Indigenous and Laboratory Assessment of the Nutritive Value of Tree Fodder.

I : Discrimination Amongst and Within Species.

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Abstract

This paper describes a study of the discriminatory powers of assessments, by farmers and laboratory techniques, of the nutritive value of tree fodder found in the middle hills of Nepal. Eight types of tree fodder (one leguminous and seven non-leguminous), used to supplement crop residue-based diets for cattle during the dry season (November to May), were sampled for destructive analysis at three times during this period of 1994 / 95. Methods for the determination of basic indicators of chemical composition, tannin fractions and two techniques for determining digestibility *in vitro* were applied. At the time of sampling, ranking exercises and informal interviews conducted with farmers were used to assess their perceptions of the nutritive value of the eight fodder types and the nature of changes in feeding value with the time of year. Large differences in nutritive value of the different fodder types studied were apparent, both from farmers' perceptions and laboratory results. The extent of farmers' abilities to discriminate the different fodder types on the basis of nutritive value appeared to be broadly similar to the discriminatory powers of combinations of laboratory nutritive value assessment methods. Seasonal changes in fodder quality were also evident from the assessment made by farmers and in the laboratory assessments. However, individual instances of farmers predicting differences that were not apparent from the suite of techniques applied in the laboratory, and *vice versa*, were recorded. It is concluded that farmers have an extensive knowledge of tree fodder quality that programmes aimed at the improvement of fodder quality and feeding strategies should seek to build upon rather than replace. On the other hand, laboratory assessments of nutritive value clearly have the potential to describe fodder quality in terms that small-holder farmers can comprehend providing that they are applied in line with farmers' objectives. A first step towards achieving this - *i.e.* to determine the consistency and complementary of nutritive value assessments made in laboratories and by farmers - has been explored in a companion paper (Walker *et al.*, this volume).

Keywords

nutritive value, indigenous knowledge, tree fodder

Introduction

Resource-poor farmers in Nepal have a detailed indigenous knowledge system for describing the nutritive value of the fodders from a wide range of tree species that are used as dietary supplements for ruminant livestock (Rusten and Gold, 1991; Thapa *et al.*, in press). Analytical chemists now have at their disposal a range of laboratory methods with the potential to predict the nutritive value of tree fodder. The study reported in this and an accompanying paper examined the discriminatory power of the two approaches for evaluating the nutritive value of different types of tree fodder and explored their comparability and potential complementarity. The research thereby addressed the role that laboratory analyses might play in supporting the maintenance of existing tree fodder feeding systems by farmers and in providing information on novel tree fodders and feeding systems in a form that might be comprehensible to farmers.

Livestock are a key component of the mixed, hill-farming systems found in Nepal. They provide draught power, income and dietary protein and promote the effective cycling of nutrients through the system (Hopkins, 1985). Fodder from trees is particularly important as a green, high nitrogen, feed source in the dry season (November to June) when other feeds are scarce (Panday, 1982). This fodder may be collected from forest areas or, increasingly, from trees grown on farmland, including the banks of crop-terraces (Carter & Gilmour, 1989). A previous investigation of farmers' knowledge (Thapa *et al.*, in press) has revealed two local classification systems for tree fodder; *posilo - kam posilo* and *obano - chiso*. These systems were found to be fundamental to farmers' perceptions of tree fodder quality.

The literal translation of the Nepali terms *posilo* and *kam posilo* are nutritious (high nutritive value) and less nutritious (low nutritive value) respectively. Farmers state that *posilo* fodders promote milk and butter fat production in lactating animals, rapid live weight gain and animal health. They are generally considered to be palatable and to satisfy appetite although these effects are, at least to some extent, dependent on the type of livestock involved. In contrast, *kam posilo* fodder is not associated with high milk yields and rapid growth rates of animals and, if fed as a sole fodder, may cause weight loss, reductions in milk and butter fat yield and a general deterioration in health.

Obano is literally translated as 'dry and warm' and *chiso* as 'cold and wet'. The terms have been taken by Rusten and Gold (1991) as referring, specifically, to the consistency of dung produced by animals consuming the different types of fodder. However, farmers also state that *obano* fodder is highly palatable, particularly during colder months, and is eaten voraciously, often causing constipation if fed in excess. *Obano* fodder is said to improve animal health and generally contributes to milk and *ghee* (clarified butter) production. It produces (literally) dry, firm dung - which must be viewed as significant in a system in which the manual collection and application of manure-compost is the primary means of maintaining soil fertility. *Chiso* fodders are reported to be less palatable and, if fed in cold months, often result in animals producing watery dung that is difficult to collect and spread.

Farmers recognise seasonal variation in the nutritive value of tree fodder. For example, as leaves mature they are typically thought to become less *chiso* and more *obano*, although this is species dependent. Intra-species variability in fodder quality is consistently recognised by farmers for some species (*Ficus nemoralis*, *Bauhinia purpurea* and *F. roxburghii*) while some farmers also recognise sub-species-level variants in a further four species (*F. lacor*, *F.semicordata*, *B. variegata* and *Saurauia nepaulensis*). The varietal distinction used by farmers for *F. semicordata* has been recognised scientifically by the Forest Research Division in Nepal (Amatya, 1989). However, varieties within the other species have not, to date, been differentiated botanically.

Laboratory analyses of feed composition (conventional proximate composition and detergent fibre determinations) and estimates of digestibility conducted *in vitro* (*e.g.* neutral cellulase digestibility) are used widely to investigate the nutritive value of a range of feeds. However, these methods are of less certain value for evaluating tree fodder which may contain anti-nutritive factors such as tannins. In one study (Wood *et al*, 1994) , fodder from twelve out of thirteen Nepalese tree species evaluated was found to contain tannins. Tannins have been associated with low digestibility and toxic effects on livestock (Hagerman and Butler, 1991; Makkar, 1993). Such observations would suggest that conventional techniques may need to be augmented for effective assessment of the nutritive value of tree fodder in the laboratory. A range of tannin assays and an *in vitro* gas production technique with the potential to meet this need have become available recently. The gas production method (Theodorou *et al.*, 1994), which uses rumen microbes, is inhibited by the presence of tannins in the substrate (Wood and Plumb, 1995), suggesting that it might be particularly useful as a predictor of the nutritive value of tree fodders.

In the study reported here, a suite of conventional and novel nutritive value assessment methods was applied to a set of tree fodder samples. These were collected to reflect the inter- and intra-species variability in nutritive value recognised by farmers. At the same time, farmers were asked to rank fodder samples in relation to their *posilo - kam posilo* and *obano - chiso* classification systems for nutritive value. The specific objectives of the research were:

- to examine the consistency of laboratory nutritive value assessments and farmer classifications of tree fodder and the extent to which they were both able to differentiate fodder from different species and types[1] at different times of the year;
- to compare farmer classifications of tree fodder with indicators of nutritive value determined in the laboratory; and
- to identify, if possible, nutritive value assessment methods that, individually or in combination, might be used to supplement farmers' assessments of tree fodder quality.

In this, the first of two papers, the first of these objectives is addressed.

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[1] - throughout this paper, and its companion, we describe distinguishable classes of trees within species by the use of the use of the term type. This is in order to avoid confusion between botanically differentiated sub-species and the distinct sub-types within species that have been identified by farmers but not by taxonomists.

Materials and Methods

Study Site and Selection of Trees

The study was undertaken within the boundaries of the Solma Village Development Committee area, Terathum District, in the middle hills of eastern Nepal. Solma comprises approximately 3500 people in a collection of hamlets on a single, East-facing, slope from 500 m to 2000 m in altitude.

Over 90 species of trees, shrubs and bamboos have been reported by farmers in Solma as being providers of fodder (Thapa *et al.*, in press). Eight representative and widely-used tree types were selected from these for the current study. The selected types included five botanically-differentiated species of which three were differentiated into distinct types. Binomial and local names of the eight tree types are presented in Table 1.

Six groups of farm households were selected within the study area as a basis for stratifying the selection of individual trees for sampling. These "farm groups" were selected as the smallest adjacent set of farms on which all of the eight tree types under consideration were represented. All groups lay at an altitude of between 1100 m and 1700 m. Two trees of each of the eight types were selected within the boundaries of each of the farm groups. Selected trees were all grown on the banks of *bari* (ie. non-irrigated) crop-terraces, were indicated by the farmers owning them as being mature, but not over mature, and were regularly lopped for fodder. Any trees showing visual indications of disease or overshaded by other trees were excluded. Trees from a total of 43 farms were selected for sampling across the six farm groups.

Ranking of Tree Fodder Quality by Farmers

Ranking Procedures

The selected trees were sampled for laboratory analyses at three sampling times (see Table 2). At the second sampling time, farmers were asked to rank the fodder from the eight tree types in terms of *obano - chiso* and *posilo - kam posilo* status. A branch with several leaves from each of the tree types was placed on the ground. Informants were first asked to identify the branch with the most *chiso* fodder. They were then asked to identify the most *chiso* of the remaining seven branches. The branch with the third most *chiso* fodder was then selected and placed in rank order relative to the first two, and so on until all eight branches had been placed in a rank order. The exercise was repeated but ranking from most to least *obano* to cross-check responses. Inconsistencies identified by the repeat were resolved, as necessary, through consultation with informants. A similar procedure was then employed, using the same sample branches, to derive rankings for *posilo - kam posilo* status.

The ranking exercises were undertaken on an individual basis by a total of 69 farmers - including 33 of the 43 owners of the fodder trees sampled for analysis. 60 of the 69 farmers (15 men and 15 women of each of the two, main ethnic groups, *Matawali* and *Bahun*, living in Solma) were treated as a core group for evaluating the rankings. Individual farmers giving rankings were asked not to attribute the same *chiso* or *posilo* status to two fodders from different tree types.

In a separate exercise, conducted at the third sampling time, 42 of the 43 farmers who owned the trees sampled during the study were asked, individually, to rank fodder from each tree type for its comparative *obano - chiso* and *posilo - kam posilo* status across the months of the year during which it was used[2]. The numbers of farmers using a particular fodder were not the same during each month and different fodder types were used for different numbers of months. Therefore, the monthly ranks given for each fodder were normalised to the number of ranks available by dividing the ranks given by each farmer by the number of months during which he or she ranked (used) the fodder. Mean, normalised ranks for each month were then calculated across the farmers using the fodder in that particular month. Data for months during which less than five farmers had ranked a particular fodder were discarded.

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[2] - The months of the Nepali calendar straddle the months of the Julian calendar. For example, the Nepali month of *Baisak* runs from the 16th of April to the 14th of May. Information on seasonal patterns given by respondent farmers referred to Nepali months. In the text, these have been altered to the form Apr/May *etc.*

Ancillary Data

The gender and ethnic group of all farmers participating in the ranking exercise were noted. The 43 farmers owning sample trees were also classified into three groups (A, B and C) depending on whether they produced surplus food, were self sufficient or experienced food deficits during the year and the size and structure of their livestock holdings were recorded. These farmers also provided, at the second sampling time, descriptive data on the sample trees, including recent lopping history, an estimate of age, site details (soil type, fertiliser regime, associated crops) and the ways in which fodder from that tree was generally used (*eg*. fed as a sole feed or in a mixture).

Laboratory Analyses

Sampling and Sample Preparation

Fodder samples were taken from each of the 96 selected trees at three sampling times during the course of the study (on the dates shown in Table 2). The exact dates taken to represent each of the three sampling times differed with tree type as a result of their differing phenologies. When sampling, four sub-samples of fodder were taken from mid-canopy on all four sides of the tree along with a further sub-sample from as high in the canopy as practicable. The five sub-samples were then well mixed to create a final, representative, bulked sample.

Leaves were removed from the top of the petiole and their surfaces cleaned with tissue paper and rinsed with water. The individual leaves were pooled and mixed to give a sample representative of the tree as a whole. This sample was chopped coarsely and oven dried at $50 \pm 3^{\circ}C$ for 72 hours (h). The dried sample was ground in a heavy duty commercial coffee grinder and sieved through a 1 mm screen. It was then mixed and, using a sample divider, subdivided for analysis in the laboratories at the Pakhribas Agricultural Centre, Nepal (proximate constituents, detergent fibre analysis and neutral cellulase digestibility) and the Natural Resources Institute, U.K. (tannin analysis and gas production).

Analytical Procedures

The dry matter content (DM) of the fresh samples was measured by taking 500g of the coarsely chopped leaf material, drying it at 100±5°C for 48h and reweighing.

Residual dry matter, crude protein (CP), ether extract (EE), total ash (TA) and crude fibre (CF) were determined using the methods of the AOAC (1980). Acid detergent fibre (ADF), neutral detergent fibre (NDF), lignin, acid detergent insoluble nitrogen (ADIN) and neutral detergent insoluble lignin (NDIN) were assayed by the methods of Goerring and Van Soest (1970). Neutral cellulase digestibility (NCD) was determined using the method of DeBoever *et al.* (1988).

Tannins were extracted into 70% aqueous acetone and analysed for protein precipitation activity (PPA), total phenols (TP) and condensed tannins (CT) using the methods described by Wood and Plumb (1995). Non extractable condensed tannins (NXCT) were estimated by washing out the extractable tannins and treating the residue with acid butanol using the conditions described by Porter *et al.* (1986). The residue was washed five times in 15 ml 70% aqueous acetone, the residue being recovered by filtration into a scinter glass crucible (porosity P160). Acetone was removed under a stream of compressed air and the residue dried at 60°C for 2 h. To 10 mg residue, weighed into a 100 ml Duran bottle, 15 ml methanol, 90 ml acid butanol and 3 ml ammonium ferric sulphate solution were added to give the reagent mixture described by Porter *et al.* (1986). The reaction conditions and optical density were measured as described by Porter *et al.* (1986), the optical densities being multiplied by 17.42 to adjust them to the same reagent volume used for extractable CT.

In vitro gas production was performed using the method of Theodorou *et al.* (1994) as described by Prasad *et al.* (1994), but the incubations were terminated after 70 h. Cumulative gas production at 12, 24, 52 and 70 h (CG12, CG24, CG52, CG70 respectively) and dry matter disappearance at 70 h (DMD70) were the variables selected for data analysis.

All data were corrected to a dry matter basis using the residual dry matter data.

Statistical Analyses

All statistical analyses were conducted using the standard directives and library procedures provided by Genstat 5, release 3.1 (Lawes Agricultural Trust, 1993).

The internal consistency of farmers' rankings for *obano - chiso* and *posilo - kam posilo* status was tested by a series of Spearman rank correlations (r_S) conducted on pairwise associations of the ranks given by individual farmers (n=3540). The consistencies of *obano - chiso* and *posilo - kam posilo* rankings between respondents of different gender, ethnic group and economic status, and for livestock holding size were tested by the application of χ^2 tests for two independent samples across ranks.

The effects of the principal factors and their interactions on the analytical variables were evaluated using the REML directive of Genstat's variance components analysis. This allowed the effects of unbalanced factors in the general ANOVA model to be evaluated and the variances within and amongst individual trees to be compared.

The analytical data comprised a number of variables that were judged likely to be intercorrelated. Canonical variates were calculated from linear combinations of the analytical variables to examine the ability of the analytical procedures, in combination, to discriminate the eight fodder types. These were used as linear discriminant functions to assess the ability of the combined laboratory analysis methods to assign individual samples of each fodder correctly to the type of tree from which it was sampled.

Results

Ranking of Tree Fodder Quality by Farmers

Consistency of Application of *Obano - chiso* and *Posilo - kam posilo* Classifications

Calculation of r_S for pairwise associations of individual farmers' rankings according to the *obano - chiso* and *posilo-kam posilo* classification systems provided a test of the consistency with which these systems were applied. For *obano - chiso* rankings, the mean r_S between pairs of farmers was significant ($P < 0.05$) at 0.762 with a standard deviation (s) of 0.247. The rankings provided by one farmer were negatively correlated with the rankings of all the other informants. Excluding this farmer increased the value of r_S to 0.799 and reduced s to 0.147. Farmers ranking for *posilo - kam posilo* status were slightly less consistent with a mean r_S of 0.553 with a value of s of 0.291

In order to test for possible systematic differences in rankings due to the background of informants, χ^2 tests were applied to test for differences amongst the rankings given by informants of different gender (male *vs* female), ethnic group (*Matawali* vs *Bahun*), or wealth class (A, B, or C). These revealed no significant differences between these classes of informant. Farmers were also divided into two groups on the basis of the numbers of cattle that they kept (four or less *vs* five or more). Farmers with more than five cows ranked *Albizzia julibrissin* as more *posilo* than farmers with less than five cows ($P < 0.01$; $\chi^2 = 18.2$, d.f. = 7). In terms of individual rankings, *A. julibrissin* was ranked most *posilo* by 21 of the 29 farmers (72%) with more than five cows but by only 12 of the 34 farmers (35%) with less than five cows.

The independence of the *obano - chiso* and *posilo - kam posilo* classification systems applied by the participating farmers to the fodder under study was investigated by calculating the value of r_S between the *obano - chiso* and *posilo - kam posilo* rankings provided by each farmer. The mean r_S for these comparisons was 0.01 with a value of s of 0.390 confirming the independence of the two systems.

Mean Rankings and Consensus Between Farmers

The generally consistent application of *obano - chiso* and *posilo-kam posilo* status and the large sample size ($n = 60$) permitted the assumption that the rankings would be distributed in an approximately normal manner. Rankings were, therefore, converted to an ordinal data set by calculating mean ranks for the fodder from each type of tree. This operation allowed issues of consensus between farmers to be explored in more detail through comparisons based on least significant differences calculated from the individual standard errors (SE_M). The means ranks for *obano - chiso* and *posilo-kam posilo* status given by individual farmers to the fodder from each tree type are shown in Table 3.

The general consistency of the rankings for both classification systems is reflected by the spread in the mean ranks (*obano - chiso*: 1.37 - 6.85; *posilo-kam posilo*: 2.40 - 7.95). However, clustering at certain points on the scale suggests that this consistency was not uniform amongst fodder types. This is illustrated, graphically, for the *obano - chiso* and the *posilo-kam posilo* rankings in Figure 1a and 1b respectively. The extent of consensus amongst farmers regarding the relative *obano - chiso* and *posilo-kam posilo* status varied considerably with the type of fodder being ranked. Little disagreement was observed regarding the *chiso* nature of *Ficus semicordata* var. *semicordata* and *Albizia julibrissin* or the *kam posilo* nature of *F. semicordata* var. *semicordata* and *Prunus cerasoides*. In general, the clearer agreement between farmers regarding *obano - chiso* status suggested by the pairwise rank correlations is further emphasised by the patterns of agreement seen in Figure 1. Interestingly, the degree of consensus for *obano - chiso* status appeared to be greater for fodder types that were ranked more *obano*.

Seasonality of Tree Fodder Utilisation and Farmers' Perceptions of Seasonal Patterns in its Quality

The utilisation patterns of the eight fodder types are summarised in Figure 2. All fodder types, except *Prunus cerasoides,* were used by more than 10% of the farmers owning sampled trees in Nov/Dec and Feb/Mar. *Albizia julibrissin* and *Ficus roxburghii* were fed earlier, in Oct/Nov, and the use of *F. semicordata* and *F. roxburghii* continued through Mar/Apr. *P. cerasoides* was only used extensively from Mar/April to May/Jun and was the only fodder utilised extensively during Apr/May. *P. cerasoides* and *Ficus nemoralis* were the only trees providing fodder in May/Jun and use of the latter persisted into Jun/Jul. *F. nemoralis* differed from all other species in having two separate periods of extensive utilisation, the first being from Nov/Dec to Feb/Mar and the second from May/Jun to Jun/Jul.

Seasonal trends in the *obano - chiso* and *posilo-kam* posilo status of the eight fodder types are summarised in Figure 3a and 3b respectively. All fodder types, except *Albizia julibrissin* and *Prunus cerasoides*, became less *obano* from Nov/Dec through Dec/Jan and then more *obano* from Dec/Jan to Feb/Mar. In contrast, *A. julibrissin* climbed almost linearly in *obano* status from its first utilisation in Oct/Nov to Jan/Feb. *P. cerasoides* was only extensively utilised from Mar/April to May/Jun during which time it also became progressively more *obano*. There were few indications of differences in the seasonal patterns of *obano* status within species although, while *F. semicordata* var. *semicordata* improved in *obano* status linearly from Dec/Jan to Mar/Apr, var. *montana* was less *obano* in Mar/Apr than Feb/Mar. Most fodder types became increasingly more *posilo* as the year progressed.

Laboratory Analysis

Effects of Farm Group

A significant, but unsystematic, effect ($P < 0.05$ - $P < 0.01$) of the farm group in which sampled trees were located was observed in several of the analytical variables (EE, CF, ADF, ADIN, NDIN, CT, NXCT, CG12). The only evidence of interactions of tree species with farm group was in the data for CF ($P < 0.001$) and NXCT ($P < 0.05$) and appeared to reflect greater variability amongst farm groups for *Ficus semicordata* and *Ficus roxburghii* respectively.

Effects of Fodder Type

Highly significant effects ($P < 0.001$) of tree species on the values of all the analytical variables were observed. The principal characteristics of the five species studied are summarised in Table 4. However, there was also evidence of compositional differences within species (*i.e.* between the fodder types identified by farmers). These are illustrated by the data presented in Table 5. The two sub-species of *Ficus semicordata* differed significantly ($P < 0.001$) in their DM and CF contents. *Ficus nemoralis* (TPD) contained significantly less extractable ($P < 0.01$) and non-extractable ($P < 0.001$) condensed tannins than *Ficus nemoralis* (SPD). These observations were consistent with the significantly higher ($P < 0.05$) NCD of *Ficus nemoralis* (TPD). There were no significant differences for *F. roxburghii.*

Effect of Sampling Time

The effects of sampling times (Table 2 summarises these for each fodder type) on all the analytical variables, with the exception of EE and CG24, were highly significant (P < 0.001). In the case of some variables (DM, CP, CF, ADIN, NDIN, TA, PPA, NXCT, NCD, CG12, DMD 70) these generally reflected trends over the three sampling times but for others (ADF, NDF, Lignin, TP, CT, CG12, CG50, CG70) differences due to sampling time were only apparent when comparing data for sampling time 3 with data for sampling times 1 and 2.

Except for TP and CG12, significant interactions (P < 0.05 - P < 0.001) were also observed between sampling time and tree species, indicating inconsistent trends in nutritive value amongst species. The effects of sampling time on the DM, CP, NXCT and NCD contents of seven fodder types are summarised in Figure 4 (the data for *Ficus roxburghii* (CPN) and *F. roxburghii* (KPN) have been pooled as no significant effects were observed of fodder type within this species on these analytical variables). DM contents of *Ficus semicordata* and *Prunus cerasoides* were similar at each sampling time whilst *A. julibrissin, F. nemoralis* (SPD and TPD) and *Ficus roxburghii* exhibited a marked decrease in DM at the third sampling. This pattern was mirrored by changes in CP content. CP contents of *Ficus roxburghii* and *Albizia julibrissin* and, to a lesser extent, both types of *Ficus nemoralis* increased significantly between the second and third samplings (percentage increases of between 13% [*F. nemoralis* (SPD)] and 61% [*A. julibrissin*] were observed). NXCT contents tended to increase over the sampling times, except in the case of *F. nemoralis* (TPD) which exhibited a sharp decrease in NXCT between sampling times 2 and 3 and *Albizia julibrissin* which remained constant in NXCT. There appeared to be little effect of sampling time on NCD, with the exception of *Ficus roxburghii* which became more digestible at the third sampling time and *Prunus cerasoides*, for which NCD appeared to vary considerably over the three sampling times.

Ability of the Analytical Variables in Combination to Distinguish Fodder from Different Tree Types

Separate canonical variates were calculated for the analytical variables for each of the three sampling times. Heavily-weighted analytical variables included CP, and indicators of tannin content (TP and PPA) and *in vitro* digestibility (NCD and DMD70) and were similar for each sampling time. The ability of the canonical variates to assign samples of fodder from individual trees to the type of tree from which each was sampled is summarised in Table 6 for each of the three sampling times. Assignments to the two non-*Ficus* species, *Albizia julibrissin* and *Prunus cerasoides* were consistently successful. Assignments to the three *Ficus* species were generally successful amongst species - except to *Ficus roxburghii* at sampling times one and two and *Ficus semicordata* var. *montana* at sampling time two. However, for all *Ficus* species, a proportion of false assignments within species were observed at all sampling times - that is *Ficus roxburghii* (CPN) and *F. roxburghii* (KPN) , *Ficus nemoralis* (SPD) and *F. nemoralis* (TPD) and the two sub-species of *F. semicordata* were not reliably discriminated. Success rates for the assignment of these types ranged from 58.3% correctly assigned to 91.7% correctly assigned.

Discussion

Ranking of Tree Fodder Quality by Farmers

Consistency of Application of *Obano - chiso* and *Posilo - kam posilo* Classifications

Correlations between the rankings given by individuals, indicated that the *obano - chiso* and *posilo - kam posilo* classification systems were generally applied in a consistent manner by farmers. This finding agreed with an earlier study of the knowledge of tree fodder quality held by farmers in Solma (Thapa *et al*, in press) and was implicit, for *obano - chiso* status, in a study conducted in the middle hills of Central Nepal (Rusten and Gold, 1991). Unpublished research on tree fodder resources in the hill districts of Uttar Pradesh, India suggests that classification of fodder values used by farmers there is consistent with the *obano - chiso* classification (Louise Garde, *pers comm*). This suggests that the *obano - chiso* and *posilo - kam posilo* systems are widely and consistently applied, indicating a widespread perception of their practical utility.

Further support for this view is provided by the lack of evidence of differences in the application of the systems across gender, and particularly, across ethnic and wealth divisions that might be expected to constitute at least partial barriers to the flow of information on tree fodder quality. Research by Thapa has also tested gender differences (n=40) and found no significant differences (Thapa *et al.*, in press) while work by Rusten and Gold (n=13) suggested a gender-based difference in the use of the term *obano* (Rusten and Gold, 1991). Differences in the rankings of tree fodder by farmers with five or more cattle and those with less than five cattle are noteworthy, although confined to differing perceptions of the relative *posilo* status of only one of the fodder types studied (*Albizia julibrissin*). This may be related to differences in the relative *posilo* status of the fodder types when fed to different livestock species and, if so, would be consistent with research findings indicating differences in the responses of large and small ruminants to protein supplementation. It is worth noting that a previous study in Solma (Thapa *et al.*, in press) and unpublished research from Uttar Pradesh (Louise Garde, *pers comm*) has shown that farmers distinguish fodder attributes according to whether they are fed to cattle/ buffalo or goats.

The independence of the *obano - chiso* and *posilo - kam posilo* classification systems suggests that farmers' perceptions of tree fodder quality are quite sophisticated in that they are able to differentiate nutritive value into more than one component. However, Thapa *et al* (in press) have found that, although *obano* fodders were generally also *posilo* fodders, *chiso* fodders are not necessarily *kam posilo* fodders. This suggests a complexity that would make the biological interpretation of the two classification systems and the elucidation of the relationships between them difficult without more detailed *in vivo* studies.

Mean Rankings and Consensus Between Farmers

The mean rankings presented in Table 3 indicate that farmers perceive a broad range of variation in the nutritive value of tree fodder as represented by both classification systems. However, a marked lack of consensus regarding the relative *obano - chiso* or *posilo-kam posilo* status of some of the fodder types studied was also apparent. There are at least three possible and not mutually exclusive explanations of this observation, as follows.

Firstly, some of the fodder types studied were similar in nutritive value. The fodder types that were not well-separated in terms of their relative *obano - chiso* (*Ficus roxburghii* and *Ficus nemoralis*) and *posilo-kam posilo* (*Ficus semicordata* var. *montana*, *Ficus roxburghii* (CPN) and *Ficus nemoralis*) status (see Table 3) were, in belonging to the genus, *Ficus*, closely related botanically. Some support for this view comes from the laboratory assessments of nutritive value. The results of the linear discriminant analysis presented in Table 6 also suggest similar nutritive values for the six *Ficus* types studied.

Secondly, differences in the rankings given by individual farmers reflected real variability in the nutritive value of the different types of fodder amongst farms. The laboratory analyses indicated effects of the farm group from which samples were taken on chemical composition and, possibly, nutritive value. However, these effects did not appear to operate consistently across the analytical variables studied and are, therefore, unlikely to explain the relatively systematic differences in consensus for individual fodder types.

Finally, although farmers were asked to consider the nutritive value of the fodder types studied for cattle feeding only, differences were observed in the application of rankings by farmers with different sizes of cattle holdings. This implies that individual farmers' perceptions of the relative value of different types of fodder are strongly dependent on the nature of their livestock holdings. An examination of the distribution of rankings for the *posilo-kam posilo* status of *Ficus semicordata* var. *montana* (see Figure 1b) illustrates this possibility. Farmers appeared to divide into two distinct groups, one centred on a rank of two and the other on a rank of six, when assessing this fodder type for *posilo* status. The mean livestock holding size for the first of these two groups of farmers was 4.61 ($SE_M = 0.83$) tropical livestock units (TLUs) and for the second 2.93 ($SE_M = 0.33$) TLUs. The larger holding sizes generally reflected higher numbers of cattle and buffalo. It is suggested, therefore, that the distribution of rankings for a particular fodder type and hence, perceptions of its quality, might well be related to its intended use. This equates with farmer distinctions between fodder for different livestock species as previously discussed.

Consensus between farmers appeared to be firmer for *obano - chiso* than for *posilo-kam posilo* status. The current study offers no obvious explanations for this observation. However, Thapa *et al* (in press) suggest that farmers may employ a wider range of indicators of *obano - chiso* status than are available for *posilo-kam posilo* status. Reasons for the greater agreement between farmers with regard to fodders at the *obano* end of the *obano - chiso* classification scale are also unclear. The observation may be an artefact arising from the fodders selected. The value attached to *obano* fodder means that it is likely to be more widely used. This familiarity might allow farmers to take a more consistent view of the relative qualities of *obano* fodder types. It has been postulated in the companion to this paper (Walker *et al.*, in press) that *chiso* characteristics might be associated with anti-nutritive factors. Levels of anti-nutritive factors vary with genotype and in response to environmental changes (D'Mello, 1992). Thus, a link between *chiso* characteristics and levels of anti-nutritive factors would make *chiso* status inherently more variable than *obano* status and, therefore, consensus regarding *chiso* fodders inherently less stable.

Seasonality of Tree Fodder Utilisation and Farmers' Perception of Seasonal Patterns in its Quality

Seasonal patterns in fodder utilisation differed considerably with tree type. The main period of utilisation of the widest range of fodder types occurred between November and April. A study conducted in the nearby village development committee of Jirkhimti and elsewhere in eastern Nepal (Thorne *et al*, unpublished data) has shown that this is also the period of most intensive usage with tree fodder often contributing more than 50% of the dry matter intakes of individual animals. However, the critical period of green fodder shortage during the year (and hence the period during which tree fodder assumes its greatest importance) is widely stated by farmers to be May - June, immediately before the onset of the monsoon rains. Only one of the eight fodder types studied (*Prunus cerasoides*) was used during this period. Panday (1982) has reported that *P. cerasoides* is one of the few widely-planted species that does not shed its leaves during this period. It is, therefore, highly valued for alleviating the late dry season fodder shortage despite its relatively poor *posilo* status. *Ficus nemoralis* was the only species to be used during two distinct periods of the year (November - March and May - July). This may due to faster regrowth of the foliage of this species following leaf shedding in May.

The information summarised in Figure 3 indicates that farmers perceive marked changes, from month to month, in the nutritive value of each of the fodder types studied. The seasonal patterns of changes in *obano - chiso* and *posilo-kam posilo* status that were indicated by farmers participating in the current study are broadly consistent with earlier reports. These have noted that farmers perceived an increase in *obano* status (Rusten and Gold, 1991; Thapa *et al.*, in press) and *posilo* status (Thapa *et al.*, in press) as leaves matured - that is, there was considered to be a general improvement in nutritive value with leaf age. However, for the *Ficus* species studied currently, there appeared to be a perception of increasing *chiso* status (a reduction in nutritive value) between November and January (early in the period of use). This suggests that, in the case of *Ficus* species at least, farmers might consider leaves of intermediate maturity to be most nutritious. Wood et al. (1994) reported that F. *roxburghii* and F. *semicordata* tended to have increased ash contents, reduced crude protein and extractable tannins in April as leaf senescence and shedding. Some other, but not all, of the 13 species studied by Wood *et al.* (1994) had similar trends. Changes in perceived nutritive value could be linked to compositional changes such as these, although the data from this study was inconclusive.

This evaluation of farmers' perceptions of changes in *obano - chiso* and *posilo-kam posilo* status was confined to seasonal trends within species. Therefore, the extent to which the data support comparisons amongst fodder types is limited. However, it is apparent from Figure 3 that some species were perceived to be improving in nutritive value at the same time as others were seen to be declining. This might have affected the relative rankings given to the fodder types by individual farmers making use of a particular fodder type at different times of year, thereby furnishing a further possible explanation of the lack of consensus in the rankings for some fodder types.

Laboratory Analysis

Effects of Farm Group

The area on the Solma hillside from which samples were taken clearly influenced the values of a number of the analytical variables. However, the differences observed did not appear to reflect the effects of any systematic source of variation such as altitude or aspect. It is likely that the effects of farm group represented the combined influences of an amalgam of environmental factors which affect tree fodder quality. There is a number of such factors (e.g. altitude, slope, aspect, photon flux density, soil type) which are also likely to interact but, there appears to be little published information that would allow the quantitative effects of environment on fodder quality to be predicted. The extent to which these relationships might be researchable to assist in the planning of practicable fodder tree planting regimes for optimising fodder quality remains uncertain.

Effects of Fodder Type

The range in protein content (121 - 263 g/kg DM), non-extractable tannin content (158 - 637 OD_{550nm}/g DM) and *in vitro* digestibility (363 - 623 g/kg DM) observed in the five species studied was consistent with farmers' perceptions of considerable variation amongst them in nutritive value. As all five species are widely used throughout Nepal (Panday, 1982), this further confirms the finding of Thapa *et al* (in press) and Garde (*pers comm*) that nutritive value is by no means the only criterion applied by farmers in tree species selection. An improved understanding of the range of and relative weights applied to these criteria would appear to be a pre-requisite for applied research aimed at the development of reliable recommendations on fodder production and feeding strategies. The current study suggests that the effective inclusion of considerations of nutritive value into this kind of research would be complicated at present by the failure of scientists to recognise systematic sources of variation within species. The perception that farmers have of distinct types of tree within species is supported by the results presented here, with significant differences observed in the chemical compositions of *Ficus nemoralis* (SPD) and *F. nemoralis* (TPD) as well as the botanically-differentiated sub-species of *F. semicordata*. In the case of the former, these differences were, notably, in tannin contents. The protein binding ability of tannins means that such differences are likely to be very important in determining the nutritive value of a tree fodder and its role in providing supplementary protein in crop residue-based feeding systems.

Effect of Sampling Time

The changes in nutritive value over time that were recognised by farmers in their *obano - chiso* and *posilo-kam posilo* classifications were also indicated by differences observed amongst the three sampling times in the analytical variables determined. Changes of similar magnitude with time were observed in an earlier study of fodder from 13 Nepalese tree species (Wood *et al*, 1994).

The analytical data strongly indicated that the nature of these changes in nutritive value were unlikely to be consistent amongst species. This probably reflects differences in the phenologies and management of the different species. Ancillary information provided by farmers owning the sampled trees suggested that differences amongst fodder types in the patterns of change in DM and CP contents was associated with the lopping regime employed. *Ficus roxburghii* and *Albizia julibrissin* were subjected to the highest lopping intensities. Some of the *Ficus nemoralis* trees sampled were lopped less intensively but, where this was the case, were generally lopped twice during the period of utilisation. Generally, levels of tannins increased with leaf maturity, except for *Albizia julibrissin* (the only legume amongst the species studied) in which they remained constant over the sampling period and *Ficus nemoralis* (TPD) in which levels declined sharply at the third sampling time. It is postulated that foliage collected from F. nemoralis during sampling time three may have been regrowth as this species tends to drop leaves during the month of May (Wood *et al*, 1994).

Ability of the Analytical Variables in Combination to Distinguish Fodder from Different Tree Types

Assignments of individual samples to their actual fodder types were less reliable between the fodder types identified by farmers than amongst the botanically differentiated species. Success rates with the botanically differentiated sub-species of *Ficus semicordata* (var. *semicordata* and var. *montana*) were intermediate. However, in no case were less than 50% of samples of a particular fodder type accurately assigned to type by the linear discriminant functions. This does suggest that real, if somewhat blurred, differences in nutrient profiles and hence in nutritive value existed amongst all fodder types.

It is interesting to draw the parallel between the reliability of assignments to species based on nutrient profiles and the degree of consensus shown by farmers with respect to the relative ranks of the different fodder types. In general, the fodder types that were less reliably discriminated by the combinations of analytical variables (*i.e.* the two type of *Ficus nemoralis* and the two types of *Ficus roxburghii*) were also those on which farmers were less able to agree relative rankings. This implies that, whilst real differences may exist in the nutritive values of these variants, these might not be large enough to affect the performance of animals under the conditions in which they are kept. It should be pointed out that the differentiation of variants practised by farmers need not necessarily be based solely on nutritive value but might also focus on morphological or agronomic characteristics.

The eight types of fodder studied were selected to represent a range in nutritive value according to the perceptions of farmers recorded by Thapa (1994). Tree fodder is used by farmers to supplement low-protein basal diets so the eight fodder types should vary considerably in their ability to supply useable protein in such diets. It is encouraging, therefore, and indicative of a general consistency between the indicators used by farmers and in the laboratory to predict nutritive value, that the most heavily weighted analytical variables in the calculated canonical variates were those that might be expected to influence protein supplies most. This observation, and the general consistency amongst sampling times in both the variables that were heavily weighted and the consistency of assignments to fodder types, suggests that a reliable suite of techniques for assessing the nutritive value of tree fodder might be devised from this work. This suite of techniques would have the advantage of going beyond a theoretical consideration of the relative importance of the different components of protein supply to being clearly focussed on the objectives that farmers have when they use tree fodder.

Conclusions

It is concluded that farmers have an extensive knowledge of tree fodder quality that programmes aimed at the improvement of fodder quality and feeding strategies should seek to build upon rather than replace. On the other hand, laboratory assessments of nutritive value clearly have the potential to describe fodder quality in terms that small-holder farmers can comprehend provided they are applied in line with farmers' objectives.

The study described in this paper has suggested that a firm biological basis may underlie the classification systems used by farmers in Nepal to describe tree fodder quality. This is not entirely surprising as these systems have been based on many years of empirical observation of the responses of animals to supplementation with different types of tree fodder. However, the *obano - chiso* and *posilo-kam posilo* classifications used are quite complex and appear to be applied with varying success depending on the type of fodder under consideration.

The study has also suggested that farmers' classifications and the information that may be gained from the application of a range of laboratory techniques for assessing nutritive value are compatible with each other. If this is shown to be the case, the application of laboratory assessment of feed quality that is properly focussed on farmers' requirements becomes possible.

In order to assess the viability of such an approach, more detailed analysis of the correspondence between farmers' ranking of different types of tree fodder and predictions of nutritive value from the analytical methods together with an evaluation of the complementarity of the two approaches is required. This is presented in a companion paper (Walker *et al.*, in review).

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Table 1: The eight types of tree used in the study.

Local name	Botanical name
Sano pate dudhilo	*Ficus nemoralis (SPD)*
Thulo pate dudhilo	*Ficus nemoralis (TPD)*
Chillo pate nebharo	*Ficus roxburghii (CPN)*
Khasro pate nebharo	*Ficus roxburghii (KPN)*
Rai khanyu	*Ficus semicordata var. montana*
Khasre khanyu	*Ficus semicordata var. semicordata*
Painyu	*Prunus cerasoides*
Rato siris	*Albizia julibrissin*

Botanical names have been adhered to throughout the text. Where distinctions are made within species, by farmers, these have been discriminated by the addition of an abbreviation of the local name (e.g. *Ficus nemoralis* (SPD)).

Table 2: Timing of fodder samples for each of the eight tree types sampled.

	Sampling time		
	Time 1	Time 2	Time 3
Ficus nemoralis (SPD)	mid Feb	end Feb	mid June
Ficus nemoralis (TPD)	mid Feb	end Feb	mid June
Ficus roxburghii (KPN)	mid Feb	mid March	mid June
Ficus roxburghii (CPN)	mid Feb	mid March	mid June
Albizia julibrissin	mid Feb	mid March	mid June
Ficus semicordata var. *montana*	mid Feb	mid March	mid April
Ficus semicordata var. *semicordata*	mid Feb	mid March	mid April
Prunus cerasoides	mid Feb	mid March	mid April

Table 3: Mean ranks and their standard errors for the *obano - chiso* and *posilo - kam posilo* status of fodder from the eight tree types (abbreviations as defined in Table 1).

Tree type	Mean rank		
Obano - chiso status			
Albizia julibrissin	1.37[g]	0.14	Most obano
Ficus semicordata var. *semicordata*	2.20[f]		
Ficus semicordata var. *montana*	3.12[e]		
Prunus cerasoides	3.70[d]		
Ficus roxburghii (KPN)	6.06[c]		
Ficus nemoralis (TPD)	6.23[abc]		
Ficus nemoralis (SPD)	6.42[b]	0.18	
Ficus roxburghii (CPN)	6.85[a]	0.17	Most chiso
Posilo - kam posilo status			
Albizia julibrissin	2.40[a]	0.25	Most posilo
Ficus semicordata var. *montana*	3.07[bc]	0.25	
Ficus roxburghii (CPN)	3.57[c]	0.15	
Ficus nemoralis (TPD)	3.83[cd]	0.23	
Ficus nemoralis (SPD)	4.10[d]	0.20	
Ficus roxburghii (KPN)	4.65[e]	0.18	
Ficus semicordata var. *semicordata*	6.40[f]	0.18	
Prunus cerasoides	7.95[g]	0.04	Most kam posilo

Means with the same superscript do not differ significantly at the 5% level.

Table 4: The principal nutritional characteristics of the five fodder tree species studied.

Species	Principal Characteristics
Ficus nemoralis	Most digestible and low in tannins, but relatively low protein content.
Ficus roxburghii	Intermediate in most respects.
Albizia julibrissin	Very high crude protein and low in tannins but high fibre content and very low digestibility.
Ficus semicordata	Lowest in protein, low tannins and intermediate digestibility.
Prunus cerasoides	Digestible but low in protein and very high tannin content.

Table 5: The effects of fodder type within species on dry matter, crude fibre, extractable condensed tannin, non-extractable condensed tannin and neutral cellulase digestibility.

Fodder type	DM (g/kg)	CF (g/kg DM)	CT (OD/g DM)	NXCT (OD/g DM)	NCD (g/kg DM)
Ficus roxburghii (CPN)	303[a]	175[ab]	393[a]	300[a]	581[a]
Ficus roxburghii (KPN)	308[ab]	176[a]	457[ab]	326[a]	566[a]
Ficus semicordata var. *semicordata*	448[d]	206[c]	478[b]	171[b]	543[b]
Ficus semicordata var. *montana*	412[c]	177[a]	446[b]	216[b]	526[b]
Ficus nemoralis (SPD)	319[b]	167[b]	340[a]	485[c]	700[c]
Ficus nemoralis (TPD)	319[b]	174[ab]	201[c]	310[a]	720[d]
Mean SE_M	6.9	4.4	41.1	38.8	9.9

Means with the same superscript do not differ significantly at the 5% level.

Table 6: The assignment of tree fodder samples to their respective fodder types by linear discriminant analysis.

Sampling period 1

Assigned fodder type	*Ficus roxburghii* (CPN)	*Ficus roxburghii* (KPN)	*Ficus nemoralis* (SPD)	*Ficus nemoralis* (TPD)	*Ficus semicordata* var. *montana*	*Ficus semicordata* var. *semicordata*	*Albizia julibrissin*	*Prunus cerasoides*
	Actual Fodder Type							
F. roxburghii (CPN)	7	2						
F. roxburghii (KPN)		10						
F. nemoralis (SPD)	5		9	2				
F. nemoralis (TPD)			3	10				
F. semicordata var. *montana*					10			
F. semicordata var. *semicordata*					2	12		
A. julibrissin							12	
P. cerasoides								12
% correctly assigned	58.3	83.3	75.0	83.3	83.3	100	100	100

Sampling period 2

Assigned fodder type	*Ficus roxburghii* (CPN)	*Ficus roxburghii* (KPN)	*Ficus nemoralis* (SPD)	*Ficus nemoralis* (TPD)	*Ficus semicordata* var. *montana*	*Ficus semicordata* var. *semicordata*	*Albizia julibrissin*	*Prunus cerasoides*
F. roxburghii (CPN)	7	4						
F. roxburghii (KPN)	3	8						
F. nemoralis (SPD)			8	4				
F. nemoralis (TPD)			4	8				
F. semicordata var. *montana*	2				11	2		
F. semicordata var. *semicordata*						7		
A. julibrissin							11	
P. cerasoides								12
% correctly assigned	58.3	66.6	66.6	66.6	91.7	77.8	100	100

Sampling period 3

Assigned fodder type	*Ficus roxburghii* (CPN)	*Ficus roxburghii* (KPN)	*Ficus nemoralis* (SPD)	*Ficus nemoralis* (TPD)	*Ficus semicordata* var. *montana*	*Ficus semicordata* var. *semicordata*	*Albizia julibrissin*	*Prunus cerasoides*
F. roxburghii (CPN)	8	4						
F. roxburghii (KPN)	4	8						
F. nemoralis (SPD)			11	3				
F. nemoralis (TPD)			1	9				
F. semicordata var. *montana*					9			
F. semicordata var. *semicordata*					3	7		
A. julibrissin							11	
P. cerasoides								12
% correctly assigned	66.7	66.7	91.7	75.0	75.0	75.0	100	100

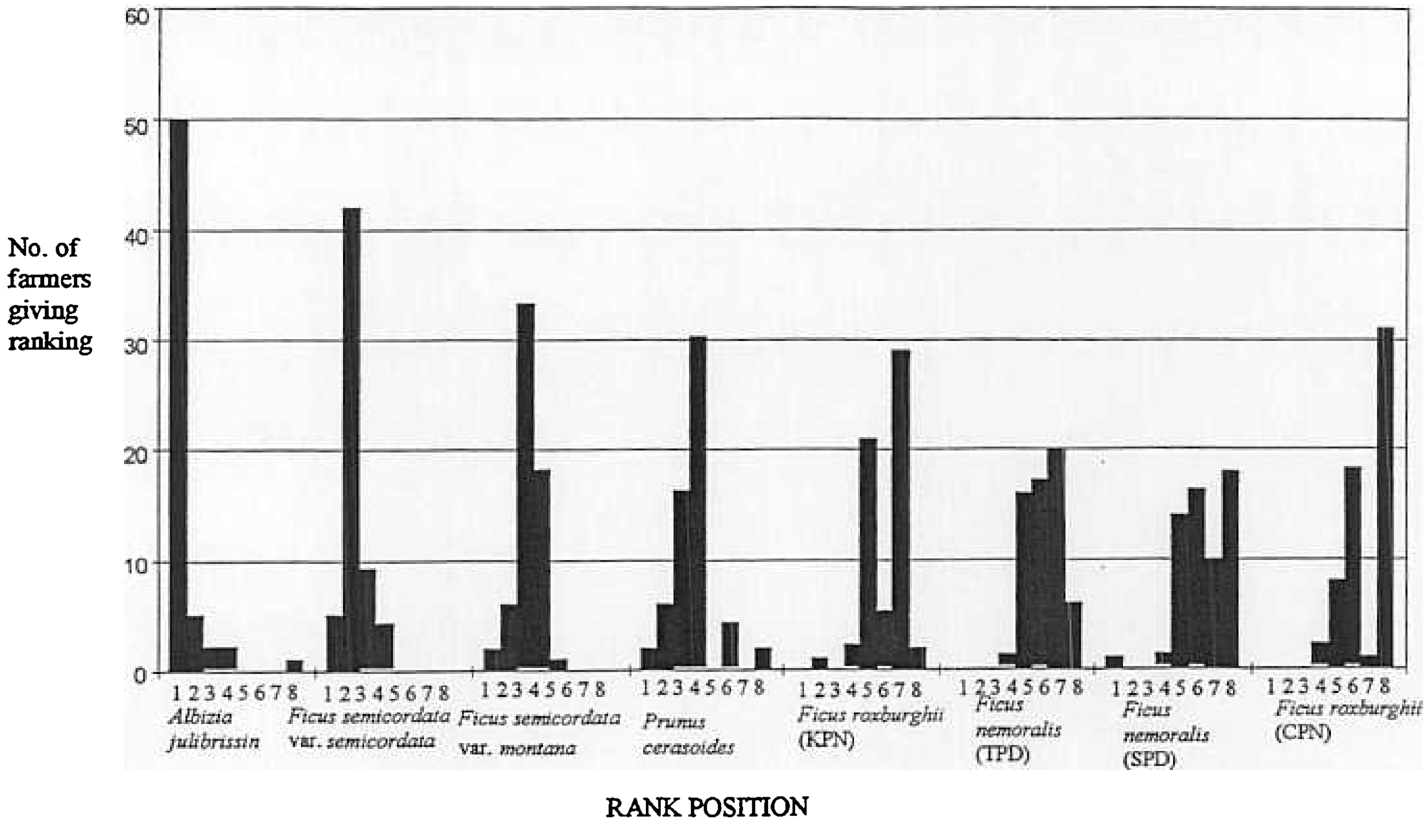
Figure 1: Consensus between farmers in the application of nutritive value classifications.

Figure 2: Seasonal patterns of tree fodder use for the eight fodder types studied. Numbers of farmers utilising each fodder type in different months of the year (the Nepali calendar is divided so that Julian calendar months are straddled).

Figure 3: Seasonal trends in obano - chiso and posilo-kam posilo status for each of the eight fodder types studied. Relative rank by month (the Nepal calendar is divided so that Julian calendar months are straddled) for each fodder type for a) the *obano - chiso* classification (where obano = 0, chiso = 1) and b) the *posilo - kam posilo* classification (where posilo =0, kam posilo =1).

Figure 4: Summary of the effects of sampling time on dry matter, crude protein, non-extractable condensed tannin and neutral cellulase digestibility for seven fodder types (Fr - *Ficus roxburghii*; Fss - *Ficus semicordata* var. *semicordata*; Fsm - *Ficus semicordata* var. *montana*; Pc - *Prunus cerasoides*; Aj - *Albizia julibrissin*; FnS - *Ficus nemoralis* (SPD); FnT - *Ficus nemoralis* (TPD).

a. Obano - chiso



b. Posilo - kam posilo

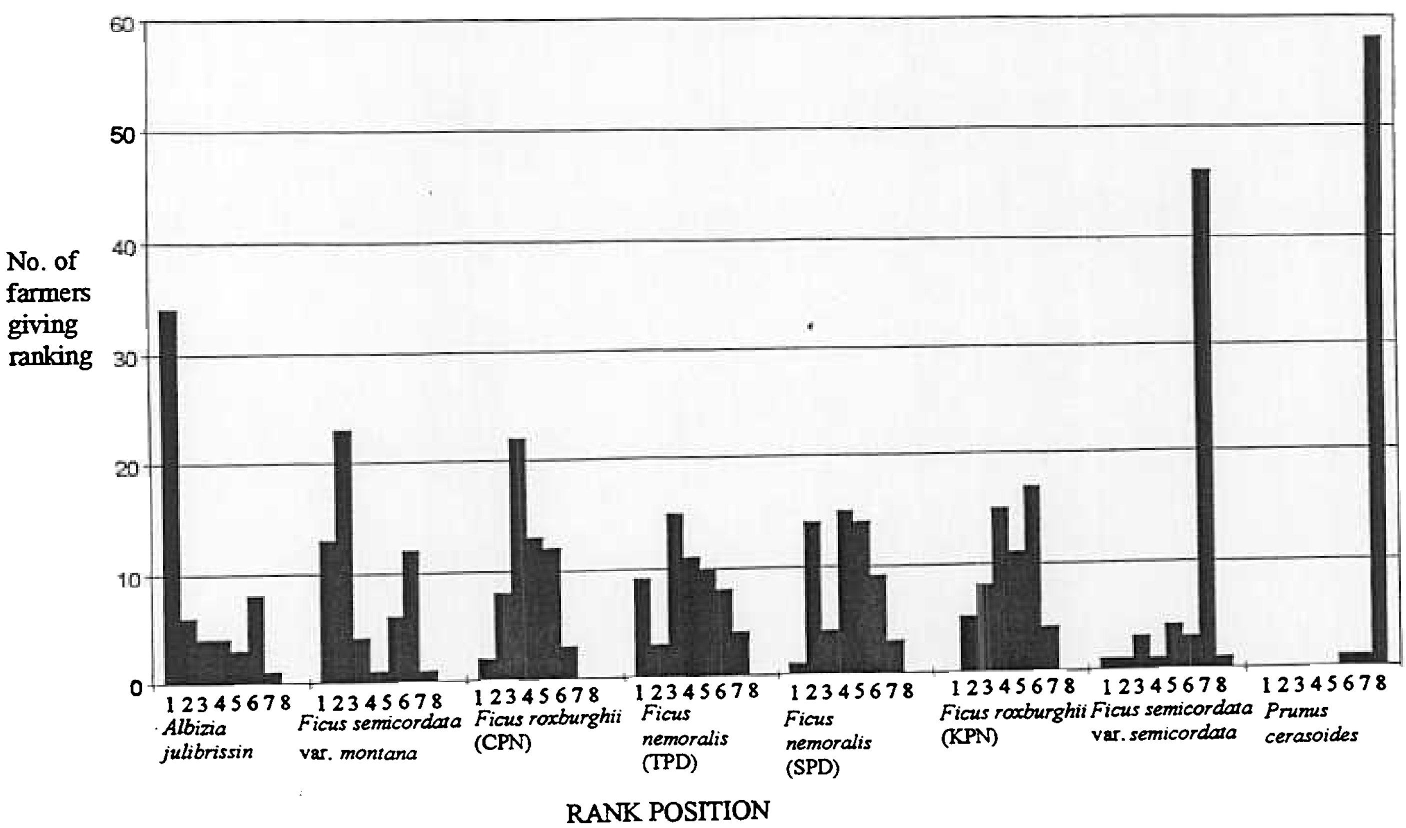


Figure 1: Thorne *et al*

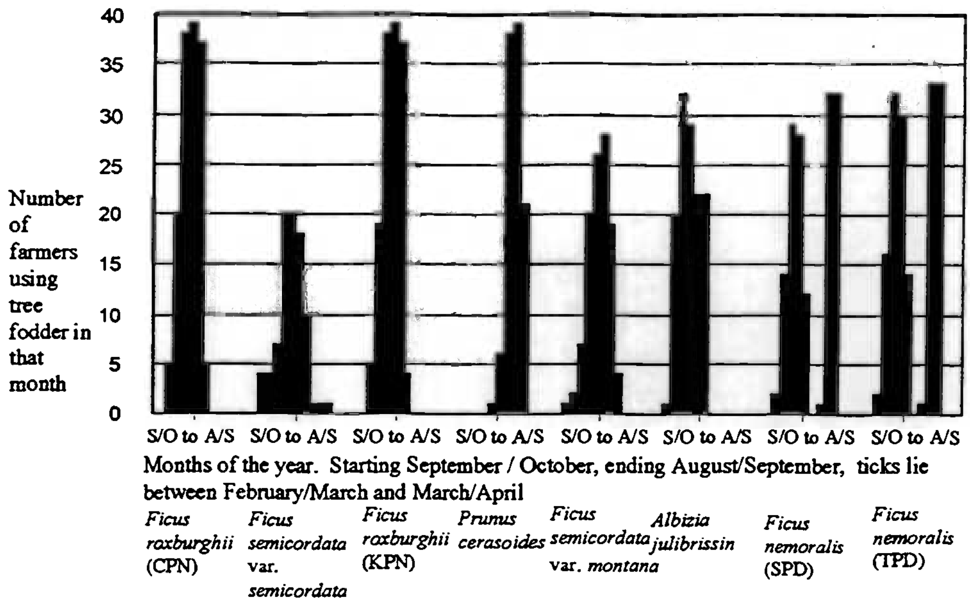
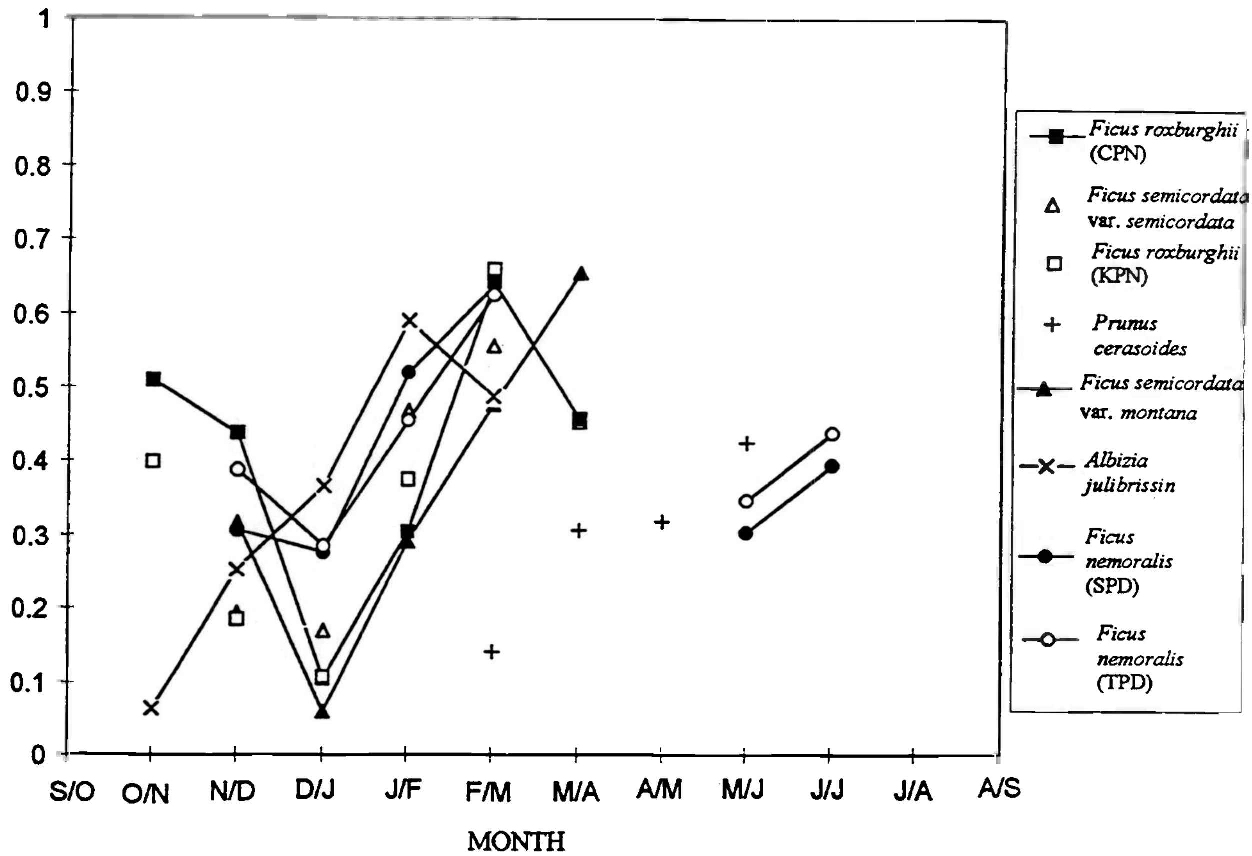


Figure 2: Thorne *et al*

a. obano - chiso



b. posilo - kam posilo

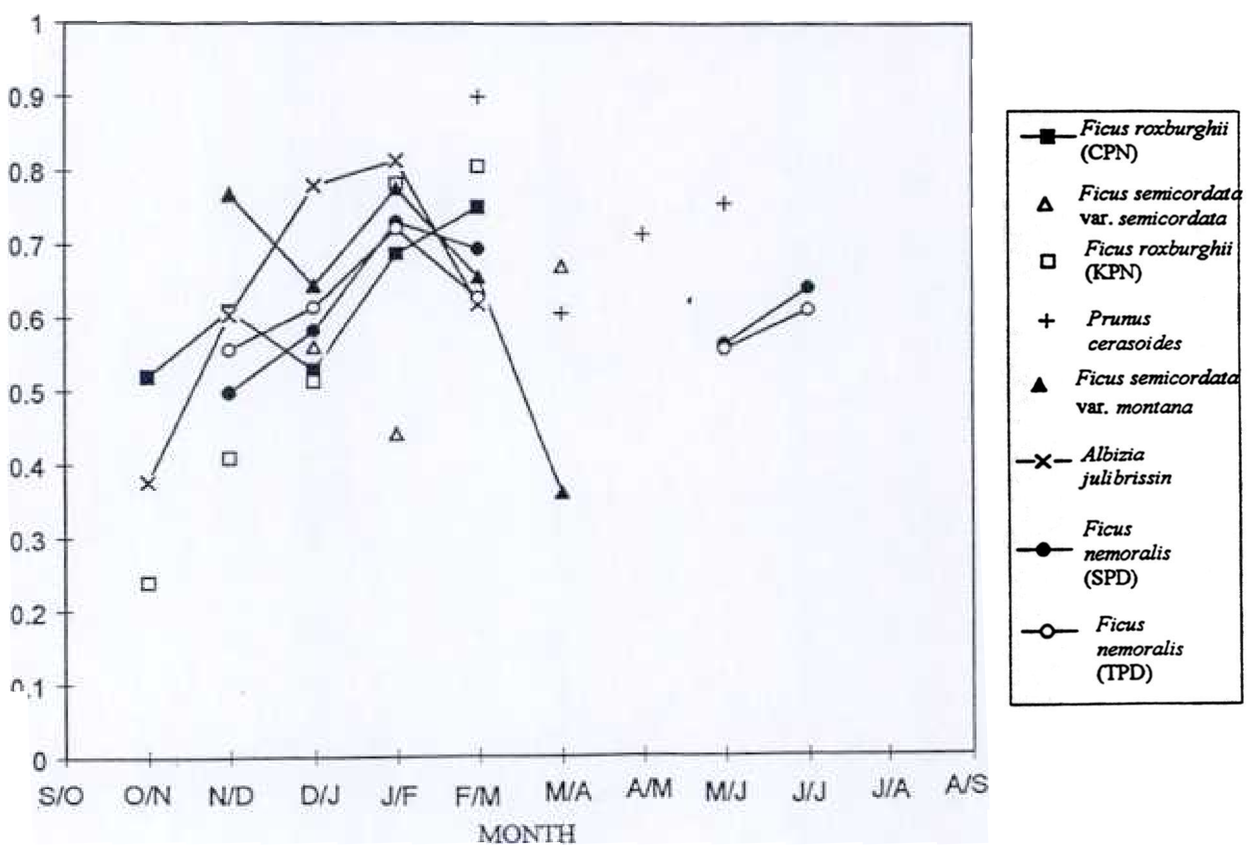


Figure 3: Thorne *et al*

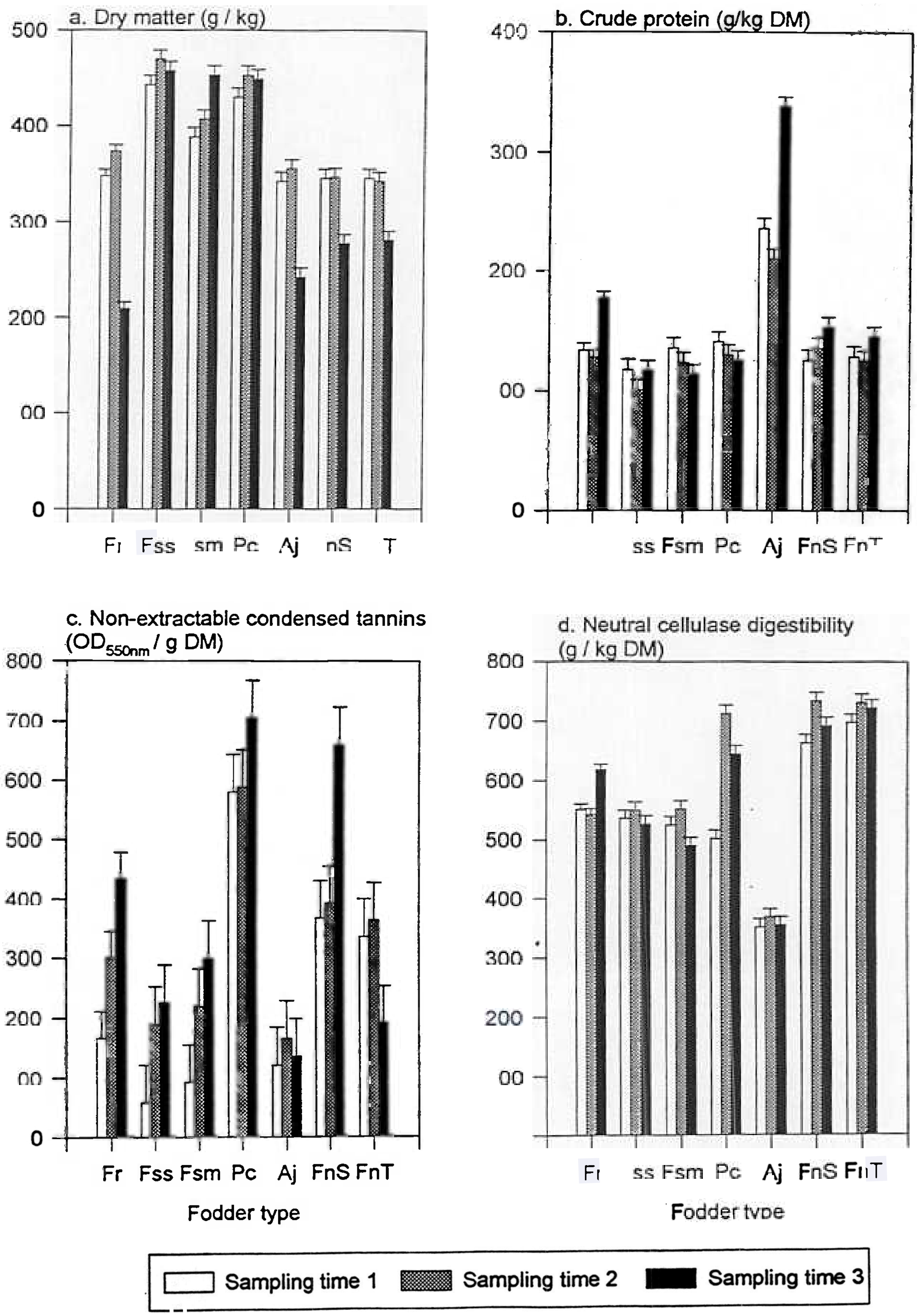


Figure 4: Thorne *et al*