summary, the project has made considerable progress, in terms of both research and dissemination of the results to the client farmers, who have shown unfailing enthusiasm and a great willingness to collaborate in project activities. There are obvious limitations to what can be achieved in an agroforestry project with a life of only 30 months, since trees take time to grow. There will be much greater impact if proposals for a further three years work are agreed, in order to bring to fruition some of the activities that were in the early stages, or which had not yet got beyond the planning phase. Further research and development of tree fodders can be expected to find ready acceptance by the farming community and should have a positive impact on both farm productivity and environmental protection, aspects of life which will be of increasing importance in East Africa as the population continues to grow into the next century.

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