Chapter Three
Research

Introduction

Innovative Bhutanese farmers have always experimented with new production methods and new species and varieties. The introduction of plants such as chilli, maize, and potato in the sixteenth century and the crossbreeding programme with mithun are testimonies to the ingenuity, curiosity, and adaptability of Bhutanese farmers.

The first documented research activities in the livestock and forage sector sponsored by the Government of Bhutan started in the early 1970s (Roder 1990a). Reviews have been carried out of the research systems under the Ministry of Agriculture in general (MOA/ISNAR 1992) and research programmes focused on the development of fodder resources in particular (Roder 1989; Roder and Dorjee 1990; Roder 1990c; Roder 1996a). Initial modest research efforts in the 1970s resulted in the development of widely used technologies. The positive results of the initial activites generated broad support for further research. At the same time the RGOB provided generous subsidies for extension activities. This momentum was not, however, sustained and the research programmes were gradually reduced and in some cases replaced by seed production programmes. The enthusiasm for fodder research waned as a result (Roder 1989; Roder 1990c). With the reorganisation of the research system within the Ministry of Agriculture in the last decade, research in fodder resource development is again receiving attention, although not as much as it warrants, given the need.

Matching the limited resources with the research needs of the variable production systems will always be a challenge in Bhutan. Rigorous priority setting and judicious planning is crucial. In the past, research activities have been largely limited to the following (Roder 1989).

- Cataloguing the resources and their management
- Monitoring trends in the resource base and livestock production
- Identifying and importing useful information and technologies
- Adapting useful technologies

Institutions

Before 1995

Early introductions of exotic fodder species such as kikuyu *(Pennisetum clandestinum)* and Napier grass (*Pennisetum purpureum)* were probably made by enterprising farmers or government officials in the early 1900s. Selected subtropical species were introduced to Samtse in the early 1960s (Wangdi 1979). The first documented introduction of white clover was made in Gogona in 1970 (Maurer 1985).

The main institutions with a fodder research component prior to 1995 are listed in Table 24. The first planned experimental activities focusing on fodder resource development were initiated by the Rural Development Programme (RDP) in Bumthang in 1974. Activities under this project increased steadily through the 1970s and reached a peak in the early 1980s (Figure 29) (Roder 1996a). Fodder development was an important component of the two large livestock development projects (Roder 1989): the Highland Livestock Development Project (HLDP) and the High Altitude Area Development Project (HAADP). Other institutions and projects with research components in the 1970s and 1980s included the Lingmethang

Table 24: Main institutions and projects with a fodder research component prior to 1995

Project/Institution	Period	Major focus
Samtse institutions		
Samtse Livestock Farm	1969-86	• Subtropical forage grown for on-station feeding of livestock
Subtropical Fodder Research Centres (Samtse/Pemagatshel)	1986-95	• Germplasm introduction and testing • Soil fertility
Bumthang institutions		
Rural Development Project	1974-82	• Forage germplasm introduction and testing (temperate and subtropical) • Forage establishment/management • Tree fodder • Seed production
Grassland and associated fodder research centres	1982-86	• Forage germplasm introduction and testing (temperate and subtropical) • Seed production • Tree fodder
National Fodder Seed Production Centre	1986-95	• Seed production
Serbithang institutions		
Grass Seed Multiplication Centre	1976-82	• Seed production
Fodder/Grass Experimental Research Centre	1982-87	• Native fodder plants • Germplasm evaluation
Temperate Fodder Research Centre	1987-95	• Germplasm evaluation
Projects and others		
Highland Livestock Development Project (Eastern Bhutan, Chhukha)	1986-93	• Germplasm evaluation and testing (Subtropical and temperate) • Forage management
Himalayan Pasture and Fodder Research Network (Bumthang)	1986-95	• Germplasm evaluation • Forage management
Applied Research Centre, Yusipang	1988-93	• Forage establishment • Forage management

Source: Adapted from Roder 1989

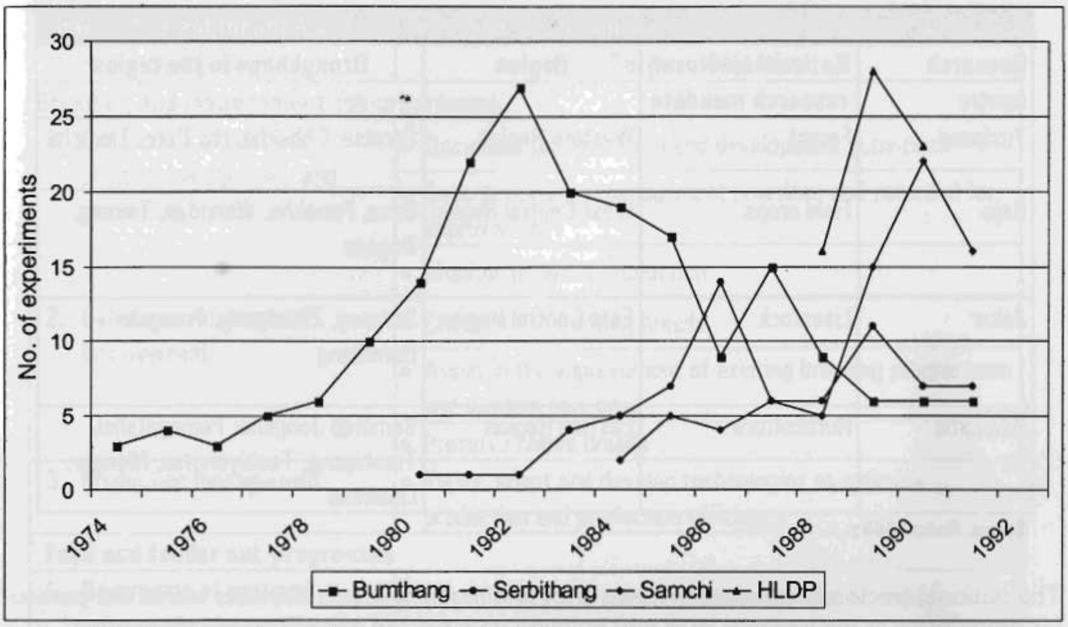

Figure 29: Number of experiments carried out by research centres/projects

livestock farm (1969-80); the Yak and Sheep Project (Bumthang, 1975-80); the Himalayan Pasture and Fodder Research Network (1986-1995); and the Applied Research Centre, Yusipang (1988-93). By 1995/96, the following three major research centres had become established (Roder 1998a).

- the Subtropical Fodder Research Centres at Samtse and Pemagatshel
- the National Fodder Seed Production Centre at Bumthang
- the Temperate Fodder Research Centre at Serbithang

Research activities up to 1995 were either part of development projects or otherwise strongly dependent on outside inputs of expertise and resources. This affected the continuity and focus of research activities. The repeated changes of personnel and focus of the Bumthang and Serbithang centres had a negative effect on the continuity and direction of the research activites (Roder 1989).

Present research system

The Ministry of Agriculture was reorganised between 1993 and 1996. The following major changes affected agricultural research and development activities (Roder 1998a).

- The research activities previously carried out under the separate departments of agriculture, animal husbandry, and forestry were merged under a new 'Research, Extension and Irrigation Division'. This was later renamed the Department of Research and Development Services.
- A new 'Crop and Livestock Services Division' and a 'Forestry Services Division' were created for the supply of inputs and the management of the state forests, respectively.
- Four 'Renewable Natural Resources Research Centres' (RNR-RCs) were established located at Jakar, Bajo, Yusipang, and Khangma. Each of these centres was entrusted with both a regional and a national mandate (Table 25).

Table 25: The renewable natural resources research centres, their mandates and regions			
Research centre	**National (sectoral) research mandate**	**Region**	**Dzongkhags in the region**
Yusipang	Forest	Western Region	Samtse, Chhukha, Ha, Paro, Thimphu
Bajo	Field crops	West Central Region	Gasa, Punakha, Wangdue, Tsirang, Dagana
Jakar	Livestock	East Central Region	Sarpang, Zhemgang, Trongsa, Bumthang
Khangma	Horticulture	Eastern Region	Samdrup Jongkhar Pemagatshel, Trashigang, Tashiyangtse, Mongar, Lhuentse

Source: Roder 1998a

The national (sectoral) mandate involves coordinating all research activities within the particular programme at the national level and building up a pool of expertise and information specific to the particular programme.

In addition to their sectoral mandates, all the RNR-RCs are entrusted with a regional mandate, which gives each centre the responsibility for all research activities under the sectors of field crops, forestry, horticulture, livestock, and farming systems for their respective regions. These responsibilities include:

- building up a pool of expertise and information;
- importing, adapting, and generating technologies to be used in extension programmes;
- supporting extension and development programmes, training, and general backstopping.

Research in the livestock sector

The RNR-RC Jakar is responsible for the coordination of the national livestock research programme. The livestock research programme is made up of separate breeding and management, feed and fodder; and health sub-programmes (Table 26).

It was assumed that 'technologies' under the breeding and management and health sub-programmes would to a large extent be imported from outside Bhutan with little or no need for further adaptation, thus major emphasis has been given to the feed and fodder sub-programme. Around 75% of the total resources for livestock research have been allotted to this programme (RNR-RC Jakar 1997c).

Responsibility for the implementation of the health sub-programme was delegated to the Royal Veterinary Epidemiology Centre, Serbithang, which is part of the Crop and Livestock Services Division (RNR-RC Jakar 1997d).

Since 1996, the RNR-RC Jakar has organised regular annual research review and planning meetings in the livestock sector (RNR-RC Jakar 1996a, 1997d, 1998b, 1999). These meetings have been important for the national coordination of research efforts.

Table 26: Sub-projects under the livestock programme	
Sub-project	**Purpose/Objective**
Breeding and management sub-programme	
1. Description of past and present management, and monitoring trends	• Document past research and development activities
	• Describe existing management practices and potential for improvement
	• Monitor trends in production
2. Genetic evaluation and improvement	• Characterise existing breeds
	• Assist in the improvement of existing breeding programmes and develop new ones
	• Preserve native breeds
3. Production management	• Verify, adapt and develop technologies to optimise production and production efficiency
Feed and fodder sub-programme	
1. Description of past and present management, and monitoring trends	• Document past research and development activities
	• Describe existing fodder resources and their management and potential
	• Monitor trends in resource quality and production
2. Genetic evaluation and improvement	• Characterise native grassland and fodder species
	• Import and evaluate exotic species
3. Production management	• Verify, adapt, and develop technologies to optimise production and to optimise synergic effects between fodder production and other components.
Health sub-programme	
1. Description of past and present management, and monitoring trends	• Document past research and development activities
	• Describe existing management practices (including traditional health practices)
	• Monitor the cost and the impact on animal health of veterinary practices
2. Epidemiological and zoonotic studies	• Study the economic importance and epidemiology of major livestock diseases
	• Identify and describe indigenous parasites and other non-specific diseases
3. Production management Treatment practices	• Verify, adapt, and develop technologies to improve animal health

Source: RNR-RC Jakar 1997c

All four RNR-RCs are strongly committed to feed and fodder research. As described above, the research activities have been divided into three main areas (Table 26).

- the description of past and present management, and monitoring trends;

- genetic evaluation and improvement; and
- production management.

These headings are used for the presentation of past research activities in the following part of this chapter.

Research needs, priorities and constraints

In the early phases little attention was given to identifying research needs and priorities at the producers' level. The pioneering institutions at Samtse Farm and RDP-Bumthang initiated their first research programmes to improve the supply of fodder for their breeding stock. Although these research activities had a strong impact on the extension programmes, due to the lack of rigorous priority setting, some important issues were neglected. The major gaps were in the identification of nutritional limitations; the description of natural vegetation and existing fodder resources; and the production and management of winter feed.

A systematic ranking of research priorities at national level was first carried out in 1989 (Roder 1989) and again in 1996 (RNR-RC Jakar 1996a) (Table 27). In 1989 priorities were further ranked within each area of research (Roder 1989; 1990c). The two top priorities identified at the national level in 1989 were to identify the main nutritional limitations, and to promote fodder production from intensively managed permanent grassland near to settlements. These two priorities remained unchanged in the 1996 ranking.

Research activities carried out between the 1989 and 1996 reviews generated little information towards a better understanding of the main nutritional limitations. Compared to the

Table 27: Ranking of national level research priorities

Areas of research	Priority ranking[1]	
	1989	1996
Identification of the main nutritional limitations to animal production (seasonal fodder production, deficiencies in energy, protein, and minerals)	1	1
Intensively managed permanent grasslands (small plots in the vicinity of settlements, including orchards)	2	2
Arable fodder (in rotation or combination with annual crops, winter fodder) for fodder, soil improvement, and soil conservation	5	3
Tree fodder, agroforestry, and silvopastoral systems	3	4
Extensively managed permanent grassland (rangeland)	4	4
Use of crop residues and by-products (paddy straw, maize stems, buckwheat stems, home brewing)	6	4
Technology development to support various programmes (seed production, fodder conservation etc)	8	5
Grazing effects on forest systems	not included	5
Social and cultural aspects (migration, culling of unproductive animals, land ownership, communal agreements on protection of crops)	7	6

[1] Lowest number indicates highest priority

Source: 1989 -- Roder 1989; 1996 -- RNR-RC Jakar 1996a

1989 ranking, the 1996 ranking saw a shift towards work on fodder resources as a part of integrated systems. Arable fodder and fodder grown in rotation systems moved up from being the fifth priority area in 1989 to the third in 1996. Research on the use of crop residues was also given more importance in the 1996 ranking. These changes were probably due to the change in the research system as the integration of crop, horticulture, livestock, and forestry research has placed more emphasis on fodder production in crop or horticulture systems.

Regional priorities will often differ from the national priorities. At higher elevations extensively managed permanent grassland is the main concern, whilst at lower elevations arable fodder, tree fodder, and crop residues have most importance. Regional research priorities, needs, and opportunities are currently being reviewed by the newly-formed research centres.

The constraints to successful research were assessed at the same time as the research priorities were worked out (Table 28). The lack of rigorous priority setting was considered to be the main constraint in 1989 and 1996. The insufficient academic level of research personnel has remained the second most important constraint.

One of the main problems in research has been the poor progress in building up the capacities of human resources in subjects such as fodder agronomy and range management. Many of these personnel have received training in India and the lack of progress can be at least partly ascribed to Indian animal production science being dominated by veterinary science. While this may be appropriate for India, where livestock production is largely based on using concentrates and crop by-products as feed, it is not suitable for Bhutan where grasslands are the major feed resource.

Table 28: Constraints to successful research in feed and fodder

Constraint/limitation	Rank 1989	Rank 1996
Lack of focus and unrealistic identification of research needs	1[1]	1
Insufficient academic background of research personnel	2	2
Insufficient interaction with farmers and herders and poor representation of target environments	5	2
Insufficient access to information	not included	3
Insufficient research personnel	4	3
Wrong priorities	8	4
Most experimental activities are limited to on-station work	4	5
Lack of coordination with extension activities	7	6
Motivation of Bhutanese research personnel	3	7
Lack of funds	9	7
Lack of equipment	7	8
Too much dependence on expatriate advice	7	9
Insufficient support by the Ministry	8	10
Too much time taken up by administrative work	not included	11

[1] Constraints ranked in declining order of importance (lowest number indicates most serious constraint)
Source: 1989 – Roder 1989; 1996 – RNR-RC Jakar 1996a

Research under 'Past and present management and monitoring trends'

Three main areas are covered under this heading: to document past research and development activities; to describe the existing fodder resource and its management and potential; and to monitor trends in resource quality and production.

Identifying the nutritional limitations to animal production was given the highest priority in both the 1989 and the 1996 ranking exercises. This suggests that there is a perceived lack of quantitative information about fodder resources, farmers' practices, nutritional constraints to livestock production, and the quality of existing fodder. Although there are numerous references on these topics, from the detailed description of Bhutan's vegetation given by Griffith (Griffith 1839) to the extensive nationwide investigations on fodder resource use by the RNR-RC Jakar in 1997 (Table 29) (RNR RC Jakar 1997a; Roder 1998b), there is still much to be done. The great variations in climate, soils, and topography has resulted in a wide range of vegetation, fodder sources, and production systems and thus the description of these fodder resources and the management practices has been a tremendous challenge for the few researchers involved . The existing descriptions of fodder resources and their management have been covered in Chapter 2.

It is expected that in future the monitoring of trends in the quality of the resource base will become more important. Considering the fragility of the grassland resources and the potentially harmful effects that management interactions may have on biodiversity, and on forest, water and agricultural resources, it will be important to build up mechanisms and develop key indicators which can quantify trends and changes over time (RNR-RC Jakar 1997c). This part of the research programme is still in its infancy, however.

Research under 'Genetic evaluation and improvement'

The characterisation of native species and the introduction and evaluation of exotic species have been the main activities under the genetic (germplasm) evaluation and improvement programmes. To date most of the fodder resources, except for crop residues, originate from native plant species. Yet limited information is available on the production potential and nutritional qualities of most of these species. In the 1970s it was expected that the fastest gains in fodder development would be made by introducing exotic fodder species, therefore much emphasis was placed on the introduction and testing of new species and varieties.

Evaluation and description of native species

Little has been accomplished in the description and evaluation of native species. The plant communities of major grassland ecosystems remain poorly documented and there are hardly any descriptions of individual species. Indications of nutritional qualities are only available for the grassland species *Schizachyrium delavayi* and *Lespedeza* sp (Roder 1983c; Roder et al. 1997b) and for less than 20 woody perennials (Roder 1981b, 1982d; Tamang 1987). The yield of some tree fodder species has been estimated on the basis of farmers' assessments (Tshering et al. 1997a) and by extrapolating from a few single tree measurements (Roder 1992).

Of all the native species, willow has received the most attention. Observations have been made of its nutritional quality over the growing season (Roder 1992, Wangdi et al. 1997, 1998), its dry matter accumulation over the growing season (RNR-RC Jakar 1997a; Wangdi et al. 1997), its potential for hay or silage making (Premasiri 1988; Roder 1992), and its intake by sheep (Premasiri 1988) and cattle (Roder 1992).

Table 29: References relating to fodder resources and their management in Bhutan	
Activity	References
Geophysical	
Geology	Eguchi 1987a; Ganser 1983; Karan 1967
Climate	Eguchi 1987b; Karan 1967; Negi 1983; Roset 1998
Soil	Campbell 1983; Gibson 1989c; Murtagh 1983; Okazaki 1987; Roder 1982a; Sargent et al. 1985
Vegetation	
Vegetation general/Flora	Grierson and Long 1983, 1984, 1987, 1991; Griffith 1839; Noltie 1994, 2000; Oshawa 1987b; Stearn 1976
Grassland vegetation	Dunbar 1979; Dunbar 1981; Gyamtsho 1996; Harris 1987; Miller 1987a, 1987b; Miller 1989a; Noltie 1994, 2000; Numata 1987a; Roder 1983c; Roder 1990a; Tsuchida 1987, 1991
Fodder resources and their management	
Early descriptions of fodder resources	Fischer 1971; Griffith 1839; Murtagh 1983
Institutions influencing resource use	Roder et al. 1987; Roder 1989
Grassland resources	Dorjee 1986; Gyamtsho 1996; Harris 1987; Miller 1987d, 1987e; Miller 1989a; Noltie 1994, 2000; Roder 1983c; Rumball 1988a; Singh 1978
Pastoralism	Dorjee 1993; Gibson 1991; Gyamtsho 1996; Harris 1987; Miller 1987b, 1987c, 1987g; Ura 1993; Wangmo 1984
Wildlife/livestock interactions	Gyamtsho 1996; Miller 1988a; Wangdi 1979
Tree fodder	AHD undated; Bajracharya 1990; Gyeltshen 1984; Premasiri 1988; Roder 1981a, 1982d, 1985, 1992; Tamang 1987; Tshering et al. 1997; Wangdi et al. 1997, 1998
Crop residues	AHD 1987; RNR-RC Jakar 1997a; Roder 1998c; Verma 1984; van Wageningen 1985, 1986
Winter feed	RNR-RC Jakar 1997a; Roder 1983c, 1998b, 1998c
Fodder quality (including antinutritional)	Bajracharya 1990; Denzler et al. 1993; Gyamtsho 1996; Premasiri 1988; RNR-RC Jakar 1997d; Roder 1981a, 1982d, 1993; Tamang 1987; Winter et al. 1992, 1994a, 1994b

Introduction and initial screening of exotic species

The methodical introduction of germplasm and its evaluation started in the early 1970s. Since then a large number of species and cultivars have been evaluated for their fodder production potential across a wide range of environments (Figure 30, Annex 2). About 50% of all the species evaluated so far were introduced to Bhutan before 1983. Except for ruzi grass *(Brachiaria ruziziensis)*, all species that are presently recommended for extension were selected before 1982. For obvious reasons it was much easier to identify species and cultivars in the early phases of these activities when no exotic fodder species were present in the country.

Figure 30: Introduction nursery temperate species (Bumthang 2,700m)

Once most of the important fodder species had been evaluated, the chances of identifying a superior species or cultivar decreased.

Germplasm introduction and testing generally included initial screening in on-station, single-plot observation nurseries, followed by multilocational testing (on-station and on-farm) with farmers' participation. The most successful species were then released for inclusion in extension programmes. The species tested so far, and stage of testing, are listed in Annex 2.

The RDP Bumthang played a key role in the introduction and testing of germplasm. Other institutions and projects with documented germplasm introduction and screening activities included Samtse livestock farm and the Samtse Subtropical Fodder Research Centre; the Serbithang Grass Seed Multiplication Centre and Temperate Fodder Research Centre; the Highland Livestock Development Project; the Himalayan Pasture and Fodder Research Network; and the RNR-RC Jakar (Roder 1989, 1996a).

The germplasm introduction and evaluation programmes have always paid major attention to the selection of legume species that may be suitable for grassland improvement, fodder production in crop and horticulture systems, green manure, and soil conservation (RNR-RC Jakar 1996a). It was recognised early on that native grasslands lack suitable legumes whilst the available grass species had good potential for fodder production. It was expected that crop yields, soil conservation, and labour productivity could be improved by incorporating fodder production with legumes in the traditional crop and horticulture systems.

Yield studies for selected species and cultivars

Substantial information is available on the production and growth of temperate fodder species from tests performed at several different locations over several years (Table 30). With only a few exceptions, white clover, red clover *(Trifolium pratense)*, lucerne *(Medicago sativa)*, and lotus *(Lotus pedunculatus)* were the highest yielding legumes. The highest yielding grass species have been cocksfoot *(Dactylis glomerata)*, tall fescue *(Festuca arundinacea)*, and Italian ryegrass *(Lolium multiflorum)*.

Only limited observations have been made of the yields of subtropical species. Most species and cultivars that have been assessed as suitable have been selected on the basis of visual assessments of their yield potential and their persistence.

Compatibility in mixtures

Most perennial fodder species are grown in mixtures combining grass and legume species. Species in a mixture have to be compatible and need to have similar management and

Table 30: Yield of selected temperate perennial fodder species				
Location		**Batbalathang (Bumthang)**	**Karsumphe (Bumthang)**	**Serbithang (Thimphu)**
Elevation		**2,650m**	**2,700m**	**2,600m**
Period/duration		1980-82 (3 years)	1983-85 (3 years)	1990-93 (4 years)
Reference		Roder 1983c	Gyamtsho 1985	AHD 1990
Legume yield relative to white clover (%)				
White clover	*Trifolium repens*	100 (6)[1]	100 (1)	-
Crown vetch	*Coronilla varia*	-	27 (1)	-
	Latyrus silvestris	-	43 (1)	-
Birdsfoot trefoil	*Lotus corniculatus*	92 (2)	24 (2)	-
	Lotus pedunculatus	111 (1)	17 (1)	-
	Medicago glutinosa	94 (1)	-	-
	Medicago media	-	66 (9)	-
Lucerne	*Medicago sativa*	72 (15)	87 (3)	-
Alsike clover	*Trifolium hybridum*	76 (1)		-
Red clover	*Trifolium pratense*	103 (11)	84 (2)	-
	Trifolium semipilosum	89 (1)		-
	Vicia tenuifolia	-	53 (1)	-
Grass yield relative to cocksfoot (%)				
Cocksfoot	*Dactylis glomerata*	100 (8)	100 (3)	100 (7)
Tall oat grass	*Arrhenatherum elatius*	79 (6)	-	-
Tall fescue	*Festuca arundinacea*	105 (3)	96 (1)	148 (7)
Meadow fescue	*Festuca pratensis*	93 (4)	-	-
Red fescue	*Festuca rubra*	87 (2)	99 (2)	141 (3)
Italian ryegrass	*Lolium multiflorum*	112 (4)	93 (2)	96 (5)
Perennial ryegrass	*Lolium perenne*	78 (4)	-	194 (3)
	L. multiflorum x perenne	59 (3)	-	138 (2)
Bahia grass	*Paspalum notatum*	-	76 (1)	-
Common meadow grass	*Poa pratensis*	73 (1)	98 (2)	85 (1)
Timothy	*Phleum pratense*	86 (4)	-	42 (1)

[1] Value ( ) indicates numbers of cultivars under observation and used to calculate average yield.

environment requirements. Thus when evaluating germplasm it is necessary to test combinations of potential partners.

Considerable work has been done on comparing grass mixtures for temperate areas, but as yet there are no quantitative data on subtropical species used in mixtures.

Information on the performance of temperate species in mixtures was collected under a range of conditions and included on-station and on-farm studies with mixture treatments, and observations made on production plots sown on a government farm. Mixtures were generally sown following recommended practices (see Chapter 4 on extension). The persistence and contribution of the seeded species was observed over periods of from 1-20 years. The relative contribution of a particular species was measured on the basis of its contribution to the total biomass (weight) or its presence in quadrats (frequency).

Experiences with mixtures have been reviewed by Roder et al. (1997a). Meadow fescue (*Festuca pratensis)*, perennial ryegrass (*Lolium perenne*), common meadow grass (*Poa pratensis*), red fescue *(Festuca rubra)*, and timothy (*Phleum pratense*) were used as the main grass species for establishing permanent pastures in the initial fodder development programme in Bumthang (Roder 1983d; Roder et al. 1997a). This was based on recommendations from experiences in northern Europe and Switzerland (Klapp 1971).

Between 1975 and 1980, about 50 ha of grassland at altitudes between 2580 and 2900m were sown with mixtures containing over 70% of the above species (meadow fescue, perennial ryegrass, common meadow grass, red fescue, and timothy) (Table 31). However, most of these grass species disappeared within a few years of sowing. Grazing and cutting management either delayed or enhanced this process in some plots but the end result remained the same. By 1997, meadow fescue, perennial ryegrass, and timothy had disappeared completely and only minor traces of common meadow grass were left. Red fescue was dominant in one plot while cocksfoot and tall fescue, although they had been used at lower rates, had increased to higher frequencies and come to contribute substantially to the total biomass of the grassland.

Table 31: Mixtures used in on-farm trials between 1975-1980

Species	Scientific name	Seed rate (%)	Frequency 1997[1]
White clover	*Trifolium repens*	16	80
Cocksfoot	*Dactylis glomerata*	12	52
Red fescue[2]	*Festuca rubra*	4.5	13
Tall fescue	*Festuca arundinacea*	12	10
Italian ryegrass	*Lolium perenne*	4	3
Common meadow grass	*Poa pratensis*	1.5	0.5
Birdsfoot trefoil	*Lotus corniculatus*	0.3	0
Meadow fescue	*Festuca pratensis*	25	0
Perennial ryegrass	*Lolium perenne*	19	0
Timothy	*Phleum pratense*	6	0
Local grasses		-	10
Total		100%	

[1] Frequency of occurrence in 0.0625 m^2 quadrats; [2] red fescue was mostly limited to one extensively managed plot
Source: Roder 1983d; Roder et al. 1997a

The results from the large area sown at the RDP-farm were confirmed by an on-station study initiated in 1980. In this study the performance of 10 mixtures containing different species and variety combinations was observed under grazing and cutting management and with three levels of P fertiliser application (Figure 31, Table 32). The seed rates used for the different species were based on seed weight and the expected contribution of the individual species. Germination was satisfactory for all the species and varieties included. The relative contribution of the individual species to the dry matter production was measured in the year of establishment and from the first harvest in the two succeeding years. The most important findings from these studies were that:

- screening species and cultivars only in pure stands and/or under cutting treatments (without grazing) is not sufficient to assess their potential in permanent grasslands and as long-term leys;

- in seed mixtures with white clover, the contribution of the legume to the dry matter production was about 70%, while in seed mixtures with red clover, the legume contribution was about 85%;
- the dominance of white clover could be manipulated by choosing different white clover cultivars. The average white clover contribution to the dry matter production was 78% for mixtures containing Ladino, 75% for mixtures with Ladino and Milkanova cultivars mixed together, and 60% for mixtures with Milkanova only;
- birdsfoot trefoil *(Lotus corniculatus)* did not make a significant contribution to dry matter production when used in a mixture with white clover;

Figure 31: Evaluating mixtures under grazing conditions

Table 32: Average contribution to total biomass by species used in the RNR-RC Jakar mixture trial

Species/cultivar		Seed rate (kg/ha)	No of mixtures	Botanical composition[1] (%)				
				Cutting only			Grazed	
				1980	1981	1982	1981	1982
Red clover	*Trifolium pratense*	5	1	93	87	76	not included	
White clover – Ladino	*Trifolium repens*	4	2	89	80	72	72	75
White clover – Milkanova		4	1	70	72	38	48	68
White clover – Milkanova & Ladino		4	4	81	82	68	65	77
Cocksfoot – Reda	*Dactylis glomerata*	5-15	2	15	22	36	22	10
Cocksfoot – Baraula		5-15	4	16	19	32	26	10
Tall oat grass	*Arrhenatherum elatius*	9	1	1	2	4	not included	
Yellow oat grass	*Trisetum flavescens*	1-3	2	<1	<1	0	<1	3.5
Red fescue	*Festuca rubra*	3	1	<1	0	0	5	<1
Perennial rye – Vigor	*Lolium perenne*	6-7	2	5	2	0	<1	<1
Perennial rye – Barvestra		7	2	1	<1	0	<1	0
Short rotation ryegrass	*Lolium multiflorum x L. perenne*	8-15	2	6	<1	0	0	1
Common meadow grass	*Poa pratensis*	4-6	2	<1	<1	0	<1	0
Meadow fescue - Merbeem	*Festuca pratensis*	10-12	6	1	<1	0	<1	0
Timothy - Topas	*Phleum pratense*	2-4	6	0	0	0	<1	0

[1] Relative contribution of the individual species to dry matter production measured in the year of establishment and from the first harvest in the two succeeding years

Source: Roder 1983c; Roder et al. 1997a

- of all the grasses tested, only cocksfoot could secure a significant percentage, but there was no difference between the two cocksfoot cultivars used. Tall fescue and Italian rye were not included in the study;
- other grass species that showed some promise were yellow oat grass *(Trisetum flavescens)* and red fescue.

Having a high proportion of white clover in grazing areas is often seen as disadvantageous as it causes bloat in livestock, needs frequent cutting or grazing, and has a high P-requirement and limited drought tolerance (Roder et al. 1997a). Therefore, in 1990 a second series of trials was initiated to:

- identify grass species that can compete with white clover;
- develop mixtures suitable for temperate areas of Bhutan; and
- compare recommended mixtures with other mixtures.

There were three trials in the series, all involving on-farm assessment of seed mixtures.

The 'on-farm mixture trial 1 (1990)' was a nationwide trial initiated in 1990 using five different mixtures of forage seed (NFSPC 1994). The mixtures used included the species recommended for extension (white clover, cocksfoot, tall fescue, and Italian ryegrass) as well as variations which included common meadow grass, meadow foxtail *(Alopecurus pratensis)*, prairie grass *(Bromus catharticus)*, and lotus. The mixtures were evaluated in farmers' fields in the Paro, Thimphu, Wangdue, Trongsa, and Bumthang dzongkhags. All species germinated well and had on average eight or more plants per square metre one year after establishment (Roder et al. 1997a). The contribution of common meadow grass, meadow foxtail, and tall fescue to the total biomass was small. One year after establishment there was less than one plant each of common meadow grass, meadow foxtail, and prairie grass in each square metre in three of the six sites (Ritchie 1992).

The 'on-farm mixture trial 2 (1994)' involved testing of a mixture containing the recommended species (white clover, cocksfoot, tall fescue, and Italian ryegrass) with the addition of common meadow grass in the Bumthang dzongkhag. The results are shown in Table 33. The average white clover contribution to the dry matter production was below 50% from the time of the first cutting for all three years tested (Table 33), indicating that white clover dominance is not as serious a problem as often alleged. The percentage of cocksfoot increased slightly over the three-year period, while the white clover percentage decreased. The average contribution of Italian ryegrass decreased from 26% in 1994 to 11% in 1996. The contribution of tall fescue and common meadow grass was insignificant.

Table 33: Species composition of a mixture study carried out on farmers' fields in Bumthang, 1994-96

Species		Botanical composition from first cutting (%)		
		1994	1995	1996
White clover	*Trifolium repens*	44.9±6.0	43.1±11.0	30.5±4.9
Cocksfoot	*Dactylis glomerata*	22.9±8.2	39.7±17.2	35.6±9.0
Tall fescue	*Festuca arundinacea*	0.6±0.4	0.8±0.8	0
Italian ryegrass	*Lolium multiflorum*	25.9±14.1	13.3±8.2	11.4±10.9
Common meadow grass	*Poa pratensis*	0.1±0.1	0.6±0.2	0.1±0.1

Source: RNR-RC Jakar 1996b

The 'on-farm mixture trial 3 (1996)' involved testing seven mixtures made up of varying amounts of white clover, lotus, tall fescue, Italian ryegrass, cocksfoot, perennial ryegrass, red fescue, common meadow grass, and meadow foxtail in single plot studies on farmers' fields and in one replicated study under on-station conditions. All the species included in the mixtures were found present 50-70 days after seeding (Table 34). As in the 'on-farm mixture trial 1' meadow foxtail and common meadow grass showed a very low frequency, particularly on-station. Perennial ryegrass had the highest frequency in both on-station and on-farm sites, but most plants disappeared during the first winter season.

Table 34: Average establishment of different species averaged over seven different mixtures and four replicates (on-station) or two sites (on-farm)

Species		Seed rate (kg/ha)	No. of mixtures	Frequency[1]	
				On-station	On-farm
White clover	*Trifolium repens*	2-3.75	6	74	61
Lotus	*Lotus pedunculatus*	5	1	85	35
Italian ryegrass	*Lolium multiflorum*	5-7.5	3	81	67
Cocksfoot	*Dactylis glomerata*	5-17.5	7	79	64
Tall fescue	*Festuca arundinacea*	10-15	7	58	61
Perennial ryegrass	*Lolium perenne*	5	4	93	74
Meadow foxtail	*Alopecurus pratensis*	2-10	2	2	20
Red fescue	*Festuca rubra*	5-7	2	74	40
Common meadow grass	*Poa pratensis*	4	1	3	20

[1] Presence in 0.0625m^2 quadrats (10 per plot) observed 50-70 days after seeding
Source: Roder et al. 1997a

Reviewing these temperate mixture trials, Roder et al. (1997a) concluded that white clover, cocksfoot, tall fescue, and, under specific conditions, Italian ryegrass, are well suited for most temperate areas of Bhutan. These findings confirmed that the choice made in the early eighties to use these species in the extension programme was appropriate. The poor results obtained with perennial ryegrass, meadow fescue, and common meadow grass suggest that these species are not suitable for Bhutan.

The same authors concluded that it is more important to conduct variety trials with the selected species, especially cocksfoot and tall fescue, than to test additional species or conduct further studies of species already deemed unsuitable in the 1970s trials. An effective evaluation of a particular grass cultivar would consider the interaction with the expected companion legume, the type of grazing animals, and current management practices by farmers. Also, further trials with prairie grass, Lincoln grass, and lotus are needed to prove whether or not they offer an advantage over the existing recommended species.

Overall the results of the above trials have not so far resulted in any changes in the species previously recommended for extension from trials prior to 1982 (Roder et al. 1997a). However, many investigations were not followed up for a long enough period to provide conclusive data, whilst others were only poorly documented.

Species recommended for extension

Since the early 1970s, a number of annual and perennial species and varieties have been recommended by various professionals for fodder production in specific environments (Table 35). Some of them have been included in the extension programmes, whilst others are still

Table 35: Species recommended for fodder production in Bhutan

Species	Year[1]	Ref.[2]	Area (ha)[3]	Present status
Annual species				
Oat *(Avena sativa)*	<1975		<100	• Recommended for winter feed
Fodder beet *(Beta vulgaris)*	1982	2	<10	• On-farm evaluation
Hairy vetch *(Vicia villosa)*	1978	1	<5	
Swede *(Brassica napus)*	1982	3	-	• On-farm evaluation
Kale *(Brassica oleracea)*	1982	3	-	
Field pea *(Pisum sativum)*	1978	1	-	
Herbaceous perennials				
White clover *(Trifolium repens)*	1978	1	100,000	• Extension programme since 1978
Cocksfoot *(Dactylis glomerata)*	1978	1	20,000	
Italian ryegrass *(Lolium multiflorum)*	1978	1	15,000	
Tall fescue *(Festuca arundinacea)*	1982	3	15,000	
Kikuyu grass *(Pennisteum clandestinum)*	1982	3	2,000	• Not multiplied, weed problems
Napier grass *(Pennisetum purpureum)*	1982	3	500	• Extension programme since 1980
Greenleaf desmodium *(Desmodium intortum)*			<500	• Provisionally in extension programme for limited periods
Lotus *(Lotus pedunculatus)*	1979	4	<50	
Lucerne *(Medicago sativa)*	1978	1	<5	• Problems in seed production
Red clover *(Trifolium pratense)*	1978	1	-	• Seed production studies
Stylo *(Stylosanthes. guianensis)*	1982	3	<50	• On-farm evaluation
Red fescue *(Festuca rubra)*	1982	3	<10	
Silverleaf desmodium *(Desmodium uncinatum)*	1982	3	-	
Guinea grass *(Panicum maximum)*	1982	3	-	
Setaria (*Setaria sphacelata)*	1982	3	-	
Crown vetch *(Coronilla varia)*	1982	3	-	• Under observation
Glenn joint vetch *(Aeschynomena americana)*	1988	5		
African clover *(Trifolium ruepellianum)*	1988	5		
Woody perennials[4]				
Willow (*Salix babylonica*)	1981	6	100	• Extension programme since 1982
Leucaena leucocephala	1981	7	<5	
Ficus roxburghii	1982	6	5000	
Ficus nemoralis	1982	6	<100	
Bauhinia purpurea	1982	6	<100	
Bauhinia variegata	1982	6	<100	
Artocarpus lakoocha	1982	6	<100	
Litsea polyantha	1982	6	<100	
Brassaiopsis hainla	1982	6	<100	
Saurauia nepaulensis	1982	6	<100	
Prunus cerasoides	1982	6	<100	

[1] Document in which species was recommended for the first time; [2] references: 1 = AHD undated d; 2 = Hickman 1981; 3 = Roder 1982c; 4 = Dunbar 1979; 5 = Gibson 1988b; 6 = Roder 1982b; 7 = Tenzing 1981b; [3] area cultivated in 1996 estimated by authors based on achievements reported and survey results; [4] area for woody perennials based on 200 trees per ha

under investigation or have been discarded due to seed production problems, limited potential, or other reasons. Species recommended and later discarded include Kenya white clover *(Trifolium semipilosum)* - due to low production (Roder 1983c); Jerusalem artichokes *(Helianthus tuberosus)* - due to wild boar problems; and meadow fescue and perennial ryegrass - due to poor persistence (Roder et al. 1997a).

Some of the most important species recommended are described below.

White clover – White clover has been the most widely used exotic fodder species in Bhutan and has proven to be the most suitable legume for grassland improvement over a wide range of conditions between 2,000m and 4,000m altitude (Gyamtsho 1996). Its first recorded introductions were made in 1970 and 1974 (Roder et al 1997b). In extensive testing over a range of locations at elevations of between 1,500 and 4,000m, red clover, lucerne, birdsfoot trefoil, and other lotus varieties produced dry matter yields equal to that of white clover; however, they were less persistent and gave lower yields under grazing (Roder 1983c).

Initial white clover establishments were only successful when seeds were inoculated with the appropriate rhizobia and sufficient P fertiliser was provided. With higher P application rates, dry matter yields reached up to 11t ha^{-1}. The potential for dry matter yield increases through white clover introduction and P application, but the effect of P decreases with increasing elevation and decreasing precipitation. Two studies at 4,000m found no significant increase in dry matter production with P fertilisation (Gyamtsho 1996; Roder 1983c).

White clover has excellent nutritional qualities (Table 36). However, its tendency to cause bloat in livestock has sometimes been a serious problem. A survey on attitudes to white clover and numbers of animal lost due to bloat was carried out across five dzongkhags (Roder 1998b); the results are summarised in Table 37. The number of animals lost due to bloat was relatively high in Bumthang and Wangdue, both regions with large areas of white clover based grasslands. Many respondents from these two dzongkhags considered white clover to be a weed (Table 37, Figure 32). However, the majority of respondents from these areas felt that there was no need to replace white clover with other legumes.

Table 36: Fodder quality of white clover compared to local species

Fodder	Crude protein (%)	Crude fibre (%)	P (%)	Starch units
White clover (at flowering)	18	22	0.29	60
Schizachyrium delavayi (before flowering)	5.4	42	0.11	24
Lespedeza sp. (before flowering)	14	35	0.16	-
Local hay	5.0	40	0.17	17
Hay from grass/clover mixture	11.0	30	0.21	50

Source: Roder 1983c

Thanks to the very successful introduction of this species through the extension programme, complimented by its spread through seed carried by grazing animals, white clover is now found throughout Bhutan, especially along roads and waterways and in cropland and grazing land.

Table 37: Farmers' assessment of white clover[1]					
Gewog[2]	No need to reduce clover	Clover causes bloat	Clover is a weed	Animals lost due to bloat (% HH)	Animals lost due to bloat (no./HH over 6 years)
Dopjari (P)	83	5	5	0	0
Narja (P)	34	9	79	0	0
Sephu (W)	50	17	45	4	0.05
Phubjikha (W)	95	47	76	36	0.55
Tangsibi (T)	61	33	2	25	0.36
Drakten (T)	92	11	0	2	0.02
Tang (B)	86	68	75	44	1.15
Chumey (B)	25	44	74	22	0.48

[1] For sample size in dzongkhags see Table 5; [2] dzongkhag, P = Paro; W = Wangdue; T = Trongsa; B = Bumthang
Source: Roder 1998b

This fast spread of a newly introduced species is very similar to the expansion of invasive weeds and so has caused some alarm. Some farmers are mainly worried by its bloat inducing properties, whilst others have called for caution in future extension programmes, have denounced it as a serious weed, or even condemned it as a menace to the existing biodiversity (Roder 1996b; Roder et al. 1997b). Although these may be overreactions, there is a need to reassess the place of white clover in future fodder development activities and to identify alternative techniques and species that:

- have lower P requirements and are more efficient in taking up P;
- can accumulate good quality fodder over the entire growing season, which will then be available for winter feed; and
- are less susceptible to water stress.

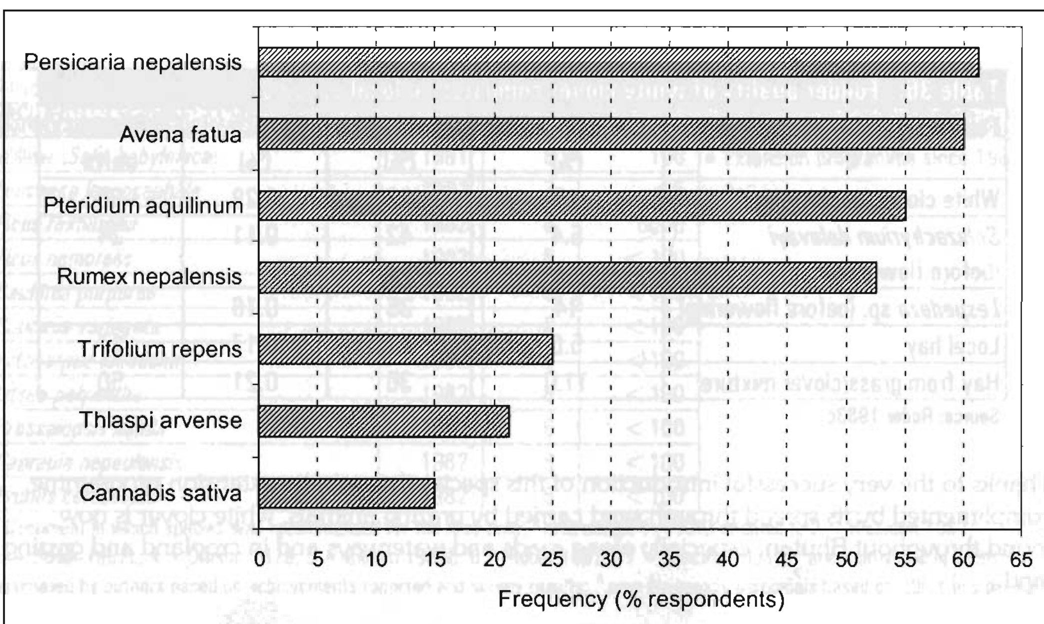

Figure 32: Most important weeds in buckwheat/wheat systems of Bumthang

Cocksfoot – Cocksfoot has a wide distribution throughout Europe, North Africa, temperate Asia, and some Himalayan regions (Bor 1960). Some authors have suggested that the species found in the eastern Himalayas may be a distinct sub-species, different from the European species (Bor 1960).

The first documented introduction of cocksfoot into Bhutan was made in 1974 (Roder 1983d). It appears, however, that the species was already in Bhutan before this date. Cocksfoot was found in permanent grassland systems in Merak Sakten (Eastern Bhutan) in 1976 (Dunbar, personal communications). Compared to exotic varieties, however, the line obtained from Merak Sakten had poor production (Roder 1983c).

Cocksfoot forms tufts and tends to have a high fibre content in advanced maturity (Klapp 1971). For European grasslands it is therefore often considered to be an inferior species (Klapp 1971). It is, however, well adapted to cyclic dry and wet conditions such as those prevailing in Bhutan and it is expected that it will gradually spread through much of the temperate grasslands of the country.

So far about 30 cultivars of cocksfoot have been introduced into Bhutan. However, with a few exceptions, they have not been systematically tested for yield, quality, or persistence (Roder 1983c; Roder et al. 1997a). A European variety 'Amba' is used at present by the extension services. In a review of temperate grass mixtures and species, Roder et al. (1997a) recommended that a systematic evaluation of cocksfoot cultivars should be performed to identify the varieties with the best potential.

Pearl lupine – Pearl lupine *(Lupinus mutabilis)*, a plant from the Andean region of South America, was first introduced into Bhutan in 1977. It was initially introduced as an oil crop, but was found unsuitable because of its high alkaloid content and the difficulties in extracting the oil (Roder 1983e; Roder et al. 1993b). Studies carried out at high elevations in Bumthang and Phubjikha found that pearl lupine was an excellent green manure crop with the following useful properties (Table 38):

- vigorous growth which suppresses weeds;
- high levels of biomass production with rates of 15.6g m^{-2} day^{-1} during peak growth, resulting in high levels of N-accumulation;
- ability to nodulate vigorously with native rhizobia strains; and
- suitability to cool climates and poor soil conditions with low P-availability.

In rotation studies, the yield of potatoes increased by 33 to 34% when the previous crop had been pearl lupine rather than fallow or potato (Roder et al. 1993b). In spite of the excellent results, it was concluded that pearl lupine should not be recommended for extension because farmers require fodder rather than green manure, and pearl lupine is not very palatable.

Table 38: Biomass yield and N and P accumulation by pearl lupine (*Lupinus mutabilis*)

Plant part	Accumulation over 7 months growing season (g m^{-2})		
	Biomass	N	P
Nodules	25	1.2	0.08
Roots	107	1.1	0.12
Stems	1,172	12.9	2.11
Leaves	157	7.6	0.68
Flowers	9	0.4	0.04
Pods	105	4.6	0.58
Total	**1,575**	**27.7**	**3.60**

Source: Roder et al. 1993b

Willow (*Salix babylonica*) – It is not known when this species of willow was first introduced into Bhutan. Early travellers to Bhutan make reference to the abundance of willow trees in Paro and Thimphu valley (Marakham 1876). Today willow is found widely throughout the country at elevations between 800 and 3,000m; it is by far the most important tree fodder species at elevations above 2,500m (Roder 1981b; Roder 1992). Experience with willow as a fodder source have been reviewed by Wangdi et al. (1998).

An initial survey carried out in 1981 in Bumthang dzongkhag (elevation 2,600 to 3,000m) found that willow was clearly the preferred fodder tree species (Roder 1981b). The farmers surveyed were found to have an average of 17.5 willow trees each. Similarly, in eastern Bhutan, farmers indicated their preference for this species (Wangdi et al. 1997). At present no other kind of tree fodder species is planted by farmers in temperate areas of Bhutan.

Willow is a multipurpose tree: farmers value it as a source of fodder but give almost equal importance to its value for fuel and fencing (Figure 33, Table 39). Although farmers appreciate its high fodder quality, they would prefer to have a species that can provide fodder during the dry winter season (Roder 1992; Wangdi et al. 1997). The fluctuations in quality and availability of willow fodder are quite similar to the seasonal pattern of natural grasslands, and the tree leaves drop in November.

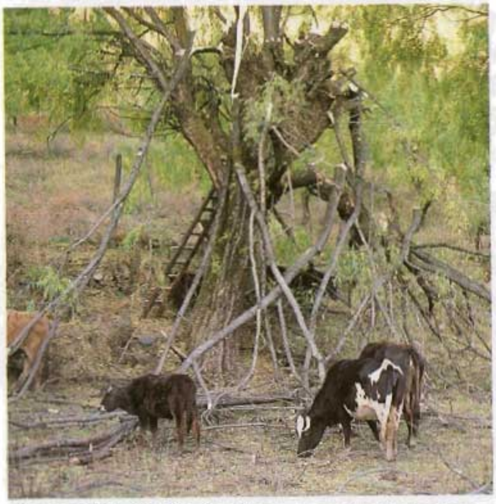

Figure 33: Cattle feeding on willow leaves

Table 39: Farmers' main motives for planting willow[1]	
Use, motive	**Respondents (%)[2]**
Fodder	80
Fencing	77
Fuel	77
Erosion Control	3
For sale (branches for planting)	6

[1] Data from willow survey 1996, the survey covered 35 farmers; [2] the sum is greater than 100% because all farmers gave two or more uses

The fodder quality of willow is discussed elsewhere in this chapter. The yield from existing stands is estimated to be 3.8 to 7.0t of dry matter per ha (Gyamtsho 1986; Roder 1992). The dry matter yield of 5 to 10 year old willow trees increases as the growing season progresses, but starts to decline in October (Figure 34). It is recommended that willow is best cut for feeding to livestock during September and early October before the leaves are shed. By using willow foliage as fodder in October, farmers can save the white clover and grass resources for grazing later in the dry winter period. Combined management of willow and white clover to extend the availability of winter fodder, was recently adopted by the Ministry of Agriculture as an extension recommendation (Roder 1999).

Jerusalem artichokes – This annual species was first introduced to Bhutan by a farmer in the 1970s (Gyamtsho 1986; Roder 1983c). In a number of studies carried out in Bumthang between 1978 and 1983, Jerusalem artichokes produced the highest dry matter yield of all the arable fodder species tested (Roder 1983c). Both tubers and stems can be used as cattle feed. It was therefore recommended as the most promising winter fodder by the RDP and the

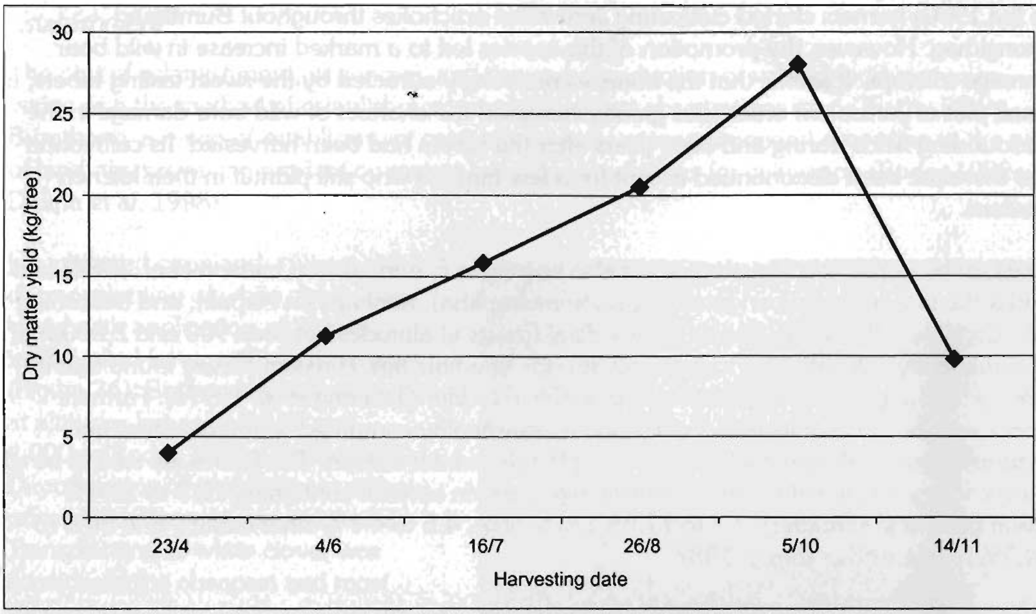

Figure 34: Effect of harvesting date on the dry matter production of willow trees

GAFRC (Grassland and Associated Fodder Research Centre) Bumthang between 1980 and 1985.

Studies carried out during this period included variety trials, fertility management, spacing, intercropping with scarlet bean (*Phaseolus coccineus*), and the effect of cutting date on the quality of stem biomass and total dry matter yield (Table 40) (Roder 1983c). These experiments found that for Jerusalem artichokes:

- cultivation is easy, thanks to strong weed suppression and the absence of pests and diseases;
- dry matter yields ranged from 10-15t ha^{-1};
- varieties varied in yield, keeping quality, and tuber form - the variety with the highest tuber yield (variety 36-64) had the poorest keeping quality; and
- the highest dry matter yields were obtained when the stems were harvested immediately before they turned yellow, towards the end of September.

Intercropping studies with scarlet bean were inconclusive.

Table 40: Effect of harvesting date on dry matter yield and quality of Jerusalem artichokes (*Helianthus tuberosus*)

Harvesting date	Dry matter yield (t ha^{-1})			Quality of above ground biomass (% of dry matter)		
	Stem	Tuber	Total	Crude protein	Digestible P[1]	Crude fibre
6 June	6.1	0.6	6.7	7.8	1.1	21.6
31 August	9.0	3.5	12.6	7.4	1.4	17.6
19 September	6.9	8.1	15.0	5.0	1.0	24.4
15 November	2.5	7.6	10.2	4.0	0.5	29.6

[1]Pepsin-HCl digestible protein

Source: Roder 1983c and unpublished data by the authors

In the 1980s farmers started cultivating Jerusalem artichokes throughout Bumthang dzongkhag. However, the promotion of this species led to a marked increase in wild boar damage to crops. It seems that the boars were strongly attracted by the sweet tasting tubers; a small plot of Jerusalem artichokes greatly increased the chances of wild boar damage in the surrounding fields during and even years after the tubers had been harvested. Its cultivation has therefore been discontinued except for a few farmers who still plant it in their kitchen gardens.

Ficus roxburghii – This Ficus species is also known as *F. auriculata* (Grierson et al. 1984) and under the local names chongmashing (in Sharchopkha), nebharo (in Nepali), and bakushing (in Dzongkha). It is widely found in broadleaf forests at altitudes between 900 and 2,000m. It is traditionally cultivated for fodder and also for its edible figs. A recent survey found that it was by far the most widely cultivated type of tree fodder (Tshering et al. 1997a). Farmers preferred it because of its high yield, good fodder quality compared with most other tree fodders (Figure 35), and availability during the dry winter season. The leaves are said to be of a satisfactory palatability with a relatively high protein content containing 12.3 to 13.4% crude protein (dry matter), 7.7 to 17.8% crude fibre, 4.5 to 4.7% ether extract, and 50.0 to 64.9% N-free extract (Singh 1982).

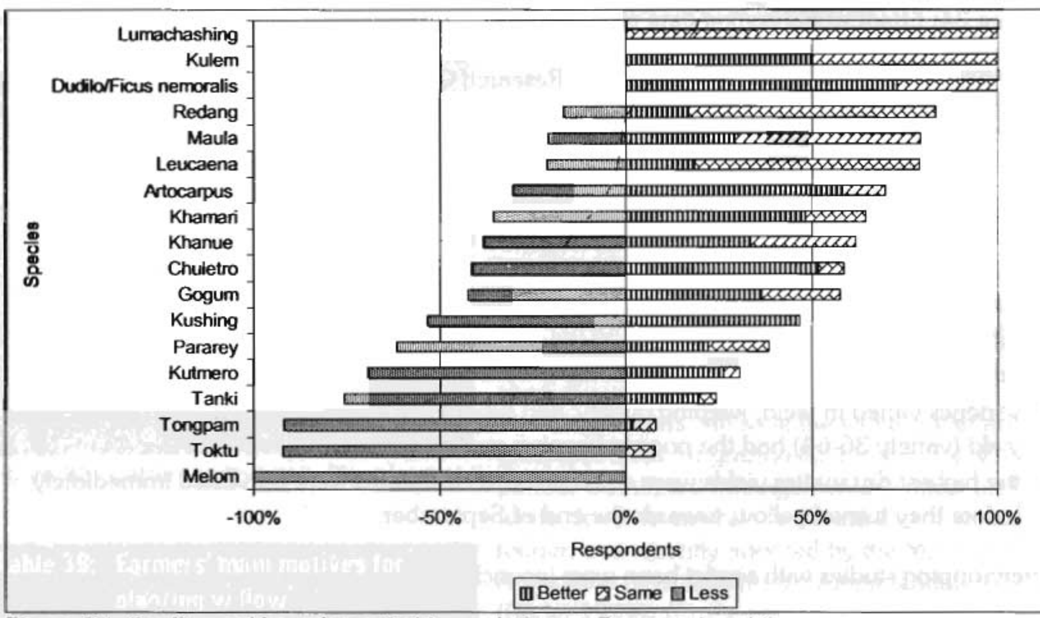

Figure 35: Quality ranking of tree fodders relative to *Ficus roxburghii*

In spite of its importance, only limited research has been carried out on this species. Ongoing activities are focusing on nursery propagation techniques and quantifying variability within population for yield and fodder quality parameters (RNR-RC Jakar 1996b).

Research under 'Production management and treatment practice'

Research under the broad heading of 'Production management and treatment practice' (of fodder) includes the areas of establishment, soil fertility management, legume inoculation, grazing and cutting management, fodder preservation, winter feed, and seed production. Of these, soil fertility management has received the most attention.

Establishment

The cost of establishment, its success, and the early production of seeded fodder species varies with the method of establishment used. Based on observations made by the RDP Bumthang, a range of establishment methods have been recommended according to the type of land, the prevailing production system, and the possibilities for cultivation (Roder 1982c; Dukpa et al. 1998).

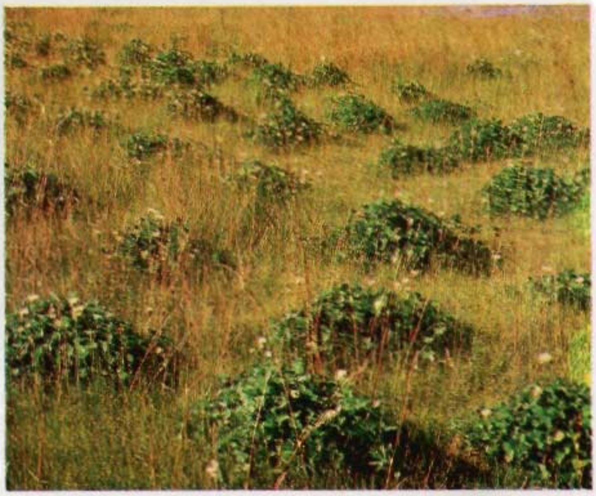

Figure 36: Establishing white clover through transplanting (Lebey, 3,000m)

Uncultivated grassland – Direct sowing or transplanting of white clover combined with application of P were investigated for uncultivated grassland (Figure 36). Both methods were tested at altitudes between 2,600 and 4,000m (Roder 1982c; Roder 1983c). Direct sowing of grass species without prior cultivation was not successful. Transplanting of white clover was considered the cheapest and most successful method for the improvement of permanent grasslands. Transplanting of lotus and crown vetch *(Coronilla varia)* has also been recommended (Roder 1981a).

Cover crop for cultivated fields – Buckwheat, maize, millet, barley, and wheat are all recommended as cover crops for establishing legume-grass mixtures (Roder 1983b). In the farming system common in Bumthang, sweet buckwheat has proved to be the best option. Seeds of the legume and grass species are sown at the same time as the buckwheat. Good seed bed preparation, the time of planting, the short growing period, and limited shading of the cover crop, all combine to make buckwheat an excellent cover crop for the establishment of grass and legume species. In other regions, maize and millet have been found to be the best options for establishing fodder species. In this case the seeds need to be broadcast immediately after the last weeding of the main crop.

Seeding into buckwheat has become the most widely practiced establishment method in higher elevation temperate areas where buckwheat is an important traditional crop. In other areas, fodder species are frequently seeded without a companion crop. This results in high labour costs, heavier weed competition, and frequent failures or else sub-standard stands of the fodder species. The increasing emphasis on the integration of fodder production with field crops and horticulture systems (RNR-RC Jakar 1996a), and the use of fodder species for mulching and soil conservation, has meant that there is a need to develop establishment methods for these systems. Furthermore, the cost of seed to cover one hectare with a white clover, stylo *(Stylosanthes guianensis)*, or desmodium *(Desmodium intortum)* based legume grass mixture is in the range of Nu 1,200-5,000 (approximately US$ 30-125) depending on the seed rate and the source of seed (Dukpa et al. 1998). This is a substantial investment, at present fully paid through subsidies. With the likely reduction of government subsidies for seeds, it will be important for farmers to optimise the success of establishment.

A series of establishment studies using relay seeding in wheat, maize, or rice was initiated in 1996 with the objectives of (1) validating earlier recommendations; (2) evaluating the possibility of relay seeding selected fodder species in to wheat, maize, or rice crops; and (3) quantifying the effect of planting date on establishment success. The results are summarised in Table 41. They showed that

- in all of Bhutan's major cropping systems, fodder and green manure species can be established by broadcast seeding in the particular crop (Figure 37);
- early seeding gives better establishment (Figure 38) – but is often not possible due to weeding requirements and concerns regarding competition with the main crop;
- wheat as a companion crop can only be recommended with spring sown wheat, or where wheat is sown or drilled in lines combined with weed control.

Figure 37: Establishing subtropical legumes by relay seeding in maize

Further studies are required in maize and rice systems to quantify the potential dry matter production of forages and the effect of legume cover on moisture, nutrient, and weed dynamics. In rice systems, the main challenge is the identification of suitable species for particular locations and cropping systems. Studies are needed to (1) evaluate planting date, moisture, and location interactions, and (2) quantify potential biomass production, effects on rice yields, and economic benefits.

Table 41: Relay seeding in field crops - summary of individual studies

Companion crop	Location	Elevation (m)	Species[1]	Planting dates (no.)	Density (plants per m^2)	Most promising species[1]
Wheat	Wangduecholling (Bumthang)	2,680	1,2,3,4,14	2	53	none
Maize	Chamkhar (Bumthang)	2,700	1,2,3,4,5, 14	3	114	3, 5 (crimson clover, hairy vetch)
Maize	Sanglajong (Zhemgang)	900	6,7,15,16	2	8	6, 7 (greenleaf desmodium, stylo)
Rice	Bhur farm (Sarpang)	300	2,3,4,5,8,9, 10,11,12,13	1	13	12 (Wynn cassia)

[1] 1 – white clover (*Trifolium repens*), 2 – red clover (*T. pratense*), 3 – crimson clover (*T. incarnatum*), 4 – sweet clover (*Melilotus officinalis*), 5 – hairy vetch (*Vicia villosa*), 6 – greenleaf desmodium (*Desmodium intortum*), 7 – stylo (*Stylosanthes guianensis*), 8 – *Trifolium rueppellianum*, 9 – berseem (*T. alexandrinum*), 10 – *Lablab purpureus*, 11 – *Aeschynomene americana*, 12 – Wynn cassia (*Chamaecrista rotundifolia*), 13 – *Vigna parkeri*, 14 – Italian ryegrass (*Lolium multiflorum*), 15 – molasses (*Melinis minutiflora*), 16 – ruzi grass (*Brachiaria ruziziensis*)

Source: Dukpa et al. 1998; RNR-RC Jakar 1997a

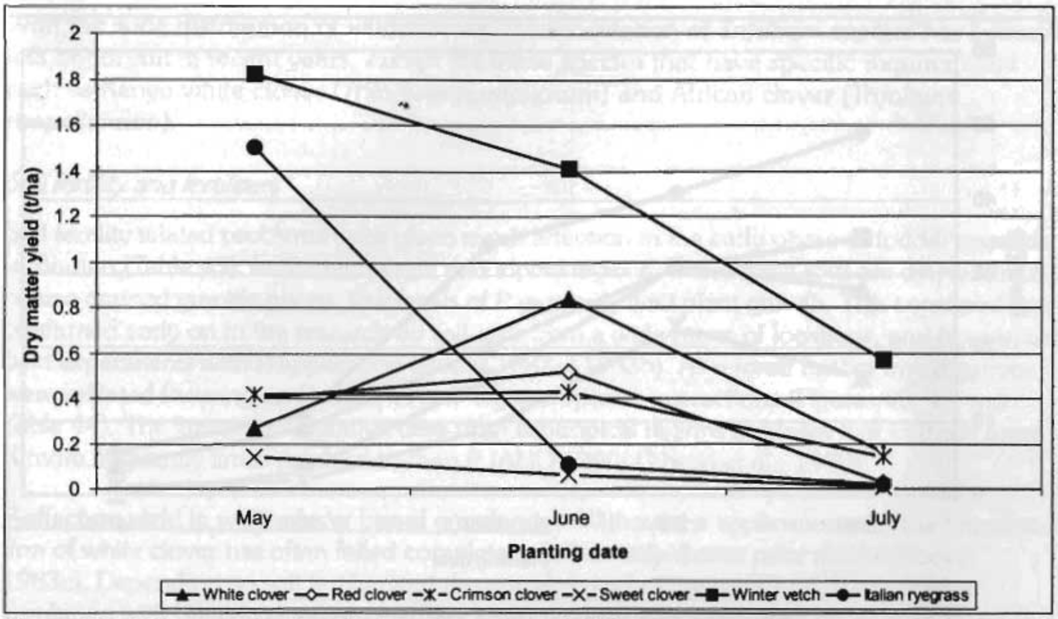

Figure 38: Effect of planting date on dry matter yield in temperate maize system

Establishment of perennial pasture after harvesting potatoes – Potato is an important crop in many temperate regions of Bhutan. Studies were carried out over two years and in two locations to evaluate the effect of planting date on the establishment of lotus, white clover, and hairy vetch *(Vicia villosa)* mixed with Italian ryegrass when planted after a potato harvest (Roder et al. 1991). The studies found that

- potato fields provide excellent seed bed conditions for the broadcast seeding of fodder species;
- the broadcast seeding of white clover, lotus, and hairy vetch can be extended as late as mid-September (Figure 39); and
- residual nitrogen from fertiliser and manure applied to potato crops favours the establishment and early growth of grass species, thus reducing clover dominance.

High elevation bamboo-dominated pasture – Studies were initiated in 1995 and 1996 on establishment method, species performance, and P interaction in a bamboo dominated, wet pasture at 3,500m in Shinkhar Ura (RNR-RC Jakar 1997a). The intermediate results indicate that

- lotus and white clover show some promise in this environment;
- direct seeding or transplanting is superior to digging and/or burning field preparation; and
- production of introduced species is poor, possibly due to micro-nutrient deficiencies.

Inoculation of legumes

Inoculation with *Rhizobium* is necessary for most species of temperate legumes (Table 42). Initial introductions of *Trifolium* and *Medicago* species in Bumthang failed because the appropriate inoculum was not available (Roder 1983d). Over the years a number of inoculation studies have been carried out to

- quantify the effect of inoculation on various legume species (AHD 1990; Gibson 1989b);
- test inoculation methods (Dorji and Roder 1980; Roder 1983d; Gibson 1989b); and
- test the quality of inoculum (AHD 1990).

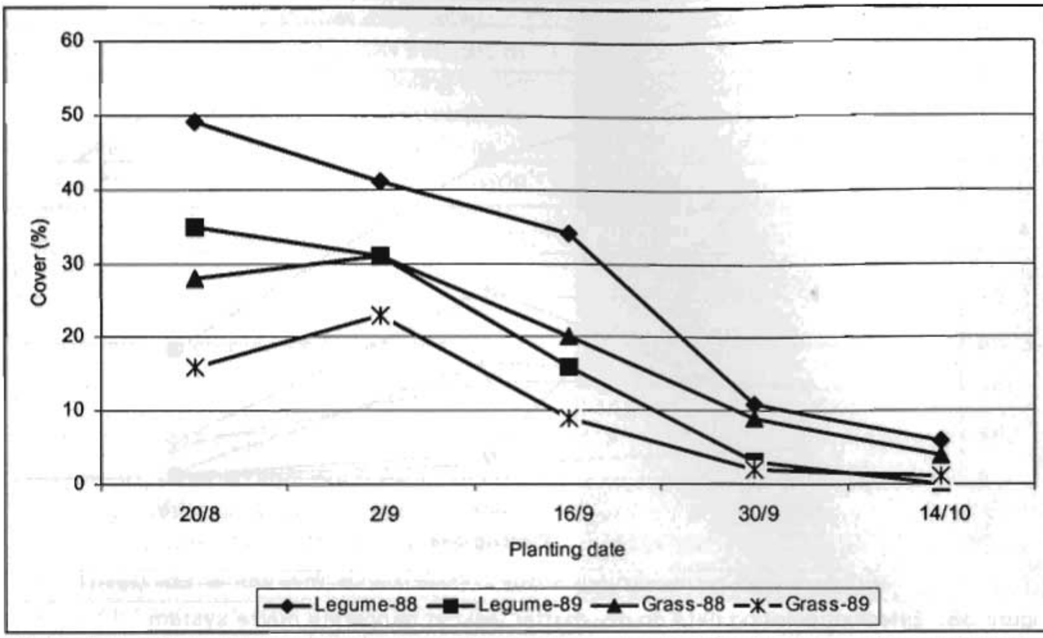

Figure 39: Effect of planting date on cover of legume species (Legume = average of white clover, lotus, and hairy vetch) and Italian ryegrass (Grass).

Table 42: Inoculation requirements for temperate fodder legumes

Inoculation requirements	Species	Reference
No survival or extremely poor growth if not inoculated	All *Trifolium* species[1]	Roder 1983c; 1983d
	All *Medicago* species	Roder 1983d
	All *Melilotus* species	Roder 1983d
	Robinia pseudoacacia	Roder 1983c
	Lotus pedunculatus	Roder 1983e
	All *Lupine* species except *L. mutabilis*	Roder 1983e
Show no or limited response to inoculation but require observation	*Lotus corniculatus*	Roder 1983d
	Onobrychis species	Authors[2]
	Lathyrus species	"
No information available on the requirement under Bhutanese conditions	*Astragalus* species	"
	Coronilla varia	"
Nodulate freely with native strains	*Vicia* species	Roder 1983d
	Lupinus mutabilis	Roder 1983e
	Pea	Authors[2]

[1] *T. semipilosum* and *T. ruepellianum* are highly specific, ordinary *Trifolium* strains are not suitable; [2] unpublished observations by authors of this review

Inoculation is less important for subtropical species as they are generally less specific in their requirement for a particular rhizobia strain. Several studies have found no significant response of subtropical legumes to inoculation (Gibson 1989b).

With the wide distribution of white clover, the inoculation of *Trifolium* species has become less important in recent years, except for those species that have specific requirements such as Kenya white clover (*Trifolium semipilosum*) and African clover (*Trifolium ruepellianum*).

Soil fertility and fertilisers

Soil fertility related problems were given much attention in the early phase of fodder research in Bhutan (Table 43). In the temperate and alpine regions, where most soils are derived from coarse-grained granitic gneiss, low levels of P generally limit plant growth. This constraint was confirmed early on in the research by soil tests from a wide range of locations, and from initial field experiments with P-application (Roder 1982a; 1983b). As a result further investigations were initiated focusing on P and P-N or P-legume species interactions (Figures 40, 41 and Table 44). The limited quantitative data from subtropical regions indicates that in those areas K more frequently limits production than P (AHD 1990; Gibson et al., 1990).

P-effect on yield in white clover based grasslands – Without the application of P, the introduction of white clover has often failed completely, or has only shown poor results (Roder 1983c). Depending on soil fertility and the management of the grassland, P application combined with the introduction of white clover increased the dry matter production by up to 30 times as compared to control plots (Table 44, Figures 40 and 42). The introduction of white clover with the application of P was found not only to increase yield but also simultaneously to increase the quality of the dry matter (Roder et al. 1997b).

Results from Kidiphu and Laya suggest that the expected gain in dry matter production through P application and white clover introduction decreases with altitude (Gyamtsho 1996; Roder 1983c). Similarly the potential to increase grassland production decreases with increasing elevation (Dunbar 1979; Harris 1987; Roder 1983c and 1990a).

In a multi-locational trial (Dorji and Dukpa 1992), the application of 26 kg of P increased the average dry matter yield by 39% whilst the application of 1.5t manure ha^{-1} increased yields by an average of 29%. This was tested at seven locations over three years (Figure 42). The comparatively low yield effects of P and manure application in this study were attributed to the experimental fields either being nashing (cultivated wetland) or pangshing (shifting cultivation land) fields, which already had relatively high levels of soil fertility. In most fertiliser trials the biomass produced was harvested by cutting and removing it from the plots rather than testing under grazing conditions, in which case there would have been a fertility input from animal waste. In a grazing study, an increase of P from 9 to 26 kg ha^{-1} increased the dry matter yield over four years by 209% (Roder 1983c).

P-fertilisers – The phosphate fertilisers available in Bhutan during the 1970s and 1980s were tricalcium phosphate (rock phosphate), mono-tricalcium phosphate (superphosphate and rock phosphate mixed), and at a later stage single superphosphate. Rock phosphate has been widely recommended because of its supposedly better effect in acid soils. However, initial applications of rock phosphate showed a very poor response, therefore several fertiliser studies were initiated to quantify the effect of these fertilisers (Gyamtsho 1986; Roder 1983c). In these studies rock phosphat, even if used repeatedly over several years, was found to have little effect on dry matter yields (Gyamtsho 1986; Roder 1983c). Based on the results of these studies, the promotion of both types of rock phosphate was discontinued in the extension programmes.

Table 43: Soil fertility studies in permanent grassland systems		
	Location	**Reference**
Subtropical		
P-effects	Pemagatshel	Gibson et al., 1990
K-effects	Pemagatshel, Samtse	AHD 1990; Gibson et al. 1990
Trace elements	Pemagatshel, Samtse	AHD 1990; Gibson et al. 1990
P-effect for establishment	Namthay	Dorji and Dukpa 1992
N-effects	Samtse	AHD 1990
Temperate		
Fertiliser effect for establishment	Batbalathang, Phubjikha	ARC 1989; Roder 1983c; RNR-RC Jakar 1997a
Dolomite effect for establishment	Phubjikha	ARC 1989
P-effects, P-level	Batbalathang, Nationwide, Mongar, Wabthang	AHD 1990; Dorjee 1989; Dorji and Dukpa, 1992; Gyamtsho 1986; Roder 1983c
P-fertilisers	Batbalathang, Lebay, Mongar	AHD1990, Roder 1983c
P-effects under grazing	Batbalathang	Gyamtsho 1986; Roder 1983c
P-legume species interactions	Batbalathang	Gyamtsho 1986; Roder 1983c
Manure	Batbalathang, Nationwide, Wabtang	AHD1990; Dorjee 1989; Dorji and Dukpa, 1992; Gyamtsho 1986; Roder 1983c
Other P sources	Batabalathang	Dorjee 1989; Dorji and Dukpa, 1992; Roder 1983c
N-effects	Batbalathang, Wabtang	AHD 1990; Gyamtsho 1986;
Boron effects	Batbalathang	Gyamtsho 1986; Roder 1983c
Potassium	Batbalathang	Gibson, 1989b; Gyamtsho 1986; Roder 1983c
Lime	Batbalathang	Gyamtsho 1986; Roder 1983c
Sulphur/gypsum	Batbalathang	Dorjee 1989; Gyamtsho 1986; Roder 1983c
Alpine		
P-effects, P-level	Kidiphu, Ura. Laya	Dorjee 1989; Gyamtsho 1986; Gyamthso 1996; Roder 1983c
P-legume species interactions	Kidiphu, Laya	Gyamthso 1996; Roder 1983c
Manure	Kidiphu	Roder 1983c
N-effects	Laya	Gyamthso 1996

Alternative sources of P – The limitations on fodder production due to low P availability and the high transportation cost of imported P inputs led to a number of studies being commissioned to evaluate possible alternative sources of P. A number of studies showed promising results with manure (Dorji and Dukpa 1992; Roder 1983c). In contrast, application of ash (from blue pine needles), compost, or blue pine needles did not increase forage yields (Gyamtsho 1986; Roder 1983c).

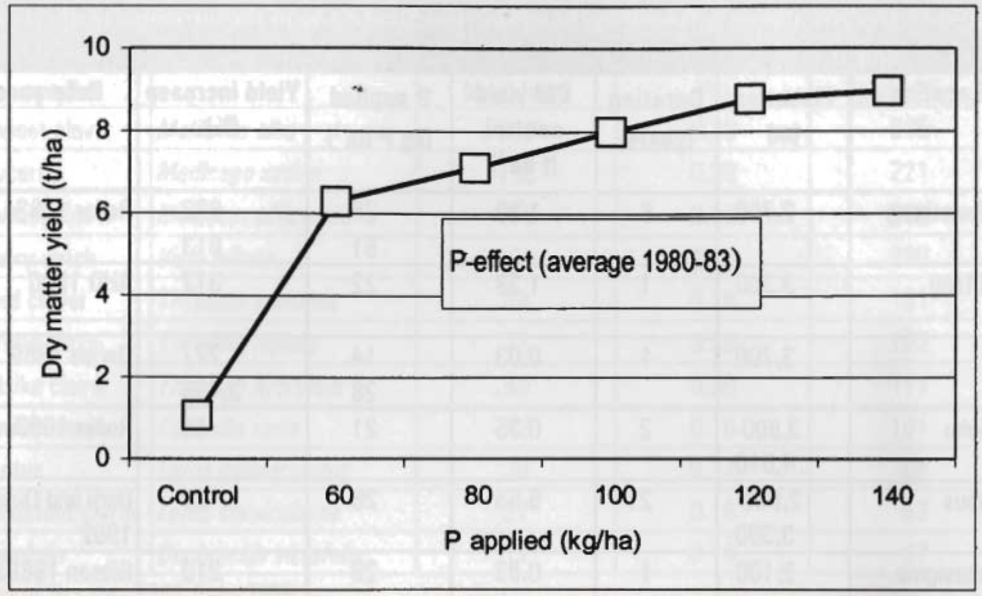

Figure 40: Effect of P on clover/grass dry matter yield in a cut and carry system

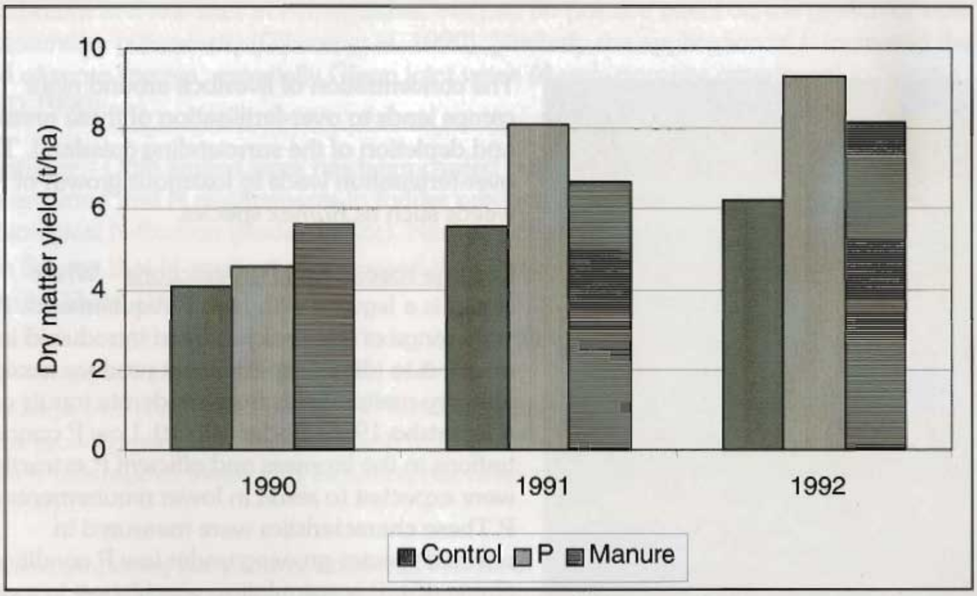

Figure 41: Effect of P and manure on dry matter yield across 7 sites

Locally produced bone meal was used for cattle feed in the 1970s (personal communication by the authors), but the quantities available were too small for large-scale use as fertiliser.

Manure, although produced in substantial quantities, is mostly used for applying to cultivated fields. It is usually collected by housing the livestock during the night or by tethering animals in crop fields. In the traditional production system there is thus a continuous flow of P from grassland to cropland. Manure accumulated in remote areas by migrating herds is often burned and the ash is applied to crop fields.

Table 44: Quantitative data from P application in combination with the introduction of white clover

Location	Elevation (m)	Duration (years)	DM yield control (t ha^{-1})	P applied (kg P ha^{-1})	Yield increase (%)	Reference
Batbalathang	2,700	6	1.29	26 51	623 813	Roder 1983c
Wabtang	3,300	1	1.38	22	317	AHD 1990
Ura	3,700	1	0.03	14 28	777 3,155	Dorjee 1989
Kidiphu	3,890-4,010	2	0.35	21	49	Roder 1983c
Various	2,600-3,300	2	5.55	26	39	Dorji and Dukpa 1992
Gonpasigma	2,100	1	0.83	29	210	Gibson 1989a
Laya	4,020	3	2.06	21 42	64 64	Gyamtsho 1996

Figure 42: Effect of P application on white clover based mixtures

The concentration of livestock around night camps leads to over-fertilisation of these areas and depletion of the surrounding grassland. This over-fertilisation leads to luxurious growth of weeds such as *Rumex* species.

Legume species and P-interactions – White clover is a legume with high P requirements. A wide range of legumes has been introduced in an effort to identify species that produce acceptable dry matter yields from moderate inputs of P (Gyamtsho 1986; Roder 1983c). Low P concentrations in the biomass and efficient P extraction were expected to result in lower requirements of P. These characteristics were measured in selected species growing under low P conditions (Table 45). P accumulation was highest in sweet clover species (*Melilotus alba* and *M. officinalis*), lucerne, and hairy vetch. Lotus and hairy vetch had the lowest P concentrations in their biomass. These findings, together with observations from screening nurseries and other trials, led to sweet clover, hairy vetch, and lucerne being recommended as alternative legumes with lower P requirement (Gyamtsho 1986; Roder 1983b, 1983c). Unfortunately these studies were discontinued in 1985.

Table 45: P-concentration and P-accumulation by selected legume species				
Legume species	Scientific Name	P-accumulation (mg/plant)	P-concentration (%)	DM yield (g/plant)
Sweet clover	*Melilotus alba*	309	0.20	635
Lucerne	*Medicago sativa*	126	0.23	221
Sweet clover	*Melilotus officinalis*	116	0.16	288
Hairy vetch	*Vicia villosa*	100	0.14	289
Red clover	*Trifolium pratense*	84	0.18	191
White clover	*Trifolium repens*	73	0.28	102
Alsike clover	*Trifolium hybridum*	56	0.20	111
Crown vetch	*Coronilla varia*	47	0.19	101
Lotus	*Lotus pedunculatus*	36	0.14	96
Birdsfoot trefoil	*Lotus corniculatus*	27	0.16	67
Sainfoin	*Onobrychis viciafolia*	11	0.16	27

Source: Gyamtsho 1986; Roder 1983c

P-effects in subtropical regions – Application of P was found to increase the yield of greenleaf desmodium at a few sites in Pemagatshel, but had no positive effect on the growth of stylo (*Stylosanthes guianensis)* (Gibson et al. 1990). Similarly the application of P increased the yield of some species, especially Glenn joint vetch *(Aeschynomene americana)* in Samtse (AHD 1990).

N-fertiliser – Only limited work has been carried out to evaluate the effect of N-fertilisers as it was assumed that N requirements in fodder production systems should primarily be covered by biological N-fixation (Roder 1982c). Nitrogen studies have found

- in Samtse that N application increased the yield of tropical grass species by 62% (Murtagh and Chhetri 1985);
- in Wobthang that N application had only a limited effect on dry matter yields of white clover-grass mixtures (AHD 1990); and
- in Laya (4,010m) that 100 kg of N fertiliser applied in two split doses at the beginning of the growing period in May/June and in August/September increased dry matter yield by 46% (average of treatments including native species, white clover, and lotus) (Gyamtsho 1996).

Studies comparing the effect of different N levels or intercropping with scarlet bean on tuber and stem dry matter yields of Jerusalem artichokes were not conclusive (Gyamtsho 1986; Roder 1983c).

Other nutrients – Other nutrients evaluated in temperate regions include potassium (K), boron, calcium, and sulphur. The application of these nutrients was found to have no significant effect on legume establishment (ARC 1989) or dry matter yields (Gyamtsho 1986; Roder 1983c). In contrast, in Pemagatshel at several locations increased levels of K or trace elements were found to be necessary for the establishment of shrubby legume species and K and trace element effects were found on white clover, lotus, African clover, and greenleaf desmodium at some sites (Gibson et al. 1990). Further studies are needed to differentiate the effects of K and trace elements. Fertiliser treatments generally had no positive effect on the growth of stylo. K and/or trace element applications also increased the dry matter yields of some species in Samtse (AHD 1990) and lime increased the growth rate of *Leucaena leucocephala*.

Cutting and grazing management

Only limited work has been carried out into the effects of cutting and grazing management on native or improved grasslands (Roder 1990a). A grazing trial with set stocking rates of 22.2, 14.5, and 7.4 ewes per hectare was carried out in Wabtang, Tang in 1989 (AHD 1990). However, the different stocking rates were found to have no effect on dry matter production of pastures and no significant effect on wool production per animal. Higher stocking rates, however, did result in better utilisation of the pasture and higher wool yields per area. In an experiment initiated in 1995, P-application and cutting intensity were found to have a strong effect on the yield and botanical composition of a white clover and grass mixture (RNR-RC Jakar 1997a) (Tables 46 and 47). The contribution of clover to the biomass yield and the quality of the biomass was substantially increased by P-application. The contribution of exotic grass species, mostly cocksfoot, increased in all treatments, probably due to a change from poor management (continuous grazing) to a system with grazing-free rest periods.

Table 46: Effect of fertiliser and cutting interval on fodder quality

Treatments		Composition (%)		
Cuts	Fertiliser	CP[1]	NFE	CF
2	Control	8.5	52.6	30.6
2	Phosphate	15.1	44.1	29.3
4	Control	15.3	43.1	30.1
4	Phosphate	26.2	40.2	22.8

[1] CP = crude protein, NFE = nitrogen free extract; CF = crude fibre
Source: RNR-RC Jakar 1997a

Table 47: Effect of fertiliser treatment on dry matter yield

Treatment	DM yield (t ha^{-1})		Botanical composition (%)[1]	
	1995	1996[2]	Clover	Grass
Cutting intervals				
2 cuttings	7.9 A	5.8 A	35 A	55 A
4 cuttings	9.5 A	11.8 B	41 A	57 A
Fertiliser				
Control	6.9 A	7.7 A	8 A	78 A
P	8.4 B	8.4 A	56 B	43 B
P & N	10.7 C	10.2 B	50 B	48 B
Coefficient of variation	15.6	9.4	45.2	34.3

[1] Observations from 1st cut in 1997; [2] numbers followed by the same letter are not significantly different at the 0.05 probability level
Source: RNR-RC Jakar 1997a

Winter fodder

The need for increased winter fodder production and higher quality of winter fodder has always been awarded high priority (Roder 1998c). Increased production of winter fodder is indirectly addressed through the work discussed under genetic evaluation and improvement. This section reviews work carried out specifically addressing improvements in winter fodder through management interventions (Table 48).

<u>Fodder conservation</u> – Methods of fodder conservation, principally hay and silage making, were evaluated in the early phases of the RDP fodder development programme. Due to the high labour requirements, farmers have not adopted silage making. Following examples from

Europe, hay making on different types of drying racks was tried but this also met with little success (AHD undated, printed in 1978; Roder 1980, 1983b, 1983d, 1998c). The high rainfall during the main growing season makes hay and silage making difficult. Furthermore, the high labour requirement for transporting plant material that has a high water content, makes silage making uneconomic for most farmers (Roder 1998c). Silage making is only feasible with a certain level of mechanisation. For the conditions prevailing in temperate Bhutan, deferred grazing (standing hay) may be the most appropriate form of fodder conservation.

Table 48: Studies aimed at increasing winter fodder availability, quality, and economic viability

Type of study	Locations	References
Fodder conservation with drying racks	Batbalathang	Roder 1983d
Fodder conservation with pit silos	Bumthang district	Roder 1983d
Fodder conservation in the field	Batbalathang	Roder 1998c
Arable fodder crops	Bumthang dzongkhag	Roder 1983c; RNR-RC Jakar 1997a
Tree fodder species	National	Roder 1983c; Tshering et al. 1997
Preservation of tree fodder species	Serbithang, Bumthang	Roder 1983c; Premasiri 1988

The feasibility of keeping standing hay was evaluated by keeping grass/clover biomass in fields for grazing between December and February (Roder 1998c). It was found that the total dry matter yield was not affected by harvesting date (Figure 43) although the dry matter content decreased gradually till January. January snowfall increased the moisture of the legume component and decreased the proportion of the legume in the total dry matter yield. Although the legume component decreased over time, the overall quality was not significantly different between November and February harvests (Table 49). If there is a loss in quality, as suggested by the increase in crude fibre of 13%, it would be below the level of losses normally associated with hay or silage making. The method of grazing standing fodder during the dry

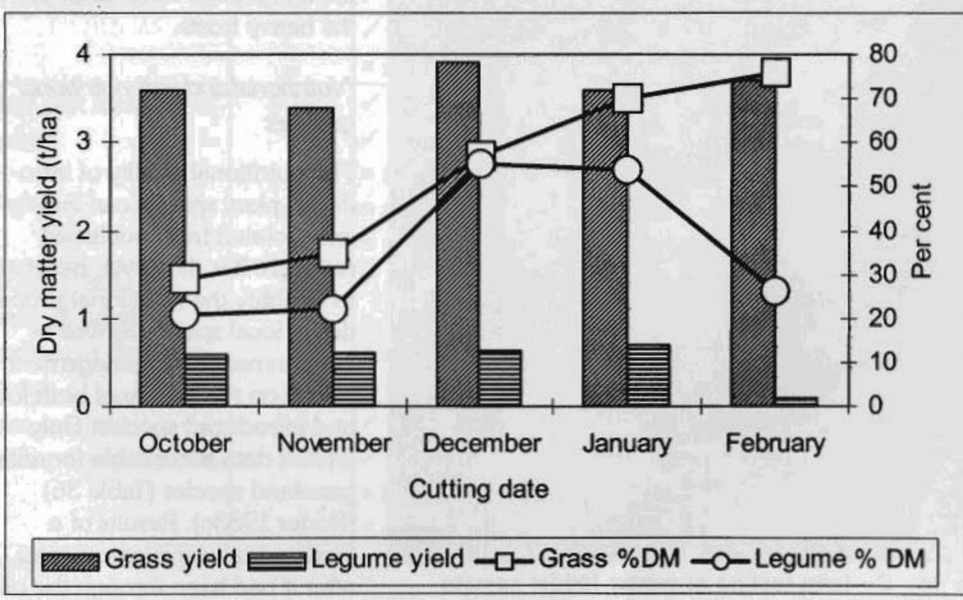

Figure 43: Effect of harvesting date on dry matter yield and content of standing hay

winter period has the advantage of reducing labour requirements for harvesting, feeding, and transport of manure.

Roder (1983c) reported that dried willow leaves were not accepted by cattle. They were, however, accepted when made into silage (Premasiri 1988).

Table 49: Effect of harvesting date on quality of standing hay

Parameter	Composition (% DM)	
	Harvest 25 Nov	Harvest 25 Feb
Crude protein	7.0 ± 2.1	9.1 ± 2.5
Crude fibre	24.6 ± 0.3	28.2 ± 2.3
Ether extract	1.4 ± 0.1	0.8 ± 0.1
Nitrogen free extract	57.8 ± 1.7	53.9 ± 4.2

Source: Roder 1998c

Crops for winter feed – The use of swede *(Brassica napus)*, hairy vetch, rye *(Secale cereale)*, willow, and other species, together with new management methods such as standing hay were recommended to increase the availability of winter feed (Table 50, Roder 1983c, 1983c, 1998e; RNR-RC Jakar 1997a). However, these innovations have not yet been adopted by Bhutan's farmers (Roder 1998c). Further investigations are needed to confirm earlier findings and refine recommended technologies.

The crops that have been most researched are Jerusalem artichoke, swede, hairy vetch, and rye. RNR-RC Jakar (1997a) reports further evidence of the high potential of swede and hairy vetch (Figure 44). Under Bumthang conditions, appreciable dry matter yields can be expected if these species are planted in late summer after the harvesting of potatoes. When planted in early August, dry matter yields were 12.7 t/ha for a rye and hairy vetch mixture, 9.7 t/ha for swede, 4.9 t/ha for turnip, 5.4 t/ha for lupine *(L. angustifolius)*, and 3.3 t/ha for sweet buckwheat. Yields declined substantially with later planting dates (Table 51, Figure 45). Sweet buckwheat is the only crop at present used by farmers for producing winter fodder (RNR-RC Jakar 1997a). It was not possible to keep the above crops in the field for extended periods over the winter months. Dry matter yields for most species were the same whether harvested in early November or early January. After this date all species except for rye, hairy vetch, and Italian ryegrass were destroyed by the heavy frosts.

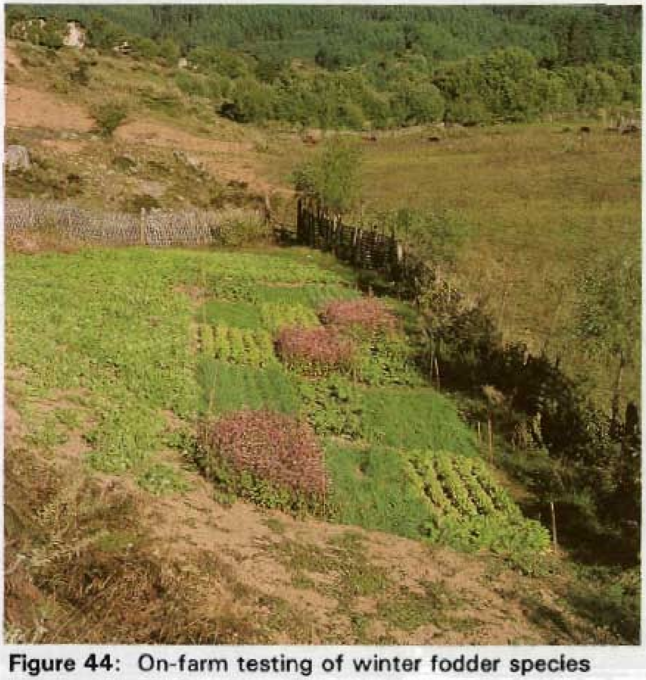

Figure 44: On-farm testing of winter fodder species (Tang, 2,700m)

Nutritional and anti-nutritional qualities

The nutritional quality of introduced plant species can largely be extrapolated from published research. It is, however, necessary to quantify the nutritional properties of local species as well as environment and management effects on the quality of both local and introduced species. Only limited data is available for native grassland species (Table 36) (Roder 1983c). Results of a feeding trial using lemon grass after it had been through the oil

Table 50: Crops evaluated for winter feed production			
Crop	**DM yield (t/ha)**	**Positive (✓) and negative (×) properties**	**Refs[1]**
Maize *(Zea mays)*	5-12	✓ high yield × requires chopping and conservation × bear and wild boar damage × requires high soil fertility	1
Oats *(Avena sativa)*	3-5	✓ traditionally used as feed × requires high soil fertility	1
Buckwheat *(Fagopyrum esculentum)*	0.5-2	✓ traditionally used as winter feed × low quality × low yield potential	2
Kale *(Brassica oleracea)*	4-6	✓ high yield, high frost resistance × insect damage, requires repeated insecticide application × requires high soil fertility	2
Swede *(Brassica napus)*	2-5	✓ high yield × needs high soil fertility or N-inputs	2, 3
Turnip *(Brassica rapa var. rapifera)*	2-4	✓ widely used ✓ no pest problems × limited yield potential, needs fertile soils	2, 3
Jerusalem artichokes *(Helianthus tuberosus)*	5-15	✓ high yield × labour for harvest × wild boar problem × needs high soil fertility or N-inputs	4, 2
Hairy vetch *(Vicia villosa)*	3-6	✓ high yield ✓ winter growth, frost tolerant	2, 3
Rye *(Secale cereale)*	3-6	✓ high yield ✓ winter growth, frost tolerant × needs high soil fertility and/or N-inputs	2, 3
Fodder beet *(Beta vulgaris*	6-15	✓ high yield ✓ can be stored till April × needs high soil fertility and/or N-inputs × pest problems × wild boar problems	2, 5
Brassica species *(B.rapa, B. napus, B. pekinensis Raphanus sativus)*	2-3	✓ high yield ✓ frost tolerant × needs high soil fertility or N-inputs	2
Lupine species *(L. albus, L. angustifolius)*	2-6	✓ high protein content ✓ no N input required × limited frost tolerance × requires inoculation	1, 2

[1] References: 1 – Roder 1983e; 2 – Roder 1983c; 3 – RNR-RC Jakar 1997a; 4 – Gyamtsho 1986; 5 – Dorji and Dukpa 1992

Table 51: Effect of planting date on dry matter yields of winter fodder species	
Treatment	DM yield (t/ha) [1]
Planting date (average of all species)	
August 2	5.8^{A}
August 23	3.4^{B}
September 11	1.7^{C}
Species (average of all planting dates)	
Swede	6.5^{A}
Turnip	2.9^{B}
Sweet lupine	2.3^{C}
Sweet buckwheat	2.8^{B}

[1] Numbers followed by the same letter are not significantly different at the 0.05 probability level
Source: RNR-RC Jakar 1997a

extracting process indicated that this material replaced over 75% of the herbage dry matter with no effect on the intake or milk production when fed to cattle (Bajracharya 1991). Dry matter disappearance of this post-processing plant material was better than from paddy straw or urea treated paddy straw.

Tamang (1987) published extensive analytical data on common fodder sources. The parameters measured included the levels of crude protein, neutral detergent fibre, acid detergent fibre, and rumen degradability (Table 52). Over 30% of the fodder species listed in his publication are tree fodders. This is a very valuable contribution as most of the

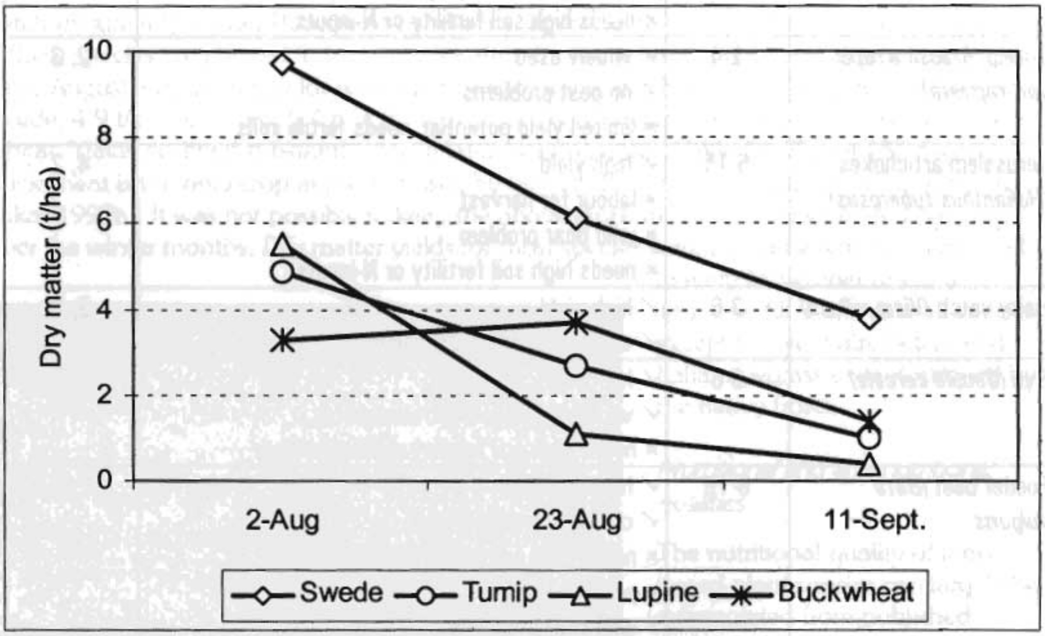

Figure 45: Effect of planting date on dry matter yield of selected winter fodder species

popular tree fodder species are native species and only limited information is available on their nutritional qualities. Additional analytical data on temperate tree fodders was generated through work carried out in Bumthang (Table 53).

Willow *(Salix babylonica)* is the most studied of the tree fodders. Analytical data are available for leaf samples taken throughout the growing season (Roder 1992; Wangdi et al. 1997). The palatability and nutritional quality have been evaluated in feeding trials with cattle and sheep. These studies confirmed that willow leaves have a high nutritional quality comparable to common forages such as lucerne. The same studies found that willow can be fed to ruminants without any adverse side effects. Leaves harvested in April, May, September, October, and

Table 52: Quality of selected subtropical tree fodder species					
Species	Crude fibre (%)	Crude protein (%)	NDF[1] (%)	ADF[2] (%)	Degradability[3]
Artocarpus lakoocha	24.1	14.7	36.2	23.1	88.9
Erythrina variegata	31.0	7.9	37.9	35.0	85.4
Elaeagnus latifolia	34.2	11.7	60.6	35.4	54.3
Ficus cunia	24.0	10.8	30.0	29.4	86.0
Celtis australis	30.4	13.1	41.4	35.4	65.0
Litsea polyantha	24.8	15.9	55.7	42.7	52.0
Ficus roxburghii	33.3	10.0	49.3	45.3	53.5
Salix babylonica (willow leaves)	38.1	10.3	48.0	14.3	75.9
Rice straw (urea treated)	39.2	7.1	75.6	59.8	63.8

1 Neutral detergent fibre; 2 acid detergent fibre; 3 rumen degradability after 48 hours incubation in fistulated animals
Source: Tamang 1987

November had crude protein contents of 25, 22, 17, 16, and 11%, and crude fibre contents of 12, 16, 15, 15, and 22%, respectively (Roder 1992). Voluntary intake of willow leaves and animal performance was high with sheep and cattle (Table 54). Voluntary intake was much lower with other traditional tree fodders used in temperate Bhutan (Table 55). In terms of rate of digestion in the rumen, willow was far superior to other tree leaves that are commonly used as feed. Digestion rates for willow, black locust *(Robinia pseudoacacia)*, *Litsea polyantha* leaves, and mixed hay were 78, 44, 31, and 31% after 24 hours of incubation, and 85, 65, 54, and 56% after 48 hours of incubation, respectively (Bajracharya 1990).

Table 53: Quality of selected temperate tree fodder species			
Species	Crude fibre (%)	Crude protein (%)	Digestible protein (%)[1]
Willow *(Salix babylonica)*	14.8	16.4	10.5
Evergreen oak *(Quercus semecarpifolia)*	30.9	9.7	1.2
Populus robusta	20.6	9.2	0.8
Local *Populus* sp	24.0	7.5	0.4

1 Pepsin-HCl soluble protein
Source: Roder 1992

Table 54: Willow intake and live-weight gain of two ruminants			
Animal type	Voluntary Intake (g DM/$W^{0.75}$)	Live-weight gain (g/day)	Reference
Bull	78	330	Roder 1992
Sheep	85	64	Bajracharya 1990

Seed production

The seed production potentials of introduced species were generally assessed in the early stages of germplasm evaluation (Table 56) (Roder 1983c), and only species that produced seed were advanced in the testing programme. White clover was an exception to this due to its high potential for improving permanent grassland and its potential for vegetative multiplication.

Table 55: Intake of tree fodders by large ruminants

Species	Month	Duration (days)[1]	No. of animals	DM intake (kg/day)
Quercus semecarpifolia	April	5	3	2.8
Quercus semecarpifolia	March	11	4	1.8
Populus robusta	October	12	2	3.4
Populus (local sp)	October	5	2	1.9

[1] Duration of feeding the particular fodder in days
Source: Roder 1992

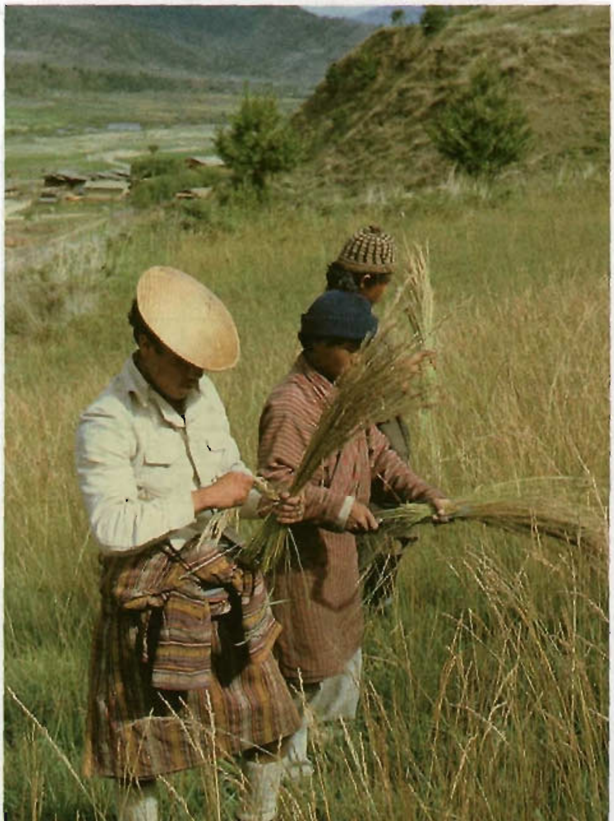

Figure 46: Harvesting tall fescue seed

Several institutions and projects took up fodder seed production (Figure 46). The ambitious targets for fodder development starting from the Fourth Plan period (1976-81) required relatively large quantities of seed, so seed production was shifted to farmers' fields. Harris (1986) reviewed the achievements in temperate seed production, and attributed the success in the seed multiplication programme to the research carried out in the early 1980s.

Cocksfoot and some of the most promising legumes, especially lucerne, red clover, lotus, and greenleaf desmodium, were not included in the initial government extension programmes because of difficulties in large-scale seed multiplication. A number of research efforts focused on seed production technologies for these species. Some of these efforts had substantial impacts on the grass seed multiplication programme. A species-wise summary of the results is given in Table 56.

Cocksfoot seed production – The seed yield of cocksfoot varieties in introduction nurseries, using plots of less than 10m^2 was found to range from 29 to 333 kg ha^{-1} in 1980 and from 17 to 446 kg ha^{-1} in 1981 (Roder 1983c). The varieties with the highest dry matter production - G 16 and Appanui - had the lowest seed yields, however. The seed yields of these varieties was still very poor when plants were established by drilling in rows 40 cm apart (Roder 1983c). It was clear that cocksfoot seed, especially for the selected varieties, could only be produced commercially if the production method could be improved. A series of experiments was initiated in 1981 focusing on spacing, N-fertiliser, and planting dates (Roder 1983c) (Figure 47). The results of these studies showed that for cocksfoot:

- insufficient spacing resulted in poor seed production;
- transplanting seedlings raised in a nursery was the best way to establish a seed production stand;

Table 56: Seed yields reported from selected individual species					
Species		Reference[1]	Entries/ years[2]	Yield (kg ha^{-1})	
				Average	Range
White clover	*Trifolium repens*	1, 2	5/1	12.1	2.7-60
Red clover	*Trifolium pratense*	1, 2	11/2	5.7	0.4-24
Birdsfoot trefoil	*Lotus corniculatus*	1, 2	6/1	5.7	0.8-16.7
Lotus	*Lotus pedunculatus*	1, 2	5/1	78.2	18.8-200
Greenleaf desmodium	*Desmodium intortum*	5	1/1	122	1.4-23
Silverleaf desmodium	*Desmodium uncinatum*	5	1/1	330	0.6-78
Italian ryegrass	*Lolium multiflorum*	1, 2	6/2	1407	654-1814
		3	4/1	531	215-1076
Cocksfoot	*Dactylis glomerata*	1, 2	12/2	146	17-446
		3	6/1	46	30-90
Tall fescue	*Festuca arundinacea*	1, 2	4/2	391	138-583
		3	1/1	1410	-
Perennial ryegrass	*Lolium perenne*	1, 2	7/2	585	145-1085
		3	5/1	648	377-1238
Timothy	*Phleum pratense*	1, 2	4/1	95	-
Meadow fescue	*Festuca pratensis*	1, 2	4/2	621	323-1071
		3	2/1	28	23-32
Red fescue	*Festuca rubra*	2	2/2	423	160-910
		4	1/1	1280	1170-1390
Ruzi grass	*Brachiaria ruziziensis*	6	1/1	147	104-233

[1] References: 1 - Roder 1982c; 2 - Roder 1983c; 3 - Dorji 1982a; 4 - Luthi 1998; 5 - Tshering et al. 1997b; 6 - Pradhan 1990; [2] number observed over number of years, 5/1 indicates 5 entries with observations over 1 year

- there was no significant effect of row spacing;
- inter-plant spacings of 10, 15, 20, and 25 cm had no effect on yields;
- white clover is a poor substitute for N-fertiliser application in grass seed production (Gyamtsho 1986); and
- planting is possible until late September (ARC 1990).

Figure 47: Study evaluating spacing effect on cocksfoot seed production

Desmodium seed production – Studies were initiated in 1996 to evaluate the effect of location on flowering and seed production of greenleaf *(Desmodium intortum)* and silverleaf *(D. uncinatum)* desmodium, and the effect of cutting management, support, planting density, and irrigation regimes on greenleaf

Table 57: Effect of location on flowering and seed production of silverleaf and greenleaf desmodium				
		Location		
		Bhur	Lingmethang	Khothakpa (Pemagathsel)
Altitude		200m	640m	850m
Flowering date	silverleaf	-	24 Oct	23 Oct
	greenleaf	-	24 Nov	21 Nov
Harvesting date	silverleaf	12 Nov-3 Dec	27 Dec	24 Dec
	greenleaf	-	29 Jan	26 Jan
Average seed production	silverleaf (g/m^2)	0.6	78	21
	greenleaf (g/m^2)	-	23	1.4

Source: Tshering et al. 1997b

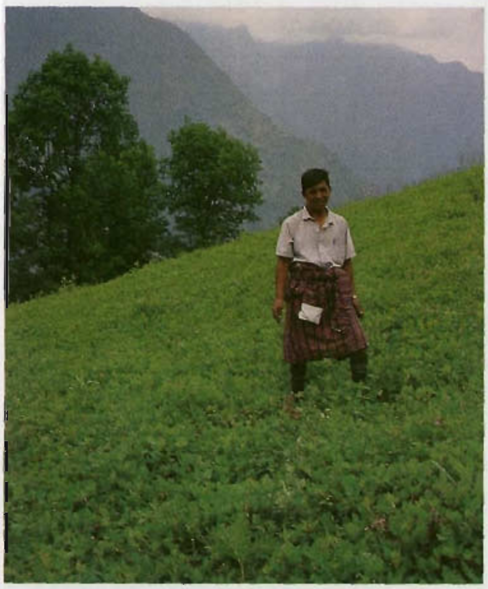

Figure 48: Desmodium seed production study, Wangdugang (1,590 m)

Table 58: Effect of location and management on flowering, pod formation and seed production of greenleaf desmodium			
Parameter	Flowering ($no./m^2$)	Pods formed ($no./m^2$)	Seed yield (g/m^2)
Location/Elevation			
Wangdugang 1,590m	64	44	3.2
Dhakphai 1,490m	44	34	7.0
Birthay 800m	29	13	1.1
Tama 1,560m	16	1	-
Tama 1,580m	21	7	-
Zurphey 1,150m	64	-	-
Cutting[1]			
No cutting	43^A	25^A	5.6^A
May cutting	44^A	23^A	3.9^A
June cutting	31^A	12^A	1.7^A
Support[1]			
No support	28^A	15^A	3.6^A
Support[2]	50^B	24^B	3.9^A
Coefficient of variation (%)	22.6	39.0	41.3

[1] Numbers followed by the same letter are not significantly different at the 0.01 probability level; [2] support with 1m high bamboo sticks

desmodium seed production (Tshering et al. 1997b). The results are summarised in Tables 57 and 58.

The most important findings from these studies were that:

- Bhutan has excellent conditions for the production of both greenleaf and silverleaf desmodium (Figure 48);
- the time of flowering, and the number of flowers per area was not influenced by altitude, or cutting and spacing treatments - flowering started almost simultaneously at all locations;
- support with bamboo sticks increased flower and pod density but not seed yield;

- seed yields may be increased through the manipulation of plant density, the exclusion of competition effects from grasses, the control of insect pests, and, where available, timely irrigation.

Integrated studies

In addition to providing more food for raising animals, improved forage production is expected to result in a multitude of benefits for any particular farming system The expected benefits include:

- improvements in soil fertility and soil and water conservation;
- weed suppression and reduced need of labour for weed control in fruit and timber plantations;
- optimisation of economic returns from marginal crops and grasslands by combining fodder and timber production; and
- synergistic effects on annual crops and perennials cultivated in association with fodder plants.

A number of studies have attempted to quantify these effects (Table 59). Most of these studies have been initiated in recent years and no conclusive results are yet available.

Table 59: Studies on combining fodder production with other production systems

	Location	References[1]
Crop rotation, cropping sequences		
Crop rotation studies	Bumthang, Yusipang, Phubjikha	1, 2, 3, 4, 5
Cropping sequence studies	Phubjikha	1, 2, 5
Cropping after white clover	Bumthang	6
Systems with fruit trees		
White clover in apple orchards	Bumthang	4
Legume species in apple orchards	Bumthang	6
Effects of sub-tropical legumes in orchards	Zhemgang	6
Systems with timber trees		
Silvopastoral studies	Bumthang	6, 7
Other systems		
Soil conservation	Zhemgang	6

[1] References: 1 – ARC 1989; 2 – ARC 1990; 3 – Gyamtsho 1986; 4 – Roder 1983c; 5 – Roder et al. 1993b; 6 – RNR-RC Jakar 1997a; 7 – Rinchen and Roset 1997

Crop rotation and cropping sequence studies

Increased soil fertility and yields in field crop and horticulture systems have been postulated to be one of the major advantages of fodder development (AHD undated; Roder 1982c; 1990c). Although several attempts have been made to investigate such effects in a variety of cropping systems, little quantitative data has been generated to support this hypothesis.

A long-term crop rotation study carried out in Bumthang combining white or red clover based fodder with buckwheat, potato, and wheat did not provide conclusive results (Dorjee 1989; Gyamtsho 1986). A crop rotation study using white clover for one to three years was carried out in Bumthang and Yusipang; but no consistent effects on potato yield were demonstrated (ARC 1992).

Crop rotation studies carried out in Phubjikha showed that potato tuber yields were increased by 34% (above continuous potato production) if the previous crop was lupine *(L. mutabilis)* and by 40% if it was white clover (Table 60) (Roder et al. 1993b). Similarly, compared to continuous potato cultivation the number of volunteer potatoes, a troublesome weed, was reduced by 73% if the previous crop was white clover (Roder et al. 1993b).

Table 60: Effect of lupine and white clover on potato yield and volunteer plants

Rotation	Yield[1] (kg m^{-2})	Volunteer potato[1] (plants m^{-2})
Continuous potato	2.1^{B}	0.56^{A}
Rye-lupine-potato	2.8^{AB}	0.31^{B}
Clover-clover-potato	2.9^{A}	0.15^{B}

[1] Numbers followed by the same letter are not significantly different at the 0.1 probability level

Source: Roder et al. 1993b

Systems with fruit trees

The effect of white clover grown under apple trees was evaluated at Nasphyel farm (Bumthang). White clover was found to have a strongly positive effect on the N-status of apple trees one year after initiation of the study (Roder 1983c). Various studies are under progress to evaluate the effect of fodder peanut *(Arachis pintoi)* in subtropical plantation systems with citrus or areca nut (Figure 49).

Systems with timber trees

With the forthcoming introduction of the private and social forestry rules under Bhutan's Nature Conservation Act, 1994 (MOA 1997b), silvopastoral systems are likely to offer excellent opportunities for landowners in temperate areas. Several studies have been initiated to evaluate the interaction of pasture plants and blue pine or larch trees under livestock grazing (Rinchen and Roset 1997; RNR-RC Jakar 1997a) (Figure 50).

In a study initiated in 1991, legume species and P-treatment were found to have no effect on tree performance (Rinchen and Roset 1997), but six years after its establishment, this silvopastoral system with white clover based pasture made a very good impression and seems to offer a viable and interesting alternative to either pangshing cultivation or exclusive timber production systems. Early returns from livestock products will make it easier for resource poor farmers to make the long-term investments in timber production.

Figure 49: Fodder peanut *(Arachis pintoi)* as a cover crop under areca nut

Figure 50: Agroforestry study evaluating herbage and timber production with larch and white clover grass combination