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Economics of bullock traction use in northern Ghana

Nematode faecal egg cycles in Ethiopian sheep

Crop response to phosphate rocks in eastern Africa

Agroforestry in African crop–livestock farming systems

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Table of Contents

Preface

During the past few months ILCA has been the venue of several important meetings: in July, the leaders of livestock research and development in Africa met to discuss the Centre's Strategy and Long-term Plan, and in the following 2 months ILCA's scientists met with African and overseas livestock experts to plan the work of each research thrust outlined in the document.

ILCA now stands at the threshold of new developments which are unlikely to bypass the Publications Division. Despite our creditable record in the field of information dissemination, ILCA must refine its reporting and distribution strategy to ensure a greater impact on livestock research and development on the continent. This may involve changes which will take some time to effect; meanwhile, two comparatively minor changes of a different kind have been introduced to which we would like to draw your attention.

Like many other agricultural journals, we have decided to adhere to the SI (Le Système International d'Unités) set of units when specifying physical quantities. This will help to achieve greater consistency in measurements and to minimise the risk of numerical errors. Examples of SI units most commonly used in agricultural science are given in the "Authors' style guide" at the back of this issue. A clear explanation of SI units is offered by Prof. J. L. Monteith in a 1984 invited article in *Experimental Agriculture* (20:105–117). More detailed information on the use of SI is available in *SI – The International System of Units *,* which is an approved translation of the revised edition of BIPM's *'Le Système International d'Unités'**.*

> * Goldman D T and Bell R J (eds). 1982. *SI – The International System of Units.* National Physical Laboratory (Department of Industry) and Her Majesty's Stationary Office, UK.
>
> ** BIPM (Bureau International des Poids et Mesures). 1981. *Le Système International d'Unités (SI),* Revised edition. OFFILIB, Paris.

The second modification concerns styling of journal and conference titles: since the use of abbreviations may be an obstacle to tracking down references, all such titles will now be spelled in full.

Inca Alipui
Editor, ILCA Bulletin
Publications Division
ILCA, P.O. Box 5689
Addis Ababa, Ethiopia

The use of bullock traction technology for crop cultivation in northern Ghana: An empirical economic analysis

ANTHONY PANIN*
Livestock Economics Division
ILCA, P.O. Box 5689, Addis Ababa, Ethiopia

* Dr. Panin is currently a post-doctoral associate at ILCA. This paper is based on his research in northern Ghana for a Ph.D. in agricultural economics at Georg August University, Göttingen, Federal Republic of Germany.

Summary

THE ECONOMIC *impact of bullock traction technology (BTT) on the farming systems in northern Ghana is assessed. Crop production data were collected in three villages during the 1982/83 cropping season from 12 hoe-using and 30 bullock-using households. Comparative analysis of the hoe and the BTT farming systems indicates that BTT is technically and economically superior to hand-hoe technology, and that it offers a solution to the low agricultural productivity in the region. Households using BTT realised higher crop production and higher income compared to those using hand-hoe technology.*

Introduction

Northern Ghana is in the semi-arid zone of West Africa, and has one rainy season which normally begins in May and ends in September. It is dominated by smallholders who depend almost exclusively on the traditional hand-hoe technology for crop production, the majority of which is used for subsistence.

The unimodal rainy season, combined with the predominant hand-hoe technology, is a major problem for smallholder crop production in the region. Even though labour is abundant, availability during the short growing period is a critical constraint. Seasonal labour shortages are one of the main factors which contribute to low productivity, the primary agricultural problem in the area (NORRIP, 1982).

To increase the production of cash crops and at the same time solve the problem of seasonal labour shortages encountered by peasant farmers, BTT was introduced in the region around 1930 by the then colonial government (Kline et al, 1969). As in most parts of West Africa, the priority given to bullock traction technology for crop cultivation shifted with changes in agricultural policies. Shortly after Ghana won independence in 1957, the newly-elected Government decided that bullock traction technology did not fit its concept of modernising Ghana's agricultural sector through the use of tractors. Consequently, Government support for BTT stopped.

This policy change hindered further spread of the technology. Farmers who had already adopted BTT had problems getting spare parts, and those who were interested in adopting it had difficulty procuring equipment. However, aid agencies which were promoting BTT in the region continued to supply farmers with traction equipment purchased from neighbouring countries, but were not able to satisfy the growing demand. After long years of somewhat frustrating experiences with tractors in the region, combined with a weak economy, new attention has been directed to BTT by the Government.

Even though BTT has survived in northern Ghana since it was first introduced, and is apparently beneficial, no effort has been made to investigate its economic impact on farming systems in the region. This paper analyses data collected from farmers in parts of northeastern Ghana, and compares the traditional hand-hoe and BTT farming systems for both technical and economic efficiency. Although the data in this analysis are from a limited area, the information is valid for other areas using BTT.

The role of BTT in raising productivity

Crop production in much of the semi-arid and arid zones of Africa is affected by the unimodal rainy season and the predominant hand-hoe technology. In these areas, land preparation cannot take place during the dry season because the soils are too dry to be worked, and farmers must wait until the beginning of the rainy season before they can start land preparation.

Because the rainy season is usually short, land clearing, seedbed preparation and planting must be accomplished quickly to ensure the highest production possible. Farmers invariably face labour shortages during the limited time they have for these operations. In households where the increased labour demand cannot be satisfied, planting can be finished on time by reducing the cropped area, or the required operations are completed late. In both cases, the economic performance of the household is negatively affected.

Because bullock-using farmers can work faster on a given unit of land than the hoe households, they can use the time saved for new tasks, such as manuring, application of chemical fertilizers and thorough weed control, which are crucial to improving agricultural productivity. Moreover, they are in a better position to increase the number of crops grown on a single piece of land.

As a result of improved agronomic practices, productivity is expected to be higher under bullock farming than under hoe farming (Jäger, 1984). In areas where arable land is abundant, the time saved through BTT can be used to expand the cultivated area. Crop production will rise because of the extra output from the additional land brought under cultivation. Other benefits of changing from hand-hoe technology to any form of animal traction are reduced labour requirements per unit output and increased cropping intensity.

The study area

The data in this paper were collected in three villages (Nakpanduri, Sakogu and Gbingbalanchet) in the northeastern part of northern Ghana from April 1982 to March 1983 (Panin, 1986). These settlements are inhabited mostly by people from the Mamprusi, Bimoba and Konkomba ethnic groups. Unlike in many parts of northern Ghana, the population density in the northeast is high. Even though the exact figure is not available, there is an indication that the area is approaching population saturation (NORRIP, 1982), which is supported by Tripp (1982) who reported that the population density in some parts of northeastern Ghana exceeds 150 persons km^{-2} compared with 17 persons km^{-2} for the whole region (Central Bureau of Statistics, 1984).

The climate of the area is similar to that throughout northern Ghana. The rainy season is from June to September, and the average monthly temperature is about 30° C, with a maximum of 33° C recorded in March. The vegetation of the area is characterised by grass and scattered trees.

Farming technology is still traditional; most farmers till their land with the traditional hand-hoe, but the use of animal traction is familiar in the area. About 20% of the farming population uses BTT, but only for ridging (Panin, 1986). Bullocks are the main draught animals used by the farmers. Unlike in other parts of West Africa where animal traction studies have been undertaken, no animal traction project had ever been established in the study villages before the farmers adopted BTT for crop cultivation.

In the study area, as well as throughout northern Ghana, farmers cultivate two types of farmland; the compound farm, which surrounds the house, and bush farms, which may be located up to several kilometres from the house. The compound and the bush farming systems are based, respectively, on the principles of permanent and shifting cultivation (Benneh, 1973; Diehl and Runge-Metzger, 1985). Chemical fertilizers are known to the farmers, but are rarely used for crop production because supplies are both inadequate and irregular.

Method

During the year of investigation, data were collected from 42 randomly selected farming households. Twelve of these households were classified as hoe farmers, since they did not own draught animals and almost exclusively used the hoe for seedbed preparation. The other 30 households belonged to the animal traction group. Each had at least one pair of bullocks which were used to prepare seedbeds for almost all the cultivated land. The sample was stratified into three groups according to the experience acquired from the use of the animal traction technology in order to evaluate the impact of this experience on farmers' performance (see Panin, 1986). For this reason, the animal traction sample was purposely over represented.

The hoe sample was chosen from 492 hoe households from all the three villages. Similarly, the bullock sample was selected from 122 bullock households. Data were collected through direct measurement, observation, and formal and informal interviews. The frequency of the interviews depended on the nature of data required. During the survey period, each plot was mapped, measured, and the crops grown were recorded, as was daily labour. Household labour, non-household labour, and farming operations performed by each category were recorded separately. The labour record did not include the time spent walking to and from the fields.

Crop yield estimates were recorded in local units of measure (baskets, pans and bowls), as indicated by the households during the triweekly visits of enumerators. A sample of the containers was randomly selected and the contents were weighed to establish kg per container. Later in the analysis, total crop output of each plot was converted into kilocalories (kcal) to provide a common basis to measure the different crops grown on a plot. Yields of minor crops, and their share of total cultivated area per household, were excluded from the analysis. Minor crops were yam, cassava, sweet potatoes, okra, tobacco, aubergine and pepper.

Household income and expenses were obtained through weekly records of sales and purchases. Income from non-farm activities was recorded monthly. In order to have uniform prices for the evaluation of food purchases and sales, prices of food crops were recorded every market day. Since food commodities were sold by local volume measures, the kg equivalent of these measures was established each time the price was recorded.

Characteristics of the sample households

Both hoe and bullock households were large, polygamous, and had a high level of illiteracy. Bullock households were larger, with an average of 14.5 members compared to 10.8 in the hoe households (Table 1). When the number of workers was compared, either in terms of adults (defined as persons aged 16–55 years) or total labour capacity, bullock households had a larger labour force than the hoe households. The total labour capacity of a household was derived by using a weighting system to convert all household members from the age of six into standard man-working equivalents. The respective mean differences of household size and number of workers between the two groups of households were highly significant (Table 1).

Table 1. *Characteristics of hoe and bullock households, northeast Ghana, 1982/83.*

Characteristic	Hoe system (c.v.)[1]	Bullock system (c.v.)
Number of households	12	30
Average household size	10.8 (33)	14.5* (35)
Average age of household head	49.3 (27)	59.0* (23)
Average number of wives per household	1.3 (36)	2.1* (44)
Average number of adults per household	3.7 (32)	6.1** (44)
Total labour capacity (ME)[2]	5.8 (38)	8.9** (34)
Household composition (%)		
Males		
0–15years	31.0	27.0
16–55years	13.2	18.0
Over 55 years	3.1	5.1
Females		
0–15 years	26.4	20.4
16–55 years	21.7	23.2
Over 55 years	4.7	5.5
Formally educated 3 household members (%)	8.5	9.2
Cultivated area (ha) of which	3.7 (60)	6.4** (46)
% ridged with bullocks	8.2	74.9
% ridged with hand-hoe	39.8	3.4
% ploughed with tractor	12.1	0.5
% not ridged	39.9	21.2
Number of cattle owned	1.5 (235)	17.3** (93)
Households owning at least one cow or ox (%)	25.0	100.0

[1] c.v. = coefficient of variation (%).
[2] Derived by using a weighting system to convert all members in the household from the age of 6 years into standard man-working equivalents (ME):

	Age group (years)			
	6–9	10–15	16–55	
Male	0.25	0.85	1.00	0.61
Female	0.20	0.69	0.85	0.52

[3] Defined as having at least 6 years of primary education.
Significance levels: * = P<0.05; ** = P<0.01.

In the bullock sample, the household heads were older. The adoption of BTT correlated with the age of the household head. In the analysis, the correlation coefficient, while significant (P< 0.05), was only 0.32. Age was a principal motive for 37% of the heads to shift from hand-hoe technology to BTT. Since cattle are kept more for security than for farming, it is most likely that the household heads, who control the cattle, release bullocks for cultivation only when they are too old to use the hoe for seedbed preparation.

The average number of cattle per bullock household was 17.3 compared to 1.5 per hoe household (Table 1). While every household in the bullock sample owned at least one cow or ox, 75% of the hoe households had no cattle. With only one exception, bullock households owned cattle before adopting BTT for crop cultivation, which indicates that the first farmers to adopt BTT were those who already had cattle.

Impacts of BTT

Cultivated area

The area cultivated per hoe household ranged from 1.4 to 7.4 ha, with an average of 3.7 ha. The average area cultivated per bullock household was 6.4 ha with a range of 1.3 to 10.5 ha (P<0.01). About 75% of the cultivated area of bullock households was ridged with bullock traction compared to only 8% of that of hoe households (Table 1).

Any major increase in average cultivated area per bullock household is usually assumed to be an effect of BTT, but in many cases households using BTT have a larger labour force (Table 1), and thus the increased area may be due to a difference in scale. Because of differences in family size, the real impact of BTT on cultivated area is assessed using a land/resident ratio, i.e. a ratio that reflects the relative factor intensity of the production technology being used (Crawford, 1982).

The average cultivated area is defined both in terms of hectares per household member and per adult (Table 2). Cultivated area measured both ways was greater for bullock households. On a per member basis, the bullock farmers cultivated 20% more land than the hoe farmers, but the mean difference was not statistically significant. Per adult, the bullock households cultivated only slightly more land (4%) than the hoe households, which again was not statistically significant. These figures compare closely to the findings of Barrett et al (1982).

Table 2. *Average cultivated area per resident for hoe and bullock households, northeast Ghana, 1982/83.*

	Hoe households		Bullock households		Area difference (%)
	Area (ha)	c.v.[1] (%)	Area (ha)	c.v. (%)	
Area cultivated per household member	0.35	62	0.44	55	+26
Adult	1.01	61	1.05	56	+4

[1] c.v. = coefficient of variation.

According to the analysis, BTT did not cause any significant change in the area cultivated per adult worker. This can be traced to the individual motives of the farmers for adopting BTT: only 27% said that the ability to farm more land was a motive, while the majority of the bullock farmers reported that larger farm areas increase the demand for labour to weed and harvest the crop if the technology package does not include weeding and harvesting equipment. The correlation between total cultivated area and the annual labour input in man-hours was 0.39 ($P<0.01$) for weeding and 0.84 ($P<0.01$) for harvesting, which supports the farmers' views.

Cropping patterns

Nineteen crops were grown in the study area. Based on the percentage of the total cultivated area planted with each crop, eight are considered major in both the hoe and bullock farming systems: millet (early and late), maize, sorghum, groundnuts, cowpeas, bambara nuts and *nari* (a sesame variety) (Table 3). Millet, maize and sorghum are the major food crops in the area, while the others are cash crops, of which groundnuts are the most important.

Table 3. *Percentage of area planted to different crops by hoe and bullock households, northeast Ghana, 1982/83.*

Crop	Percentage of area planted	
	Hoe households	Bullock households
All cereal crops	79.6	73.9
Millet (early and late)	33.8	29.5
Sorghum	12.6	9.6
Maize	33.2	34.8
All cash crops	19.1	24.6
Groundnuts	10.3	17.7
Cowpeas	6.5	3.4
Bambaranuts	1.5	2.6
Nari (sesame variety)	0.8	0.9
Others[1]	1.3	1.5

[1] Okra, pepper, garden eggs (aubergine), tobacco, sweet potatoes and yams. The cultivated areas of these crops are usually very small.

There was little difference between the two groups in the area planted to the major food crops, and in both systems these crops predominated – almost 80% for the hoe households and 74% for the bullock households. The bullock households had 5.5% more land under cash crops. BTT had only a small effect on the cropping pattern and does not appear to put the staple food crops at risk.

Mixed cropping systems

The 19 individual crops were usually grown in mixtures (Table 4). Bullock households allocated slightly more land to mixed crop enterprises than the hoe households. While farmers planted between two and five crops on a piece of land, the majority of the land (64% for hoe households and 54% for bullock households) was planted to only two crops.

Table 4. *Percentage of cultivated areas planted to multiple crops, northeast Ghana, 1982/83.*

	Percentage of cultivated area	
	Hoe households	Bullock households
Number of crops planted per field		
1	19.1	13.9
2	63.6	53.6
3	6.6	21.7
4	10.7	9.1
5	0.0	1.7
All crop mixtures	80.9	86.1

Of particular interest was the crop diversification in the bullock households. The bullock households allocated as much as 33% of their total cultivated area to mixtures of three or more crops, while the area covered by such crop mixtures in the hoe farming systems was only 17%. This relatively high level of diversification among the bullock farmers is consistent with one of their reasons for adopting the technology; 60% of the bullock sample said that diversification was a motive for BTT adoption. The bullock farmers were able to achieve greater diversification than their hoe-using counterparts because of per hectare labour time saved from ridging and planting operations.

Crop yields

The effect of BTT on crop yield is not clear. Reports from experiment stations show that crop yields increase on animal traction farms (Eicher and Baker, 1982; Pingali et al, 1987), but evidence from farmers' fields indicates only modest yield increases (Lassiter, 1982). In this study, bullock households had average yields of 3327 kcal ha^{-1}, while those of the hoe farmers averaged 2861 kcal ha^{-1}, a 16% difference (Table 5: $0.01 < P < 0.20$).

Table 5. *Average crop yields[a] of hoe and bullock farms, northeast Ghana, 1982/83.*

	Average yield (kcal ha^{-1})	c.v.[b] (%)	Yield difference (%)
Hoe households	2 860.9	49	
Bullock households	3 327.2	27	+ 16.3

[a] Yields of minor crops are excluded (see Table 3, footnote).
[b] c. v. = coefficient of variation.

Regression analysis was done to determine the potential impact of BTT on crop yields at the plot level (Table 6). The analysis at this level also eliminates any underestimate of the BTT yield effect due to hoe farmers borrowing bullocks for ridging and/or to a failure of bullock farmers to ridge all their plots with BTT. Its results show that BTT had a positive impact on the level of crop yield ($P < 0.01$). This contrasts with most studies on animal traction which did not show any significant yield effect (Pingali et al, 1987).

Table 6. *Estimate of the relationship between yield of all crops from both hoe and bullock households and selected factors which influence yields[a], northeast Ghana, 1982/83.*

Independent variable	Regression coefficient[b]
Labour input (ME-h ha^{-1})[c]	0.184 (3.695)**
Seed input (¢ ha^{-1})[d]	0.000 (0.020)
Use of bullock traction (dummy, 0–1)	0.321 (8.005)**
Number of crops in a mixture	0.257 (3.496)**
Fertilizer input (kg ha^{-1})	0.013 (2.407)**
Intercept	6.243
No. of observations	249
Overall F-ratio	23.202**
R^2	0.32
Adjusted R^2	0.31

[a] Cobb-Douglas production function: dependent variable is yield per hectare of all crops measured in kilocalories.
[b] Figures in parentheses are student T-values of regression coefficients. Significance level: ** = $P<0.01$.
[c] ME-h = man-equivalent hour.
[d] ¢ = cedi (in 1982, ¢ 2.75 = US$ 1).

Labour use for field work

Total labour use per farm was greater in bullock than in hoe households (Table 7). On an average hoe-using farm, the total average annual labour input per hectare was 568 ME-hours, while on an average bullock farm it was 625 ME-hours. The mean difference was not statistically significant, but the result contrasts with those of similar studies (e.g. Barrett et al, 1982).

Table 7. *Average labour use per farm and per major farming operation, northeast Ghana, 1982/83.*

Farming operation	Hoe farms		Bullock farms	
	Av. labour[a] (ME-h ha^{-1})	c.v.[b] (%)	Av. labour (ME-h ha^{-1})	c.v. (%)
Clearing	39.9	80	48.4	55
Ridging	42.0	78	28.1 *	40
Planting	77.6	45	69.9	43
Weeding	208.9	50	229.7	73
Harvesting	192.5	43	233.2	37
Mounding[c]	0.3	268	3.1[+]	175
Fertilizer application[d]	6.7	178	12.4	279
Total	567.9	29	624.8	38

[a] Average labour is given in man-equivalent hours (ME-h).
[b] c.v. = coefficient of variation.
[c] Mounding and fertilizer application are not major farming operations in the study area. Mounding is done for yam cultivation which, unlike in other areas of northern Ghana, does not play any significant role in the study area.
[d] Fertilizer application depends on quantity and timely delivery. As observed in the study area, the supply of fertilizers was usually late, irregular and inadequate.
Significance levels: * = $P < 0.05$; [+] = $P < 0.10$.

The use of BTT significantly reduced the per hectare labour requirement for ridging from 42 ME-hours under the hand-hoe farming system to 28 ME-hours ($P < 0.05$). Per hectare labour requirement for planting was also reduced, but the mean difference was not statistically significant. On the other hand, bullock farmers had higher clearing, weeding and harvesting labour requirements per hectare than the hoe farmers. However, none of the mean differences were statistically significant.

The overall increase in labour-use intensity on the bullock farms should not be surprising, because besides ridging, which benefits most directly from the use of BTT, all the other operations are performed manually. The drop in labour input for planting is an effect of ridging, because planting or sowing is faster on ridged plots than on flat land.

Increased labour requirements for clearing, weeding and harvesting may be explained as follows:

- The shift from hand-hoe to bullock traction technology requires that land be cleared more thoroughly. The usual practice in hoe farming is to burn the vegetation and leave the stumps and roots, whereas with BTT, stumps and roots must be removed to avoid potential damage to both implements and animals. The extra work initially increases the labour per hectare to clear the land, but this effect is likely to disappear after the first 2 years.
- Deeper ridging enables both crops and weeds to grow faster, thus increasing the need for weeding on bullock farms. In addition, more diverse crops may also require more labour for weeding.
- The higher crop yields achieved under bullock farming require more harvest labour.

A linear regression analysis, which included farm size, household labour force, and the use of BTT (a dummy variable) as independent variables and labour intensity as dependent variable (Table 8), showed that overall, the use of BTT did not significantly affect the total labour input per hectare.

Table 8. *The influence of farm size, total labour capacity and bullock traction use on labour intensity, northeast Ghana, 1982/83.*[1]

Independent variable	Regression coefficient [2]
Farm size (ha)	–66.79 (–4.498)**
Household labour capacity (ME)	37.30 (2.923)**
Use of bullock traction (dummy)	56.37 (0.684)
Intercept	634.04
No. of observations	42
Overall F-ratio	7.38**
R^2	0.37
Adjusted R^2	0.32

[1] Dependent variable is total man-equivalent (ME) hours per hectare used for field work.
[2] Figures in parentheses are student T-values of regression coefficients. Significance level: ** = P< 0.01.

Variations in labour intensity are explained by the first two variables only. The regression coefficient of farm size was negatively related to labour intensity, whereas household labour capacity was positively related. The regression coefficients for both variables were highly significant (P<0.01).

Annual labour input of household members

shift from hand-hoe technology to BTT for crop cultivation changed the labour input of individual household members. On average, males in the bullock households worked more hours than their counterparts in the hoe households, even though the mean differences were not statistically significant (Table 9). The greatest increase was among elderly men (over 55 years) in the bullock households, who worked an average of 63% more hours. This is attributed to the overall increase in labour requirements for harvesting.

Table 9. *Annual labour input by household members in different sex-age categories, northeast Ghana, 1982/83.*

Sex-age category	Hoe households		Bullock households	
	Labour (ME-h $year^{-1}$)[a]	c.v.[b] (%)	Labour (ME-h $year^{-1}$)	c.v. (%)
Males				
10–15 years	142.5	158	227.0	80
16–55 years	426.1	60	450.1	54
Over 55 years	126.7	158	206.2	102
Females				
10–15 years	53.3	74	43	146
16–55 years	229.1	69	201.6	59
Over 55 years	41.1	292	75.7	129
Man equivalent of household member	290.9	49	323.9	39
Household head	401.6	42	382.7	72

[a] ME-h = man-equivalent hour.
[b] c.v. = coefficient of variation.

The annual labour input from 10–15 year-old boys in the bullock households was 59% more than that contributed by boys in the hoe households. This increase, which has also been identified by Norman et al (1981), is because with the introduction of BTT the boys are used to lead the bullocks during ridging. Active male workers (16–55 years) in the bullock households worked only 16% more hours than the same age group in the hoe households.

In contrast to boys and active men, girls (10–15 years) and active women (16–55 years) in the bullock households worked on average fewer hours than the same groups in the hoe households (Table 9). The mean differences were not statistically significant. However, the data do not confirm the view of several writers (e.g. Boserup, 1970; Tinker, 1976) that new agricultural technologies may increase women's workload and reduce those of men.

As was the case with elderly men, elderly women in the bullock households spent on average more hours working on the farm than did their counterparts in the hoe households, but the mean difference was not statistically significant (Table 9).

When all labour in a household is considered in terms of man-working equivalents, each man-equivalent in the bullock households spent on average 11% more hours working on the farm than did each man-equivalent in the hoe households. The annual labour supplied by the heads of hoe households was higher than that of the bullock household heads, which is a function of their age difference and the differences in the consumer/worker ratio, as well as in the number of adults per household (Panin, 1986).

Household income

The economic evaluation of hoe and bullock households is based on the 1982/83 farm household income statement (Table 10). Crop production is by far the largest source of household income in both farming systems, accounting for 76% in the hoe households and 73% in the bullock households. Trading, processing and gathering of agricultural produce is the next most important source of income in both types of household –20% in the hoe households and 13% in the bullock households. Income from livestock enterprises is third.

Table 10. *Summary of annual farm household income and returns to production for hoe and bullock households, northeast Ghana, 1982/83.*

	Hoe households		Bullock households	
	Income (¢)[a]	c.v [b] (%)	Income (¢)	c.v. (%)
Income				
Total gross value of crop production	79 951.7	55	152 868.7**	(45)
Value unsold	70 951.7		134 563.0	
Value sold	8 080.5		18 305.7	
(Production costs)	(7 492.8)	(60)	(11 363.6)*	(48)
Net revenue (A)	71 539.4	58	141 505.1**	48
Other net income[c] (B)	18 532.1	118	25 867.2	99
Livestock (C)	2 020.3	109	14 968.7**	74
Net farm income (A+B+C)	92 091.8	54	182 341.0**	42
Income from other sources	1887.3	161	11 587.3**	132

(D)				
Total net household income (A+B+C+D)	93 979.1	51	193 928.3**	41
Returns to production				
Returns to household labour				
Net production income				
per man-equivalent (¢ ME^{-1})a	12 630.2	45	16 728.2	46
per active worker (¢ ME^{-1})	19 708.9	45	26 371.0	51
per ME-h[e] of household labour (¢ $ME\text{-}h^{-1}$)	48.3	59	53.3	34
Net farm income				
per man-equivalent (¢ ME^{-1})	16 403.6	46	21 570.7^{+}	41
per active worker (¢ ME^{-1})	25 182.1	42	35 291.1	57
Net household income				
per man-equivalent (¢ ME^{-1})	16 850.3	44	22 794.9*	38
per active worker (¢ ME^{-1})	25 761.2	39	37 419.4^{+}	56
Returns per unit of land (¢ ha^{-1})				
Net crop production income	20 831.8	29	26 646.8*	32
Net farm income	28 824.0	46	35 513.3	34
Net household income	29 835.7	45	38 203.1^{+}	38

[a] ¢= cedi (in 1982, ¢ 2.75 = US$ 1).
[b] c.v. = coefficient of variation..
[c] Income from trading, processing and gathering agricultural produce.
[d] ME = man-working equivalent.
[e] ME-h = man-equivalent hour
Significance levels:$^{+}$ P <0.10; * = P< 0.05; **P< = 0.01.

Agricultural trading, processing and gathering is the major source of cash income in both the hoe-using (66%) and the bullock households (35%). Crop production ranks second for the hoe households (15%), but livestock enterprises are second for the bullock households (26%) (Table 11). Average net income from crop production and average total net income were higher for the bullock households.

Table 11. *Summary of annual statement of cash income for hoe and bullock households, northeast Ghana, 1982/83.*

Source	Hoe households		Bullock households	
	Net cash (¢)[a]	c.v.[b] (%)	Net cash (¢)	c.v. (%)
Crop production	3 042	326	11 190	155
Livestock enterprise	2 020	109	14 969**	74
Trading, processing and gathering of agric. produce	13 699	188	20 054	87
Other sources	1 887	161	11 587*	132
Net cash income per				
Household	20 648	(83)	57 800**	61
Household member	1 912	(82)	3 986**	50

[a] ¢ = cedi (in 1982, ¢ 2.75 = US$ 1).
[b] c.v. = coefficient of variation.
Significance levels: * = P< 0.05;** = P< 0.01.

To eliminate the influence of land and labour availability on the absolute net incomes, both systems were compared on the basis of returns to land and labour. Bullock farmers had 23–28% more income per hectare and, with one exception, their returns to labour were 32–45% higher (Table 10).

Most household income is from crop production, but only a small portion of the total harvest is sold. A summary of the annual cash income, which is relevant for the adoption of BTT, is presented for both groups of households in Table 11. Net cash income per household was ¢ 20 648 in the hoe farming system and ¢ 57 800 in the BTT system (P<0.01). On a per caput basis, the difference was still large and statistically significant (P< 0.01) – ¢ 3986 per bullock household member and only ¢ 1912 per hoe household member.

Conclusions

Comparative analysis of the hoe and the BTT farming systems in northern Ghana indicates that households using BTT realised higher crop production and higher income compared to those using the traditional technology. Farmers changed from hand-hoe technology to BTT to reduce labour bottlenecks and shorten field work time, but this was difficult to achieve because the package is limited to ridging.

It is recommended that the technological package be improved to include traction implements for sowing, weeding and harvesting. In addition, farmers should be taught to diversify the use of draught animals for other labour-intensive and time consuming household activities usually performed by women, such as transportation of water and firewood. And last but not least, government policy should be geared towards the provision of credit with reasonable repayment conditions to enable peasant farmers purchase bullocks. It is very likely that when these recommendations are followed, the adoption rate of BTT in the region will increase, and, consequently, the living standard of smallholders will improve.

References

Barrett V, Lassiter G, Wilcock D, Baker D and Crawford E. 1982. *Animal traction in eastern Upper Volta: A technical, economic and institutional analysis.* International Development Paper No. 4. Michigan State University, East Lansing.

Benneh G. 1973. Land tenure and farming systems in a Sissala village in northern Ghana. *Bulletin de l'IFAN* (Dakar) 2:361–379.

Boserup E. 1970. *Women's role in economic development.* St. Martin's Press, New York.

Central Bureau of Statistics. 1984. Population census of Ghana: Preliminary report. CBS, Accra.

Crawford E W. 1982. *A simulation study of constraints on traditional farming systems in northern Nigeria.* International Development Paper No. 2. Michigan State University, East Lansing.

Diehl L and Runge-Metzger A. 1985. Formen gartenartiger Landwirtschaft in Nord-Ghana. *Entwicklung + ländlicher Raum* 19(4):13–16.

Eicher C K and Baker D C. 1982. *Research on agricultural development in sub-Saharan Africa: A critical survey.* International Development Paper No.l. Michigan State University, East Lansing.

Jäger K J. 1984. Animal traction and resource productivity: Evidence from Upper Volta. In: C B Flora (ed.), *Animals in the farming systems.* Proceedings of the Third Annual Farming Systems Research Symposium held at Kansas State University from 31 October–2 November 1983. Kansas State University, Kansas. pp. 431–460.

Kline C K, Green D A G, Donahau R H and Stout B A. 1969. *Agricultural mechanisation in equatorial Africa.* Institute of International Agriculture Research Report No. 9. Michigan State University, East Lansing.

Lassiter G C. 1982. The impact of animal traction on farming systems in eastern Upper Volta. Ph.D. dissertation. Deptartment of Agricultural Economics, Cornell University, Ithaca, New York.

Norman D W, Newman M D and Ouedradago I. 1981. Farm and village production systems in the semi-arid tropics of West Africa. *ICRISAT Research Bulletin* No. 4 (Vol. 1).

NORRIP (Northern Region Rural Integrated Program) Technical Unit. 1982. Draft report: Regional development strategy for the Northern Region. NORRIP, Tamale, Ghana.

Panin A. 1986. A comparative socio-economic analysis of hoe and bullock farming systems in northern Ghana. Ph.D. dissertation. Department of Agricultural Economics, Georg August University, Göttingen, F.R.G.

Pingali P L, Bigot Y and Binswanger H. 1987. *Agricultural mechanisation and the evolution of farming systems in sub-Saharan Africa.* Johns Hopkins University Press, Baltimore.

Tinker I. 1976. The adverse impact of development on women. In: I Tinker, M Bransen and M Buvinic (eds), *Women and world development, with annotated bibliography.* Praeger, New York. pp. 23–34.

Tripp R B. 1982. Time allocation in northern Ghana: An example of the random-visit method. *The Journal of Developing Areas* 16:391–400.

Seasonal changes in nematode faecal egg counts of sheep in Ethiopia

TEKELYE BEKELE, E. MUKASA-MUGERWA and R. G. SCHOLTENS
ILCA, P.O. Box 5689, Addis Ababa, Ethiopia

SUMMARY

FROM JULY 1985 *to June 1986, 651 faecal samples were collected from sheep slaughtered at the Addis Ababa abattoir and analysed to determine the quantity of eggs per gram of faeces (epg) produced by gastrointestinal nematodes in different months. The epg peaked in August 1985 and March 1986, roughly during the two rainy seasons in Ethiopia. Faecal egg counts reflect nematode transmission levels in host populations and the recent level of infective larval population on pastures. The data suggest that strategic treatment of sheep with anthelmintics in June and January is most likely to reduce the shedding of ova at critical periods and minimise transmission levels during the rainy seasons.*

INTRODUCTION

sheep population of Ethiopia is estimated to exceed 23 million (FAO, 1986). They are hosts to multiple species of gastrointestinal helminths (FAO, 1968; London University, 1971; Scott et al, 1974; Graber, 1978). These parasites cause diarrhoea, anaemia, reduced weight gains, increased mortality rates and increased production costs (Barger, 1982). There are few reliable estimates of the true economic significance of gastrointestinal helminths in African countries (Akerejola et al, 1979; Bahru Gemechu and Ephraim Mamo, 1979).

principal gastrointestinal nematodes of sheep in Ethiopia have been described by FAO (1968) and Graber (1978). Surveys at the Addis Ababa abattoir from October 1979 to March 1980 found high numbers of infested sheep. *Trichostrongylus colubriformis* (89%), *Trichuris barbetoensis* (83%), *Haemonchus contortus* (67%), *Oesophagostomum columbianum* (53%) and *Bunostomum trigonocephalum* (34%) were the most prevalent species (Bekele Mamo et al, 1982).

control of gastrointestinal nematodes is possible only after surveillance has provided enough information to understand the prevailing epidemiological factors influencing transmission (Armour, 1980; Schwabe, 1980). This paper describes the seasonal pattern of nematode faecal egg counts from mid-1985 to mid-1986 and suggests possible strategic measures for the control of gastrointestinal nematodes of sheep in central Ethiopia.

MATERIALS AND METHODS

Specimens for this study were acquired from sheep slaughtered at the Addis Ababa abattoir from July 1985 to June 1986. Twenty faecal samples were collected weekly from the rectum of slaughtered sheep and kept overnight at 4–8°C. The next morning, the number of nematode eggs per gram of faeces was determined using the McMaster technique with saturated sodium chloride as a flotation solution (Soulsby, 1982).

age, sex and origin of the slaughtered sheep were recorded during sampling. Meteorological data for the study period were obtained from the National Meteorological Services Agency of Ethiopia and from ILCA records. Mean monthly rainfall values were calculated for those areas from which the sheep originated.

RESULTS

Most slaughtered sheep were adult females; only a few males and young animals were seen. The sheep came from the mid northern and central parts of Ethiopia, particularly Wello, Arsi and Shewa administrative regions, which agrees with findings reported by Getachew Asamenew (1977).

Strongyle and trichostrongyle faecal egg counts for each month of the study are given in Table 1. Most sheep were infested. The mean monthly counts peaked in August 1985 (5020 epg) and in March 1986 (2914 epg). Following these peaks, they progressively decreased to 912 epg in December 1985 and to 1416 epg in June 1986. The overall annual mean epg per animal was, 2351. The proportion of infested animals was lowest (78%) when epg rates were lowest (December 1985), and highest (96–100%) when epg rates were highest (July–August 1985).

Table 1. *Strongyle and trichostrongyle faecal egg counts, Addis Ababa abattoir, July 1985–June 1986.*

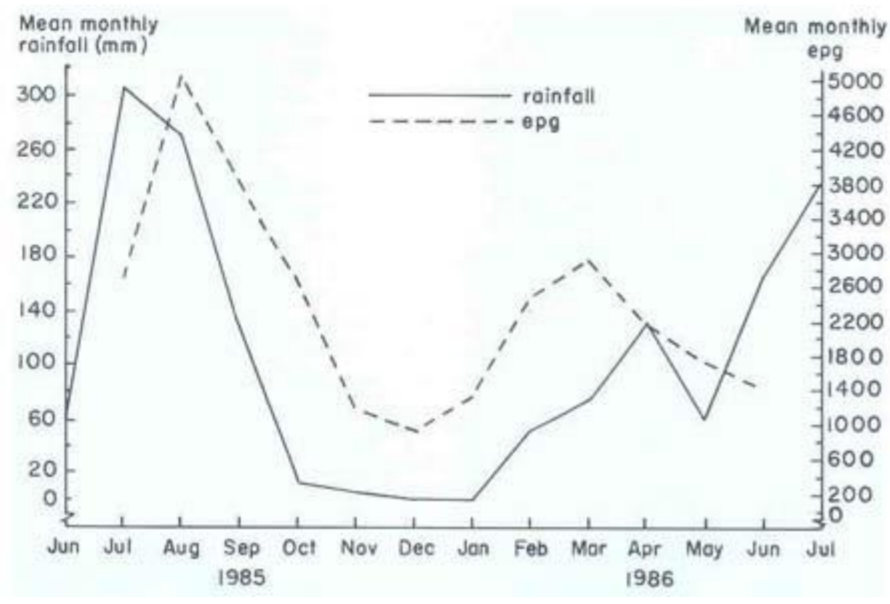
Year/month	No sheep examined	Mean monthly epg	Range (min-max)	No. sheep with positive egg counts	Percentage positive
1985					
July	39	2682.1	200–12 200	39	100.0
August	29	5020.7	0–40 800	28	96.5
September	30	3780.0	0–29 600	28	93.3
October	56	2664.3	0– 7 600	48	85.7
November	59	1169.5	0– 7 000	48	81.3
December	78	912.8	0– 5 000	61	78.2
1986					
January	36	1305.6	0– 6 800	32	88.8
February	43	2469.8	0– 8 800	38	88.3

March	84	2914.3	0–15 000	80	95.2
April	40	2160.0	0–31 400	35	87.5
May	79	1726.6	0–19 800	75	94.9
June	78	1416.7	0– 9 900	69	88.4
Mean	54.3	2351.9		48.4	89.9

The free-living stages of each nematode species require optimum temperature and humidity to develop; however, all thrive better in moist rather than dry environments. In Arsi and Shewa regions, temperature variations ranged from an average minimum of 10.0°C to an average maximum of 21.8°C during July 1985 to June 1986. There was no record available for Wello region.

Ethiopia has two rainy seasons. The long rains extend from July to September and the short rains are usually from March to April. Figure 1 shows the relationship between rainfall and faecal egg output during the period of this study.

Figure 1. *Correlation of mean monthly rainfall[a] with mean monthly epg counts, June 1985–July 1986.*



[a] For Arsi, Shewa and Wello administrative regions.
Source: National Meteorological Services Agency (Ethiopia) and ILCA.

DISCUSSION

Different factors influence the egg output of gastrointestinal nematodes. These include the age of the host, the species and age of the nematode population, the overall health of the host (including the nutritional level), and physiological factors such as pregnancy and previous exposure to parasites. In addition, epg measurements can be affected by the volume and consistency of faeces. Due to these factors, the epg of faeces is not always directly correlated with the number of gastrointestinal nematodes in a host. It is therefore an index of little value for individual animals, but becomes increasingly useful as larger populations are studied.

Roberts and Swan (1981) found a quantitative correlation between worm count and epg on a flock basis in ovine haemonchosis. Barger (1982) used epg as an index to determine the degree of pasture infestation with nematode ova. Vercruysse (1983) used the seasonal changes of nematode faecal epg counts to suggest periods of strategic treatment for sheep in Senegal.

The ova of different nematode genera can be divided into two broad groups, depending on whether or not they can be distinguished from one another. The first group includes strongyles and trichostrongyles, whose ova are similar. The second group comprises those species whose ova can be easily identified—*Ascaris, Trichuris, Nematodirus* and *Strongyloides.* For the quantitative determination of epg, all eggs were counted except those of *Trichuris* spp. This was done partly because the life cycle and effects of *Trichuris* are different than for most other gastro-intestinal parasites, and partly because the eggs are only partially recoverable with the technique used.

The peaks in the epg counts coincided with the two rainy seasons. The peak during the long rains was higher than the short-rain peak count. The epg associated with the short rains increased as the short rains approached, but peaked before the rainfall, which may be due to the uneven rainfall' distribution during this season. The epg after both peaks showed a progressive decline corresponding to the reduction in rainfall. The dry months of November, December and January had the lowest epg counts.

When climatic conditions become favourable, more nematode larval stages develop in the environment and the level of infestation rises. Larvae in a state of arrested development within the host also resume development when external environmental conditions improve (Dunn, 1978; Armour, 1980). Both factors cause the epg to increase. Some helminths, such as *Haemonchus contortus,* which are highly prolific during a short generation interval, can multiply faster and cause heavy pasture infestation (Lapage, 1968; Dunn, 1978). This may account for the rapid increase in epg immediately after the rains start (Vercruysse, 1983).

Ova are shed throughout the year. Lower epg counts during the dry months are due to arrested development and reduced infestation rates. Since adult nematodes are responsible for pasture infestation and renewed transmission of parasites during favourable periods, treatment that reduces this reservoir can greatly reduce the effects of nematode parasites.

Two strategic treatments with broadspectrum anthelmintics, one in June and the other in January, would appear to be most effective. These treatments could reduce the worm burden and minimise pasture infestation with ova. It is only with carefully timed and rational use of anthelmintics that effective control can be expected (Michel et al, 1981). Irregular, frequent or indiscriminate use of anthelmintics can promote the development of resistance (Donald and Waller, 1982).

Although the use of anthelmintics is expensive and not widely applicable in Africa, carefully planned strategic treatment of flocks rather than individual animals can reduce parasite transmission rates and help keep the host–parasite relationship within reasonable bounds. However, it is advisable to remember that although "effective chemotherapy is available for most helminth diseases, because of their complex epizootiology it is paradoxically simple to treat the individual but almost impossible to control the disease" (Allonby, 1980).

REFERENCES

Akerejola O O, Schillhorn van Veen T W and Njoku C O. 1979. Ovine and caprine diseases in Nigeria: A review of economic losses. *Bulletin of Animal Health and Production in Africa* 27:65–70.

Allonby E W. 1980. Strategies and costs of helminth control with indications for research. In: *Impact of animal disease research and control on livestock production in Africa.* Proceedings of the conference held in Nairobi, September 1980. OAU/ILRAD/ ILCA/DSE, Berlin. pp. 135–140.

Armour J. 1980. The epidemiology of helminth disease in farm animals. *Veterinary Parasitology* 6:7–46.

Bahru Gemechu and Ephraim Mamo. 1979. A preliminary survey of bovine fascioliasis in Ethiopia. *Ethiopian Journal of Agricultural Science* 1(1):5–12.

Barger I A. 1982. Helminth parasites and animal production. In: L E A Symons, A D Donald and J K Dineen (eds), *Biology and control of endoparasites.* Academic Press, Sydney. pp. 133–155.

Bekele Mamo, Shibru Tedla and Feseha Gebre-Ab. 1982. Survey of gastrointestinal helminths in sheep slaughtered at the Addis Ababa abattoir, Ethiopia. *Ethiopian Journal of Agricultural Science*4(2):87–94.

Donald A D and Waller P J. 1982. Problems and prospects in the control of helminthiasis in sheep. In: L E A Symons, A D Donald and J K Dineen (eds), *Biology and control of endoparasites.*Academic Press, Sydney. pp. 157–186.

Dunn A M. 1978. *Veterinary helminthology.* William Heinemann Medical Books, London. 323 pp.

FAO (Food and Agriculture Organization of the United Nations). 1968. Report to the Government of Ethiopia on veterinary parasitology survey. FAO, Rome. 38 pp.

FAO. 1986. *Monthly bulletin of statistics,* Vol. 9. FAO, Rome. 68 pp.

Getachew Asamenew. 1977. The organisation of meat market in Addis Ababa. ILCA, Addis Ababa. 59 pp.

Graber M. 1978. Helminths and helminthiasis of domestic and wild animals in Ethiopia Vol. l. Institut d'élevage et de médecine vétérinaire des pays tropicaux, Maison Alfort, France. 200 pp.

Lapage G. 1968. *Veterinary parasitology.* 2nd ed. Oliver and Boyd, Edinburgh and London. 1182 pp.

London University. 1971. A veterinary survey of cattle and sheep in Jijiga, Harar and Tigre provinces and in the Addis Ababa Dairy Development Project (Ethiopia). London University, Royal Veterinary College/Ethiopian Research Team. 131 pp.

Michel J F, Latham J O, Church B M and Leech P K. 1981. Use of anthelmintics for cattle in England and Wales during 1978. *Veterinary Record* 108:252–258.

Roberts J L and Swan R A. 1981. Quantitative studies of ovine egg counts and total worm counts. *Veterinary Parasitology* 8:165–171.

Schwabe C W. 1980. Animal disease control, Part 2: Newer methods, with possibility for their application in the Sudan. *Sudan Journal of Veterinary Science and Animal Husbandry* 21(2):55–65.

Scott J M, Pegram R G, Wubeshet Ambaye, Abebe Tessema and Turungo Tessema.1974. Debre Berhan experimental sheep station (Ethiopia). Report made to the Ministry of Agriculture. Shoa Province Veterinary Investigation Laboratory, Ethiopia. 19 pp.

Soulsby E J L. 1982. *Helminths, arthropods and protozoa of domesticated animals.* 7th ed. Lea and Febiger, Philadelphia. 809 pp.

Vercruysse J. 1983. A survey of seasonal changes in nematode faecal egg count levels of sheep and goats in Senegal. *Veterinary Parasitology* 8:165–171.

Literature review and economic analysis of crop response to phosphate rocks in eastern Africa

EDJIGAYEHU SEYOUM and JOHN McINTIRE
Livestock Economics Division
ILCA, P.O. Box 5689, Addis Ababa, Ethiopia

SUMMARY

DIRECT APPLICATION *of ground phosphate rock to crops grown on acid soil is a simple and low-cost method of substituting refined phosphates, especially if the rock is locally available. The relative agronomic and economic effectiveness of phosphate rocks has been examined using data from the literature and from ILCA trials in the Ethiopian highlands.*

In general, phosphate rocks gave lower agronomic responses than refined phosphates, but the yields were well above the control. Although the residual effects of phosphate rocks improved yields in 70% of cases, they were rarely large enough to make the use of rock more profitable than that of refined phosphates. The economic effectiveness of phosphate rocks could be improved by using more concentrated rock, which would reduce transportation and other related costs.

INTRODUCTION

Increased demand for costly phosphatic fertilizers to improve crop yields necessitated the identification of different phosphate sources as alternatives to refined phosphate (RP) in eastern Africa. One of the first steps was to exploit the large deposits of a primary phosphate (francolite) in Uganda, near the Kenya border. Research on phosphate rock (PR) began in the region in the 1940s (cf EAAJ, 1949; EAAFRO, 1948, 1950, 1951). Some results suggested that direct application of ground phosphate rock could replace refined phosphate on acid soils, especially if the rock is locally available. Haque and Jutzi (1985) came to the same conclusion in Ethiopia.

The literature was reviewed to put available results in a general context and to evaluate them economically. The review sought to answer three questions: What is the performance of phosphate rock compared with other phosphates? What are the conditions under which it raises yields? Is it profitable to use it? The review is supplemented by estimates of responses to rock and other phosphates in trials conducted by ILCA in the Ethiopian highlands.

STUDIES ON PHOSPHATE ROCKS IN EASTERN AFRICA

Previous reviews

Duthie and Keen (1953) reviewed crop responses to fertilizers and manures in East Africa (Table 1). Nearly all of the work reported was on cereals, much of it from Kenya, and most of the phosphate studied was Uganda rock phosphate (URP) or sodaphosphate (SOP), a processed form of URP.

Table 1. *Sources for the review of phosphate effects on crop production in eastern Africa.*

Literature source[1]	Area or country	Crop	Phosphate source[2]
Duthie and Keen (1953)			
Jones G H G	Kenya	Mainly wheat	URP, SOP, SP
Doughty L R	East Africa	Cereals	SOP, URP, SP
Holme R and Sherwood E G P	Kenya	Wheat, maize	URP, SOP, SP
Bellis E	Kenya	Wheat, maize	SOP, SHP
Kroll U	Kenya	Pyrethrum	URP, SOP, SP
Dougall H W	Kenya	Grasses	SP
Peat J E	Tanzania	Cotton, millet	SOP, SP
Gunn J S	Tanzania	Wheat, tobacco, pyrethrum	SOP, SP
Le Mare P H	Tanzania	Groundnuts, maize, sorghum	SP
Mills W R	Uganda	Finger millet, maize, cotton	URP, SOP, SP
Tidbury G E	Tanzania	Trees, rice, maize, sorghum, sunflower	SP
Pereira H C	Kenya	Coffee	URP, SOP, SP
Eden T	East Africa	Tea	SP
Lock G W	Tanzania	Sisal, grasses	SOP, SP
Jones G H G and Robinson P	Kenya	Wheat, maize, sorghum finger millet,	SOP, SP
Jones and Robinson (1965)	Kenya	Napier grass	NAP, BSG, SP

Anderson (1965)	Tanzania	Grass	MRP
Birch (1959)	Kenya	Clover, oats	URP, SP, KF1, BSG
Gosnell and Weiss (1965)	Kenya	Napier grass	SOP, NAP, MRP
Haque and Jutzi (1985)	Ethiopia	Forages	ERP, TRP, SP

[1] Undated sources are cited in Duthie and Keen (1953).
[2] URP = Uganda rock phosphate; SOP = sodaphosphate; SP = superphosphate; SHP = Seychelles phosphate; NAP = North African phosphate; NRP = neutralised rock phosphate; MRP = Minjingu rock phosphate; BSG = basic slag, KF1 = Kenaf no. 1; ERP = Egyptian rock phosphate; and TRP = Togo rock phosphate.

The vast reserves of phosphate in Uganda were expected to yield fine-grained francolite with an average of 25% phosphoric oxide. Some trials indicated that only about half as much of 'early available' phosphate was released from URP, compared with other commercially worked phosphate rocks, and "it became apparent that Uganda phosphate was not suitable for application by itself to annual crops" (Jones, cited by Duthie and Keen, 1953). Subsequent work was on calcination of URP—which contained about 25% total P_2O_5 of which 2–4% was citric acid soluble (c.a.s.)—with crude sodium carbonate to make phosphate more rapidly available.

Doughty (cited by Duthie and Keen, 1953) reported that studies of cereals carried out between 1947 and 1951 on laterised and deeply dissected granite and ancient sediment soils in Tanzania showed URP to be effective. In most experiments, the benefits from its use were apparent only after application for two or three seasons. On lighter-textured upland soils with variable rainfall, triple superphosphate (TSP) was more effective than SOP with 23% total and 19% c.a.s. P_2O_5, which in turn was more effective than URP.

Holme and Sherwood (cited by Duthie and Keen, 1953) experimented with URP, SOP and superphosphates (SP) on wheat grown in Kenya during 1948–50. URP at 290 kg ha^{-1} and 580 kg ha^{-1}gave negligible responses except in one experiment, and even there it was much less effective than the two other phosphate sources. Only in one area were the effects of double superphosphate (DSP) and SOP equal. In the others, the quantity of the c.a.s. P_2O_5 of SOP had to be 20–45% larger in order to give a similar wheat yield per hectare as SP. Similar experiments with maize showed that URP had no appreciable effect in the first year.

Pot experiments on cereals in Kenya showed that although URP had a low early availability, it promised a good response if applied heavily and in a sufficiently fine form (Bellis, cited by Duthie and Keen, 1953).

Sodaphosphate was as effective as an equivalent dressing of SP on tobacco, pyrethrum and wheat planted in Tanzania on granite soils deficient in P; however, high transportation costs made it essential to supply concentrated phosphate (Gunn, cited by Duthie and Keen, 1953).

Mills (cited by Duthie and Keen, 1953) argued that low responses to phosphate in most of the early cereal trials in Uganda were due to the low levels of its application. He reported on experiments comparing the direct effects on maize and the residual effects on cotton of two P_2O_5 levels of URP, SP and SOP. At one site with red Latosols, URP and SOP tended to be more beneficial than SP on maize in an abnormally wet year. In trials at another site with similar soil and rainfall conditions, neither URP, SOP or single superphosphate (SSP) increased maize yields significantly, although there was a residual P effect of about an 18% yield increase for all three fertilizers on cotton. At a third site where a yellow Latosol had been fallow under grass for 3 years and then grazed, there was no direct effect on maize and no residual effect on cotton.

Birch (1948) conducted a literature review of soil phosphates. He found that while acidity favoured PR use, fluorine concentration in the rock did not, and that the variable results with PR were, in part, explained by these conflicting tendencies. Large applications of PR, sometimes larger than 2400 kg ha^{-1}, may in time approach the effectiveness of SP. He also found that the phosphate sorption capacity of the soil is satisfied only by a large quantity of phosphate rock which changes into a more soluble form only after a long period of time. Therefore, in the short run, RP should be expected to give a greater response. He made no specific mention of PR use with forages.

Review of material at ILCA

ILCA's library database provided 75 references related to fertilizer and 49 to phosphate use in eastern Africa. From the 124 references, only eight were studies on PR, of which one (Haque and Jutzi, 1985) was done in Ethiopia, while the remaining seven were undertaken in Kenya, Tanzania and Uganda. Further searches provided no references with detailed data. In addition to the literature referred to, many results were inaccessible, such as several reports of the East African Agricultural and Forestry Research Organisation (EAAFRO).

Ethiopia

In "Some notes on the soil status" (Anon., s.d., a) it was stated that in a sample of 22 Ethiopian soils, of which 19% were 1700 m above sea level, only 8% were not deficient in P. It was concluded that 40% of the soils in the Ethiopian highlands were acid and had a high P fixation capacity.

Haque and Jutzi (1985) reported on the effects of TSP and Egyptian rock phosphate (ERP) on a native Ethiopian clover *(Trifolium steudneri).* The ERP contained 29.4% total P_2O_5 of which 12.8% was elemental P. Fertilizers were broadcast on P-deficient Vertisols (1 mg P kg^{-1}) with a pH of 6.0. *T. steudneri* was harvested after 96 days.

Egyptian rock phosphate was most effective below 45 kg P_2O_5 ha^{-1}; at 30 kg P_2O_5 ha^{-1} it gave 25% and 18% more DM in 1984 and 1985 respectively than TSP (895 kg DM ha^{-1} and 2485 kg DM ha^{-1}) (Table 2). In terms of cumulative effect, TSP was significantly more effective at 45 and 60 kg P_2O_5 ha^{-1} , giving 39% and 25% more DM respectively. Overall, the agronomic responses to both sources of P were much higher than the control.

Table 2. *Average response (AR) and relative agronomic effectiveness (RAE) of TSP (triple superphosphate) and ERP (Egyptian rock phosphate) on* Trifolium steudneri, *Ethiopia, 1984 and 1985*[a].

Crop	Source of phosphate	P_2O_5 rate (kg ha^{-1})	Direct effect		Crop	Residual effect		Cumulative effect	
			AR (kg DM ha^{-1})	RAE (%)		AR (kg DM ha^{-1})	RAE (%)	AR (kg DM ha^{-1})	RAE (%)
T. steudneri on Vertisols, 1984	TSP	15	888	100.0	*T. steudneri* on Vertisols, 1985	1862	100.0	2751	100.0
	TSP	30	895	100.0		2485	100.0	3379	100.0
	TSP	45	1419	100.0		7212	100.0	8631	100.0
	TSP	60	2535	100.0		3740	100.0	6275	100.0
	ERP	15	1043	117.4		2783	149.5	3826	139.1
	ERP	30	1120	125.1		2938	118.3	4058	120.1
	ERP	45	1382	97.4		3853	53.4	5235	60.7
	ERP	60	1553	61.3		3182	85.1	4736	75.5

[a] Trials were conducted without additional N.
Sources: I. Haque (ILCA, Addis Ababa, Ethiopia, unpublished data) and Haque and Jutzi (1985).

Kenya

Gosnell and Weiss (1965) tested the response of Napier grass *(Pennisetum purpureum* Schum.) to different P sources on grey-brown clay soils with a pH of 5.6, which were deficient in N and P (8 mg P kg $^{-1}$ in the top layer). Phosphates were applied at planting and, with the exception of N which was not applied in the first year, they were reapplied annually. An experiment with different rates of TSP showed that 81 kg P_2O_5 ha $^{-1}$ applied annually increased the total yield of green matter (GM) over 4 years by about 41% compared to a control yield of 28 t GM ha^{-1}.

A second experiment (Table 3) compared the responses to different forms of P and N. The main treatments were TSP, SOP, Minjingu rock phosphate (MRP) with about 30% total and 15% c.a.s. P_2O_5, and neutralised rock phosphate (NRP) with 25% total and 11.5% c.a.s. P_2O_5. The fertilizers were applied at 45 and 90 kg P_2O_5 ha $^{-1}$ in the furrow at planting and not reapplied thereafter. Nitrogen was used as a single dressing of 224 kg ha^{-1} during the second and third years.

Table 3. *Average response (AR) and relative agronomic effectiveness (RAE) of rock and refined phosphates in Kenya and Tanzania.*

Source, crop	Source of phosphate[a]	P_2O_5 rate (kg ha^{-1})	Direct effect		Residual effects				Cumulative effect	
					1st year [b]		2nd year[b]			
			AR[c] (kg ha^{-1})	RAE (%)	AR[c] (kg ha^{-1})	RAE (%)	AR[c] (kg ha^{-1})	RAE (%)	AR[c] (kg ha^{-1})	RAE (%)
Gosnell and Weiss (1965), Kenya										
Napier grass on gray-brown clay soils	TSP	45	13 838	100.0	6 425	100.0	2 718	100.0	22 980	100.0
	TSP	90	20 015	100.0	12 849	100.0	5 683	100.0	38 548	100.0
	SOP	45	6 425	46.4	3 954	61.5	3 212	118.2	13 591	59.1
	SOP	90	15567	77.8	10 625	82.7	4 942	87.0	31135	80.8
	NRP	45	9 637	69.6	5 930	92.3	2 224	81.8	17 791	77.4
	NRP	90	12 355	61.7	8 649	67.3	4 201	73.9	25 204	65.4
	MRP	45	8154	58.9	3 212	50.0	2 965	109.1	14 332	62.4
	MRP	90	10 872	54.3	8 649	67.3	6 425	113.0	25 946	67.3
Birch (1959), *Kenya*										
Clover and oats on weedy, old arable land	TSP	188	35 830	100.0	7 413	100.0	n.a.[d]	n.a.	n.a.	n.a.
	TSP	282	40 030	100.0	7 413	100.0	n.a.	n.a.	n.a.	n.a.
	BSG	188	31 382	87.6	5 930	80.0	n.a.	n.a.	n.a.	n.a.
	BSG	282	34 841	87.0	9 637	130.0	n.a.	n.a.	n.a.	n.a.
	KF1	188	33 606	93.8	6 672	90.0	n.a.	n.a.	n.a.	n.a.
	KF1	282	41 019	102.5	7 413	100.0	n.a.	n.a.	n.a.	n.a.
	URP	75	27 244	76.0	6 336	85.5	n.a.	n.a.	n.a.	n.a.

	URP	110	32 313	80.7	5 702	76.9	n.a.	n.a.	n.a.	n.a.
Jones and Robinson (1965), Kenya										
Napier grass on red loam soils	DSP	47	2 941	100.0	741	100.0	n.a.	n.a.	3 682	100.0
	NAP	47	1 261	42.9	494	66.7	n.a.	n.a.	1 755	47.7
	BSG	47	2 916	99.1	2 051	276.8	n.a.	n.a.	4 967	134.9
	NAP+	47	1 681	57.2	247	33.4	n.a.	n.a.	1 928	52.4
	BSG+	47	2 546	86.6	322	43.4	n.a.	n.a.	2 867	77.9
Anderson (1965),Tanzania										
Grass on Ferrisols and Vertisols	DSP	53	1 019	100.0	2 401	100.0	836	100.0	4 256	100.0
	MRP*	53	1 119	109.8	2 130	88.7	849	101.6	4 098	96.3
	MRP	53	352	34.5	2 047	85.3	692	82.8	3 091	72.6

[a] TSP = triple superphosphate; SOP = sodaphosphate; NRP = neutralised rock phosphate; MRP = Minjingu rock phosphate; BSG = basic slag; KF1 = Kenaf No. 1; URP = Uganda rock phosphate; DSP = double superphosphate; NAP = North African phosphate; NAP+ = North African phosphate with ammonium sulphate; BSG+ = basic slag with ammonium sulphate; MRP* = Minjingu rock phosphate with muriafe potash.
[b] First and second residual effect years refer to second and third experiment years.
[c] Gosnell and Weiss (1965) and Birch (1959) reported AR results in green matter and Anderson (1965) and Jones and Robinson (1965) in dry matter (DM).
[d] n.a. = not available.

The effects of fertilizers were marked in the cuts taken during the rains, but there were no significant differences in the dry-season cuts. These affected the annual totals and reduced some results to a non-significant level. Overall, yields were higher at the higher application rate. Though TSP gave the best results for the first and second years, all phosphates gave similar responses in the third year. The P effect lasted 3 years and was still very significant at the fifth cut.

While stimulating yields, phosphate lowered the protein content of the fodder, especially at higher application rates. However, the 3-year mean showed that SOP gave the best protein yields, followed by TSP, MRP and NRP, and all results were well above the protein yield of the control.

Gosnell and Weiss (1965) concluded that the less soluble phosphates (SOP and MRP) gave total GM yields not much lower than TSP, and better protein yields. There was no marked difference between SOP and MRP at equivalent levels of P_2O_5, and phosphate did not have to be reapplied for at least the first 2 years after the first application since residual effects were important.

Birch (1959) reported that high levels of P_2O_5 (212 kg ha^{-1}) doubled ryegrass yields on very weedy, old arable land (pH 5.3). A second experiment compared the effects of TSP and basic slag (BSG), which had about 18.1% total and 14.5% c.a.s. P_2O_5, on *Trifolium tembense* grown on a soil with a pH of 5.0. There was a log-linear effect of TSP, which was greater than that of the slag. The effect of BSG declined at a higher rate of application. The response of the legume to phosphate was in general significantly higher than the control.

A third experiment involved subterranean clover and Lampton oats on a soil of pH 5.1; the oats were sown in the second year of the trial after the clover had been harvested (Table 3). Kenaf no. 1 (KF1), TSP and BSG at 0, 188 and 282 kg P_2O_5 ha^{-1}, and URP at 75 and 110 P_2O_5 kg ha^{-1}, were compared. Two bare fallowed plots, one with the higher rate of TSP and one without phosphate, were also compared. Three cuts were taken. Although URP did not stimulate clover yields much, the protein content of the URP-fertilized clover was only slightly lower than that of the TSP fertilized clover.

Uganda phosphate gave significantly lower oat yields than did soluble chemical phosphates. The fallowed plot with TSP (282 kg P_2O_5 ha^{-1}) outyielded all other oats plots. The protein content of oats was less with TSP than with the other phosphates.

Jones and Robinson (1965) evaluated three types of phosphate applied to Napier grass *(Pennisetum purpureum)* on red loam soils (Table 3). Napier was planted during the short rains of 1953, after a harvest of a maize silage crop in the previous season. DSP, North African rock phosphate (NAP) with 29% c.a.s. P_2O_5 and BSG were compared, the last two with and without ammonium sulphate. DSP and BSG significantly raised yields but not significantly more than ammonium sulphate alone which gave a DM response of 1730 kg ha^{-1}. The NAP plots showed the least response, both with and without ammonium sulphate, and a similar lower residual effect. The authors concluded that consistent yield increases were obtainable with DSP and BSG at 47 kg P_2O^5 ha^{-1}.

Tanzania

Anderson (1965) compared the effects of MRP and DSP on grass at three sites representing major soil types in Tanzania. Three treatments were applied to each of the sites in 1960: DSP, MRP and MRP with muriate of potash. In 1961, the plots were trimmed and all treatments reapplied. The means of all site yields (Table 3) for 1961–63 showed no marked differences between treatments, but all treatments were significantly better than the control. Response to MRP was lower than that to DSP. The low direct response suggests that MRP was inferior to DSP on annual crops, but not on permanent pastures because of the residual effects.

On poor red soils, 125 kg DSP ha^{-1} or 375 kg MRP ha^{-1}—an equivalent of 53 kg P_2O_5 ha^{-1}—could increase the stocking rate by 50% for at least 2 years. Economic analysis at one site showed a return of 45 kg DM per shilling invested in DSP, in the presence of adequate N. At another site, the return was 13 kg DM per shilling invested. Overall, MRP gave only about 75% of the agronomic response of DSP, but should be cheaper to use because it is locally obtainable.

The Mlingano and Naliendele Agricultural Research Institutes of Tanzania undertook 6-year comparative fertilizer trials (Anon., s.d., b and c). PR, TSP and a TSP/PR mixture were applied periodically to cereals on a rhodic Ferralsol and luvic Arenosol with respectively 6.7 and 5.0 pH and 4.7 and 5.1 mg P kg^{-1}. The trials were completed in 1986 after all plots had received a total of 180 kg P_2O_5 ha t.

Phosphate rock applied at the rate of 30 kg P_2O_5 ha^{-1} every season over the 6 years gave a total maize response much higher than did TSP at the same rate. However, when fertilizers were applied at 60 kg P_2O_5 ha^{-1} every second season or 90 kg P_2O_5 ha^{-1} every third season, the maize response to PR was significantly lower than that to TSP. With only an initial application of 180 kg P_2O_5 ha^{-1}, response to PR was 17% more than the total maize response to TSP over the 6 years (3770 kg ha^{-1}). Fertilizer mixture was more efficient when PR and TSP were used at the rates of 60 and 30 kg P_2O_5 ha^{-1} rather than the reverse. Response to PR was, in most cases, relatively lower in the first year.

Similar trials showed that the response of sorghum to PR was at least 30% lower than that to TSP at all rates considered. The trials with the TSP/PR mixture gave almost the same results as those with maize which at the best rate yielded an average of 800 kg ha^{-1} $year^{-1}$ over the control.

For both sorghum and maize, the return per shilling invested in fertilizer was higher for PR because the cost of TSP was almost three times more than that of PR, assuming that the fertilizer prices are farm gate prices and that all other costs are equal for both phosphate sources. However, price and yield variations over the 6 years might affect this result.

RELATIVE EFFECTIVENESS OF PHOSPHATE ROCKS

Relative agronomic effectiveness (RAE)

Tables 2 and 4 show average response (AR) and relative agronomic effectiveness (RAE), calculated from the Ethiopian data. Average response is the mean change in yield over the control as a result of fertilization. Relative agronomic effectiveness is the percentage representation of AR to phosphate fertilizers in the AR to RP at the same rate. The RAE of PR is for example computed as:

$$RAE_{pr} = (AR_{pr}/AR_{rp}) \times 100$$

where: pr = phosphate rock, and rp = refined phosphate (SPs).

Accordingly, the RAE of SP is at any given rate equal to 100. RAE is estimated at equivalent rates of fertilizer application.

Direct effects

Table 2 shows that in 1984, the RAE of ERP on *Trifolium steudneri* was 117 and 125% at 15 and 30 kg P_2O_5 ha^{-1} respectively, but was only 61 % at 60 kg P_2O_5 ha I . Much better RAEs were obtained in 1985 at the rates of 15 and 60 kg P_2O_5 ha^{-1}.

Results with *T*. *quartinianum* show that the RAEs of ERP are below 70% in all cases (Table 4). The performance of Togo rock phosphate (TRP), which has 36.7% total P_2O_5 and 16%

elemental P, was even less. Lucerne response to ERP and TRP gave RAEs less than 85%, although the RAEs of ERP were usually higher than those of TRP. Only in one case did ERP (at 160 kg P_2O_5 ha^{-1}) give a better RAE (122%).

Table 4. *Average response (AR) and relative agronomic effectiveness (RAE) of rock and refined phosphates, Ethiopia, 1985.*[a]

Crop	Source of phosphate[b]	P_2O_5 rate (kg ha^{-1})	Direct effect	
			AR (kg DM ha^{-1})	RAE (%)
T. quartinianum on Vertisol, 1985	TSP	20	1 093	100.0
	TSP	40	2 060	100.0
	TSP	80	3 423	100.0
	TSP	160	3 178	100.0
	ERP	20	259	23.7
	ERP	40	679	32.9
	ERP	80	1 911	55.8
	ERP	160	2 176	68.5
	TRP	20	87	8.0
	TRP	40	604	29.3
	TRP	80	805	23.5
	TRP	160	1 516	47.7
Lucerne on upland soil, 1985	TSP	20	492	100.0
	TSP	40	849	100.0
	TSP	80	1 062	100.0
	TSP	160	1 090	100.0
	ERP	20	326	66.2
	ERP	40	544	64.1
	ERP	80	861	81.1
	ERP	160	1 326	121.6
	TRP	20	274	55.7
	TRP	40	452	53.3
	TRP	80	683	64.3
	TRP	160	659	60.5
T. quartinianum on Vertisol, 1985	TSP	60	7 760	100.0
	TSP/ERP	45/15[c]	2 704	34.8
	TSP/ERP	30/30	3 690	47.6

	TSP/ERP	15/45	3 305	42.6
	ERP	60	2 810	36.2
T. quartinianum on Vertisol, 1985	TSP	60	3 245	100.0
	TSP/TRP	45/15[d]	3 518	108.4
	TSP/TRP	30/30	2 292	70.6
	TSP/TRP	15/45	2199	67.8
	TRP	60	1713	52.8
*Desmodium sanduicense*on upland soil, 1985	TSP	50	1299	100.0
	TSP/ERP	37/12[c]	1252	96.4
	TSP/EPR	25/25	1007	77.5
	TSP/ERP	12/37	1263	97.2
	ERP	50	1125	86.6

[a] Trials were conducted without additional N. Residual values were not available.
[b] TSP = triple superphosphate; ERP = Egyptian rock phosphate; TRP = Togo rock phosphate.
[c] Rates of P_2O_5 from TSP and ERP respectively.
[d] Rates of P_2O_5 from TSP and TRP respectively.
Sources: I. Haque (ILCA, Addis Ababa, Ethiopia, unpublished data) and Haque and Jutzi (1985).

Mixtures of TSP and ERP were applied to *Desmodium sanduicense* and *T. quartinianum* (Table 4). Comparable TSP/TRP mixtures were also used on *T. quartinianum.* On desmodium, there was no significant difference between TSP/ERP applications of 37.5/12.5 kg P_2O_5 ha^{-1} and 12.5/37.5 kg P_2O_5 ha^{-1}. On trifolium, the highest fraction of TSP in the TSP/TRP mixtures and an equal proportion of TSP/ ERP gave better results. The higher the proportion of TSP in the TSP/TRP mixture, the better were the RAEs.

Table 3 shows analyses from the literature review in Kenya and Tanzania. There is some difficulty in comparing results because of the use of different crops and materials. Nonetheless, it appears that PRs were generally inferior to RPs, while their yields were often superior to controls.

Residual effects

Because phosphate rocks release P more slowly than refined phosphates, the profitability of using rock sources should be higher if residual effects are included. In Tables 2 and 3, residual effects are examined by comparing the cumulative RAE to the direct RAE – if the cumulative RAE is greater, then including residual effects improves the value of phosphate rock.

Using TSP as a reference, only four residual values are available for ERP in Table 2; two are greater than the direct RAE, therefore rock values are not improved by including residual effects. In Table 3, nine out of 12 values are greater than the direct effects, so it is possible to conclude that residuals improve the agronomic efficiency of phosphate rocks. This is also supported by most results of the 6-year trials with cereals in Tanzania.

Effects of phosphate rocks on protein yield

In general, phosphates did not improve the protein content of fodder except in clover response to ERP and URP. Although phosphate rocks were not as quick stimulants of response as refined phosphates, they gave better or comparable protein content. It is possible to conclude that adjusting DM results for protein content might favour phosphate rock use, and that both rock and refined phosphates would raise the yield of protein per hectare.

Effects of phosphate rocks on cereals

Phosphate rock was tried on cereals. Apart from very few applications on maize, rock gave lower responses than did refined phosphates, although detailed trial results were not always available. In the 6-year comparative trials in Tanzania, PR was agronomically less efficient on sorghum than TSP. The tendency for rock to be inferior on cereals suggests that PRs would be more effective in long-term fodder production, because of residual effects.

Relative economic effectiveness (REE) of phosphate rocks

The economics of phosphate rocks depend mainly on phosphate prices, on the RAE value, and on the concentration of P_2O_5 in each source. Because of rock's lower concentration, transportation costs will favour refined phosphates. The relative economic effectiveness (REE) is:

$$REE = RAE \times (P_{rp}/P_{pr})$$

where:

P_{rp} = price per kg P_2O_5 of refined phosphate, and

P_{pr} = price per kg P_2O_5 of phosphate rock (Haque and Godfrey-Sam-Aggrey, 1980).

The assumptions used in calculating the prices of P_2O_5 delivered to Addis Ababa are:

	ERP	*TRP*	*TSP*
Average price (US$ t^{-1} product)	45	45	155

P_2O_5 content (%)	29.4	36.7	46.0
Transportation costs to Addis Ababa		= US$ 100 t^{-1} product	
Cost of P_2O_5 at Addis Ababa (US$ t^{-1})	493	395	554

Because TSP sources of P_2O_5 are 12–40% more expensive than PR, rock can be that much less agronomically efficient than TSP and still be competitive. If the prices of rock and refined phosphates per kg of nutrient were equal, the REE would be equal to the RAE for any comparison. If rock phosphate has an REE greater than 100, it is more profitable than refined phosphate at the specified rate. This approach assumes that application, handling and other costs are equal for all phosphate sources.

Table 5 shows that phosphate rocks are economically less efficient on *T. quartinianum* and lucerne, except at one rate on lucerne. ERP was generally more efficient at 30 kg P_2O_5 ha^{-1} or less on *T.steudneri.* On desmodium only a 1:1 mixture of P_2O_5 from TSP and ERP and ERP alone were less effective. This is partly due to the lower agronomic efficiency of phosphate rock compared to that of refined phosphate, and partly to the higher price of P_2O_5 kg^{-1} because of the higher transportation costs for rock. With *T. steudneri,* inclusion of residual effects improved the results only at the rates of 15 and 60 kg P_2O_5 ha^{-1}.

Table 5. *Relative economic effectiveness (REE) of rock and refined phosphates, Ethiopia, 1984 and 1985*[a].

Crop	Source of phosphate[b]	P_2O_5 rate (kg ha^{-1})	REE	
			Direct effect (%)	Cumulative effect (%)
T. steudneri on Vertisols, 1984	TSP	Any	112.2	112.2
	ERP	15	131.7	156.1
	ERP	30	140.5	134.8
	ERP	45	109.3	68.1
	ERP	60	68.8	84.7
T. quartinianum on Vertisols, 1985	TSP	Any	112.2	n.a.[c]
	ERP	20	26.6	n. a.
	ERP	40	37.0	n. a.
	ERP	80	62.7	n.a.
	ERP	160	76.9	n.a.

	TSP	Any	140.3	n.a.
	TRP	20	11.2	n.a.
	TRP	40	41.1	n.a.
	TRP	80	33.0	n.a.
	TRP	160	66.9	n.a.
Lucerne on upland soil, 1985	TSP	Any	112.2	n.a.
	ERP	20	74.3	n.a.
	ERP	40	71.9	n.a.
	ERP	80	91.0	n.a.
	ERP	160	136.5	n.a.
	TSP	Any	140.3	n.a.
	TRP	20	78.1	n.a.
	TRP	40	74.7	n.a.
	TRP	80	90.2	n.a.
	TRP	160	84.8	n.a.
T. quartinianum on Vertisols, 1985	TSP	Any	112.2	n.a.
	TSP/ERP	45/15	39.1	n.a.
	TSP/ERP	30/30	53.4	n.a.
	TSP/ERP	15/45	47.8	n.a.
	ERP	60	40.6	n.a.
T. quartinianum on Vertisols, 1985	TSP	Any	140.3	n.a.
	TSP/TRP	45/15	152.1	n.a.
	TSP/TRP	30/30	99.1	n.a.

	TSP/TRP	15/45	95.1	n.a.
	TRP	60	74.0	n.a.
*Desmodium sanduicense*on upland soil, 1985	TSP	Any	112.2	n.a.
	TSP/BRP	37/12	108.2	n.a.
	TSP/BPR	25/25	87.0	n. a.
	TSP/ERP	12137	109.1	n. a.
	ERP	50	97.2	n.a.

[a] Trials were conducted without additional N. Fertilizer prices are as shown in the text. P_2O_5 content is 46 % for TSP, 29.4 % for ERP and 36.7 % for TRP. Because the RAE of TSP equals 100, the REE of TSP gives the percentage difference in price between TSP and TRP.
[b] TSP = triple superphosphate; ERP = Egyptian rack phosphate; TRP = Togo rock phosphate.
[c] n.a. = not available.
Sources: I. Haque (ILCA, Addis Ababa, Ethiopia, unpublished data) and Haque and Jutzi (1985).

Table 6 shows the REEs of various rock and refined phosphates on forage crops in Kenya and Tanzania. URP, MRP, NRP and NAP seem to be clearly less efficient, except in one instance on grass in Tanzania where MRP was used with muriate of potash (Anderson, 1965). Inclusion of residual effects did not change the results. Sensitivity analysis of the REEs to changes in fertilizer cost showed that a decline as large as 50% in PR price or in the transportation costs of product did not affect most of the results.

Table 6. *Relative economic effectiveness (REE)*[a] *of rock and refined phosphates, Kenya and Tanzania.*

Source, crop	Source of phosphate [b]	P_2O_5 rate (kg ha^{-1})	REE	
			Direct effect (%)	Cumulative effect (%)
Gosnell and Weiss (1965), Kenya				
Napier grass on gray-brown clay soils	TSP	Any	n.a.[c]	n. a.
	SOP	45	40.8	52.0
	SOP	90	68.4	71.0
	NRP	45	66.6	74.0

	NRP	90	59.0	62.5
	MRP	45	67.6	71.5
	MRP	90	62.3	77.2
Birch (1959), Kenya				
Clover on weedy, old arable land	TSP	Any	n.a.	n.a.
	BSG	188	60.6	n.a.
	BSG	282	60.2	n.a.
	URP	75	68.3	n.a.
	URP	110	72.5	n.a.
Anderson (1965), Tanzania				
Grass on Ferrisols and Vertisols	DSP	53	n.a.	n.a.
	MRP*	53	138.0	121.0
	MRP	53	43.4	91.2
Jones and Robinson (1965), Kenya				
Napier grass on red loam soils	DSP	47	n.a.	n.a.
	NAP	47	52.1	57.9
	BSG	47	75.1	102.2
	NAP+	47	69.4	63.6
	BSG+	47	65.6	59.0

[a] Calculated from the literature.
[b] TSP = triple superphosphate; SOP = sodaphosphate; NRP = neutralised rock phosphate; MRP = Minjingu rock phosphate; BSG = basic slag; URP = Uganda rock phosphate; DSP = double superphosphate; MRP* = Minjingu rock phosphate with muriate potash; NAP = North African phosphate; NAP+ = North African phosphate with ammonium sulphate; BSG+ = basic slag with ammonium sulphate.
[c] n.a. = not available.

Possible reasons for the poor agronomic performance of phosphate rocks

literature suggests that PRs gave poorer agronomic performances because of low solubility and P release. As few trials were undertaken with more than two PR rates, it is also possible that fertilizers were used below or above the appropriate rates, thereby affecting the yield. In most cases, residual effects were not tested for longer than 2 years. Because the trials were done under different conditions—using different plants, sites, methods and times of application—it is difficult to estimate the effects of other factors. For example, Anderson (1965) reported that when the same trial was done in three sites, the responses to MRP differed markedly although the comparison with refined phosphate did not differ as much.

CONCLUSIONS

All studies confirmed a phosphate response. The response was probably greater on acidic soils, and was found in cereals, forages and tree crops. Overall, phosphate rocks gave poorer responses than refined phosphates. Only *T. steudneri* in Ethiopia and pyrethrum (genus *Chrysanthemum)* in Kenya gave better agronomic responses to PR than to RP in the year of application.

It has generally been suggested that residual effects will be greater for phosphate rocks. Few experiments measured such effects: those outside Ethiopia confirmed that residual effects favoured rock application, although the residuals were never large enough to effect any significant changes in the economic efficiency of rock relative to that of refined phosphate.

The poorer agronomic response to phosphate rocks makes the economics of using them marginal. There were some clear instances where it would be profitable to use phosphate rocks, but identification of such cases depends on the type of crop, rock, soil and other factors. Whatever the physical responses to phosphate rock, it will still be necessary to use more concentrated rocks in order to reduce the burden of transportation and other related costs, especially if the rock is not locally available. In addition, if rock is more difficult to apply than refined phosphate, then application costs should be considered in any further economic analysis.

REFERENCES

Anderson G D. 1965. Estimates of the potential productivity of some pastures in the Mbulu highlands of Tanganyika by application of fertilizers. *East African Agricultural and Forestry Journal*30(3):206–218.

Anon. s.d., a. Some notes on the soil status of the central highlands of Ethiopia with particular emphasis to phosphorus availability. s.l.

Anon. s.d., b. Comparative trials with rock phosphate/triple superphosphate. Mlingano Agricultural Research Institute, Tanga, Tanzania.

Anon. s.d., c. Comparative trials with rock phosphate/triple superphosphate. Naliendele Agricultural Research Institute, Mtwara, Tanzania.

Birch H F. 1948. Soil phosphates—a review of the literature. *East African Agricultural Journal* 14(t):29–33.

Birch W R. 1959. High-altitude ley agronomy in Kenya. 2. The effects of phosphates and nitrogen. *East African Agricultural Journal* 25(2):113–120.

Duthie D W and Keen B. 1953. Crop responses to fertilizers and manures in East Africa. *East African Agricultural Journal* 19(3):19–57.

EAAFRO (East African Agricultural and Forestry Research Organization). 1948, 1950, 1951. *Annual Reports.* Nairobi.

EAAJ (East African Agricultural Journal). 1949. Report on discussion on fertilizer experiments in East Africa. *EAAJ* 15(2):61–68.

Gosnell J M and Weiss E A. 1965. Vleiland development in west Kenya. 2. Pasture fertilizer and grazing trials. *East African Agricultural and Forestry Journal* 30(3): 169–177.

Haque I and Godfrey-am-Aggrey W. 1980. Response of cowpea *(Vigna unguiculata)* to phosphorus sources of different citrate solubility in Sierra Leone. *Journal of Agronomy and Crop Science*149:14–20.

Haque I and Jutzi S.1985. Relative effectiveness of refined and rock phosphates on the growth of an African clover. *ILCA Newsletter* 4(3):5.

Jones P A and Robinson J B D. 1965. Response of mature Napier grass to fertilizers and cattle manure in Kenya. *East African Agricultural and Forestry Journal* 31(3):276–285.

Application of agroforestry to African crop–livestock farming systems

JOHN C. TOTHILL
ILCA, P.O. Box 5689, Addis Ababa, Ethiopia

SUMMARY

THE VALUE OF *tree legumes and constraints to their production in the different agro-ecological zones of Africa are assessed. Considerable research effort is required to solve the problems of germplasm availability and adaptation. Management issues, such as the identification of suitable entry points, are emphasised as the key factors determining the contribution of woody legumes to African farming systems. Depending on ecological conditions and the farming system, different management strategies can be adopted, including alley or terrace farming, fodder banks or intensive feed gardens, compound planting and plantation farming.*

INTRODUCTION

ILCA's interest in agroforestry is limited to its application to mixed farming systems in which animals are important (Gryseels and Getachew Asamenew, 1985). Two of its basic agroforestry-related activities are acquisition and evaluation of tree germplasm and screening of fodder trees for nutritional factors, including both anti-nutritive and anti-dietary. The third is on-farm application of an alley farming model with *Leucaena leucocephala* and *Gliricidia sepium* in the humid zone, designed to improve animal feed supplies and soil fertility. The use of leguminous trees in mixed crop–livestock systems has recently been reviewed by Torres (1983).

The potential of leguminous trees to increase crop–livestock production in sub-Saharan Africa is discussed. Key management issues influencing tree introduction and contributions to these systems are described, followed by a detailed account of the management techniques suitable for different agro-ecological zones.

THE ROLE OF LEGUMES

The main constraints to plant and animal production in sub-Saharan Africa are nutrient shortages, particularly N and P, and water. Legumes can play various roles in improving the soil nutrient status, which in turn can positively affect the water constraint.

Soil nitrogen deficiency may be overcome through the use of fertilizer, manure or biological N fixation (BNF) by leguminous plants. BNF is an economical method to improve soil fertility that leads to a more active soil biology, which in turn improves nutrient cycling and soil physical conditions, such as bulk density, water infiltration and water-holding capacity (R. Lal, IITA, pers. communication). Legumes thus have two clear functions in mixed farming systems: they build soil fertility, thereby improving crop and forage yields, and enhance forage quality for animal production (Tothill, 1986).

The level of dietary forage intake by animals is determined by the quality and quantity of protein. Another factor influencing the rumen function is the level of tannins, which varies in different types of forage plants, particularly the woody species (van Soest, 1982). ILCA's animal feeding trials using browse and herbaceous legumes to supplement low-quality, straw-based diets demonstrated considerable differences in animal productivity between different species of leguminous fodder plants (ILCA, 1986a).

POTENTIAL OF TREE LEGUMES

Advantages

Because of the beneficial effects of legumes on plant and animal production, serious consideration has recently been given to the value of these plants to African farming systems. The woody species or multipurpose trees (MPTs) appear to have considerable potential for use in crop–livestock systems. Their advantages are:

- *Multipurpose use.* Forage, fertilizer (crop mulching), fuel, poles, building timber, shade, shelter from wind, soil conservation, fencing and forage conservation are all possible uses.
- *Perennial habit.* Most tree legumes are medium- (> 2 years) to long-term (> 10 years) perennials.
- *Deep-rooting habit.* Most trees are deep-rooted and can access soil water and nutrients that are out of reach of most crop and forage species. This enables them to produce or retain high-quality green forage even during the dry season. By tapping soil nutrients inaccessible to other plants, trees may also act as ‘nutrient pumps’. Topsoil fertility is enhanced if tree cuttings are returned to the soil, either directly as mulch or indirectly as animal residues.
- *Dietary quality.* Because of the often prolonged production of green material, the dietary quality of prunings, usually determined by protein content, can remain high for most or all of the dry season. The effects of secondary polyphenolic compounds such as tannins, which tend to be more prevalent in tree legumes, can protect protein to various levels from rumen digestion. This may be used to both advantage or disadvantage in the overall digestion process.

Availability of germplasm

The use of leguminous trees in many African farming systems depends on the availability of exotic germplasm. This is because few vegetation systems are naturally endowed with adequate populations of leguminous trees, and germplasm availability is inadequate over all agro-ecological zones. ILCA is presently assembling germplasm from a wide variety of environments; other organisations and individuals are collecting MPT germplasm in Africa, Southeast Asia and Central and South America. Table 1 shows the present MPT germplasm holdings in ILCA's genebank.

Table 1. *Woody species germplasm in ILCA's genebank, September 1986.*

Genus	No. of species	No. of accessions	Agro-ecological zone[1]
Acacia	64	113	A to SA
Aeschynomene	9	94	H to SH, HL
Albizia	5	16	H to SH, HL
Altriplex	17	35	SH to SA
Cajanus	1	106	SH to SA
Cassia	9	14	H to SH
Casuarina	7	11	SH to SA
Chamaecytisus	2	30	SH, HL
Desmanthus	7	105	SA to SH
Erythrina	10	49	H to SH, HL
Gliricidia	1	87	H to SH
Leucaena	11	126	H to SH
Prosopis	7	14	A to SA
Sesbania	11	59	H to SH, HL
32 other genera	92	135	

[1] A = arid, SA = semi-arid, SH = subhumid, H = humid, HL = highlands (>1500 m a.s.l.).

Germplasm adaptation

A tentative assessment of germplasm adaptation to African agro-ecological zones indicates that problems occur in all zones except the humid:

- *Humid zone.* There is adequate germplasm available for this zone and adaptation is facilitated by ecological conditions.

- *Subhumid zone.* Because of acid soils (pH <5.5 and high aluminium content) and the widespread occurrence of a hard pan which impedes drainage and prevents root penetration, most legume trees establish and grow poorly in this zone.
- *Semi-arid zone.* The main problem in this zone is that selection for increased drought tolerance leads to decreased productivity. Thus, the management strategy must be oriented much less to optimising mulch or forage production than to maintaining reserves of forage for strategic feeding of certain animal classes.
- *Arid zone.* The relationship between tolerance and productivity is even more inversely proportional than that outlined for the semi-arid zone.
- *Highlands.* Locating woody browse species for the highland areas is also difficult, presumably because of the low temperature and high radiation. Since most temperate zones are in the higher latitudes, day-length control over plant phenology and function may be an adaptational barrier.

A more comprehensive account of MPTs is given by Burley (1985). Germplasm availability is limited partly due to inadequate germplasm exploration and definition of germplasm requirements. This applies particularly to *Acacia albida* which, despite its pan-African distribution and known genetic variability, has not been systematically collected for agroforestry[1].

[1] The workshop on "Tree improvement in the Sahel", held in Nairobi from 27 February to 5 March 1987 by the International Union of Forestry Research Organisations (IUFRO) for the 16 Sahelian countries, confirmed that substantial A. albida germplasm is available in the semi-arid to arid zones. In these zones forestry and agroforestry have similar objectives.

Okigbo (1986) and others have reported that a large number of indigenous legume trees are already used by farmers for various purposes. A greater knowledge of these plants, their uses and potential in managed agricultural systems is needed to enable their complementary use with exotic species.

MANAGEMENT ISSUES

Some woody legumes have been used by man for a long time, and their potential to increase plant or animal production has been studied for many years. Why then has their adoption in crop–livestock farming systems been so slow? Probably because such management issues as practical ways to incorporate or use legume trees in these systems have not been researched.

Grass and tree balance

Where naturally occurring woody and herbaceous plants both contribute to the agricultural productivity of the system, as in the pastoral areas, an important management issue is to maintain the balance between the two components of the system. Either grass or tree species may dominate due to such factors as soil type, rainfall seasonality, grazing pressure, species type, fire etc. The factor(s) causing deviations from the desired balance must be identified and corrective measures introduced to ensure long-term productivity and sustainability of the system.

The introduction of additional forage elements, such as crop residues or herbaceous legumes, may, in certain situations, also upset the desired balance. For example, increased grazing pressure on species that are not adapted to high levels of defoliation may lead to the loss of one (e.g. the grass) component.

Entry points

Perhaps the most important management issue in agropastoral areas is the identification of points at which agroforestry technology can be introduced into the farming systems.

Traditional agricultural systems have two distinct phases: the fallow phase and the crop phase. During the fallow phase land is left to bush or grass for a period of time to rebuild soil fertility. Planting leguminous trees as a replacement for natural fallow will accelerate the rejuvenation process, and is thus a suitable entry point. The introduction of legume trees into the crop phase improves soil fertility and allows crop production to continue either indefinitely or for a considerably longer time than before.

Even though sensible entry points and apparently appropriate interventions can be defined, it is necessary that they should be tested in on-farm trials. The experience gained from these trials and feedback to researchers teach important lessons for technology adoption (Atta-Krah and Francis, 1986).

Mulch or fodder

If forage trees are planted in crop fields, a quantitative relationship has to be developed between the amount of foliage needed to maintain or restore soil fertility and that which could be harvested for animal feed.

Free-ranging livestock

Management of communal grazing lands poses another problem for which there is too easy solution. Agroforestry cannot be successfully implemented unless some communal management strategy is adopted (such as the livestock exclusion zones in Ethiopia) to prevent free-ranging animals from damaging seedlings and young trees. Goats can be particularly damaging.

Tree establishment

Finally, establishment is a critical management issue in agroforestry: most tree species are relatively slow to establish, require protection from animals and considerable labour input for weeding. Many agroforestry projects fail at this stage for lack of attention.

MANAGEMENT STRATEGIES

Different tree management strategies are suitable to different agro-ecological situations.

Arid and semi-arid zones

ILCA's East African rangelands programmes in Kenya and Ethiopia aim to exploit the more favourable environmental conditions in pastoral areas for the opportunistic production of crops and forages. This opportunity comes from the increased sedentarisation of the pastoralists and their realisation that supplementary calf feeding can substantially increase calf survival while maintaining milk offtake from dams. An appropriate strategy for growing legume trees in this zone is alley or terrace farming.

Alley or terrace farming. Under this technique hedgerows of leguminous trees are grown either in parallel rows or along a succession of contours; the intervening space is used to grow crops which are mulched with prunings from the hedges.

International Institute of Tropical Agriculture in Ibadan, Nigeria, pioneered alley cropping with *Leucaena leucocephala* and *Gliricidia sepium,* using 4-m hedgerow spacing (Kang et a1, 1981). ILCA expanded on this work by introducing an animal feed component to the on-farm application of the technology, to test dry-season feeding of small ruminants (Atta-Krah et a1,1986).

The technique has also been adopted in Ethiopia's semi-arid zone (mid-altitude and lower highland areas) for terrace farming with *Sesbania sesban* on slightly sloping, easily erodible Vertisols (ILCA, 1986b).

Subhumid and humid zones

In the mixed smallholder farming systems of the more humid areas, a number of management strategies can be applied:

Fodder banks. These are small, densely sown stands of tree legumes providing high-quality fodder for dry-season feeding with natural forage or crop residues. Fodder banks with stylosanthes are being tested by ILCA's Subhumid Zone Programme (Mohamed-Saleem and Suleiman, 1986).

Intensive feed gardens (IFGs). This is specialised feed production on small plots of land. Fodder trees are grown either in pure stands or in combination with other forages such as herbaceous legumes and productive grasses. The gardens can provide high-quality supplementary feed for smallholder livestock (usually sheep and goats); the technique is being tested by ILCA's Humid Zone Programme (Atta-Krah et a1,1986).

Both fodder banks and IFGs may allow optimum use of light, manure or fertilizer in small areas, and perhaps also water through simple impounding. In the East African semi-arid zone, environmentally favoured areas are being selected for opportunistic cropping and, potentially, also for IFGs.

Compound planting/live fencing. Woody plants can be used in and around housing compounds and farm lands. Such fence and compound trees could supply fruits, vegetables, construction poles, fuelwood and fence poles. Moreover, small ruminants left around the housing area would greatly benefit from a regular supply of good-quality forage.

Fencing both the compound and cropland is usually important in the more humid zones. The fence can be made of spaced poles with wire strung between or as a close-planted barrier. Live fences tend to be more termite-resistant than dead fencing materials. Multipurpose trees such as leucaena, gliricidia, ficus and erythrina have all been used in fence development, the last three mainly for pole cuttings.

Water-point development. Because animals regularly congregate around water points, these areas are often heavily overgrazed or become denuded. Depending on the nature of the water point and the intensity of its use, forage banks with tree legumes could be developed at such sites. In the drier zones, many of the trees may require only a small amount of water in the establishment year, after which they have access to deep-soil water. However, the ever present threat of premature browsing is likely to be greater around water points.

Agroforestry development around water points can provide shade and shelter, and windbreaks to minimise soil erosion. These are being considered as companion developments to ILCA's pond development scheme for the southern Ethiopian rangelands.

Plantation farming. Under this technique a woody plantation crop is underplanted with a herbaceous ground crop and/or forage material. ILCA's Forage Agronomy Section has been investigating herbaceous leguminous forages suitable for underplanting coffee on smallholder mixed farms, but the technique can be used with other tree crops as well. Underplanting with forage legumes provides extra fodder while replacing weeds.

CONCLUSIONS

Fodder trees can play an important role in livestock farming systems in the tropics. However, research in this area is limited, as are genetic resources, particularly in tropical highland, dryland and acid soil situations. Useful species such as *Acacia albida,* found naturally in the subhumid and semi-arid zones of Africa, represent an enormous reservoir of genetic diversity, but have not been widely collected and evaluated. A further problem is the habitual cutting or pollarding of trees for fuel and fodder.

Management is likely to be different in an agroforestry-based system, and it is notable that such promising species as leucaena have had a long and chequered adoption career, mainly for management reasons.

Tree legumes can be grown under various agro-ecological conditions and managed for a variety of purposes or products. Thus they have a great potential for use in African small-scale farming systems, particularly those where fuelwood and forage resources are reduced.

Various types of MPT-based feed packages have been designed and tested, mainly in the humid zone. However, there is a considerable potential to introduce such packages also in the other zones, provided that germplasm identification, collection and acquisition for particular packages is closely coordinated with on-farm implementation and management.

ACKNOWLEDGEMENT

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REFERENCES

Atta-Krah A N and Francis P A. 1986. The role of on-farm trials in the evaluation of alley farming. Paper presented at the International Workshop on Alley Farming for Humid and Subhumid Regions of Tropical Africa, held in Ibadan, Nigeria, March 1986.

Atta-Krah A N, Sumberg J and Reynolds L. 1986. Leguminous fodder trees in the farming system. An overview of research at the Humid Zond Programme of ILCA in southwestern Nigeria. In: I Haque, S Jutzi and P J H Neate (eds), *Potentials of forage legumes in farming systems of sub-Saharan Africa.* Proceedings of a workshop held at ILCA, Addis Ababa, Ethiopia, 16–19 September 1985. ILCA, Addis Ababa. pp. 307–329.

Burley J. 1985. Global needs and problems of the collection, storage and distribution of multipurpose tree germplasm. Science and Practice of Agroforestry 2. ICRAF (International Council for Research in Agroforestry), Nairobi.

Gryseels G and Getachew Asamenew. 1985. Links between livestock and crop production in the Ethiopian highlands. *ILCA Newsletter* 4(2):5–6.

ILCA (International Livestock Centre for Africa). 1986x. Leguminous browse in straw diets for sheep. In: *ILCA Annual Report 1985/86*. ILCA, Addis Ababa. p. 50.

ILCA. 1986b. Legume technology. In: *ILCA Annual Report 1985/86*. ILCA, Addis Ababa. pp. 5–6.

Kang B T, Wilson G F and Sipkins L. 1981. Alley cropping maize and *leucaena* in southern Nigeria. *Plant and Soil* 63:165–179.

Mohamed-Saleem and Suleiman H. 1986. Nigeria and West Africa: Fodder banks. *World Animal Review* 59:11–17.

Okigbo B N. 1986. Agroforestry: Potentials in development of sustainable agriculture and combating African environmental crisis. Paper presented at the International Conference on Drought, Desertification and Food Deficits in Africa, held in Nairobi, Kenya, 3–6 June 1986.

van Soest P J. 1982. *Nutritional ecology of the ruminant.* O and B Books, Corvallis, Oregon, USA.

Torres F. 1983. Role of woody perennials in animal agroforestry. *Agroforestry Systems* 1: 131–163.

Tothill J C. 1986. The role of legumes in farming systems of sub-Saharan Africa. In: I Haque, S Jutzi and P J H Neate (eds), *Potentials of forage legumes in farming systems of sub-Saharan Africa.* Proceedings of a workshop held at ILCA, Addis Ababa, Ethiopia, 16–19 September 1985. ILCA, Addis Ababa. pp. 162–185.

ABBREVIATIONS

A	arid (zone)
a.s.l.	above sea level
BNF	biological nitrogen fixation
BSG	basic slag
BTT	bullock traction technology
¢	cedi (Ghanaian currency)
c.a.s.	citric acid soluble (P_2O_5)
c.v.	coefficient of variation
DM	dry matter
DSP	double superphosphate
EAAFRO	East African Agricultural and Forestry Research Organisation (Kenya)
epg	eggs per gram
ERP	Egyptian rock phosphate
FAO	Food and Agriculture Organization of the United Nations (Italy)
GM	green matter
H	humid (zone)
h	hour
ha	hectare
HL	highlands
IFG	intensive feed garden
EAAJ	East African Agricultural Journal
IUFRO	International Union of Forestry Research Organisations (Austria)
kcal	kilocalorie

KF1	Kenaf no. 1
kg	kilogram
ME	man equivalent
MPT	multipurpose trees
MRP	Minjingu rock phosphate
N	nitrogen
NAP	North African rock phosphate
NORRIP	Northern Region Rural Integrated Programme (Ghana)
NRP	neutralised rock phosphate
P	phosphorus
PR	phosphate rock
RP	refined phosphate
SA	semi-arid (zone)
SH	subhumid (zone)
s.d.	sine dato
s.l.	sine loco
SOP	sodaphosphate
SP	superphosphate
SSP	single superphosphate
TRP	Togo rock phosphate
TSP	triple superphosphate
URP	Uganda rock phosphate

Authors' style guide

POLICY AND AUDIENCE

aims of the *ILCA Bulletin* are to present the results of livestock research by scientists at ILCA and at African national institutes, spread the knowledge of results in related disciplines, encourage national scientists to test new research techniques and technological innovations, and stimulate the adaptation to local conditions of applied research carried out by ILCA.

Thus the main audience of the *ILCA Bulletin* is made up by the following groups in sub-Saharan Africa: scientists working in livestock research and related fields, agricultural policy makers, administrators and development workers. The *ILCA Bulletin* is also distributed to scientists working outside Africa and to ILCA's donors.

MANUSCRIPTS

Articles may be submitted in English or French and should be from 3000 to 7000 words. The original, typed double-spaced on one side of the page only, and two photocopies, should be sent to the Director of Training and Information, ILCA, P.O. Box 5689, Addis Ababa, Ethiopia. Papers submitted will be reviewed by two internal referees whose comments will be passed on to authors. If in the referees' opinion a paper is acceptable for publication, the author should send an amended draft to the Editor of the *Bulletin* for editing and publication.

FORMAT AND STYLE

Authors should give their names and initials, titles, programme or department, institute, postal address, and telex number if available. Articles should include a summary and, whenever possible, the following sections: introduction, materials and methods, results and discussion. The findings reported should be discussed in the broader context of livestock and agricultural production in Africa.

Data in figures and tables should be clearly presented and their salient points adequately discussed in text. In the case of figures please send original artwork with the final copy, not photocopies. Sources of figures and tables should be referenced. Abbreviations and symbols used in a figure or table should be explained in footnotes below. Good-quality black-and-white photographs are acceptable for publication. A full list of references must appear at the end of the paper, and authors may also include acknowledgements, disclaimers and/or a list of less common abbreviations and acronyms.

International System of Units (SI) should be used to specify the magnitude of physical quantities. SI units are divided into three classes: base (e.g. m, kg, s and mol), derived (e.g. m^2 and m^3), and supplementary units.

range offered by base units can be expanded by using decimal multiples and sub-multiples described by such prefixes as kilo (10^3), mega (10^6), deci (10^{-1}), milk (10^{-3}), micro (10^{-6}) etc. The choice of the unit will depend on the number of significant figures available: when there are two or more, the numerical component should fall between 1 and 100 (e.g. the mean weight of cereal grain should be reported as 42.6 mg rather than 0.0426 g or 42600 l.g), but when only one is available, it should be between 1 and 10 (e.g. yields were between 1 and 2 t ha^{-1}, not between 0.1 and 0.2 kg m^{-2} or between 100 and 200 g m^{-2}). Applying this *scale rule* will help eliminate the frequent use of zeros or decimal points. Some SI units and symbols recommended for use in agricultural literature are given in the 'Examples' section.

Articles will be edited to maintain a uniform style; substantial editorial changes will be referred to authors for approval.

EXAMPLES

SI units and symbols

- *Time:* Although the second (s) is the base SI unit for time, it is rarely used in agriculture. The hour (h), day (d) and year should therefore be applied.
- *Area:* m^2 (appropriate for studies in crop physiology), km^2 (for areas under specific crop), and ha (acceptable to quote the size of a farm or field).
- *Population density:* ha is the conventional reference area for plantation crops and animal stocking densities, but for plant densities m^{-2} is more appropriate. This descriptor conforms to the scale rule since an expression such as 10 to 20 plants m^{-2} is much easier to visualise than, for instance, 100 000 to 200 000 ha^{-1}.
- *Mass or weight:* kg, t (tonne; tolerated in compound units such as US$ 100^{t-1} product), and mg g^{-1} or g kg^{-1}(weight of dry matter produced by a crop per unit of water).
- *Crop yields:* kg m^{-2} (fresh yields) but g m^{-2} (dry matter yields); t ha^{-1} is convenient when describing agronomic response.
- *Fertilizer application:* kg ha^{-1} and g m^{-1} for experimental plots.
- *Volume:* The base SI unit of m^3 is rarely convenient for agricultural measurement. Thus we will use the litre (1 dm^3) as a more relevant unit, although we will not abbreviate it because of the potential confusion with the numeral 1. Rainfall will be expressed in mm and evaporation rates in mm d^{-1}.
- *Concentration:* mg kg^{-1}, not 'parts per million' (ppm).
- *Force:* 1 N (Newton) = 1 kg m s^{-2}.
- *Pressure:* The unit commonly used by crop physiologists and soil scientists for pressure, the bar, can be converted to mega Pascals (MPa), a multiple of the SI unit, the Pascal (Pa), by multiplying by 0.1.
- *Energy:* J (Joule; which replaces the now obsolete erg and calorie), kJ g^{-1} (energy content of animal fodder or human food), MJ d^{-1} (animal energy consumption), and MJ d^{-1} kg^{-n} (in nutritional work).
- *Power:* 1 W (watt) = 1 J s^{-1} (for exchange of thermal energy between plants or animals and their environments).

Note that the product of two units is written by introducing a space between them and that the quotient is indicated by a negative index, thus kg/ha becomes kg ha^{-1} in the SI system.

Treatment of numbers

The numbers one to nine should be written as words, except when used as measurements or units (e.g. 1 kg, 1 month, 1 litre but one cow). All other numbers should be written as numerals: note that numbers from 1000 to 9999 should be written with out a comma or space, while from 10 000 onward a space should be included.

Common expressions and abbreviations

An increase of 6%; milk yield and consumption increased by 5% and 3% respectively; meat offtake decreased by 2 to 3%; 1300 h; 10° C; No.; 1.3 million; 1980/81 cropping season but ... Nigeria, 1980–82 (in table captions); 13 g Mo; 1 kg N; Figure, *not* Fig.; use Jan, Feb, Mar, Apr, May, June, July, Aug, Sept, Oct, Nov, Dec in tables and figures if space is not sufficient; pp. 12—19, 365 pp. (in references) but 'see page 3' (in text); P = probability (P<0.05, P<0.01 and P<0.001); LSD = least significant difference; SE ± = standard error; d.f. = degrees) of freedom; MS = mean square; CV = coefficient of variation.

Distinguish between 'East African Shorthorned Zebu' (specific breed) and 'zebu' cattle (humped *Bos indicus* cattle); 'Boran' cows but 'Borana' people; 'West African Dwarf goat' (breed) but `the dwarf goats of West Africa'; N'Dama cattle etc.; sp./spp. = species (sing./pl.); cv(s) = cultivar(s); var = variety.

REFERENCES

General: Do not italicise 'et al'; write 'ed.' for 'editor' and 'eds' for 'editors'; write date of publication without brackets; do not use fullstops after authors' initials; italicise titles of published books or reports; write titles of journals, conferences and their proceedings in full; italicise titles of journals and give the volume, issue and page numbers of articles published in them.

Journal articles

Murray M and Trail J C M. 1984. Genetic resistance to animal trypanosomiasis in Africa. *Preventive Veterinary Medicine* 2:541–551.

Books

Wilson R T. 1984. *The camel.* Longmans, London.

Chapters or sections in books

Wagenaar-Brouwer M. 1984. Preliminary findings on the diet and nutritional status of some Tamasheq and Fulani groups in the Niger delta of central Mali. In: A G Hill (ed. *), Population, nutrition and health in the Sahel: Issues in the welfare of selected West African communities.* Kegan Paul Int., London.

Articles in conference proceedings

Maina J A. 1984. Animal health in subhumid Nigeria. In: R von Kaufmann, S Chater and R Blench (eds), *Livestock systems in Nigeria's subhumid zone.* Proceedings of the Second ILCA/NAPRI Symposium held in Kaduna, Nigeria, 29 October–2 November 1984. ILCA, Addis Ababa.