Fodder Production and Double Cropping in Tibet

TCP/CPR/2907-3101

Training Manual

Editor in Chief: Ian R. Lane

December 2006

Fodder Production and Double Cropping in Tibet - Training Manual TAAAS / FAO

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This manual was one of the major outputs of the projects TCP/CPR/2907-3101 "***Fodder Production and Double Cropping in Tibet***" implemented in 2004-2006 with the objectives of developing and demonstrating double cropping technologies, training researchers, extension staff and farmers in these technologies, and contributing to the formulation of a Medium Term Programme for disseminating the technologies throughout appropriate areas of Tibet. Given that few training manuals of this type are available it has been decided to make the material available to a wider audience in the Himalayan countries as well as some African and Latin American countries.

For additional copies or CD-ROMs please contact **Caterina.Batello@fao.org** and note that the full text is also available in electronic format on the FAO Grassland webpage
www.fao.org/ag.AGP/AGPC/doc/pasture/eleclibrar_year.htm

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Front cover

Zero-till drilling vetch into winter wheat stubble with six row drill on August 28, 2005	***Close-up of vetch drilled into winter barley stubble (above) and winter wheat stubble (below), observed on September 25, 2005***

Photo: Nick Paltridge　　Photos: Ian Lane

Establishment of vetch by zero-till drilling into cereal stubbles at TARI field station, Lhasa, 2005

Conversion tables

Mass

kilograms (kg)	kg / jin	jin
0.5	1	2
1.0	2	4
1.5	3	6
2.0	4	8
2.5	5	10
3.0	6	12
3.5	7	14
4.0	8	16
4.5	9	18
5.0	10	20

1 litre of water weighs 1 kg

Area

hectare (ha)	ha / mu	mu
0.067	1	15
0.133	2	30
0.200	3	45
0.267	4	60
0.333	5	75
0.400	6	90
0.467	7	105
0.533	8	120
0.600	9	135
0.667	10	150

Some villages use a large mu
1 large mu = 2 standard mu

Mass/area

kg/ha	kg/ha / jin/mu	jin/mu
7.5	1	0.133
15.0	2	0.267
22.5	3	0.400
30.0	4	0.533
37.5	5	0.667
45.0	6	0.800
52.5	7	0.933
60.0	8	1.067
67.5	9	1.200
75.0	10	1.333

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Disclaimer

Citation

TAAAS / FAO. 2006. *Training Manual on Fodder Production and Double Cropping in Tibet*. (ed. Ian R. Lane). Published by Tibet Academy of Agricultural and Animal Husbandry Sciences (Lhasa, Tibet Autonomous Region, Peoples Republic of China) and the Food and Agriculture Organization of the United Nations (Beijing, Peoples Republic of China) under TCP/CPR/2907-3101. 283 pages.

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Ian Lane

FOREWORD

Having achieved regional sufficiency in grain production in line with national guidelines, the Government of the Tibet Autonomous Region is keen to boost meat and milk supplies. The lack of quality fodder, especially during winter, is a major limiting factor in improving livestock production. In order to sustain food grain production while increasing fodder production, there is urgent need to increase the utilization rate in the limited arable land areas below 3650m altitude where there is a potential growing period of 2 - 3 months for second crops (and double cropping systems) in the period July-October. These second crops can be purely for fodder or produce a product for market as well as good quality fodder. Adjusting cropping systems to make full use of the growing season is low cost and will allow farmers to increase their income with relatively modest inputs.

At the request of the Government of the Peoples Republic of China, the Food and Agriculture Organization of the United Nations (FAO) projects TCP/CPR/2907-3101 "Fodder Production and Double Cropping in Tibet" have been implemented in the period 2004-2006 with the objectives of developing and demonstrating double cropping technologies, training researchers, extension staff and farmers in these technologies and formulating a Medium-Term Programme for dissemination of the technologies throughout the region. The area of focus has been in the lower and middle reaches of the Yalong Tsangpo River and the middle reaches of the Lhasa River and the Government Implementing Agency has been the Tibet Agricultural Research Institute (TARI).

This manual is one of the major outputs of the projects, summarizing up-to-date information with locally collected data on aspects of cereal production, new fodder crops, cropping systems, zero-tillage, various aspects of fodder production and conservation, animal nutrition of local and improved milking cows, and the economics of double cropping and feeding of high quality fodder crops to milk cows. It provides a large body of information and excellent illustrations which will be of lasting benefit for researchers and extension workers and from which material can be extracted for other specific and targeted publications for farmers.

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December 2006

ACKNOWLEDGEMENTS

The authors give thanks to everyone they have worked with over the course of this project, including the farmers at village level, village leaders, and all staff of township and county agricultural and animal husbandry bureaux, the Department of Agriculture and Animal Husbandry, staff of TARI, TLRI and TAAAS, and all other institutions and projects. The materials included in this manual have been selected and developed specifically in relation to double cropping for fodder production in central Tibet, with possibilities for broader application throughout crop lands of the region. This has only been possible through the close cooperation, insight and guidance of the above people, which has continued throughout the project including the intense debates and participation of many and varied participants at the Final Workshop.

Special thanks are given to Dr. Nyima Tashi, Vice-President of TAAAS and National Project Co-ordinator for guiding preparation of the Manual from the beginning of the project. A number of versions have been discussed, and he has been instrumental in setting both the level and the scope of individual chapters, both through direct review of earlier versions, and through discussions on the future of agriculture and animal husbandry within crop production zones. Mr. Jin Tao and staff of the Division of Cultivation Biology including Sang Bu, Liu Guoyi, Biaba Zhuoma, Ci Yang and Song Guoying have worked closely with the authors throughout the project, and many of the outputs of station trials and field extension have been incorporated. Mr. Liu Guoyi receives special thanks for translating chapters of the Manual for the Workshop, with positive feedback. Many staff of TARI have worked closely with the authors, and are thanked for their contributions and ideas.

Although it has not been possible to work so closely with staff of the Tibet Livestock Research Institute due to their training and work commitments, thanks are due to Dr. Qiumei Ji, Dr. Tsam Yu, Ms La Ba and Ms Da Wa Yang La for detailed discussions on both fodder production in Tibet and on aspects of ruminant nutrition as they affect milk production from both local and improved cows. It is their interest that has inspired extra detail in the chapter on the feeding of fodder crops.

Special thanks are also due to staff of projects that have operated alongside this TCP, who have been most willing to share their insights and experience with various authors. This includes staff of the ACIAR forage legume inter-cropping project, especially Nick Paltridge, who helped guide project staff in their work. Ms Lynda Nicholls of the CIDA rural and agricultural project has been the inspiration for participatory approaches, as she set out at the Final Workshop and are reflected in the introduction to the Manual. Dr. Karl Kaiser and staff of the EU Panam project, now finished, provided valuable insights to the cropping and farming systems in valleys at higher elevation, and this has led on to continuing work with farmers on zero-tillage. This is reflected throughout the manual, including the economic analysis for growing spring barley.

The national consultants are thanked for their ongoing involvement in the project despite severe time constraints. This has resulted in the authors having a much deeper understanding of the local situation in Tibet, and China as a whole, than would otherwise be the case. Thanks are due to Mr. Liao Chongguang for managing funding of the manual, and the final translation. The lead authors have acknowledged contributions made directly from their previous colleagues, and the published sources they have used. Lengthy discussions have been held with numerous persons during the preparation of this manual. Finally the lead authors would like to thank Dr. Steve Reynolds, former AGPC officer, and Caterina Batello, Agricultural Officer AGPC, for their continuous involvement and support in discussion of possible content, development of written materials, and assistance with editing.

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TABLES

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PLATES

Abbreviations and Acronyms

#	number
%	percent
+	the plus sign when used as a mathematical expression; for temperature, above zero
-	the minus sign when used as a mathematical expression
-	in tables, used to denote missing values, or ‘not applicable’
x or *	the multiplication sign when used as a mathematical expression
/ or ч	the division sign when used as a mathematical expression
±	the plus or minus sign
=	the equals sign
≡	equivalent to
<	less than
>	greater than
√, (√)	Correct, good, desirable; in brackets - less correct, not so good, less desirable
‘o’	degree – for example as the number of degrees in a circle
^{o}C	degrees of temperature: degrees centigrade or degrees Celsius
0-Till	Zero-Till drilling; Zero Tillage
2,4-D	A selective post-emergence herbicide to control broadleaved weeds in cereals

A, a

a.i.	active ingredient, for agrochemicals
ACIAR	Australian Centre for International Agricultural Research
ADAS	UK Agricultural Development and Advisory Service
ADF	Acid Detergent Fibre
ADIN	Acid Detergent Insoluble Nitrogen
ADIP	Acid Detergent Insoluble Protein
ADL	Acid Detergent Lignin
AFRC	Agriculture and Food Research Council
am.	ante-meridian = before midday = in the morning
AN	Ammonium Nitrate fertiliser
APL	Animal Production Level

B, b

bar	unit of pressure: 1 bar = 1 atmosphere
Bo	Boron
BOD	Biological Oxygen Demand

C, c

C	Carbon
C	Concentrate feed dry matter
C3, C4	Photosynthetic pathways
CA	Conservation Agriculture
Ca	Calcium
CAAMS	Chinese Academy of Agricultural Mechanisation Sciences, in Beijing

CCC	Canola Council of Canada
CDM	Corrected Dry Matter, in silage
CF	Correction Factor, usually as a proportion in estimation of DMI
CF	Crude Fibre
CIDA	Canadian International Development Agency
Cl	Chlorine
cm	centimetres : 1 cm = 1/100 m; 100 cm = 1 m
Co	Cobalt
CO_2	Carbon dioxide
CP	Crude Protein (equals N x 6.25)
Cu	Copper

D, d

DAP	Di-ammonium Phosphate fertiliser
DC	Double Crop or Double Cropping
DCF	Digestible Crude Fibre
DCP	Digestible Crude Protein
DE	Digestible Energy
DEE	Digestible Ether Extract
Defra	UK Department of Environment, Food, and Rural Affairs
DM	Dry Matter
DMD	Dry Matter Digestibility
DMI	Dry Matter Intake
DMTP	Digestible Microbial True Protein
DNFE	Digestible Nitrogen Free Extract
DOMD	Digestible Organic Matter in the Dry matter, expressed as g/kg DM
DQ	Dongqing varieties, such as Dongqing #1 winter barley
DUP	Digestible Undegraded feed Protein
D-value	Digestible Organic Matter in the Dry matter, expressed as a percentage

E, e

EE	Ether Extract
epNDF	Effective Neutral Detergent Fibre
ERDP	Effective Rumen Degradable Protein
et al	and other authors, or other workers
etc	etcetera = and so on
ET	Evapo-transpiration
EU	European Union

F, f

F1	First cross, as in breeding cows
FAO	Food and Agriculture Organization of the United Nations
Fe	Iron
Fm	Feimai variety of winter wheat

FME	Fermentable Metabolisable Energy

G, g

g	gram
GE	Gross Energy
GoTAR	Government of the Tibet Autonomous Region

H, h

H	Hydrogen
H	Height
H.Y.	High Yielding varieties
ha	hectare (1 ha = 15 mu)
HP	Horse Power – used for rating the power of tractors and other machinery = 0.746 kW

I, i

i.e.	that is
IFI	International Feedstuffs Institute, Utah State University
in sacco	nylon (Dacron) bag digestibility or degradation
in situ	nylon (Dacron) bag digestibility or degradation; literally in place within the animal
in vitro	in the laboratory, literally 'in glassware'
in vivo	in the live animal

J, j

jin	Local unit of weight: 1 jin = 0.5 kg; 1.0kg = 2 jin

K, k

K	Potassium. In NPK fertilisers applied as Potash, K_2O
k	the efficiency of conversion of metabolisable energy to net energy
K_2O	Potash, in fertiliser
KFN	Kilogram of Fertiliser Needed
kg	kilogram = 1000 grams
kg/ha	kilogram per hectare
k_n	the efficiency of conversion of metabolisable protein to net protein
KNN	Kilogram of Nutrient Needed
kW	kilo Watt – as a measure of power – 1 kW = 1.341 HP

L, l

L	Leaf
l	litre or liter
Log_e	Natural logarithm
Ltd	Limited, as in limited company
LW	Liveweight

M, m

m	metre or meter
m.a.s.l.	metres above sea level
M/D	Concentration of Metabolisable energy in the Dry matter, as MJ ME / kg DM

m^2	square metre
MADF	Modified Acid Detergent Fibre
MAFF	UK Ministry of Agriculture, Fisheries and Food
MCP	Microbial Crude Protein
ME	Metabolisable Energy
Mg	Magnesium
MJ	Megajoules = one million joules of energy
mm	millimetre: 1000 mm = 1 m
Mn	Manganese
Mo	Molybdenum
MOP	Muriate of Potash - fertiliser
MP	Metabolisable Protein
MS	Main Stem
mu	local unit for land area (1 mu = 1/15 ha). Some counties use a "large mu" = 2 mu.

N, n

N	Nitrogen, in animal feeds and in soil nutrients and fertilisers
N	Node of a cereal plant
n	number, the position in a series such as week n of lactation
N/A, n/a	Not Applicable, or Not Available
N_2	di-nitrogen molecules
Na	Sodium
NAEF	National Agricultural Engineering Federation
NCD	Neutral detergent Cellulase Digestibility
NCDG	Neutral detergent Cellulase + Gammanase Digestibility
NDF	Neutral Detergent Fibre
NE	Net Energy
NFE	Nitrogen Free Extract
NH_3N	Ammonia nitrogen
No., no., N^o	number
NP	Net Protein
NPK	Nitrogen / Phosphorous / Potassium plant nutrients, as used in fertilisers
NPN	Non-Protein Nitrogen

O, o

O, O_2	Oxygen
ODM	Oven Dry Matter
OM	Organic Matter
OMD	Organic Matter Digestibility

P, p

P	Phosphorous. In NPK fertilisers applied as Phosphate, P_2O_5
P_2O_5	Phosphate, in fertiliser
PGRO	Pea Growers Research Organisation

pH	logarithmic scale of acidity/alkalinity
pm.	post-meridian = after midday = in the afternoon or evening
PNIF	Percentage Nutrient in Fertiliser
Point dg	Point degradability
popn	population
Pre-	A prefix that means "before"
psi	pounds per square inch - pressure

Q, q

q	the metabolisability of the ration, defined as ME/GE
QDP	Quickly Degradable Protein

R, r

r^2, R^2	coefficient of determination = proportion of total variation accounted for by a relationship
RDP	Rumen Degradable Protein
RPM, rpm	Revolutions Per Minute
RRS	Rumen Resistant Starch
RS	Rapeseed
RSM	Rapeseed Meal
RUMNUT	Ruminant Nutrition software

S, s

S	Sulphur, Sulfur
SB	Spring Barley
SC	Second Crop
SD, S.D.	Short Duration varieties
SDP	Slowly Degradable Protein
sec	second, as in time: 60 seconds = 1 minute; as in metres per second
SEU	Sheep Equivalent Units (1 mature sheep of 30kg requires approximately 200 kg TDN per year)
Si	Silicon
SW	Spring Wheat
SWOC	Strengths, Weaknesses, Opportunities and Constraints (analysis used in participatory approaches)

T, t

T	Tiller
TA	Total Ash
TAAAS	Tibet Academy of Agriculture and Animal husbandry Sciences
TAR	Tibet Autonomous Region
TARI	Tibet Agricultural Research Institute
T-boom	A sprayer boom that is shaped like the letter 'T'
TCP	Technical Cooperation Programme of FAO
TDN	Total Digestible Nutrients (as percent of DM, or as weight of nutrients)
TLRI	Tibet Livestock Research Institute/Tibet Institute of Animal Husbandry and Veterinary Sciences
T_{max}	Maximum temperature
T_{min}	Minimum temperature

TMR	Total Mixed Ration
TN	Total Nitrogen
ton, t	The ton used in this document is the metric tonne, where 1 ton = 1000kg

U, u

UDP	Undegradable Dietary protein
UK	United Kingdom = Great Britain
USA	United States of America

V, v

VFAs	Volatile Fatty Acids
vs	versus = compared to

W, w

W	Liveweight
WB	Winter Barley
WCWS	Whole-Crop Wheat Silage
WW	Winter Wheat

X, x

X, x	‘X’ as in Cross bred sheep, ‘x’ as in local cross Simmental cows

Y, y

y	year, as in kg/ha/y
Y	Yuan
Y	Yield, as in Milk Yield

Z, z

Z	Zadoks decimal growth stages
Zn	Zinc
Zo	Hybrid between cattle and yak

Section 1 INTRODUCTION

Chapter 1 FODDER PRODUCTION AND DOUBLE CROPPING

Ian Lane

ANNEXES

Section 1 INTRODUCTION

Chapter 1 FODDER PRODUCTION AND DOUBLE CROPPING

1.1. Background

In 2000, the Tibet Autonomous Region's total farmland was about 230,000 hectares. The main crops are barley, wheat, pea, broad bean, potato, rape and beet. Some small areas are dedicated to faba bean, phaseolus bean, corn, peanut, Chinese cabbage, turnip, buckwheat, spinach, garlic, rice, and tobacco. In 2000, the total cereal production was about 960,000 tons (60 per cent barley and 30 percent wheat). Approximately 68 percent of the cultivated land is irrigated.

Livestock are as important as crop production (46 % of total agriculture gross value). The variety of livestock in Tibet includes yak, cattle, pien niu (offspring of a bull and a female yak), horse, donkey, sheep and pig. In 2000, livestock numbered 24 million head: 4 million yaks, 980,000 oxen, 270,000 pien niu, 1.55 million milk cows, 140,000 horses, 11.4 million sheep, 5.77 million goats and 180,000 pigs. Livestock products are major export resources and the main raw materials of the textile and processing industries. Tibet has 82 million hectares of natural grassland. Fodder availability and quality is limited during winter and spring restricting the development of livestock production.

Counties in the lower and middle reaches of the Yalong Tsangpo River and the middle reaches of the Lhasa River (Dazi, Qushui, Duilong, Gongka, Naidong, Zhanang and Qiongjie) have a relatively high population density compared to crop and range lands in other parts of Tibet. The area is predominantly one of food grain production with about 80% of the cropping area under barley and wheat and the area has a grain surplus. Although farmers raise livestock such as cattle, sheep and pigs, there is a regional deficit in livestock products.

The Government of the Tibet Autonomous Region (GoTAR) has followed national guidelines for regional sufficiency in grain production. All land capable of growing cereals has been in a continuous cereal rotation, and fodder production was restricted to poor quality land. Winter wheat and barley varieties were introduced in the 1960s, and have been adopted by farmers in the valleys below 3650m for the past 25 years. Only in 2005, in line with national policies on developing income generation by farmers, has GoTAR adopted policies that allow farmers in general to diversify into commercial livestock production supported by fodder production on good quality irrigated land.

Lack of quality fodder, especially during winter, is a major limiting factor in improving livestock production in the lower and middle reaches of the Yalong Tsangpo River and the middle reaches of the Lhasa River. During winter, there are few areas where animals can graze. A survey of available livestock feed in Gongka and Linzhou indicated that more than 70 percent of the available non-mountain feed was straw and stover of low quality, especially in terms of protein, for stock to meet their dietary needs. This reliance by farmers on poor quality crop residues results in many animals being undernourished and weak by the spring. The typical cycle has been to fatten cattle in summer in an attempt to carry them through the winter and spring period when little feed is available.

In order to sustain food grain production while increasing fodder production in an area where the arable land is limited, there is urgent need to increase the land utilization rate by introducing double cropping systems. Winter barley and winter wheat are sown in early October and mature in the following July and August respectively. After the cereal harvest in areas below 3650m altitude there is a potential growing period of 2 - 3 months. This period is currently underutilized, and can be sown to second crops for fodder in a double cropping system. These second crops can be purely for fodder, such as forage legumes. Alternatively they can produce both a product for the market and a good quality fodder for farm animals, such as turnips. Adjusting cropping systems to make full use of the growing season is low cost and allows farmers to increase their income with relatively modest inputs.

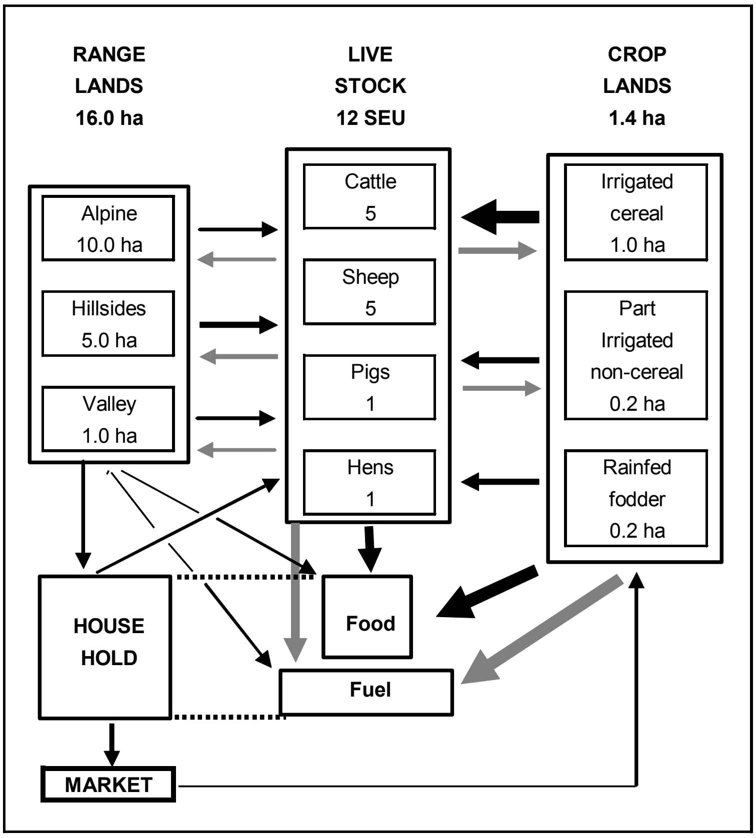
1.2. Factors that result in successful adoption of new technology

A recent review of the factors that have resulted in successful adoption of forage legumes in tropical countries lists the following in declining importance:

1) the technology meets the needs of the farmers and provides profits
2) the technology matches the socio-economic circumstances and skills of the farmers
3) critical partnerships are in place between the government, the commercial sector and the farmers
4) key stakeholders in government and the commercial sector provide long term commitment
5) farmer-centred research, development and extension programmes are implemented.

In some circumstances changes in government regulation are also required for a major change in agriculture. The needs of farmers, beside profits, include food security, greater personal convenience, control of risk, affordability of adoption and intellectual satisfaction. Farmers need access to information in relation to the complexity of the development, and ongoing supply of technological inputs.

Within agricultural development, fodder production is unique in that it generally has no direct marketable output itself, although markets for fodder can be developed. Farmers generally only grow a pure fodder crop in response to development in livestock production that generates sufficient income to justify the investment in land, labour and capital. An example is a dairy development project, which may be focussed on a few villages.



SEU – Sheep Equivalent Unit

Figure 1.1. Model of the Farming System in lower valleys of central Tibet for one household

However, governments also have a responsibility to develop sustainable livelihoods for as many farmers as possible through county and township programmes. Here, farmers can benefit through improved nutrition of all their livestock, even though such benefits are seen indirectly through better family health and more sustainable farming systems. These farmers readily adopt dual purpose crops as second crops, which provide a market return as well as supplementary fodder. They can also adopt second crops grown purely for fodder provided the factors listed above are in place.

1.3. Opportunities to develop fodder production and double cropping

Agricultural livelihoods in central Tibet are made up of several sub-systems which interact both positively and negatively (Figure 1.1). Lands include irrigated, partially irrigated and rainfed croplands, and rangelands in alpine (plateau) areas, hillsides and valleys. Livestock are now restricted to cattle, sheep, goats, with some pigs and poultry. Areas and numbers of livestock shown in Figure 1.1 are indicative only. It is possible to put yield data to this model (Annex 1.1.1, summarised in Table 1.1), to include output of grains, straws and pure fodders; as well as fodder utilised by grazing and grains used as feed. If allowance is made for levels of utilisation, fodder, feeds and grazing can be converted to yields of utilised nutrients such as TDN (Total Digestible Nutrients) and CP (Crude Protein). From these, the number of stock which the household can keep can be estimated in terms of SEU (Sheep Equivalent Units). It is also possible to estimate the quantity of straws and animal dung available as fuel.

The values in Table 1.1 need to be revised with actual data recorded from farmers' fields and households. However with 1 ha (15 mu) of irrigated cropland, it is estimated that a typical family growing mainly Feimai winter wheat (WW) and Dongqing#1 winter barley (WB) will produce 3.5 tons cereal grains and 9 tons of fodder (mainly straws + weeds + grazing of croplands and limited hill grazing). Half the fodder is used for feeding, with an actual stocking rate estimated from utilised TDN and CP of 12 Sheep Equivalent Units.

Table 1.1. Summary of outputs from farming system models

	Farming System	
	Current Single Cropping	**Improved Double Cropping**
Irrigated Croplands (ha)	1.0	1.7
Rainfed Croplands (ha)	0.2	0.2
Rangelands (ha)	16.0	16.0
Total grain yield (kg)	3450	4300
Total fodder yield (kg DM)	9340	11460
Total fodder utilised as feed (kg DM)	4310	8202
Fodder utilisation (%)	46	72
Utilised fodder and feeds TDN (kg)	2454	5190
Utilised fodder and feeds CP (kg)	332	944
Stocking Rate (SEU)	12	26
Total Fuel / Manure (kg DM)	4608	5252

1.4. Analysis of Strengths, Weaknesses, Opportunities and Constraints

The current single cropping system practised in the lower valleys of central Tibet can be analysed for its Strengths and **W**eaknesses, and **O**pportunities identified to intensify the system through double cropping in order to improve livelihoods of farmers on a sustainable basis (Annex 1.2). It is the **C**onstraints that farmers face in taking up these opportunities that have been addressed through the current project, indicated as Actions Required. Actions of a technical nature are the focus of this training manual.

The SWOC (Strengths, Weaknesses, Opportunities and Constraints) analysis shows how activities in crop production, fodder production and livestock keeping and the wider environment are closely linked. The main "Actions Required" addressed by this training manual include:

Cereal breeding and Crop agronomy

- Breed, introduce and select new WW and WB varieties that mature early but also have high yields of straw and grain
- WB breeders to combine the earliness of Dongqing #1 with the higher yields of grain and straw of later maturing varieties
- Study the agronomy of short duration WW and WB varieties, especially responses to NPK fertilisers and methods of weed control

Tillage methods

- Introduce "Conservation Agriculture" that consists of zero tillage and mulching with crop residues by planting one crop into the stubble of the previous crop with minimal soil disturbance.
- Introduce integrated control of weeds as a central component of introducing double cropping and zero-tillage technologies to farmers
- Train farmers in the use and benefits of zero-tillage equipment and more effective and profitable crop management practices related to this new tillage system.

Fodder production, Conservation and Feeding

- Train farmers in new technology for double cropping on irrigated lands - includes the testing and production of various fodder crops as second crops, and the establishment of these fodder crops by relay sowing and the use of reduced tillage drills
- Provide farmer training on a village basis on the production and conservation of fodder on rainfed lands
- Provide farmer training on production and processing of dual-purpose crops
- Assess forage legumes for nodulation by rhizobia, and introduce inoculation of legume seeds to farmers where necessary
- Research and demonstrate alternate uses of WW as fresh and conserved fodder and feed
- Given the large quantities of underutilised wheat straw, evaluate and extend to farmers cheap forms of treatment for straw - to include fractionation into leaf and stem, and treatment with urea
- Have farmers keep "Fodder and Feed Diaries", and extend their use to include crop inputs and utilisation of animal manures

Progress in farming systems in lower valleys of central Tibet over the past 25 years, and anticipated over the next 10 years as a result of project and training activities, is summarised in Table 1.2. Anticipated results from the introduction of improved farming systems that incorporate Double Cropping with fodder crops and conversion to Conservation Agriculture are summarised in Table 1.2 and detailed in Annex 1.1.2. Again the values in these tables need to be revised with actual data recorded from farmers' fields and households. The same land areas are used and include 1 ha (15 mu) of irrigated croplands. It is projected that half of the traditional WW (Feimai or Bussard) is relay sown to vetch in mid July with a fodder yield of 3 ton DM/ha. All of the short duration WW is zero-till drilled (double cropped) to vetch with a fodder yield of 4 ton DM/ha. One third of the area sown to WB (DQ#1) is double cropped to each of vetch, turnip and annual ryegrass, with fodder yields of 5, 5 and 4 DM tons/ha respectively. All the short duration WW grain is used for feeding, together with a small amount of Feimai grain. Yield of vetch grown on rainfed land has been increased from 3 up to 4 ton/ha due to use of supplementary irrigation and rhizobial inoculation. However offtake of pre-harvest weeds and grazing of crop lands have been greatly reduced.

Table 1.2. Progress in Farming Systems in central Tibet on lands below 3650m in altitude

Years	Crops	Tillage	Livestock	Grazing
Before 1980	Spring barley Spring Wheat Peas	Yak / Zo / Cattle Plough x 4 Broadcast seed	Yak/Zo/Cattle for draught power Local Sheep	All stock sent to alpine region for whole summer
1980 - 2005	Winter Barley Winter Wheat Spring Barley Rapeseed	15 HP 2-wheel tractor 20 HP 4-wheel tractor Plough Level (hand / tractor) Drill (cereals)	Local cattle for subsistence production and monetary reserve Local Sheep	Sheep grazed on hillsides / low mountain Cattle stall fed in Spring Post-harvest all stock graze stubbles
2006 - 2015	Winter Barley // DC Vetch Winter Barley // DC Turnip Winter Wheat / Relay Vetch Winter Wheat // DC Vetch Spring Barley Cash crops - Rapeseed	25 HP 4-wheel tractor Zero-till drill Chemical weed control (Conservation Agriculture)	Simmental x Local Cows for commercial milk production Cross-bred Sheep for Fat Lamb production	X-bred sheep graze hill sides then post harvest on stubbles Cows stall fed fodders Lambs fattened on cut fodders

It is therefore estimated that a typical family will produce 4.3 tons cereal grains and 11.5 tons DM of fodder. Of this fodder, 4.2 tons are cultivated fodder crops and other green fodders, while the rest are crop residues. 72% of the total fodder produced is used as feed. Including the grain fed the actual stocking rate has been doubled to 26 Sheep Equivalent Units - but this is derived from fodders of much higher nutritive value which can support higher levels of animal production. The remaining straw available as fuel is slightly reduced from 3.1 to 2.4 ton. However, the dung collected at the homestead is estimated to increase from 1.5 to 2.8 ton DM. It will be essential to return as much of this dung to the field as possible as manure in order to maintain soil fertility, soil structure and crop yields on a sustainable basis.

1.4. Potential benefits

The rainfall in the period July to September is nearly 70% of the annual total and the first frost in this region starts usually around 15 October. Temperature and rainfall conditions in Gongka, Zhanang, Zedang, Nimu, and Qushui are slightly more favourable than in the Lhasa area. However, the temperature in the Lhasa area has increased slightly over the last thirty years and it may be possible to grow winter barley in some areas where previously this was not possible. Also, newly developed varieties of winter barley are more resistant to freezing temperatures and can survive the winter period. These climate changes and technological innovations provide an opportunity for Tibet to grow new crops and adopt new farming systems. Winter wheat, winter barley, maize, vegetables and some fodder crops are new to Tibet as compared with just thirty years ago. The double cropping system would also be an innovative approach that may help both to maintain the grain production level while increasing high quality fodder production.

Initial trials in the region have shown that late maturing winter wheat usually yields about 4-6 ton/ha. In these trials early maturing winter wheat (maturing in July) yielded more than 4.5 tons/ha, and in some cases it reached about 5 tons/ha. When winter wheat matures before the rainy season, the grain quality is much better than the late maturing one. Introduction of high-yielding good grain quality winter wheat could be an innovative approach to pursue improved marketability of wheat and increased income generation from wheat cultivation. In addition, early maturing winter wheat increases the growing window for the following second crop of fodder. This ensures the benefits of maintained wheat production, improved feed quality, and increased fodder production for winter.

Winter barley was introduced to this area in the 1980s and many farmers have been growing winter barley. The average yield of winter barley is usually 10-15% higher than that of spring barley (3.5 ton/ha on average). The total profit from cultivating winter barley, if followed by a fodder crop, could be double that of a single crop of spring barley.

As both rainfall and water are available for irrigation and the temperature is favourable, high yields of fodder crops can be achieved provided the fodder crop is protected from free livestock grazing. These crops include nitrogen-fixing legumes such as Jiashewandou (Japanese vetch), peas, and beans; fodder oats or triticale with accompanying legume crops; and other crops such as turnips and fodder-beet.

According to a survey in Nima and Qushui County, the dry-matter of one hectare of turnip can feed 30 cattle. After the turnip root is dried, ground into powder and fed to the milking cow, milk production increased by 20%. Also, one hectare of turnip root can feed about 22-30 pigs with body weight of about 200 kg. Currently, in the lower and middle reaches of the Lhasa River alone, there are more than 10,000 ha cultivated for winter crops. If 3,000 ha were converted to double crop farming, the total fodder dry matter production could be 15,000 tons on the basis of 5 ton/ha yield, which can feed around 9000 head of beef cattle. An experiment in test plots showed that if Jianshewandou is grown after winter barley, fresh-matter production may reach 20-40 tons/ha which could support 7 sheep equivalent animal units.

The expansion of livestock production and the numbers of entrepreneurs involved in livestock raising in the lower and middle reaches of the Yalong Tsangpo River is increasing in response to local government activities, but is still limited by the amount of good quality feed available over the winter and spring period. The double-cropping system is a potential solution that still requires technical assistance and advice, and new cultivars and crop varieties, to be able to demonstrate it to farmers. New fodder crops and new cultivars/varieties of traditional fodder crops and of winter barley and wheat are needed, as well as assistance for improving the management of the more complex cropping systems. With the TCP assistance and training it is expected that double-cropping systems based on winter barley and winter wheat will be the means to finding the solution to the problem of lack of winter feed for livestock as well as to increasing feed and food production per unit of land. As mentioned previously, the initial target for double cropping area is of 3,000 ha which would potentially benefit 9000 farm families. These farmers are considered some of the poorest in China.

Expected benefits include:

- production of both food grain and fodder from the same land area and increased total biomass production per unit of land;
- production of improved fodder and thus livestock production to meet the increasing demand;
- improved soil fertility through biological nitrogen fixation;
- improved farmer livelihoods and food security.

Annex 1.1.1. Models for Crop-dominated farming systems <3650m altitude in central region of Tibet - Current single cropping system

Lands	Areas	Yield of crops		Yields (DM) Fodders / Feeds		Utilisation Fodders / Feeds		Fodder quality		Utilised nutrients	
								TDN	CP	TDN	CP
	ha	kg/ha	kg	kg/ha	kg	Proportion	kg DM	%	%	kg	kg
Croplands											
Irrigated											
WW-Fm	0.6	4000	2400	4800	2880	0.25	720	50	4.0	360	29
WW-SD	0.1	3000	300	3600	360	0.25	90	50	4.0	45	4
WB	0.3	2500	750	3000	900	0.80	720	55	4.5	396	32
SB	0.0	2000	0	2400	0	0.80	0	55	4.5	0	0
RS	0.0	1000	0	2000	0	0.10	0	40	5.0	0	0
Pre-harvest Weeds				1000	1000	0.50	500	60	12.0	300	60
Total	**1.0**		**3450**		**5140**		**2030**			**1101**	**125**
Rainfed											
Vetch	0.2			3000	600	1.00	600	65	14.0	390	84
Lucerne	0.0			1500	0	1.00	0	70	16.0	0	0
Total	**0.2**				**600**		**600**			**390**	**84**
Grazing of crop lands											
WW-Fm	0.6			1000	600	0.7	420	55	6.0	231	25
WW-SD	0.1			1000	100	0.7	70	55	6.0	39	4
WB	0.3			2000	600	0.8	480	55	6.0	264	29
SB	0.0			1000	0	0.8	0	60	8.0	0	0
RS	0.0			1000	0	0.5	0	55	6.0	0	0
Vetch	0.2			1000	200	0.8	160	65	14.0	104	22
Lucerne	0.0			1000	0	0.8	0	70	16.0	0	0
Total					**1500**		**1130**			**638**	**81**
Grains used as feed											
WW-Fm	0.6			3400	2040	0.0	0	87	13.5	0	0
WW-SD	0.1			2550	255	0.0	0	87	14.5	0	0
WB	0.3			2125	637.5	0.0	0	83	12.0	0	0
SB	0.0			1700	0	0.0	0	83	13.0	0	0
RS (meal)	0.0			850	0	0.6	0	82	36.0	0	0
Total							**0**			**0**	**0**
Rangelands											
Alpine	10.0			100	1000	0.0	0	65	10.0	0	0
Hillsides	5.0			200	1000	0.5	500	60	8.0	300	40
Valley	1.0			100	100	0.5	50	50	6.0	25	3
Total	**16.0**				**2100**		**550**			**325**	**43**
TOTALS			**3450**		**9340**		**4310**			**2454**	**332**

Stocking Rate **(Number of Sheep Equivalent Units (SEU) (30kg sheep) at 200 kg TDN @ 55% / SEU / y)** **12**

FUEL & MANURE [1]

	kg DM
Croplands	
Cereal straws	3110
Dung[2]	1498
Sub-total[3,4]	**4608**

Crops

WW-Fm	Winter Wheat Fenmai (or Bussard)
WW-SD	Winter Wheat current Short Duration variety
WB	Winter Barley
SB	Spring Barley
RS	Rape Seed

Notes

1. Yield of fuelwood from rangelands is not estimated
2. Yield of dung included as fuel / manure includes an estimate of half the dung produced by grazing livestock
3. Traditionally most dung and straw are mixed and used for fuel; with increasing use of oil and gas for cooking, more dung and straw can be returned to crop lands as Manure
4. Ash from burning fuel is mixed with manure so most P and K is returned to crop lands

Annex 1.1.2. Models for Crop-dominated farming systems <3650m altitude in central region of Tibet - Improved Double Cropping system

Lands	Areas	Yield of crops		Yields (DM) Fodders / Feeds		Utilisation Fodders / Feeds		Fodder quality		Utilised nutrients	
								TDN	CP	TDN	CP
	ha	kg/ha	kg	kg/ha	kg	Proportion	kg DM	%	%	kg	kg
Croplands											
Irrigated											
WW-Fm	0.6	5000	3000	6000	3600	0.50	1800	50	6.0	900	108
Relay Vetch	0.3			3000	900	0.90	810	70	20.0	567	162
WW-SD	0.1	4000	400	4800	480	0.50	240	50	6.0	120	14
DC-Vetch	0.1			4000	400	0.90	360	70	20.0	252	72
WB	0.3	3000	900	3600	1080	0.90	972	55	4.5	535	44
DC-Vetch	0.1			5000	500	0.90	450	68	18.0	306	81
DC-Turnip	0.1			5000	500	1.00	500	70	15.0	350	75
DC-Annual ryegrass	0.1			4000	400	1.00	400	75	17.0	300	68
Pre-harvest Weeds				200	200	0.50	100	60	12.0	60	12
Total	**1.7**		**4300**		**8060**		**5632**			**3390**	**636**
Rainfed											
Vetch	0.2			4000	800	1.00	800	65	14.0	520	112
Lucerne	0.0			1500	0	1.00	0	70	16.0	0	0
Total	**0.2**				**800**		**800**			**520**	**112**
Grazing of crop lands											
WW-Fm	0.3			1000	300	0.7	210	55	6.0	116	13
WW-SD	0.0			1000	0	0.7	0	55	6.0	0	0
WB	0.0			2000	0	0.8	0	55	6.0	0	0
Vetch	0.2			1000	200	0.8	160	65	14.0	104	22
Lucerne	0.0			1000	0	0.8	0	70	16.0	0	0
Total					**500**		**370**			**220**	**35**
Grains used as feed											
WW-Fm	0.6			4250	2550	0.2	510	87	13.5	442	69
WW-SD	0.1			3400	340	1.0	340	87	14.5	295	49
WB	0.3			2550	765	0.0	0	83	12.0	0	0
Total							**850**			**736**	**118**
Rangelands											
Alpine	10.0			100	1000	0.0	0	65	10.0	0	0
Hillsides	5.0			200	1000	0.5	500	60	8.0	300	40
Valley	1.0			100	100	0.5	50	50	6.0	25	3
Total	**16.0**				**2100**		**550**			**325**	**43**
TOTALS			**4300**		**11460**		**8202**			**5190**	**944**

Stocking Rate **(Number of Sheep Equivalent Units (SEU) (30kg sheep) at 200 kg TDN @ 55% / SEU / y)** **26**

FUEL & MANURE[1]	kg DM
Croplands	
Cereal straws	2428
Dung[2]	2824
Sub-total[3,4]	**5252**

Crops

WW-Fm	Winter Wheat Fenmai (or Bussard)
WW-SD	Winter Wheat current Short Duration variety
WB	Winter Barley
DC	Double Crop fodders

Notes
1. Yield of fuelwood from rangelands is not estimated
2. Yield of dung included as fuel / manure includes an estimate of half the dung produced by grazing livestock
3. Traditionally most dung and straw are mixed and used for fuel; with increasing use of oil and gas for cooking, more dung and straw can be returned to crop lands as Manure
4. Ash from burning fuel is mixed with manure so most P and K is returned to crop lands

Annex 1.2. SWOC analysis for the current single cropping system in the lower valleys of Central Tibet

Strengths	Weaknesses	Opportunities	Constraints	Actions Required
1. A high proportion of crop lands can be irrigated	Farmers / villages can not control time and amount of water supplied Rainy season is short so most crops can not be grown on rainfed lands	Introduce participatory farmer management of irrigation facilities Improve water use efficiency at the field and distribution level so more land can be irrigated. Grow fodder crops on rainfed lands - either perennial drought resistant crops such as lucerne, or catch crops such as vetch with a short growth period Introduce pumping systems so that supplementary irrigation can be provided to extend the growth period available to perennial and catch fodder crops	Control of water is now with the Water Bureaux who do not work closely with farmers. Farmers' water user associations are weak Farmers need commercial output from livestock to justify the costs of growing fodder crops Farmers lack knowledge on fodder production and conservation and on supplemental irrigation Farmers lack inputs – seeds, fertilisers and crop protection chemicals, and pumping equipment and supplies	GoTAR to require Water Bureaux to work with farmers at village level for "Participatory Water Management" of irrigation facilities Introduce participatory programmes for commercial livestock development Provide farmer training on village basis on fodder production and conservation, and supplemental irrigation Assist farmers with inputs for forage production on rainfed lands through Farmers' Associations: - seeds and fertilisers - pumps - systems for forage conservation
2. A wide range of temperate crops can be grown with good market for crop products	Until 2005 all suitable land has been planted to cereals in order for Tibet to be self-sufficient in grains Shop keepers in towns have organised good quality supplies of cereals and pulses imported from mainland China	Government is now supporting farmers to develop sustainable livelihoods through cash crops and commercial livestock keeping Traditional pulse crops can be grown again as part of rotations Rapeseed is being introduced to meet factory demands Farmers can now grow a range of dual purpose crops with a good market value together with potential for high value forage	Farmers lack organisation at village level to develop production and marketing of cash crops and livestock products Farmers lack knowledge, skills, and facilities to produce cash crops to meet current market standards Many dual purpose crops come from vegetable growing and are new to farmers - for production and marketing, and conservation / feeding of fodder components	Assist the formation of Farmers' Associations at natural village and higher levels Provide farmer training on the production, processing and marketing of pulse, rapeseed and dual-purpose crops Assist farmers with inputs supply and product marketing through Farmers' Associations

Strengths	Weaknesses	Opportunities	Constraints	Actions Required
3. Winter wheat (WW) has been widely adopted by farmers, with higher yields than spring wheat (SW)	The varieties of WW adopted by farmers are late maturing, so that harvest occurs during the rains and results in poor grain quality Wheat is largely sold at low controlled government prices, so that it is uneconomic for farmers to use additional inputs Wheat yields are low because of poor crop management and so more land is needed to grow cereals to meet food needs than would be needed if wheat yields were closer to potential	Breed and introduce to farmers new WW varieties that mature earlier and have good grain quality Introduce double cropping to farmers through the use of relay and double crops for fodder - to replace WW straw with conserved high quality fodder for feeding in winter and spring; and to improve stubbles for late summer grazing WW is the highest yielding crop. Use it as fodder and/or feed for commercial livestock. Conserve the whole crop at an immature stage as silage; and give coarsely milled grain as a high energy feed to highly productive animals Close the yield gap from actual to potential wheat yields by improving management and introducing more sustainable conservation agriculture practices	Cereal breeders in general ignore the value that farmers place on straw for fodder and fuel, and do not even measure straw yields of varieties in observation and evaluation plots New WW varieties adopted by farmers such as Bussard have higher grain yields and good straw yields, but have the same maturity as Feimai Early WW varieties offered to farmers have lower yields of both grain & straw with poor grain quality, and are unacceptable CIMMYT early WW varieties have high grain yields but very short straw, and are rejected by farmers Both relay sowing and direct drilling of fodder catch crops following WW are new technologies for farmers The benefits of double cropping with fodder have to be demonstrated before farmers will adopt early WW varieties that have lower straw yields Economically, farmers need to keep livestock commercially before they will think of feeding wheat as a grain or whole-crop silage Land preparation and soil structure is poor resulting in cloddy, uneven fields. The results are poor stands, poor irrigation and fertiliser management and efficiency, more weeds and low yields	Breed, introduce and select through farmer participatory trials new WW varieties that mature earlier but also have high yields of grain and straw - marginal reductions in growing period of 1-2 weeks will still improve grain quality and potential production of fodder crops Study the agronomy of short duration WW varieties (especially NPK responses) in order to produce yields of grain and straw that equal traditionally grown Feimai but with earlier harvest Research and demonstrate whole WW/Fodder double crop combinations when introducing short duration WW varieties to show the extra green fodder that can be grown and conserved Increase research and demonstration of alternate uses of WW as fodder and feed - and link this programme to participatory livestock development. This will become important when additional supplies of imported cereals result from opening of the railway, with reduced prices for wheat Conduct participatory farmer demonstrations on better wheat management including the introduction and promotion of conservation agriculture practices – zero-tillage, mulching and rotations, and the balanced use of fertilisers and better integrated weed control

Strengths	Weaknesses	Opportunities	Constraints	Actions Required
4. Winter barley (WB) has been widely adopted by farmers with higher yields than Spring barley (SB) Farmer prices are higher for naked barley than for wheat – and will be maintained even if wheat price falls	The popular WB variety Dongqing #1 used for double cropping, although early maturing, has relatively low yields, weak straw and poor eating quality Barley yields are low because of poor crop management and so more land is needed to grow cereals to meet food needs than would be needed if barley yields were closer to potential	Include Dongqing #1 in WB breeding and selection programmes to provide varieties with both earliness and better grain yields and quality With harvest in early-mid July DQ#1 remains the best main crop for double cropping with fodder crops as relay or second crops Farmers are already growing turnip as a second crop after DQ#1 DQ#1 has good quality straw for feeding livestock Close the yield gap from actual to potential barley yields by improving management and introducing more sustainable conservation agriculture practices	Tibet is the main centre of origin of naked barley, so there are few external genetic resources All varieties tested under the WB observation and evaluation trials were 2 weeks later to mature than Dongqing #1 Farmers need commercial output from livestock to pay for input costs of fodder crops Both relay sowing and direct drilling of fodder catch crops following WB are new technologies for farmers Farmers lack seeds of new fodder crops Land preparation and soil structure is poor resulting in cloddy, uneven fields. The results are poor stands, poor irrigation and fertiliser management and efficiency, more weeds and low yields	WB breeders to continue to combine earliness of DQ#1 with higher yields of grain and straw of later varieties, and to collect cold tolerant native landraces of naked barley from high altitude sites around the Tibet-Qinghai Plateau. WB breeders to work with breeders of naked barley in USA (Pacific coast regions) who have bred new commercial varieties Train farmers in new technology for double cropping, and assist supply of inputs through Farmers' Associations Conduct participatory farmer demonstrations on better barley management as for wheat Develop agronomy of DQ#1 WB through use of crop growth regulators with higher fertiliser (N) levels to increase farmer yields of DQ#1 grain, maintain straw yields, and overcome lodging
5. Most irrigated crop lands have medium fertility	Continuous cropping with cereals is mining the soil of nutrients, so amounts of fertiliser required to maintain crop yields are increased Dung from stall-fed animals is mixed with straw and used as fuel, with loss of N and organic matter from the system Rainfed lands have low soil fertility and poor soil structure	Introduce sound rotations that include grain and forage legumes with balanced applications of manure and fertiliser Introduce "Conservation Agriculture" with zero tillage / direct drilling of one crop into the stubble of the previous crop Develop alternate fuel supplies including village wood-lots so that more dung and urine can be returned to crop lands as manure Grow renovation crops of green manure / fodder on rainfed lands - to be ploughed in or grazed *in situ*	Problems of farmers' knowledge, organisation and business capacity noted above Fields are grazed bare before autumn cultivations, which also compacts the soil Current tree planting programmes are top-down and are primarily for long term environmental conservation. Linkages between various state bureaux need to be developed during planning and implementation of village wood-lots Poor quality lands may lack rhizobial bacteria for legume nodulation	Assist formation of Farmers' Associations and their ongoing activities Use more soil testing and application of balanced doses of fertiliser – potassium seems to be one major element that is becoming deficient. Farmers to keep grazing livestock off fields with second crops - so autumn crops can be sown directly into stubbles with residues present Develop linkages between various state bureaux to assist the planning and implementation of village wood-lots for fuel and fodder Assess forage legumes grown for land renovation for nodulation, and introduce legume inoculants

Strengths	Weaknesses	Opportunities	Constraints	Actions Required
6. Incidence of crop pests and diseases is low due to cold winters	Farmers have low incomes and can not afford agro-chemicals to control pests and diseases. The range of agro-chemicals is limited, and the cost through commercial companies is high Proper application techniques are not well known	Introduce more diverse crop rotations to break potential pest and disease cycles Introduce more profitable cash crops which will provide better returns and justify use of agro-chemicals Ensure companies are available to supply agro-chemicals, and that training is provided to farmers in their safe and correct use Promote more integrated approaches to crop protection	The problems with introducing new crops noted above The incidence of crop pests and diseases needs to be monitored closely Farmers may not recognise important pests and diseases, especially on new crops Poor linkage between farmers' needs for agro-chemicals and training in their use, and establishment of supplies through state or commercial channels	Include input supply and marketing of products at village level as core activities for Farmers' Associations If not available, establish a crop monitoring service through TARI / Agricultural Bureaux for the valleys of central Tibet Train farmers to recognise crop pests and diseases, appropriate agro-chemicals to use for their control if necessary, and correct use of crop sprays and sprayers through better application techniques
7. Weed seedlings are killed over winter due to cold	Weed seeds germinate in spring Farmers either do not use chemicals to control weeds, or are restricted to 2,4-D for annual broadleaved weeds Severe weeds include perennial grass weeds with rhizomes, and deep rooted broadleaved weeds such as Rumex species Weed growth following harvest of winter cereals is fast, and can result in large numbers of weed seeds which enter the seed bank Proper equipment and training it their use is not available	Control perennial grass and broadleaved weeds which reduce cereal yields even with traditional tillage methods Introduce safe and cost effective weed control to farmers as part of programmes to introduce both double cropping of fodder and dual purpose crops, and zero-tillage Replace part of stubble grazing with second crops of fodder, which compete well with weeds Make proper equipment available and train farmers in good herbicide application methods and integrated weed management systems	Little work has been carried out on the use of modern herbicides available in China on the weed problems of central Tibet Farmers lack sprayers and knowledge of how to use them for effective herbicide application and weed control The range of herbicides available to farmers is limited, and expensive	Increase research and development by TARI on weed control in the project area for traditionally grown crops Include control of weeds as a central component of introducing double cropping and zero-tillage technologies to farmers Train farmers in weed recognition, herbicide selection, and safe and effective herbicide application Facilitate the supply of good quality sprayers and appropriate herbicides to farmers through programmes for the introduction of double cropping and zero-tillage; and afterwards through Farmers' Associations and commercial channels

Strengths	Weaknesses	Opportunities	Constraints	Actions Required
8. Most farmers use 2 and 4 wheel tractors for cultivation of crops, and have ploughs and seed drills	Implements for tractors are limited to ploughs and seed drills For most of the year tractors are mainly used for commercial transport	Introduce zero-till drills (Direct drills) for use in Conservation Agriculture - through private farmers, village farmer mechanisation groups, or through local farmer contractors	4 wheel tractors in the project area are generally small, maximum 20 HP Mechanical support for tractor owners is limited and farmers do all basic repairs and maintenance themselves	Reduce the number of rows used on zero-till drills from six down to four, so they can be used with farmers' 20 HP 4-wheel tractors Include existing farmer contractors within the programme to develop Conservation Agriculture - they have larger tractors for 0-till drills with 6 rows Facilitate the development of mechanical workshops at village level - either private or through Farmers' Associations Make sure that spare parts are available for repair
9. Strong demand for livestock products from increasing size and wealth of urban populations	Lack of marketing structures, so unless within a project it is difficult for farmers to sell products in cities Shop keepers in towns have organised good quality supplies of butter and dried meat imported from mainland China	Develop village level livestock producer groups to increase the quantity of animal products available; and to match the quality required by urban customers Establish livestock marketing chains so that animal products produced in the village can be marketed in urban centres	Multi-bureaux approach needed within villages / townships to cover fodder and feed production as well as animal production, processing and marketing Farmers within villages have little experience of selling livestock products as most are produced for subsistence only	Through participatory processes assist farmers within villages / administrative villages / townships to set up marketing organisations for dairy, meat and other livestock products - either through ongoing and planned projects, or through Animal Husbandry Bureaux
10. Most farming households keep cattle and sheep	Most livestock are kept for family subsistence without a commercial output Despite long term government programmes, most are traditional breeds. These are small, & slow to mature with low milk yields. Many mature non-productive stock are kept for status and financial reasons Improved breeds and cross breeding programmes are restricted to projects in a few villages of each county	Link livestock improvement and fodder development Establish markets for breeding animals which allow the improved genetic merit / production potential of cross bed animals to be reflected in their economic value Encourage farmers to exchange several unproductive mature local animals for one productive cross-bred animal Animal Bureaux to extend to the rural community in general activities presently restricted to development projects	Close liaison is required between agricultural and livestock / veterinary research institutes and state bureaux Procedures for marketing breeding animals have yet to be developed Most methods of livestock improvement require qualified staff and substantial financial inputs, and can only be implemented slowly across counties	Introduce exotic breeds for cross breeding that can utilise high forage diets effectively: in cattle, use dual purpose Simmental rather than breeds that require high levels of concentrates such as Holstein and Jersey Ensure close liaison between research institutes and bureaux so that livestock improvements are linked with development of fodder crops including double cropping Extend livestock improvement and fodder development more broadly through working with Farmers' Associations and producer groups Train farmer groups and village level technicians to carry out the activities previously restricted to projects

Strengths	Weaknesses	Opportunities	Constraints	Actions Required
11. The cereal based cropping system produces large quantities of straw which is used both as the main fodder for livestock and , when mixed with dung, as fuel	Straw based rations are totally inadequate to support improved livestock production. Use of dung mixed with straw as fuel removes N from the system, even if the ash is returned to crop lands	Produce fodder and dual purpose crops within double cropping systems on irrigated crop lands, and short duration or perennial fodder crops on rainfed lands - as noted above. In addition to fodder, these will lead to more dung production Treat cereal straws to improve fodder feeding value Develop straw based rations that include fresh and/or conserved fodders, and meet the production requirements of cross-bred livestock Develop fuel and fodder wood-lots - as noted above Promote more solar energy for cooking and heating.	Constraints to fodder production as noted above Bacterial treatment of straw has been introduced to farmers. The method involves pits lined with cement. The pits and the bacterial inoculant are expensive for the improvements in feed quality obtained, so that uptake by farmers is low Lack of data on actual fodder and feeds fed in relation to animal production in the project area; and lack of data on nutritive value of actual fodder and feeds fed as well as analyses on fodder crops grown locally Constraints to development of wood-lots as noted above	Evaluate and extend to farmers through participatory methods cheaper forms of treatment for crop residues, especially straw from WW - to include fractionation of straw into leaves (fodder) and stems (fuel) [animals can do this themselves if fed surplus straw]; and treatment of WW straw with fertiliser urea, under simple plastic covers Have farmers keep "Fodder and Feed Diaries" to record fodder and feeds fed, and animal production from those feeds. Take records once a month for an entire year. To estimate livestock responses to fodder crops include farmers with local and with cross-bred livestock, and without and with fodder crops. Collect samples of all fodders and feeds including the straws, and analyse for nutritive value. Extend Fodder and Feed Diaries to include crop inputs and uses of dung, to model N cycles and the impact of the introduction of fodder crops
12. Livestock graze on croplands in August - September. This reduces grazing pressure on hillside rangelands. Through return of dung and urine directly to the land it improves soil fertility. It also controls reproduction of weeds.	Summer grazing of crop fields is the only time cattle are well fed. The fat they put on at this time is used to support weight loss during winter and spring All the livestock from the village graze the crop lands once harvested crops are removed. Individual farmers have no control over the grazing of their own plots	Provide high yields of top quality fodder for grazing in August - September by relay sowing or immediate zero-till seeding of fodder double crops after WB; alternatively cut and carry green fodder to stall-fed livestock Add N to the soil with forage legumes nodulated with effective rhizobia	Constraints to fodder production are noted above Labour is a constraint to stall feeding hand cut fodder Nodulation of legumes may not be effective, especially in fields which flood with summer rains	Within participatory programmes, encourage farmers with cross-bred livestock to stall feed cut green fodder. This will maximise fodder production and minimise compaction of crop lands under Conservation Agriculture Make sure legumes are nodulated, and use a specific inoculant if required. Select non-legume fodder catch crops such as annual ryegrass on land liable to flood

Section 2 CROP PRODUCTION AND TILLAGE METHODS

Chapter 2 WHEAT AND BARLEY PHENOLOGICAL DEVELOPMENT AND ENVIRONMENTAL CONSTRAINTS IN TIBET

Helena Gymez MacPherson

Section 2 CROP PRODUCTION AND TILLAGE METHODS

Chapter 2 WHEAT AND BARLEY PHENOLOGICAL DEVELOPMENT AND ENVIRONMENTAL CONSTRAINTS IN TIBET[1]

2.1. Introduction

Extreme temperatures and water shortage are the major non-biological factors limiting growth and yield of cultivated cereal crops in Tibet. The rainfall in the period from July to September is nearly 70% of the annual total and the first frost in this region usually starts around 15 October. Thus irrigation is needed during the spring to reach yield potential.

In many cases, winter wheat is sown in dry autumn conditions delaying germination until spring. Otherwise, plants survive low temperatures during winter thanks to the ability to withstand cold temperatures during the vegetative phase. Crop management should aim to have wheat or barley plants in the most cold-resistant stage when freezing arrives and to have water available at the right times to form the yield components that maximize grain production. Irrigation, crop growth and development should be manipulated so that key developmental stages proceed under the best environmental conditions.

Besides low temperatures and water shortage, other environmental factors that may reduce yield significantly are any predominant damaging weeds, pests or diseases. Understanding the relationships between all these factors and crop growth and yield is a first critical step towards developing management strategies for the special conditions of any location.

2.2. Crop growth and development

Crops need both growth (get bigger -- quantitative changes) and development (develop various plant structures -- qualitative changes). The simplest way of thinking about development is to split it into two categories, vegetative development that includes production of leaves, tillers and roots; and reproductive development meaning the parts that finish up as the stalk and ear (head or spike) with its grains.

There are many steps for both vegetative and reproductive development but there is one big step that switches the plant from predominantly vegetative to predominantly reproductive development. Without that switch wheat would continue to produce only leaves and tillers.

The switch involves the length of day (longer days for a faster switch) and temperature (winter wheat requires low temperature first to accelerate the switch). The plant senses day length and temperature continuously and in effect records and sums them until it reaches the totals required by the variety to turn on the switch. Vernalization (cold requirement) or photoperiod (day length) provide the switch from the vegetative to the reproductive phase. In regions with cold winters, this is important because cold acclimation occurs in the vegetative phase. Additionally, vegetative plants can re-acclimate following warm periods.

Growing bigger

Plants grow bigger by absorbing carbon dioxide (CO_2) from the air through tiny controlled apertures (stomata) in their green surfaces (Figure 2.1). The carbon in the CO_2 is converted into sugars inside the plant using energy from sunlight in a process called photosynthesis. These sugars, in different forms and combinations with inorganic nutrients extracted from the soil via the roots, become the

[1] This text is based in two FAO books: *Irrigated wheat - managing your crop* (2000) and *Explore on-farm* (2003). All figures and photos in the text were previously used in these books except Plate 2.1.

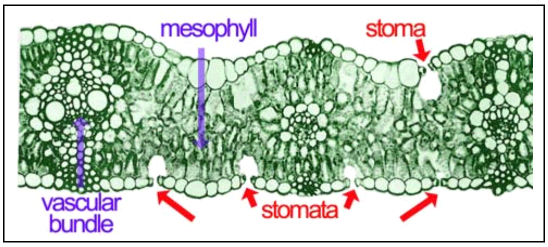


Figure 2.1. Cross section of a wheat leaf

bricks from which the plant is built. Some sugars go straight into growth while others are put into a storage bank for later withdrawal and use, particularly for filling the grains. The stems can be a good sugar store. It follows that as long as the crop has enough sunlight and CO_2, water and inorganic nutrients (see chapter on nutrition), and it is warm enough, all organs will grow as big as their potential allows.

There is one drawback to photosynthesis, water leaks out through open stomata as the CO_2 diffuses in. The hotter, drier and windier the air is, the faster the precious water is lost for each unit of CO_2 that enters. Though some passage of water from the roots to the leaves is necessary to extract nutrients from the soil, the plant must retain adequate water for essential growth processes. A severely drought affected crop keeps its stomata closed to stop water loss, but this prevents CO_2 from entering which in turn prevents growth. This is why crops that run out of water soon die. They starve as well as dehydrate. When the crop is under water stress, the organs growing at that time will be proportionately less able to reach their potential size.

Developing: more parts of the same type

To a certain extent, the more sunlight that the crop can absorb to drive photosynthesis, the better it grows. As more of the ground is covered by green leaf, the more sunlight is intercepted. So before a crop can grow at its greatest absolute rate, it must develop many leaves. Every leaf takes approximately the same time to expand (measured in temperature time) and the next one queued on any shoot cannot start to expand until the previous one is well under way. Development is all about waiting in turn in a sequence. The size that any unit achieves is dependent on how much plant substrate is available when its turn comes to grow.

The crop can produce many shoots (tillers) that eventually grow fairly independently with each tiller having its own leaves. However, tillers are subject to the same queuing rules that apply to leaves and even more so to the amount of substrate the plant has available when their turn comes to grow.

If the plant is short of substrate (because of drought, low light or nutrient shortage) when a tiller's turn comes to grow, it will remain dormant and possibly never grow. The next tiller in the sequence will start growing again only if conditions improve.

In order to survive winter conditions, winter wheat must acclimate or acquire cold tolerance (winter hardiness) before freeze-up. Cold acclimation is related to soil temperature and begins once soil temperatures at crown level drop below $+9^{o}C$ (4 - 8 weeks below this soil temperature are normally required to fully acclimate plants). Cold acclimation can be stopped, reversed or restarted by changes in temperature. Once fully acclimated, wheat plants will be fairly tolerant to the cold. If there is a snow layer, the tolerance will be much more since the snow buffers the plant against the effects of air temperature changes.

Winter hardiness gradually decreases over the winter so growth in the spring is permitted. This process also depends on soil temperature. The crown contains all the tissues necessary for the regeneration of leaves and roots; it just needs a few days of warm weather and soil temperature to resume growth.

To assess plant survival it is necessary to look for new white roots in the crown. The plant is in good condition if the crown appears healthy and with new roots. Dried leaves do not necessarily indicate winter injury. Most winter-killing occurs in late winter when reduced hardiness due to warm temperatures is followed by a new onset of cold temperatures. Winter temperatures well below 0°C can kill vegetative growth (Plate 2.1).

Stepping from vegetative to reproductive development

Crops don't really stop one process and then start another. There is always an overlapping progression of processes; new leaves are still expanding long after the crop starts to grow its microscopic ears. In Plate 2.2, the green bar labelled **"leaf appearance"** extends beyond the picture of the ear at terminal spikelet. But just as each leaf and tiller queues to develop and have their final size set by plant substrate at the time of their growth, the reproductive parts (ears, spikelets, florets and finally grains) are subject to those rules. Whether the next floret starts to grow depends on the state of the previous floret and whether substrates are available to support it.

An attempt to show this interplay is in Plate 2.2. This Plate may seem complex but it is simple compared with what actually happens in the plant or crop. It shows when the plant components that bear the yield structures are forming. It also identifies when the processes are potentially most sensitive to stresses. In some cases it might require higher inputs or farmer management when an impact on yield can be made.

2.3. The Zadoks decimal growth stages

Growth is a complex process with different organs developing, growing and dying in overlapping sequences. However, it is easier to think of it as a series of growth stages as in the Zadoks scale, a system for cereal crops like wheat and barley (Table 2.1). This has 10 main stages, labelled 0 to 9, which describe the crop. These are named in the Table 2.1. Stages of "booting", "heading" and "anthesis" are illustrated in Plate 2.3.

Table 2.1. Zadoks decimal growth stages (Z0.0 to Z9.9)

main stage	DESCRIPTION	*sub-stage*	**main stage**	DESCRIPTION	*sub-stage*
0	germination	*0.0-0.9*	**5**	heading	*5.0-5.9*
1	MS leaf production	*1.0-1.9*	**6**	anthesis	*6.0-6.9*
2	tiller production	*2.0-2.9*	**7**	grain milk stage	*7.0-7.9*
3	MS node production (stem elongation)	*3.0-3.9*	**8**	grain dough stage	*8.0-8.9*
4	booting	*4.0-4.9*	**9**	ripening	*9.0-9.9*

Notes: 1. MS = main stem or shoot, or parent shoot
2. Growth stages follow Zadoks, J.C., Chang, and T.T., Konzak, C.F. (1974)

To determine the growth stage it is easier to decide first which of the main stages best describes the crop, and then to look more closely in order to decide the decimal value for each sub stage. These sub stages depict the degree of completion of the main stage. For example, stages Z1.1 to Z1.9 are when the main stem (MS) leaves 1 to 9 become visible. Similarly, Z2.1 to Z2.9 covers the appearance of the 9 tillers on the plant, and Z3.1 to Z3.6 the presence of the 6 nodes or joints on the main stem.

Main stages 1 and 2 describe leaf and tiller production that actually occur in parallel, not in sequence. Similarly there is some overlap of main stages 2 and 3. This overlap means that the crop can have two or even three Zadoks stages at one time. The drawings in Figures 2.2 and 2.3 illustrate the early stages during vegetative growth and the later reproductive stages respectively, with their Zadoks decimal codes (identified as Z in this manual but elsewhere often abbreviated to DC for Decimal Code).

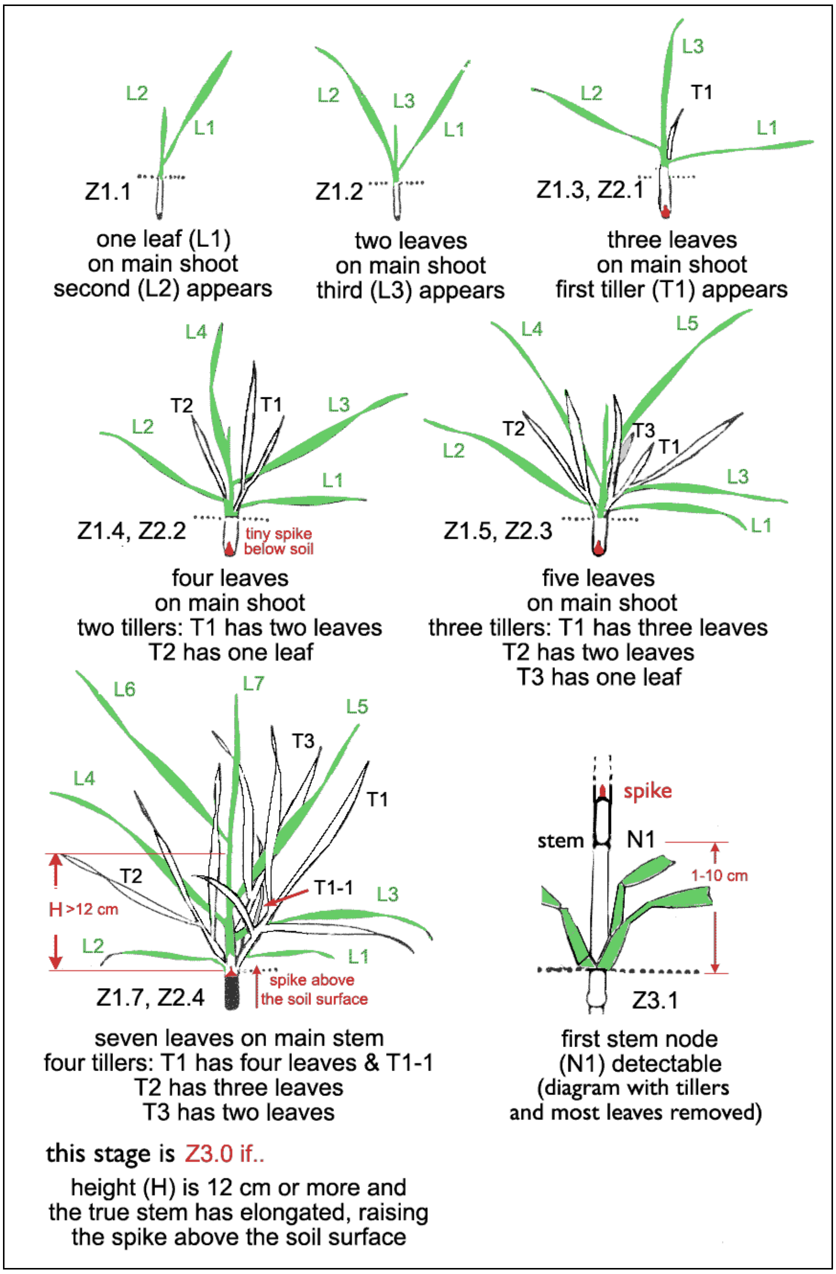


Figure 2.2. Drawings to help identify the early Zadoks (Z) growth stages

Booting, heading and anthesis

These stages are easily identified (see Figure 2.3 and Plate 2.3). As with earlier stages, the number following the decimal point denotes the degree to which the process is complete. So Zadoks 5.1 is when the tip of the average spike in the field is 0.1 or 10% emerged (ear peep) while Z5.9 is when 0.9 or 90% of the average spike is above the flag leaf collar. The anthesis stage or flowering marks the beginning of grain setting and filling. When the anthers are freshly displayed they are bright yellow. They bleach white within 3 or 4 days (mid anthesis or Z6.5).

The internal stages that drive development

Zadoks stages can also describe what cannot be seen with the naked eye (Plate 2.4). It is the apex, spike or growing point of the plant, which cannot be seen enclosed inside the leaf sheaths, that is the first indicator of when the plant steps through its main stages. It is the control room of the plant. Two important stages of the growing point are double ridge and terminal spikelet. The double ridge stage signifies that the plant's main growing point will produce no more primordial leaves, and instead will produce primordial spikelets of the young spike. At that time, the enclosed growing point is still at the crown of the plant below the soil surface. Terminal spikelet is when the tiny spike has produced all its spikelets. Then that spike, which is only 2 mm long, will dominate less advanced growing points in the tillers; some will die, as will their tillers. To see that tiny spike, split a shoot with the thumb nails about 1 cm above the crown and peel off the little leaves. Though it is very small, it already looks much like an emerged spike.

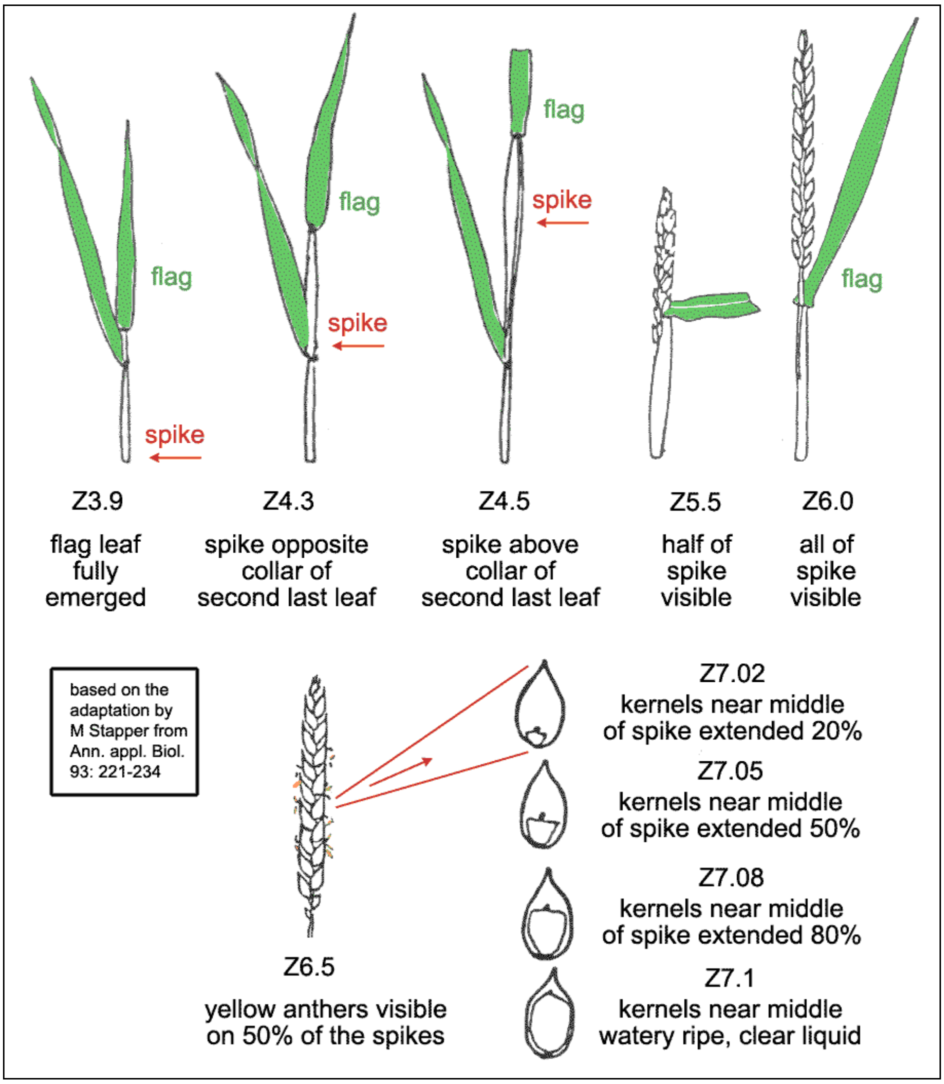


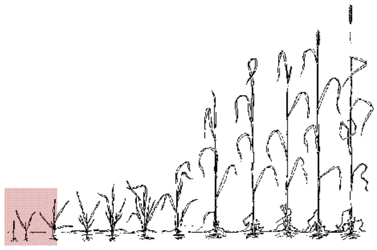
Figure 2.3. Drawings to identify the later Zadoks (Z) growth stages

2.4. Problem identification

The following check lists will help to identify problems at different crop stages.

Check list for problems at planting, taken at the two-leaf stage (Z0.0 to Z1.2)

Is the young crop stand poor?

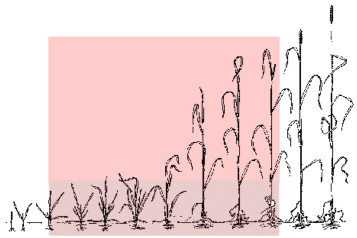


Problem where?	What you see	What may be wrong
In whole crop	emerged leaves look weak - with poor colour	• seed planted was old • seed planted too deep • seedlings are diseased • herbicide damage • high soil temperature • too little water at sowing
In patches	Un-emerged seedlings or bent	• soil crusted
	uneven emergence	• water stress • seed depth not uniform
	emerged leaves look weak	• poor soil preparation • uneven incorporation of residues • waterlogging • insects • diseases
	emerged leaves look normal - but too few plants	• low seeding rate • some seeds were dead • weeds are dominant • birds removed seedlings or seed • insects removed or ate seeds

Poor crop stands. Why?

Wheat has the useful growth habit that it tillers. A few plants can therefore produce many leaves and tillers in a relatively short time to exploit the resources of a land surface. This means that seedlings do not have to be spaced perfectly as tillers will eventually fill most of the gaps in a crop canopy. However, it takes longer to fill gaps by tillering than if all seedlings emerge at the same time and at uniform spacing, and time can be important to yield. Poor crop canopies are the major constraint to yield. Poor canopies result from one or more of the following: poor seedbeds (inadequate land preparation); seedbed too dry; poor seed (viability) and poor planting technique. Planting at the 'wrong time' can make these problems worse.

Check list for three-leaf stage to spike emergence (Z1.3 to Z5.0)



Is crop ground cover poor?
Are there too few shoots?
Are there too few spikes?

Problem where?	What you see	What may be wrong
In whole crop	thin canopy	• seed planted too deep • low seeding rate • too little water • poor nutrition • low radiation and high temperature • frost
In patches	thin canopy	• diseases • insects • weeds are dominant • waterlogging

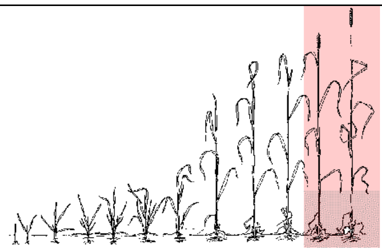
Does the crop not look healthy?

Problem where?	What you see	What may be wrong
In whole crop	lighter coloured band across expanding leaves	• frost
	banding on spikes	• frost
	wilted leaves	• too little water
	leaves look unhealthy	• poor nutrition
	too many older leaves dead	• saline soil or salty water • frost
In patches	leaves look diseased	• diseases
	leaves look diseased	• poor nutrition
	plants or leaves are physically damaged	• insects • hail
	older leaves have yellow tips	• waterlogging
	crop stems bent, plants lying down	• lodging, foot rots

Lodging

Lodging is when the crop falls over. A normal vertical crop is finely balanced, so anything that upsets the balance will cause it to lodge: strong winds, heavy rain, a very wet soil during late grain filling, tall thin or soft stems that bend, or root or stem rots that weaken the plant base. Winds associated with excess water are the worst combination. Lodging destroys the canopy structure. Solar radiation is no longer intercepted efficiently with high light to young upper leaves and low light to old leaves. Heads are covered in the tangle and the collapsed crop becomes more susceptible to pests and diseases.

Lodging during early stem elongation has a relatively small effect on yield as the crop will right itself and reform the canopy. From heading onwards the effects of lodging are large. For every day that the crop is lodged yield declines by more than 1%. So for crops severely lodged shortly after anthesis and remaining so, final yield will be less than half that of the upright crop. Any lodging also makes harvesting more difficult and increases the likelihood of losing grain during harvesting.

Check list for spike emergence to early kernel growth (Z5.0 to Z7.02) ***Do the spikes look abnormal?*** ***Is kernel number low?***	
What you see	What may be wrong
few small spikes, spikelets at tip and base of ear may be empty	• water stress
band on spikes with empty spikelets	• frost
dark spikes with no grain	• low temperatures
florets gaping open with shrivelled anthers	• frost • boron deficit on alkaline soil
low grain number per spikelet	• low radiation and high temperature • nutrient deficit
empty spikelets randomly within spike	• boron deficit on alkaline soil • birds
patches of damaged spikes	• diseases • insects

Check list for anthesis to harvest ripeness (Z6.8 to Z9.2) ***Are kernels small or shrivelled?***	
What you see	**What may be wrong**
small kernels	• water stress • high temperature, winds • lodged crop • frost
too few green leaves	• water stress • late nutrient deficit • diseases • Insects

The crop canopy: green leaves after heading

Growing grains need nitrogen as well as carbohydrates. The plant extracts little nitrogen from the soil after anthesis so the developing grains, which grow entirely after anthesis, have to get virtually all their nitrogen from storage in the plant. An important store is the green leaves.

A main reason that leaves lose their green colour and die is because their nitrogen is removed and redistributed to the grains. The less nitrogen stored, the more quickly the leaves die. How much is stored depends on how much was available in the soil before anthesis, as determined by management.

2.5. Wheat field sheets. A guide to recording observations

Structured records remind the researcher of any special observations made of the experimental crop and any management actions taken. The usual way to make such records is on a date basis in a diary. Making them on both a date and a crop development basis on field sheets, will make them even more useful when the time comes to interpret the trial. Basing observations on development allows the researcher to make comparisons between crops in different locations and their state at equivalent stages of development.

Use the same field sheet (see field sheets below) each time the researcher visits the field. At each visit, note unusual conditions of the crop such as herbicide damage, frosted leaf tips, frost damage on spikes and any leaf curling. An accurate record of crop management as the season progresses (sowing, fertilizers, weed and disease control, irrigations, harvest) will help to identify which factors limit yield most.

The field sheet calculations assume that the crop was drilled in 18 cm rows but they will be equally useful for other row spacings or a broadcast crop.

Where to sample

Observations should be representative of the whole field, taken usually in the same areas each time the experiment is visited. Avoid headlands, crop edges and areas near trees.

Seedling counts

Use a stick one metre long with a mark at 0.5 m to assess plant density: locate the stick between two rows in one of the pre-selected areas and count the seedlings in the crop rows on either side of the stick – take two counts in five pre-selected areas. Record the 10 counts on the field sheets. Seedling counts are done most quickly when there are only one or two leaves per plant (Z1.2 or 1.3). The presence of tillers later on makes counting more difficult. If the crop is broadcast, a square with 0.5 metre sides using the stick or three sided frame (the fourth side can be used to square the frame) can be used to count all seedlings inside the square.

Spike counts

Spike numbers should be assessed when the flag leaf (final leaf) has emerged on the main shoots (Z3.9) even though the spikes aren't out at that stage: take two counts in each of the five selected areas without counting any late regrowth tillers. Shoots that have nodes at this stage (the term 'shoots' always means both tiller shoots and main shoots) will give a good approximation of final spike number. Only water stress at later stages could reduce that number.

Ground cover

Ground cover can be estimated by looking at the crop 2 metres in front through a circle formed with the thumb and index finger and held about 10 cm from the eye. The ground area covered by leaves and shadows should be guessed, repeating for different areas and looking in different directions. The best time of the day to estimate ground cover is midday. These values are important to gauge if and when full ground cover is reached. Ground cover and yield are generally closely related in irrigated cereals.

Figure 2.4. Estimation of ground cover
Crop cover here is about 60% green leaves

The average number of green leaves per spike-bearing shoot after Z3.9 is counted from the flag leaf (top) down. Fractions of green leaves are considered if other parts are yellow.

Leaf diseases

To estimate the percentage of the crop that is infected, collect 50 shoots while walking diagonally across the field. From the collection, count the total number of green leaves, and the number of green leaves with a particular infection. Calculate the percentage of infected green leaves in the 50 shoot sample for each disease present as:

$$\% \text{ infected} = \frac{\text{number of infected leaves}}{\text{total number of green leaves}} * 100$$

Whether or not to spray will depend on the susceptibility of the variety to the disease, and the growth stage of the crop.

Lodging score

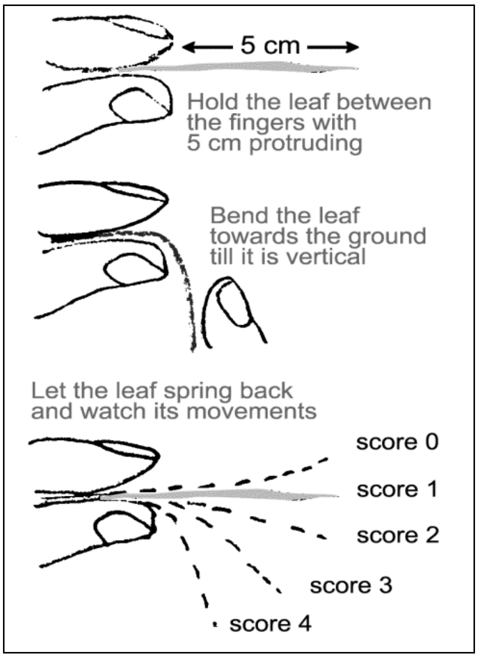
The Lodging Score has two components

1. The percentage of the whole field that is affected by lodging
2. The degree of lodging from slight to moderate to severe within those areas.

Slight lodging is when the plants are just leaning over. With moderate lodging the plant height is reduced to half the plant length. Severe lodging is when the crop is flat on the ground.

Wilting score

Assess the wilting score between 11 am. and 3 pm. in the lowest green leaf on a shoot, after any dead material at the end of the leaf has been removed. Follow the three steps in Figure 2.5. When the leaf springs above the horizontal to score 0 the leaf is fully turgid. The score of 4 in which the leaf has no spring, but remains hanging vertical, is the worst score illustrated. If any leaves have become tightly rolled to half their usual width, this is score 5, indicative of a severely stressed plant. This will probably be the top leaf as others will have died from drought. Check the Wilting Score before each irrigation. A score of 0 means irrigation is unnecessary that day. Score 1 (on the day of irrigation) indicates that watering is just in time. A score of 2 or more indicates that the soil is being allowed to dry too far so that growth and yield are suffering - reduce the time between irrigations.



After R.A. Fischer

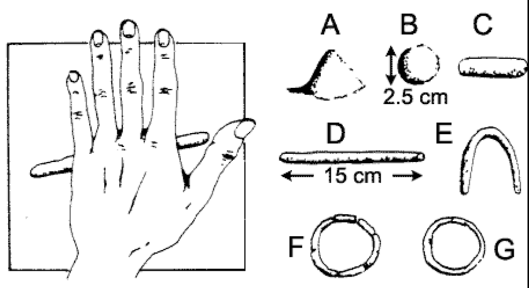
Figure 2.5. The wilting score indicates when to irrigate

Soil types

Carry out the following steps in order to determine Soil Type:

1) drip water on to one tablespoon (30 g) of fine dry soil held in the hand
2) squeeze and roll the soil until it just starts to stick to the hand
3) gain a rough idea of the texture class by the extent to which it can then be shaped as in the drawing in Figure 2.6:

(A) *Sand.*	Soil remains loose and single-grained and can be heaped, but not formed.
(B) *Sand loam.*	Can be shaped into a ball that easily falls apart
(C) *Silt loam*	With more silt it can be rolled into a short thick cylinder
(D) *Loam.*	About equal sand, silt and clay and can be rolled into a thick thread about 15 cm long that breaks when bent.
(E) *Clay loam.*	Soil can be rolled as above but can also be bent carefully to a U shape without breaking.
(F) *Light clay.*	Soil feels smooth and can be bent into a circle with some cracks.
(G) *Clay.*	Handles like plasticine and can be bent into a circle without cracks.



Method and drawings after Ilaco (1985)

Figure 2.6. Evaluation of soil texture by feel

How to estimate how much soil moisture is available to the crop

Once we know the soil texture class, estimate how much soil moisture is potentially available to the crop using Table 2.2.

Table 2.2. Estimation of the amount of water in soil by feel

The amount of water potentially available to wheat roots per metre of soil depth is shown in bold				
	Sand, loam sand	Sand loam, silt loam	Loam, clay loam	Light clay, clay
Above Field Capacity	water appears if soil is bounced in the hand	water released when soil is kneaded	water can be squeezed out of the soil	undisturbed soil has a water sheen
At Field Capacity	no free water appears on the soil when it is squeezed but a wet outline of the soil ball remains on the hand			
Water Available	**60-100 mm**	**100-150 mm**	**150-200 mm**	**200 - 250 mm**
75-100% of Field Capacity	sticks together slightly, may just form a ball	forms a ball but it breaks easily	forms a ball that is very pliable	ribbons flat between the fingers
Water Available	**± 70 mm**	**± 110 mm**	**± 155 mm**	**= 200 mm**
50-75% of Field Capacity (stress likely)	seems dry and will not form a ball when squeezed	forms a ball which does not hold together	forms a ball, somewhat plastic	forms a ball and ribbons between fingers
Water Available	**± 50 mm**	**± 80 mm**	**± 110 mm**	**= 140 mm**

Source: Irrigation Practice and Water Management (FAO, 1984)

Wheat roots may eventually grow to 1.2 m, but if their depth is less than 1 m the amount of moisture available to them is reduced proportionately (so if roots have only grown to 0.5 m depth, the values in bold in Table 2.2. must be halved).

Determining rooting depth

This method follows Lafitte (1994). The root system of a mature wheat plant can reach a depth of 1 to 1.2 m, but if some barrier exists in the soil above 1.2 m, the roots will stop at the barrier and be unable to tap deeper water and nutrients. Potential yields will be reduced.

1) select a day when the soil is near field capacity; digging in dry soil can be difficult

2) dig a hole with a spade in an area where the plants look uniform

3) break the cores at several places to see if roots are still present at different depths

Adaptation of wheat field sheets to local conditions

The field sheets include target values corresponding to good crops. The observations can be used to calculate whether the crop is ahead of or behind the target values. If the calculated numbers disagree substantially with the targets, there is a list of things that may be checked in the crop. Use the drawings of the Zadoks growth stages in Figures 2.2 and 2.3 to help enter the stages of development correctly.

Table 2.3. Wheat field sheet 1: From sowing to end of stem elongation

farmer name: **field:** **variety:** **Field Sheet 1**

date	**GROWTH STAGES**			**MANAGEMENT DECISIONS & ACTIONS**	
	CODE	DESCRIPTION		MANAGEMENT BEFORE THE CROP EMERGES	
When growth stage seen				pre-sowing fertilizer:	pre-emergence herbicides:
				type:.............................	type:................................
				date / rate /....................	date / rate /.......................
				crop on: / beds / flat /	row spacing: ....
	0.0	**Sowing**		seed size: small / medium / large	seed treatment: ...
				sowing depth (cm):/ 0 / 2 / 4 / 6 / 8 /	sowing rate (kg/ha):
	0.3	germination, seed swollen		sowing fertilizer:	seedbed: / very dry/ dry / moist / wet
	0.5	radicle emerged from seed		type:......	tilth: / poor / good / excellent /
	0.7	coleoptile emerged		date / rate (kg/ha)	watered up: / yes / no /
	1.0	**Emergence**			crust after sowing: none / moderate / bad
	your individual seedling counts :				
(A)	av. seedling establishment:			target: 30 - 40 plants/m row length if using 18 cm row spacing	
POOR STAND? CHECK THESE	crust / water stress / low seeding rate / sowing too deep / bad seed / bad seedbed / weeds / waterlogging / bad incorporation of residues / nutrient problem / herbicide toxicity / birds / insects / diseases				
		Leaves on main shoot	Ground cover	MANAGEMENT AFTER THE CROP EMERGES	
	1.1	1st leaf more than half visible		fertilizer/type/: ...	
	1.2	2nd leaf more than half visible		date / rate /	
	1.3	3rd leaf more than half visible			
	1.4	4th leaf more than half visible		fertilizer/type/	
	1.5	5th leaf more than half visible		date / rate /	
	1.6	6th leaf more than half visible			
	1.7	7th leaf more than half visible		fertilizer/type/:.................	
	1.8	8 or more leaves visible and stem not elongating		date / rate /....................	
	aim for 120 shoots/ m row length the target number of tillers/plant is therefore (120 / (A)) -1 = example for 30 plants / m row length the target is 3 or more tillers per main shoot if using 18 cm row spacing				
		Tillering			
	2.1	main shoot and 1 tiller		herbicide/type/:................	weeds:..................................
	2.2	main shoot and 2 tillers		date / rate /....................	results: / poor / good / excellent /
	2.3	main shoot and 3 tillers			
	2.4	main shoot and 4 tillers		herbicide/type/:................	weeds:..................................
	2.5	main shoot and 5 tillers		date / rate /....................	results: / poor / good / excellent /
	2.6	main shoot and 6 tillers			
	2.7	main shoot and 7 tillers			
		Stem elongation			
	3.1	1st node detectable		fungicide/type/:	disease:.......
	3.2	2nd node detectable		date / rate /...	% infected:..................
	3.3	3rd node detectable			
	3.4	4th node detectable		fungicide/type/:.........	disease:.......
	3.5	5th node detectable		date / rate /...	% infected:.................
	ground cover at this stage should be more than 90% (= effectively complete) the N° of shoots with nodes is a first approximation of final spike number. Target is at least 85 of these shoots /m row				
IF POOR GROUND COVER, OR IF LOW SHOOT NUMBER CHECK THESE			sowing too deep / frost / water stress / nutrient problem / diseases / insects / waterlogging / weeds		
CROP UNHEALTHY? CHECK THESE			nutrients/ diseases / water stress / insects / frost / lodging / waterlogging / salinity		

Table 2.3 (continued) Wheat field sheet 2: From flag leaf visible to harvest

farmer : **field:** **variety:** **Field Sheet 2**

date		**GROWTH STAGES**		**MANAGEMENT DECISIONS / ACTIONS**
	CODE	DESCRIPTION	Ground cover	Irrigations
		Booting stages		1. dates ...... to......
	3.7	flag leaf visible		volume.....................
	3.9	flag leaf collar just visible		wilting score.........
	4.1	early boot, flag leaf sheath extending		
	4.3	mid boot, boot opposite collar of 2nd last leaf		2. dates ...... to...........
	4.5	late boot, boot above collar of 2nd last leaf		volume.....................
	4.7	flag leaf sheath opening		wilting score... 0.........
	4.9	first awns visible		
		Heading stages		3. dates......... to......
	5.0	1st spikelet of spike just visible		volume.....................
	5.2	20% of spike visible, early heading		wilting score... ......
	5.5	50% of spike visible, mid heading		
	5.8	80% of spike visible, late heading		
	6.0	full heading, but not flowering		
		your individual spike counts:		
(B)		your average spike number:.........	target: 80 - 100 spikes /m row length (18 cm row width)	
	IF LOW SPIKE NUMBER CHECK THESE		frost / insects / water stress / nutrient problem / diseases	
		Flowering	Green leaf N°	Lodging
	6.2	20% of spikes are flowering, early flowering		1. date..............
	6.5	50% of spikes are flowering, mid flowering		% field affected ...
	6.8	80% of spikes are flowering, late flowering		slight/ moderate/ severe
		Kernel extending		
	7.02	kernels near middle of spike extended 20%		2. date.............
	7.05	kernels extended 50%		% field affected..
	7.1	kernels watery ripe, clear liquid		slight/ moderate/ severe
		Milk development		
	7.3	early milk, liquid off white		3. date..............
	7.5	mid milk, contents mostly milky liquid		% field affected...
	7.7	late milk, increase in solids		slight/ moderate/ severe
	7.9	very late milk, half liquid, half solids		
	your individual kernel counts:			depending on variety
(C)		your average kernel N° per spike...............	**(B)** x **(C) =**	target 2300 - 3000
	IF SPIKE DAMAGED OR LOW KERNEL NUMBER CHECK :			frost / insects / water stress / nutrients / diseases / birds
		Dough development		Spike distribution in field
	8.1	v early dough, mostly solids if kernels crushed		uniform density & height?
	8.3	early dough, kernels soft and almost dry		irregular, no rows missing?
	8.5	soft dough, finger nail impression not held		irregular, missing rows?
	8.7	hard dough, finger nail impression held		
		Ripening		**Harvest date:** ....
	9.0	kernels hard, difficult to divide by thumb nail		
	9.2	harvest ripe, can not be dented by thumb nail		
	9.3	kernels loosening in day time		
(D)		final average kernel weight (mg) ...44 mg.............		
	IF SMALL SHRIVELLED KERNELS CHECK THESE			water / nutrients / disease / frost / insects / high temperature / wind
Estimated Grain yield (10% moisture) =		**(B) x (C) x (D) / (row spacing in cm) x 1100 =**		.... **t/ha**
		Harvested grain yield =		.... **t/ha**

Field sheets adapted from Maarten Stapper and David Murray (SIRAGCROP)

2.6. Irrigation timing and moisture stress

Irrigation frequency and amount of water needed will differ depending on many factors, but there are four stages additional to sowing when water should not be allowed to be limiting. These are:

- crown root initiation when tillering is starting (Z2.1 to Z2.2)
- the jointing stage (Z3.0)
- anthesis (Z5.0), and
- the grain milk stage (Z7.0)

Of the four stages, **tillering** and **anthesis** are most sensitive to water stress.

Is moisture stress a problem?

A stressed crop rapidly loses potential yield. When a young crop has too little water its first response is to conserve what water there is by closing its stomata. These are small pores on the leaves that let carbon dioxide into the plant for photosynthesis, but at the same time when open they let water escape from the plant. Without carbon dioxide photosynthesis stops, so the sugar the plant normally makes from the carbon is no longer available for growth. So growth stops. The first growth response to water shortage is that leaves stop expanding. The tiller buds that are ready to grow into tillers remain as dormant buds. Usually the main shoot struggles on with its development. If moisture remains limiting, the crop eventually runs out of time to produce leaves, tillers and spikes and this results in a thin canopy with a few small spikes, few grains and low yield.

If moisture stress occurs after anthesis the grains are affected, as they are now the growing part of the crop. Again the stomata close, the leaves roll and die from oldest to youngest, and the plant rushes to move as much material from storage into the grains to fill them as full as possible before everything dies. The consequence of post-anthesis stress at the milk stage is that grains are pinched, shrivelled and small.

Estimation of how much soil moisture is available to the crop

It is possible to work out how many days it will take before the crop is short of water if it is not irrigated or if it does not rain. If around 50% of the water that the soil can hold has already been used, the crop is probably already stressed and potential yield is declining. To make the calculation it is necessary to have the soil moisture content for the soil textural class and the weather data. The following three step method is adapted from Lafitte 1994.

Step 1. How much water does the non-stressed crop use each day?

water use per day by the crop (mm)	=	evaporative demand (from Table 2.3)	x	crop coefficient (from Table 2.4)

The number calculated in Step 1 approximates the amount of water needed to apply as irrigation to replace each day's loss.

Take evaporative demand in mm/day (evapo-transpiration) from Table 2.3 or calculate it from weather data.

Table 2.4. Average monthly ETo in Lhasa (mm/day)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1.7	2.2	2.9	3.7	4.3	4.4	3.9	3.7	3.2	2.8	2.1	1.7

from FAO CLIMWAT

Table 2.5. Evapo-transpiration Crop Coefficients for crops reaching 80-90% full ground cover by heading[1]

Growth stage	**Zadoks code**	**Crop coefficient**	**Crop ground cover**
early vegetative growth	Z1.0 - Z1.3	0.3	10-30%
tillering	Z1.3 - Z3.0	0.8	30-80%
stem elongation to flowering	Z3.0 - Z6.8	1.0	70-100%
grain filling	Z6.8 - Z8.7	0.5	50-20%

Notes: 1. Reduce coefficients for crops with less ground cover
2. Coefficients from Wright (1981)

Step 2. How much water in the soil is available for crop use before stress begins? - Calculate for the current rooting depth of the crop

water available = mm soil moisture present now **minus** mm soil moisture present when 50% soil moisture is available (ie 50% of field capacity)

Step 3. How many days can the crop go without irrigation or significant rainfall before stress begins? This is:

$$\text{number of days before stress} = \frac{\text{mm water in the soil to be used (from Step 2)}}{\text{mm water the crop uses per day (from Step 1)}}$$

Example for a well grown cereal crop in Lhasa valley, heading in June, and growing on a soil that forms a ball when it is squeezed, but the ball breaks easily (sandy loam)

Step 1

- from Table 2.3. the evapo-transpiration for that environment and month is 4.4 mm water per day
- from Table 2.4., as the crop is at heading (Z5.5), it has a crop coefficient of 1.0

water use per day by the crop (mm)	=	4.4 mm evaporative demand	x	1.0 crop coefficient

- **therefore the crop is losing 4.4 mm water / day.**

Step 2

- from Figure 2.6 the soil is a sandy loam
- from Table 2.2. a sandy loam soil that forms a ball that breaks easily is at 75-100% of Field Capacity and contains 110 mm water now
- from Table 2.2. a sandy loam soil at 50% of Field Capacity contains 80 mm water
- we assume the crop roots reach down to 1m, so that all the water stated in Table 2.2 can be used by the crop

water available	=	110 mm soil moisture present now **minus** 80 mm at 50% of field capacity

- **therefore 30 mm of water is available before the crop suffers moisture stress**

Step 3

number of days before stress	=	30 mm of water to be used	(from Step 2)
		4.4 mm water the crop uses per day	(from Step 1)

- **therefore there is no need to irrigate this crop for 7 days if no rain falls**

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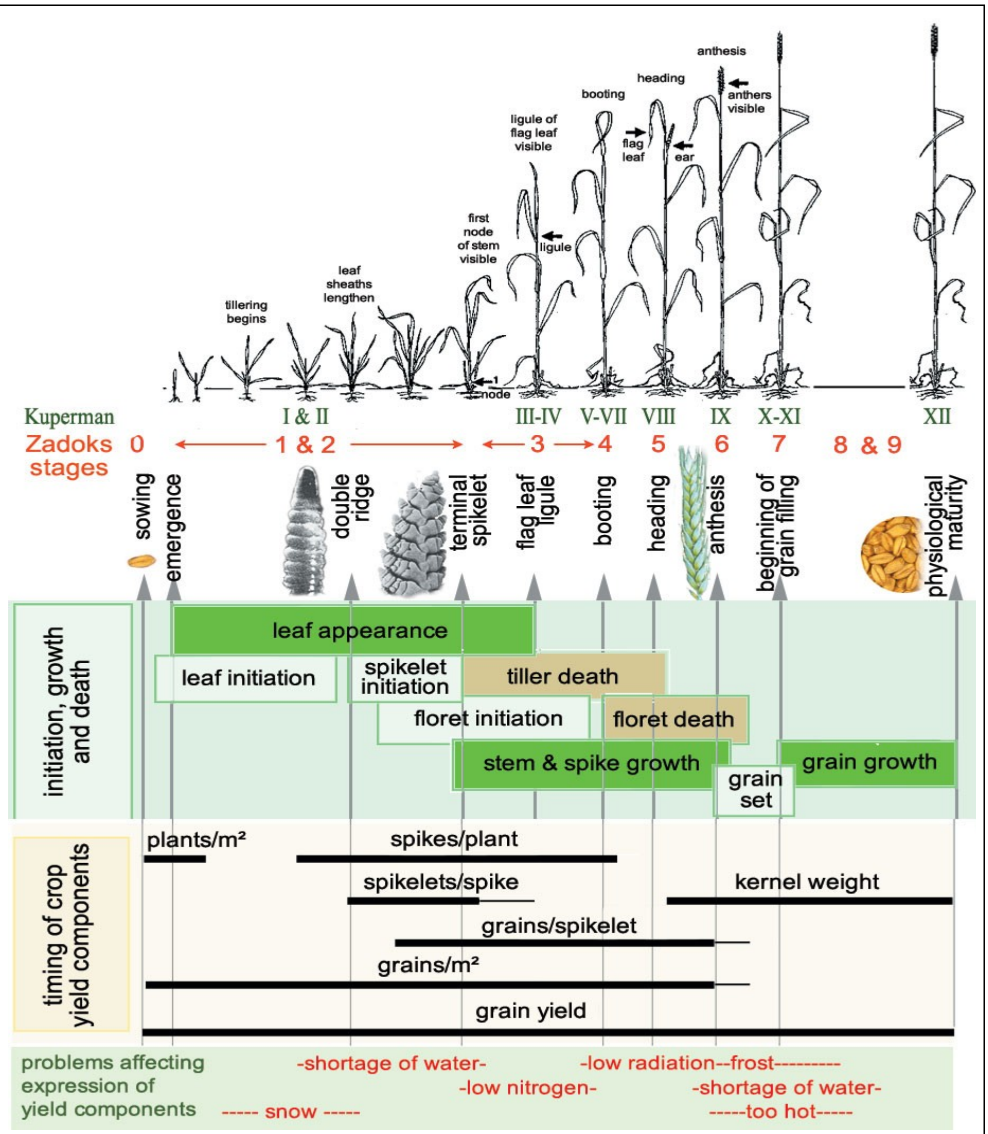
H GomezMacpherson

Plate 2.1. Winter kill in cereal crops

The top section shows pictures of the crop and names of some stages. The next section shows pictures of two internal flowering stages, double ridges and terminal spikelet and when they occur. Below again are the components of growth, overlapping in their timing and competing for resources. Next are the yield components and when they form in relation to everything else. Finally at the bottom on a green background are stages when the crop is particularly sensitive to certain stresses or lack of resources.

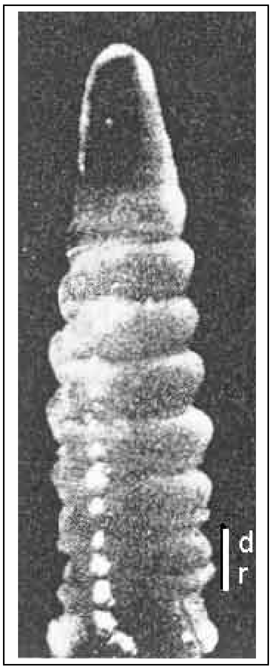


HM Rawson

Plate 2.2. How the crop develops, continually sensing and responding to its environment

H.M. Rawson

Plate 2.3. Illustration of Booting, Heading and Anthesis in cereals



HM Rawson

Plate 2.4. Double ridge stage of growing point of the cereal plant

Chapter 3 LAND PREPARATION AND CROP ESTABLISHMENT

Peter Hobbs

Chapter 3 LAND PREPARATION AND CROP ESTABLISHMENT

3.1. Introduction

Land preparation (also called tillage or cultivation) and crop establishment go together, since land preparation influences the ability of the crop to emerge and produce a good, uniform crop stand. This is a major pre-requisite for a good yield. Land preparation has been carried out since agriculture first started and farmers moved from being hunters and gatherers to living as more sedentary villagers. Land preparation has changed from a manual to a power-assisted activity over the centuries, depending on the availability of different energy sources. Today tractors provide a major power source for tillage that allows many different variations. Manual and animal assisted tillage is still practiced though, and is evident in Tibet where tractors are only a recent introduction.

Tillage benefits

Although there is an array of tillage implements and power sources, the main reasons for tillage remain the same:

1) To help control weeds through uprooting or burying them
2) To soften the surface soil and prepare a good seedbed to allow easier seeding of crops
3) To expose the soil organic matter to oxygen and help release soil nutrients for crop growth
4) To reduce compaction of the soil and reduce its bulk density to allow for rooting and to improve soil structure
5) To help improve the infiltration of water
6) To incorporate any soil amendments including organic materials, lime or basal fertilizers
7) To help control various pests and diseases associated with soils
8) To assist operations that are needed to shape or level the land in order to allow more uniform water application

Obviously, farmers find these benefits very important for their farming and have adapted various techniques to suit the soil types available on their farms. No one recommendation can be given for all farms or cropping systems in a country.

Tillage drawbacks

Land preparation, however, also comes with some disadvantages that need to be considered:

1) Tillage costs money. It can account for more than one-third of the costs of growing a crop
2) Tillage takes time, especially if manual and animal drawn systems are used or farmers make multiple passes to obtain a good seedbed. This is time that delays planting and is time that is not available for farmers to do other activities or find employment for other sources of income
3) Tillage exposes the soil organic matter to air and results in loss of soil organic matter. This can be considerable over time and make soils less productive. Soil with reduced organic matter can also become hard and when tilled become cloddy (Plate 3.1)
4) A fine soil tilth is degraded by the impact of the energy of rain drops. The result is a breakdown of the surface structure, clogging of soil pores, surface capping and a rapid reduction in infiltration of water. Since the water cannot go vertically, it moves horizontally and causes erosion (Plate 3.2)
5) A fine tilth is also susceptible to wind erosion that leads to loss of the valuable topsoil (Plate 3.3)
6) If tractors are used for tillage, large quantities of fossil fuel (usually diesel) are consumed and contribute to cost but also contribute substantial greenhouse gas emissions to the atmosphere (mostly carbon dioxide)

7) If animals are used for tillage, farmers must feed the animals to keep them alive for the tillage, adding significantly to the cost of production, and taking up land to grow fodder and feeds
8) Tillage disrupts the root and microbial channels and porosity of the soil that are essential for root growth and good crops.
9) Tillage often disrupts the level of the field, especially the moldboard plow used in Tibet. The farmer must then invest more time and money in leveling the field, otherwise water and fertilizer management will be inefficient either through waterlogging or drought in the same field.

3.2. Minimum Tillage methods

Reduced and zero-tillage

As farmers seek to grow more crops with less cost and investment of time, the notion of zero- or reduced tillage has developed.

- In *reduced tillage*, minimal soil disturbance is done to get a good plant stand (Plate 3.4)
- *Conservation tillage* is a form of reduced tillage where one-pass of the plow is done and a layer of residue is left on the soil surface. This helps increase water infiltration, reduce erosion and reduce costs
- In *zero-tillage*, another variation of reduced tillage, the equipment used makes a narrow slot in the field where the seed is dropped and the rest of the field is un-tilled (Plate 3.5)
- Although confusing, the term "*Conservation Agriculture*" (CA) is used to define zero-tillage combined with permanent surface mulch (Plate 3.6)

It is important to understand the importance of the surface mulch since it determines the success or failure of zero-tillage; without the surface mulch the soil gets compacted and yields are low, whereas with the mulch, the surface soil physical and biological properties are improved leading to a healthy soil and a good crop. Choosing which reduced tillage system to use will depend on the local situation, soil texture, and the availability of suitable equipment. The key to conservation agriculture adoption is the availability of equipment to farmers that can seed into soils that have not been tilled and have loose residue mulch.

Advantages of conservation agriculture

If conservation agriculture – minimal soil disturbance plus mulch – can be adopted there are many benefits:

1) Savings in time - farmers can use this time to do other income generating activities but also it can result in timelier planting and better yields
2) Less cost - savings in fuel costs, also fuel for pumping water, and less wear and tear on tractors and equipment
3) Savings in water and therefore increased water use efficiency - better water infiltration and better moisture in the soil profile
4) Less soil erosion since water infiltration is better
5) Although weeds are a major issue initially, minimal soil disturbance actually brings less seed to the surface for germination (see Chapter 5 on Integrated Weed Management). With the mulch and time, weed problems are reduced. Mulch from cereal residue has allelopathic properties that reduce weed germination
6) Soil organic matter increases, especially at the soil surface where it is most important
7) Soil physical properties including surface soil aggregates improve. Soil porosity improves because of the action of the previous crop roots that leave a network of continuous pores that allow for easier root penetration of the next crop (Plate 3.7)

8) Soil biological diversity increases leading to more biological tillage and better recycling of nutrients (Plate 3.8)

9) If zero-till seed and fertilizer combination drills are used there is more uniform seed distribution and more precise fertilizer placement compared to broadcast systems

10) It has been shown that once this system has stabilized, pest and disease problems are less. For pests, the residue on the surface promotes and provides a habitat for beneficial insects. For diseases, soil microbial diversity is increased leading to better disease control and reduction in proliferation of just a few pathogenic diseases.

3.3. Crop Residues

Many farmers in Asia remove crop residues for livestock fodder and for cooking fuel. Others incorporate the residues during initial tillage operations or later, after they have been passed through animals to become farmyard manure. Burning is becoming more popular as it shortens turn-around time between crops. However, burning leads to reduced soil organic matter and degradation of soil physical properties, in turn increasing the likelihood of waterlogging, crusting and disease. All these practices reduce soil organic matter with resulting poor soil structure. Poor soil structure often results in cloddy fields after ploughing and surface capping after rain or irrigation. Residues can help alleviate this problem when kept as mulch. That will then require the use of zero-tillage and planting into the loose residues to keep the mulch on the surface. Residues up to 9 t/ha will completely cover the soil with a mulch layer several centimetres in thickness; 4 t/ha of residues will just cover the soil surface when spread uniformly. Zero and minimum till equipment is available to sow through deeper layers of residues and still achieve uniform seedling emergence (Plate 3.9).

Positive attributes of crop residues

The positive attributes of crop residues should not be overlooked:

1) Used as mulch they conserve water, and keep the soil cool and free from crusting

2) They increase soil microbial activity (they provide food for the microbes and arthropods) and maintain or increase populations of earthworms, which in turn increase soil aeration

3) Retained stubble reduces wind and water erosion

4) Stubbles can be grazed by animals, though not when the soil is wet as this can lead to the formation of a soil pan

5) Some crop residues like cereal straw also have allelopathic properties that help control weeds.

Negative attributes of crop residues

1) If managed incorrectly in wet soils they increase the incidence of disease, which may reduce yield

2) Root rots such as *Rhizoctonia* and *Pythium* species can be a problem in wet soils

3) If trash from the previous crop was full of weeds the incidence of weeds in the current crop will also be significant

4) The residues can also tie up nitrogen through the soil microbes with signs of nitrogen deficiency occurring in the growing crop. In some cases more nitrogen may be needed, but over time more nitrogen is recycled and made available to the plant.

However, some evidence suggests that by increasing the diversity of the soil microbes through mulch, the incidence of disease can be controlled.

3.4. Crop establishment

Before the discussion of tillage in double cropping systems in Tibet, a few paragraphs on crop establishment are in order.

There are several major principles for obtaining good plant stands:

1) Use good quality seed, free of weed seed, not mixed with other crops or varieties, and with good germination. Germination can be easily checked by selecting 100 seeds and rolling them up in wet newspaper for enough time to initiate germination. Count how many seed are viable. Adjust seed rates to reflect this figure. Farmers should buy good seed from a reliable source or carefully grow a patch of crop for seed purposes the previous year, rogue it of off types and thresh, clean and dry the seed for safe storage.
2) Adjust seed rates to the field conditions and method of seeding. Less seed is needed if seeds are drilled uniformly at constant depth, than if the seeds are broadcast. Too much seed and dense stands can lead to lodging and lowered yields.
3) Each crop has optimal spacing which also depends on field conditions and method of seeding. If the crop is spaced too wide it cannot compensate and yields are reduced. If the spacing is too close, disease and insect problems will be more and lodging will be more likely because of weaker stems. Use of seed drills helps to maintain proper spacing. Barley and wheat are usually planted at 15 to 25 cm spacing.
4) The seed must have good soil-seed contact so it can take up sufficient moisture to start the germination process. In zero-tillage, the use of the correct machinery helps achieve this – with proper placement and the use of press wheels. For zero-tillage, higher soil moisture results in lower soil strength and so seeding is best done when soils are wetter than would otherwise be done with tilled soils. In reduced tillage where a rotovator is used the soil is fluffed up and loses soil moisture. Seed must be placed deep enough and the soil compacted by the roller to get good germination.
5) Weeds should be adequately controlled so they don't compete with the crop while it is struggling to emerge and cover the ground.
6) There should be sufficient soil moisture for germination. Irrigation can often be used to remedy low soil moisture, if available.
7) Seed treatment with chemicals may be needed with some crops if seed borne diseases or pests are present, but this is best avoided through production or purchase of good seed.

3.5. Tillage and crop establishment issues for double cropping cereals and fodder crops

The FAO project is promoting two double cropping systems:

1) Relay of fodder crops into standing cereal crops before the cereal is harvested, and
2) Establishment of the fodder crop immediately after the cereal harvest using reduced or zero-tillage systems for crop establishment

The tillage needs for these systems will be discussed next, but a third option is to increase the yield of the cereal crop (through good crop establishment and integrated management) so less land is needed for cereals, leaving the leftover land for fodder or other crops. This latter option can be obtained through improved crop management that can include the use of zero and reduced tillage, better plant stands and attention to fertility, water, weed and crop protection issues.

Farmers can be relied upon to know the limitations imposed by the crops with which they work. In particular local naked barley varieties both winter barley (WB) and spring barley (SB) have soft straw. These varieties are very susceptible to lodging after heading, during the storms experienced at the start of the rains in July. Farmers know that if they sow vetch into the WB, they are likely to damage the crop by walking through it. At the same time, should the vetch grow strongly, farmers know it will climb on the barley and pull it down. Barley is the farmers' staple food crop, and can also be openly traded on the local market with a higher value than wheat. It is for these reasons that farmers have not adopted relay sowing of vetch into WB. However, given the early maturity of WB compared to current varieties of winter wheat (WW), it is reasonable to double crop vetch immediately following harvest of WB using standard methods of cultivation or methods of reduced tillage introduced by the project.

The reverse of the above arguments refer to relay sowing of vetch into WW. The straw is strong, so the crop is relatively resistant to lodging, even if farmers walk through the crop after heading. At the same time, WW straw can support vetch even if the legume grows strongly. Finally, most wheat is sold to a state organisation at a low fixed price, so the crop has a relatively low social and economic value to farmers. The harvest date for current varieties of winter wheat is early August, and this is too late for high yields of vetch from cultivation as a second crop, even with reduced tillage methods. However, good yields are possible by relay sowing vetch by mid July, after the rains have come.

Relay cropping vetch

The relay crop system is a true zero-tillage system since there is no tillage or equipment involved. The following are some recommendations:

1) Obtain a good source of seed for the fodder crop (the project is promoting vetch using the local Gansu 333 variety)
2) Soak the seed for 24 hours in cold water, or 1 minute in freshly boiled water, before broadcasting into the standing winter cereal crop. Once the rains have come it is not necessary to soak the seed
3) A seed rate for vetch of 6 kg / mu (90 kg / ha) of dry seed is commonly used for relay sowing. The weight is higher after the seed is soaked and then part dried
4) Broadcast the seed on to soil that has good surface moisture or when rain is expected
5) Sow the seed between 25 June and 20 July, at least 10-15 days before the cereal is harvested
6) Cut the cereal crop so 20 cm of stubble is left in the field to support of the vetch crop and to provide valuable organic matter for the system
7) Control weeds if necessary - this has to be done during growth of the cereal crop. Apply 2, 4-D while annual weeds are small in spring. If perennial grass and broadleaved weeds are a problem, spray with "Roundup" while they are still active in autumn, before sowing the cereal crop
8) Protect the fodder crop from animal grazing after cereal harvest
9) Allow the vetch crop to grow as long as possible before harvesting for green feed or conservation in September / October
10) Use zero-till or reduced till methods to establish the next winter cereal crop into the vetch residue after harvesting this fodder crop. Apply "Roundup" if needed to control perennial weeds
11) Apply fertilizer to replace nutrients removed in the combined cereal and vetch crops (nitrogen, phosphorus, and if possible potassium) if the soil is to maintain its fertility and not be mined
12) If wider spacing is used in the cereal crop, there is more space for relay planting the fodder crop. Experiments show that 30 cm spacing or a double row spacing (2 rows 15cm apart with the double rows 40-50 cm apart) show no yield loss of cereal but help establish a better fodder crop

Reduced tillage for Double Cropping

This is possible by manipulating the variety, harvest dates, and reducing the turnaround between crops. The following is being promoted by the FAO project:

1) Remember the principles of good seed, seed rates and spacing. Use Gansu 333 variety for vetch and the recommended variety for turnip
2) Use the reduced tillage rota-seeder or zero-tillage equipment for seeding the vetch or turnip or other crop immediately after Dongqing #1 WB is harvested (WW and late maturing WB or SB will result in lower yields of vetch with this system)
3) Reduced tillage with the Rota-seeder - since vetch does not need to be planted too deep and rain is expected, shallow tillage and seeding works in this system. Adjust the planter to seed just below the surface. Good weed control over the whole cropping cycle is essential, as the rota-seeder stimulates annual weed seeds to germinate. It is possible to create a false seed-bed with a first pass of just the rotavator; followed by a second pass ten days later when weed seeds have germinated using the full rota-seeder. This will kill weed seedlings, and establish vetch or turnip into a clean seed-bed.
4) The reduced tillage rota-seeder can be adjusted to act as a strip-till seeder. In this system only the blades that till the soil where the seed is dropped are used. The rest are removed. This is more of a zero-tillage system, uses less power and fuel, and may work in some situations where weeds are not a major problem
5) Use the zero-till drill to plant the vetch in rows into the standing cereal stubble. Adjust seed depth based on soil type, moisture and experience.
6) In all three systems, vetch seed rate can be reduced to 45 kg/ha (3 kg/mu) since the seed is drilled in close contact with the soil; mix turnip seed with sand to allow for the low seed rates used with this crop
7) Seed depth does not need to be too deep but just below the soil surface.
8) Control perennial weeds by application of "Roundup" herbicide immediately after seeding. This will be a major plus for this system. Use of Roundup or other herbicide may be needed in the first few years if weeds are a major problem after harvesting the WB.
9) Apply some di-ammonium phosphate fertilizer with the vetch seed to boost growth. The zero-till seeder is a combination drill - apply DAP below the seed.
10) Winter cereals are strongly vernalized by the severe cold weather in central Tibet – local experience shows that time of seeding in autumn is not critical, as harvest dates depend on crop and variety regardless of when they are sown
11) Just like the relay crop above, make the final harvest of the fodder and then sow the winter cereal crop directly into the fodder residue using reduced or zero-till systems.

By following the above recommendations, the farmer is assured of the maximum benefit from this double cropping system. The choice of the system and equipment to use will depend on experience, availability of equipment, the local soil texture and soil moisture conditions and the presence of weeds. Zero-till systems where residues are left in the field will result in healthier more productive soils over time than those with tillage and no surface residues.

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Plate 3.1. A cloddy soil formed after tillage in a soil low in organic matter

Peter Hobbs

Plate 3.2. Soil erosion caused by water

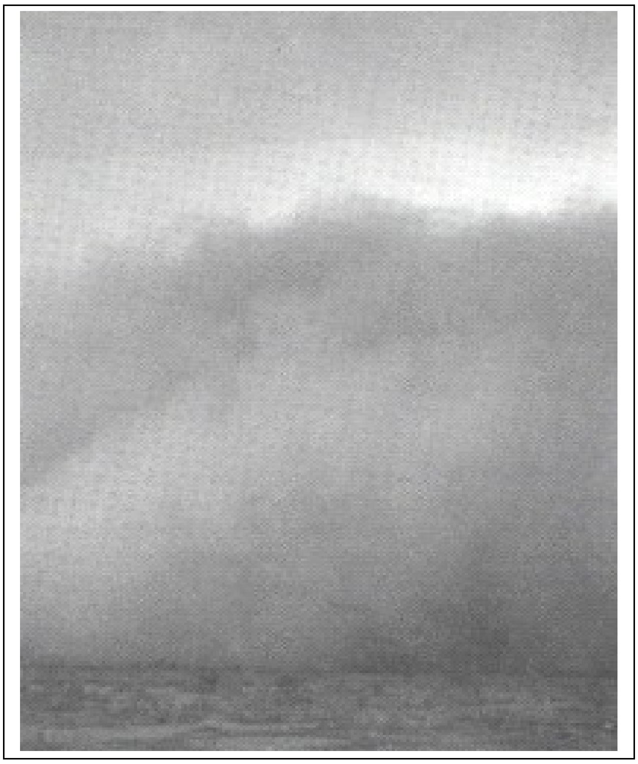

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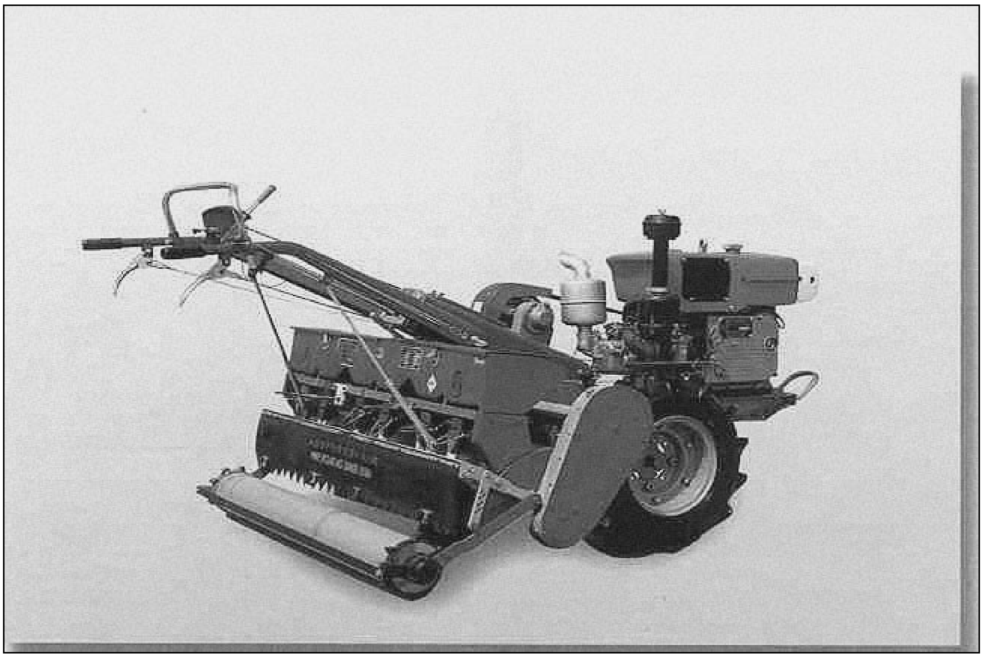
Plate 3.3. Wind erosion



National Agricultural Engineering Federation (NAEF) and Scott Justice, Kathmandu Nepal

Plate 3.4. Rotavator cum seeder (Rota-seeder) attached to a 2-wheel tractor for reduced tillage and seeding in one operation

Ian Lane

3.5.1. Note opening tines with tube for placing fertilizer, following tine with seed tube, and final spring-loaded press wheel (plastic seed cups and tubes are still to be fitted)

Nick Paltridge

3.5.2. Jin Tao operating Zero-till drill with 25 HP 4-wheel tractor to seed vetch into Winter Wheat stubble at TARI, Lhasa, 28 August 2005

Plate 3.5. Zero-till drill with combination seed and fertilizer box

Peter Hobbs

Plate 3.6. Conservation agriculture – zero-till plus soil cover

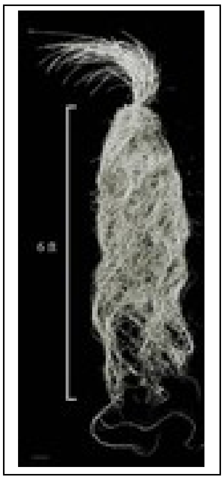


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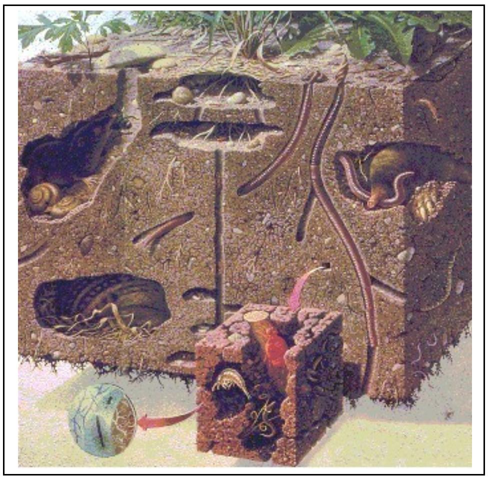
Plate 3.7. Root Systems



Peter Hobbs

Plate 3.8. Biological tillage

H GomezMacpherson

Plate 3.9. A wheat crop drilled directly into the residues of the preceding crop

Chapter 4 MINERAL NUTRITION REQUIREMENTS AND CONSTRAINTS FOR WHEAT AND BARLEY IN TIBET

Helena Gymez MacPherson and Peter Hobbs

Chapter 4 MINERAL NUTRITION REQUIREMENTS AND CONSTRAINTS FOR WHEAT AND BARLEY IN TIBET[1]

4.1. Mineral nutrition

All crops need nutrients to produce healthy roots, leaves and grains. To grow, plants get food by taking up water and mineral substances from the soil, carbon dioxide from the air, and energy from the sun. Like humans, plants need a balanced diet containing a mixture of different nutrients. Good soil fertility management means that farmers know the nutrient needs of each crop: the kinds and amounts required, and when they should be applied to coincide with the growth phases of each crop.

If the soil cannot meet the basic needs of plants, then the soil is unproductive, or infertile, and the plant will not grow well. The ability of the soil to supply enough nutrients for plant growth is called soil fertility. How plants take up nutrients and use them in their metabolism is called plant nutrition. The fertility of a soil depends on the quantities of nutrients the soil contains. If all the nutrients that plants need are present in the soil in sufficient, well-balanced quantities, then the crops will grow well. If a farmer applies enough fertilisers (mineral or organic), and the soil can store the nutrients it contains, then the soil is fertile; it acts like a nutrient bank. When the farmer adds fertiliser to the soil, it is like depositing money in the bank. When crops are grown and produce removed from the field, nutrients are 'withdrawn' from this 'soil bank'. However, more fertiliser than necessary should not be applied, since this wastes money and is inefficient; it may reduce yields instead of increasing them, it increases costs, and any excess nutrients may leach down to the groundwater and pollute it.

For best growth, wheat and barley and fodder crops all need many nutrients, in particular, the macro-nutrients oxygen (O; about 48% of dry matter), carbon (C; 42%), hydrogen (H; 6%), nitrogen (N 2%), potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg) and sulphur (S). The amounts of each nutrient steadily accumulate in the crop as it grows but their concentrations decline as the crop matures. Old tissues have lower concentrations of nutrients than young ones. Crops also need very small amounts of the micro-elements iron (Fe), manganese (Mn), boron (Bo), zinc (Zn), copper (Cu), sodium (Na), molybdenum (Mo), chlorine (Cl), cobalt (Co), and silicon (Si). Apart from the first 3 elements (O, C and H), which come from the air and water, the remaining 16 come from the soil solution and can be managed to some degree by soil and/or crop treatments.

Recommendations for applications of N, P and K, the three major soil elements, differ widely with soil type and fertility, and the expected efficiency of fertilizer use by the crop. A very short duration crop will not have sufficient time to use as much fertilizer as a long duration crop. Fertilizer recommendations must be based on local practices, target yields and crop rotations. Bigger crops need more fertilizer but an excess of nitrogen may result in ground water pollution and lodging of the crop. If nitrogen is limiting, yield and probably grain protein will be reduced. Applying nitrogen after spikes emerge generally increases grain protein.

To obtain maximum benefit from the fertiliser applied, crop stand and crop protection (from weeds, pests and diseases) must also be optimum. Using extra fertiliser will not compensate for poor crop husbandry. Indeed, the optimum amount of fertiliser to apply will be less if crop growth is reduced by factors other than the supply of mineral nutrients.

As a rough guide, a 7 t/ha wheat crop removes from the field as grain 150-190 kg nitrogen (N), 25-35 kg phosphorus (P) and 45-60 kg potassium (K). Total removal of straw for feeding or for fuel takes away at least half of these amounts again. These nutrients must be returned to the soil after every crop to avoid mining soil nutrient reserves. Lower crop yields remove proportionately less nutrients. For example a 4 t/ha yield of grain removes about 150 * 4 / 7 kg N, that is 85 kg N.

[1] This text is based in two FAO books: Rawson and Gymez Macpherson (2000); Hughes and Venema (2005).

The specific fertiliser type that a farmer will need depends on the soil nutrient level. It is not possible or wise to make blanket recommendations because different plants use different nutrients at different rates, most farmers do not know the amount of nutrient reserves in their soil, and because levels change with time and by soil type and location.

To calculate the amount of fertiliser to apply, how much of the nutrient element the crop needs should be known, as well as the nutrient content of the fertiliser:

KFN (kg of fertiliser needed) = KNN (kg of nutrient needed) / PNIF (% of nutrient in fertiliser).

For example, if 50 kg of nitrogen is needed per hectare, and ammonium nitrate is being used which contains 34% nitrogen, then 147 kg of ammonium nitrate must be applied per hectare (50 x 100 / 34 = 147 kg).

Calculating the amount of fertiliser needed for a given area is difficult at first, but after some practice, it becomes easy. For example, suppose a 7-t/ha-wheat crop needs 170 kg N/ha, and the unfertilised soil can provide 30 kg N/ha; the crop will need a further 170-30=140 kg/ha. If no fertiliser N is lost, 140 kg N/ha needs to be applied. However, if part is lost by leaching or other means, the amount applied needs to be increased by the amount lost.

When plants do not receive enough of a nutrient to satisfy their requirements, or receive too much, they grow poorly and, if the imbalance is large enough, they show symptoms of the problem. Symptoms for most deficiencies or toxicities are generally most obvious on the leaves.

If a soil nutrient is being progressively depleted by the growing crop, and the nutrient cannot be moved from older to newer leaves, the symptoms will be more apparent on **young leaves**. If the nutrient is mobile in the plant, the plant will extract it from the old leaves for use in the young leaves. Then the **old leaves** will show the symptom. Some nutrients like boron show no significant symptoms on the leaves; it is only at anthesis when the sterile florets of the heads gape that the deficiency become apparent.

Depending on the cause and nutrient, symptoms will appear on older or younger leaves. The appropriate flow chart will help to make a first-order identification of the problem. Checklists in Plate 4.2 are based on those in Grundon (1987).

Major nutritional symptoms will occur in large areas of the field. If the cause is disease, the symptoms are likely to be on isolated plants or in patches in the crop. Unfortunately, micro-nutrient deficiencies also occur in patches.

Acidity or alkalinity is measured in pH units with a scale of 1 to 14. A pH of 7 is neutral. Values from 7 to 4 are increasingly more acid and from 7 to 10 increasingly alkaline; cereals grow best between pH 5.5 and 7.5, shown as a yellow zone in Plate 4.1.

At extreme pH certain nutrients become too available and toxic to the crop while others become less available and show up as crop deficiencies (symptoms are given in Plate 4.2, and illustrated in Plate 4.3). In Plate 4.1 deficiencies are where the red bars are narrow. In acid soils aluminium and manganese can become very soluble and toxic, but in addition they reduce the plant's ability to take up calcium, phosphorus, magnesium and molybdenum. Phosphorus in particular is unavailable to the plant in acid soils. If boron, copper and zinc are present in the soil, they too can become toxic at low pH. In medium alkaline soils boron, copper and zinc become deficient and phosphorus again becomes unavailable. Soil pH has relatively little effect on nitrogen.

Timing of fertiliser applications

Basal application: fertiliser is applied before planting, or shortly after planting but before crop emergence. Compound fertilisers (that contain more than one element) are generally used for basal applications. Basal application gives plants the initial boost needed to achieve the crop's yield potential. Nutrients such as phosphorus are important for rapid root development and must be available during early plant growth. Therefore basal fertiliser should be rich in phosphorus.

Top dressing: fertiliser is applied after seed emergence and establishment of a crop. Top dressing may be applied as late as the flowering stage of an annual crop. Nitrogen is the most commonly applied top-dress fertilizer because it can easily be lost from the soil before roots are well developed. Nitrogen fertilizers often top-dressed include ammonium nitrate (AN) and urea (46% N) in cereals.

Split applications: top-dressing can be done in several stages to reduce nutrient losses. This will also depend on soil type. Sandy soils and irrigated crops require more frequent applications of nitrogen and some other nutrients, compared to clay-type soils. For example, nitrogen fertiliser is easily lost from freely-draining soils by leaching, as water moves downwards through the soil. These losses can reduce the effectiveness of the fertiliser and can cause pollution of groundwater. Losses can be high if most of the N is applied at planting time, because initially, there is no network of plant roots to gather up the N supplied. Therefore, it is usually best to divide the total fertiliser N into a series of applications, called split applications. Split application allows a farmer to apply nutrients as and when needed. This increases the efficiency with which nutrients are absorbed by the crop.

A farmer can delay or withhold fertiliser application if the season is very dry or if there is waterlogging, in order to avoid N losses. Unlike N, which moves very readily in moist soil, P does not move much away from the point of application. Hence there is no advantage in using split applications with P fertiliser. In fact, all the P should be applied at planting. Potassium is in-between N and P as regards to its movement within the soil. There can be some advantage in split applications of K.

4.2. Is mineral nutrition a problem?

Walk through the field at different growth stages. Look for large areas of poorly growing or pale coloured plants with poor growth. Look more closely and decide whether the old or young leaves are most affected. If you see any of the symptoms described in the illustrations in Plate 4.3, you can be fairly sure that the problem is already reducing yield.

Causes of nutrient problems

1) If a soil has a long history of heavy cropping without sufficient replacement of nutrients - not enough fertilizer and manure has been applied. Check the cropping history and fertilizer / manure applications of this and earlier years. Calculate whether nutrients are likely to be limiting from the difference between nutrients removed in yields and fertilizer / manure applied.
2) If the soil is low in organic matter - insufficient manure has been applied, and/or insufficient crop residues are returned to the soil
3) If fertilizer was applied but lost due to leaching from heavy rain or over-irrigation, water run off, volatilisation to the atmosphere, or lost to competing weeds or an intercrop.
4) If fertilizer was applied when the crop could not use it optimally. What was the crop stage when the fertilizer was applied, the fertilizer type and amount, and was the fertilizer broadcast or banded?
5) If soil pH is such that certain nutrients were unavailable. Test soil pH. If it is less than 5.5, magnesium deficiency is possible and phosphorus may be unavailable. If greater than 8, deficiencies of zinc, iron, copper and boron are possible. Compare with assessments already reached from the photo keys in Plate 4.3.
6) If waterlogging occurred from heavy rainfall, over-irrigation and/or poor drainage on heavy soil. Check for symptoms of waterlogging, soil type, and check rainfall and irrigations
7) If wheat or other straw was used as mulch or large amounts of residues were incorporated. Nitrogen can be tied up by soil microbes and not be available to plants

8) The soil is saline
9) Check soil depth as a plough pan or other physical layer may be restricting roots to the upper soil profile, so that nutrients in deeper layers are unavailable.

4.3. What to do about nutrient problems

1) Before planting get help to do a soil test to check for deficiencies of zinc, phosphorus or potassium particularly if your last crop had deficiency symptoms. Nitrogen is best monitored during the season using tissue analysis.
2) Phosphorus is not mobile in the soil so place it with the seed at sowing. Diammonium phosphate (DAP) may injure the seed, so it is best to place it below or to one side of the seed using a combination seed and fertilizer drill
3) Increase rates of fertilizer for the limiting nutrient. Consider foliar application if a rapid response is required though the effects are usually of short duration e.g. for nitrogen use urea, for manganese use manganese sulphate, for iron use inorganic salts or chelates and for copper use copper sulphate. Apply only dilute solutions of these nutrients to avoid burning the tissue.
4) Consider adding farmyard manure if available as this contains most micro and macro nutrients. Using zero-till and maintaining a mulch of crop residue will help build surface organic matter. The stubble also contains lots of potassium that may be limiting in some soils. Alternatively, grow and leave a green manure mulch or cover crop before the next season to improve soil organic matter.
5) Change fertilizer application method and/or timing so that less is lost by run off, leaching or volatilisation. About 65% of nitrogen applied at planting may be lost, but losses of only 35% occur if fertilizer is placed at the first node stage (Z3.1). Generally it is best to split your nitrogen applications between planting and first node. Top-dress fertilizer just before irrigations or before rain to aid infiltration.
6) Improve drainage. Consider using a raised bed system for next season with its inherently better drainage and more efficient use of water.
7) Remove weeds to make more nutrients available to the crop.
8) Before next season increase soil pH towards 6 in very acid soils by adding lime or limestone and dolomite but care should be taken not to over-lime as deficiencies of potassium, magnesium, iron, manganese, boron, zinc or copper may result.
9) Apply micro-nutrients if indications from plant symptoms and pH measurements suggest they are limiting. If your field is sulphur-deficient, use a fertilizer that contains sulphate sulphur at planting.

4.4 What is mineral fertiliser?

Commercial fertilisers contain plant nutrients that are manufactured industrially from non-living materials. Therefore they are called mineral fertilisers or inorganic fertilisers. Farmers can use these fertilisers to meet plant nutrient requirements or to correct soil deficiencies. Note that plant nutrients such as nitrogen, potassium etc are elements. The fertiliser that farmers apply contains these elements, e.g. nitrate fertilisers contain the element nitrogen.

Many different brands of mineral fertilisers are sold. But many farmers do not fully understand which type is best for their needs or, in many cases, they do not know the best way of applying them. Also, some farmers think that N, P, K elements are all that a plant needs.

The quality of a fertiliser depends on its nutrient content, the chemical form of these nutrients, moisture level of the fertiliser, dust content, and the hardness and size of the fertiliser particles. Proper packaging is important to maintain the quality of fertiliser.

There are strict regulations on the type of bags (or containers) for mineral fertilisers, and how they should be labelled. The label should contain the names of all the main nutrients, the contents of the fertiliser (in most cases also the nutrient forms) and the analysis or grade of the fertiliser. The main nutrients are usually expressed as percent N-P_2O_5-K_2O (sometimes with the addition of trace elements Ca and S). They are always given in this sequence. For example, 7-14-7 means that the fertiliser contains 7% of N, 14% of P_2O_5 and 7% of K_2O.

To convert P to P_2O_5 and K to K_2O:
- Divide kg P_2O_5 by 2.29 to get kg P. For example, 10 kg P_2O_5 /2.29 = 4.4 kg P
- Divide kg K_2O by 1.20 to get kg K. For example, 10 kg K_2O /1.2 = 8.3 kg K

Types of mineral fertilisers

Fertilisers come in many forms. Mineral fertilisers sold in China can be divided into two types: straight fertilisers and compound fertilisers. The latter are also known as multi-nutrient, mixed, or blended fertilisers.

Straight fertilisers contain one main plant nutrient, but they may also contain some minor nutrients such as sulphur and calcium. The three main nutrients are nitrogen (provided in the form of nitrates or urea), phosphorus (provided in the form of phosphates), and potassium. Calcium nitrate is a common straight fertiliser, and is preferable because it does not make the soil acidic (as ammonium nitrate does). However, calcium nitrate is more expensive. Urea is a common high nitrogen content (46%) fertilizer manufactured commercially by using energy (fossil fuel) to combine N, O and C into this organic compound. Phosphate fertilisers are sold as either granules or in powder form. Both types are chemically identical. Farmers generally prefer to use the powder form because it is easier to apply, and also cheaper. However, the granular form is believed to deliver nutrients more effectively to plants. Of the potassium fertilisers, some farmers prefer muriate of potash (MOP) for its low cost. However, in cases where sulphur is also deficient in soils, then potash sulphate should be used.

Compound fertilisers contain at least two of the main plant nutrients. In general, the three main nutrients (N, P and K) are mixed in different ratios to make up the different types of fertiliser sold on the market. Most compounds also contain sulphur and other micronutrients.

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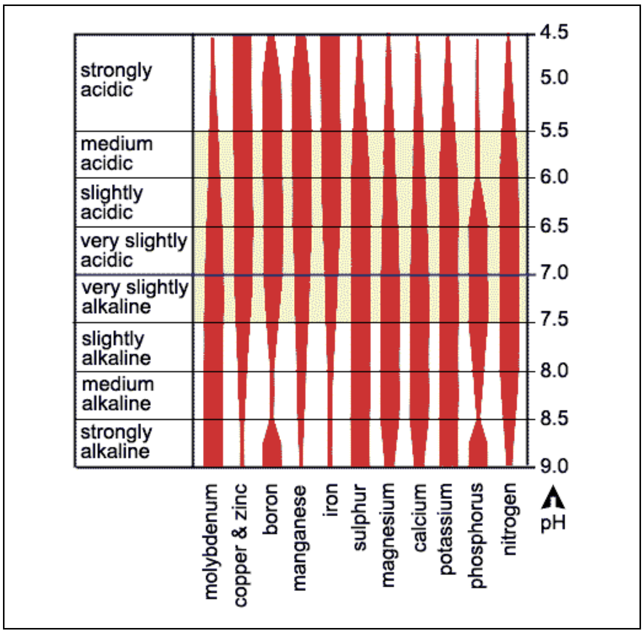
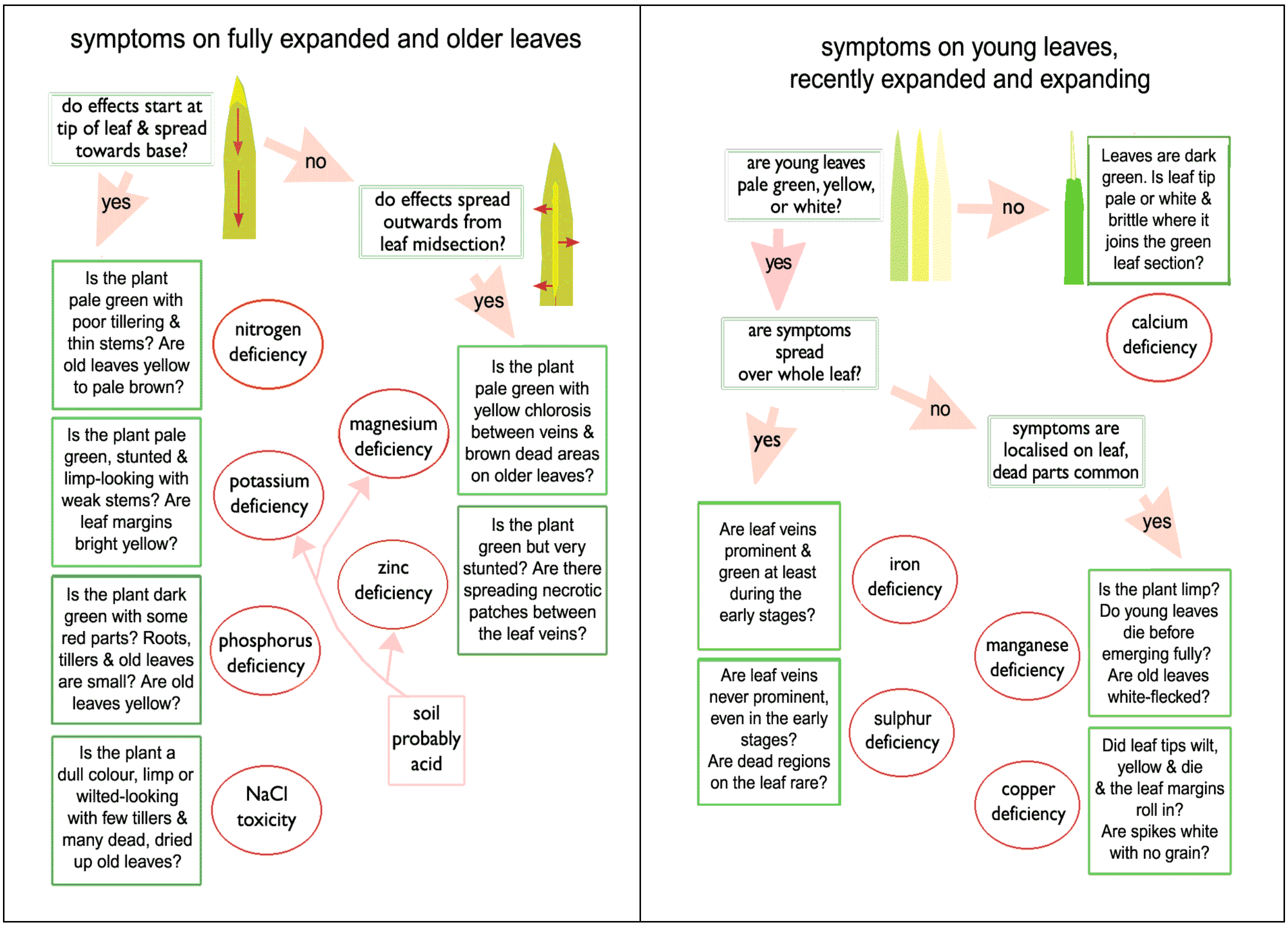


Figure based on Pratt (1965)

Plate 4.1. Effect of soil pH on nutrient availability.

Notes: 1. pH 5.5 to 7.5 is most suitable, shown with yellow background

2. Narrower red bars means less availability of the nutrient.



Grundon (1987)

Plate 4.2. Diagnostic chart for mineral deficiency symptoms

N nitrogen deficiency	**K** potassium deficiency	**P** phosphorus deficiency	**NaCl** salt toxicity	**Mg** magnesium deficiency	**Zn** zinc deficiency

Plate 4.3.1. Deficiency and toxicity symptoms in mature leaves

Fe iron deficiency	**S** sulphur deficiency	**Mn** manganese deficiency	**Cu** copper deficiency	**Ca** calcium deficiency

Adapted from NJ Grundon

Plate 4.3.2. Deficiency and toxicity symptoms in young leaves

Chapter 5 INTEGRATED WEED MANAGEMENT AND WEED CONSTRAINTS FOR WHEAT AND BARLEY IN TIBET

Peter Hobbs

Chapter 5 Integrated Weed Management and Weed Constraints for Wheat and Barley in Tibet

5.1. Introduction

Controlling weeds is essential for good yield because weeds compete for moisture, light and nutrients with the crop; every gram of nutrient or water used by a weed leaves one gram less for the crop. Some weeds also damage the crop by producing toxic substances or acting as hosts for diseases. Weeds can be a problem during harvesting; weed seeds can contaminate the grain and the green matter from late maturing weeds can contaminate the straw. Annual weeds compete most effectively with wheat during the seedling stages and early tillering. So this is the critical period for weed control. Once the crop is covering 50-70% of the soil surface at jointing, it will dominate most newly germinating weeds.

However, it is expensive to control weeds and it may not be economic to do so if weed populations are below critical levels in the field. Weeds are also an important component of farming systems that let animals graze the weeds after harvest. If the weeds are controlled, the farmer must identify other sources of fodder and may incur a cost for this. Each farmer must assess the benefits of not weeding against the losses in crop production. This is an individual decision that can only be made by each farmer. If the decision is made to control weeds, then use of integrated methods is recommended. In integrated weed control, the use of multiple systems available to the farmer is used rather than just one method. Some examples of different methods include:

1) Always try to prevent the weeds from setting seeds in the field but also on the field borders and canals. That often means pulling or controlling the weeds before they are mature enough to produce viable seed. Remember weeds are able to produce viable seed even if uprooted before they are mature. So carry the plants away from the field. If weeds such as Wild Oats are fed to animals when they have mature seeds, the seeds are likely to pass out undigested in the dung. If this dung is spread on the land as manure, weed seeds will re-infest the land.
2) Select and use clean seed since many invasive weeds can be introduced with seed. Sieve the crop seed with a large sieve that allows good seed to pass through, but may remove large seeded weed species. Repeat with a small sieve that removes the crop seed for sowing, but lets small weed seeds to pass through.
3) Use tillage to control weeds and select the most appropriate system depending on the weeds present. Zero-tillage is good because it reduces the exposure of seeds to the surface where they germinate. With the advent of herbicides like glyphosate, zero-tillage is more suitable because weeds present at seeding can be easily controlled. Using the strip-till system reduces the weed seed exposure and results in less weeds germinating than full tillage, assuming weeds present at seeding are controlled.
4) Use mulches to help suppress weeds. This happens only in a zero-till system and the two complement each other. This can include mulch with black plastic which prevents light reaching the weeds; however this is more suitable for vegetable cropping, and use of plastic by farmers is restricted in China in order to protect the environment.
5) Manual weeding is the most commonly used method of weed control in Tibet, and if used intensively can be very effective in preventing weeds from setting seeds.
6) Simple cultivation tools – hoes, rotary weeders etc. – can be used to control weeds if crops are planted in rows rather than broadcast at random.
7) Rotation is a good system to help control weeds since continuous cropping of the same crops often leads to an increase in certain weeds adapted to those crops.
8) Herbicides are chemicals used to kill weeds but not injure the crop. Herbicides will be discussed in more detail later in this section. They can often be combined with rotations to control difficult weeds.

Combinations of all of the above are referred to as integrated weed management where synergies are exploited by using a combination of methods. By using an integrated approach weeds can be controlled more efficiently and over time at less cost and inconvenience. Absolute weed control may not be possible and is definitely not economic, but good weed control procedures will go a long way to keep the problem under control.

5.2. Herbicides

Many selective herbicides are highly effective against weeds in the crop but they may cause some damage to the crop, as may manual or mechanical weed control methods. The likely yield loss from chemical or mechanical damage should be assessed against the yield loss from the weeds. Pre-emergence herbicides cause little or no damage so often result in better yields than later sprays.

There are many herbicides available for controlling weeds. If used properly with the correct equipment and proper safety measures they can be a useful tool to help farmers get control of weed growth. They can be grouped into various categories:

1) ***Non-selective herbicides*** kill any weed they come into contact with. Examples of non-selective herbicides include “paraquat” a broad spectrum contact herbicide and “glyphosate”, a broad spectrum systemic herbicide.

2) ***Selective herbicides*** are, as the term says, selective and each chemical only kills certain groups of plants. They can be broadleaf herbicides, like 2,4D and “metsulfuron”; or grass killers, like “triallate” and “haloxyfop”. There are also herbicides that control both broadleaf and grassy weeds, but not all of them (“trifluralin” = “treflan”). This specificity is exploited in weed control in specific crops.

3) ***Contact herbicides*** require that the herbicide hits the leaves since it only kills the parts of the plant with which it comes into contact. Full coverage of the herbicide is essential for effective weed control with these products

4) ***Systemic herbicides*** are absorbed and translocated to the site of action including the roots after they contact the plant surface. Absolute coverage is not essential in this case, but sufficient herbicide must be absorbed to be effective.

5) Herbicides are formulated differently:
   - ***Granular*** formulations are broadcast by hand or machine without sprayers
   - ***Liquids*** must be mixed with water and applied with sprayers
   - ***Powders*** either have to be mixed with water, or can be broadcast.

6) Herbicides can also be grouped according to the timing of application:
   - ***Pre-planting herbicides*** like treflan and triallate are applied before planting and may need to be mixed into the soil to be effective, while others must not be mixed. Both treflan and triallate need to be mixed in the top layer of soil.
   - ***Pre-emergence herbicide is applied after sowing the crop but before the crop emerges***. These include ***non-residual*** non-selective herbicides such as glyphosate, which is de-activated by the soil and only kills plants actually growing when applied. These also include ***residual*** selective herbicides that remain active in the surface layers of the soil, and kill weed seeds as they germinate but not germinating seedlings of the crop.
   - ***Post-emergence herbicides*** are applied after the crop emerges – when we rely on the selective nature of the chemical to kill the weed but not the crop; 2,4-D is an example commonly used in Tibet.

Knowledge of the different herbicides, their timing for application, and knowledge of which weeds they control in which crop is essential for effective weed control - and just as important, prevent undue herbicide injury to the crop. Haloxyfop is a herbicide for grassy weeds that is phytotoxic to cereals, but is used for controlling grass weeds in legume fodder crops and in broad leaved vegetable crops.

There are also various amendments (additives) that can be mixed with herbicides to make them more effective. Stickers make the herbicide stick on the leaf. Surfactants allow herbicides to penetrate the waxy outer layer of leaves and increase absorption. These amendments not only improve effectiveness but are used to reduce the dosage rates of the herbicides and thus reduce costs.

Herbicides can also be mixed to help broaden the spectrum of weeds controlled. However, care must be taken since some combinations are antagonistic while others are synergistic. When two herbicides are antagonistic, they lower each others effectiveness when used together while synergistic combinations enhance effectiveness.

5.3. Herbicides available in Lhasa

The following is a short summary of the various herbicides that can be procured in China for use on the project:

1) **Glyphosate** is commonly known by the trade name "***Roundup***". This is a systemic herbicide that kills most plants including the crop. It is absorbed by the leaves and translocated throughout the plant including the roots, where it kills the plant. It can take up to two weeks before the weed dies. This herbicide has made it possible for zero-tillage to be used since it can be applied as a substitute for tillage. It can be applied to weeds pre-planting or before emergence of the crop. It is quickly de-activated once it touches the ground and has little residual action - this explains why it can be used just after planting. Drift of the spray has to be avoided since it can damage crop plants in close vicinity on windy days.

2) **Paraquat** is a contact herbicide that acts by desiccating (drying) the leaf tissue that it comes into contact with. It is also a useful herbicide in zero-tillage. It is applied pre-planting or just after seeding, just like Glyphosate. Good plant coverage is essential. It is toxic to humans and safety measures are needed when it is applied. It is, however, comparatively cheap compared with Glyphosate.

   Paraquat is a brown liquid that looks just like Cola drink - it must at all times be kept in its original containers, and stored out of reach of children and animals. It is highly poisonous with no practical remedy if drunk. Poisoning of children who drink Paraquat by mistake is the most common cause of fatalities due to herbicides.

3) **2,4-D** is a selective broadleaf weed killer that is applied post emergence in cereals. It is used to kill weed seedlings, not mature weeds. If applied too late it can have phytotoxic effects on the crop. It has a plant hormonal action that shows very quickly in the form of twisting of the affected weed.

4) **Metsulfuron** is a sulfonylurea compound with selective mainly broadleaf weed activity used in cereal crops. It can be applied pre or post emergence. It is a systemic herbicide that takes 2-4 weeks to kill the weeds.

5) **Chlorsulfuron** is another sulfonylurea compound that is also used post emergence in cereals. It is effective against broadleaves but also some grasses like *Poa annua*, a common weed in cereal fields in Tibet.

6) **Tribenuron** is the third sulfonylurea herbicide applied post emergence in cereals. It is formulated as a wettable powder. It controls mostly broadleaf weeds.

7) **Haloxyfop** is a herbicide used against annual and perennial grass weeds and is used in vegetables, rapeseed, vetch and other fodder legumes like alfalfa. It can be applied pre or post emergence. This is very useful for grass control in vetch - with reduced grass weeds in the subsequent cereal crop.

8) **Triallate** is a thiocarbamate compound that is applied pre or post planting, but before emergence, that needs to be incorporated into the upper layers of soil. It controls grass weeds in pulse and vegetable crops and can be used in cereals to control "Wild Oats" (*Avena fatua*) and "Black Grass" (*Alopecurus sp.*). Care must be taken in using this compound in cereals to prevent phytotoxicity. Moisture must be sufficient for activation of this chemical.

9) **Trifluralin** commonly known as "***Treflan***" is a dinitroaniline compound applied pre-planting or emergence and must be incorporated into the surface layers. It prevents the germination of small seeded weeds. It can be used in vegetables, cereals and large seeded legumes. It controls some broadleaf and grass weeds.

There are many other herbicides for specific purposes but they may not be readily available in the Tibet Autonomous Region (TAR).

5.4. Herbicide application

Farmers and scientists often complain of poor weed control when using herbicides. The most common reasons for this are:

1) Poor application technique; and
2) Use of poor or inappropriate equipment

Herbicides can only be effective if they reach the weed, and for many herbicides, if they get good uniform coverage of the plant. This can only be done by applying the herbicide uniformly over the treated field or other area. It is important that the correct dose of herbicide is applied uniformly over the treated area; if too much is applied, usually because of overlapping coverage, toxicity can occur in the crop, while if too little is applied or some areas are missed, weeds will not be controlled.

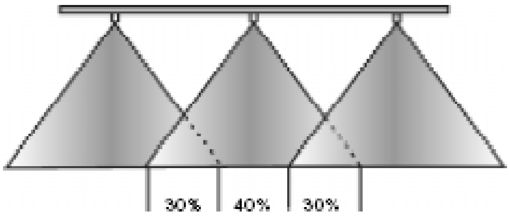
The basic spraying system is shown in Plate 5.1. The sprayer (Plate 5.1.1) consists of a spray tank (the one shown is manually pumped using the lever on the left) and a spray boom that can consist of a single or multiple nozzles (the one shown has 4 nozzles). Each nozzle consists of various components (Plate 5.1.2). The strainer is an important component that keeps dirt particles from clogging the spray tip. Herbicide application requires clean water but the strainer is used to catch any fine particles that may be present. It is essential that the strainer is dismantled and cleaned after every application. Even with the strainer in place the spray tips can get clogged. They should be removed and carefully cleaned with water or a soft brush; never use a metal pin or nail.

Spray tips

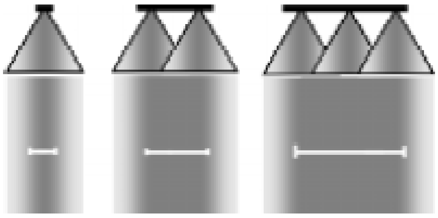
The selection of the spray tip is a key component of successful herbicide application. There are many different types but the following three spray tips are available for herbicides. They all have different attributes and spray patterns. Plate 5.2 shows these three different spray tips and their spray patterns:

Cone spray tips: produce a fine spray that gives good coverage but are mainly used for insecticides and fungicides. They are common on the sprayers sold in Lhasa and can be used for herbicides as a single nozzle if the other spray tips are not available. The spray pattern is narrow and so will require multiple passes to get uniform coverage and spray drift is a problem.

Flat fan spray tips: are designed specifically for multiple boom systems and herbicide applications. The spray pattern is tapered from the centre (full flow) to the edges (lighter flow) and is designed to overlap with adjacent nozzles, creating a uniform pattern across a spray boom as shown in the diagram below:

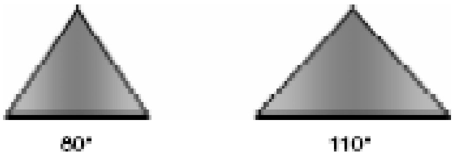


A 30% overlap ensures uniform coverage



Effective spray width of different booms

The two most common flat fan spray tip angles are 80° and 110°. This refers to the size of the angle of the spray pattern from side to side:



In general, 80ɵ nozzles, most commonly used for herbicides, will be spaced 50 cm apart on the boom and 110ɵ nozzles will be spaced at 75 cm when the boom is used 50 cm above the target. Flat fan spray tips also come in different nozzle capacities depending on spray output (gallons per minute). An 8002 flat fan spray tip has an 80 degree angle and a nozzle capacity of 0.2 gallons per minute at 40 psi pressure (0.91 litres per minute at 2.72 bar pressure (1 bar pressure – 1 atmosphere)).

Flood spray tips: are designed to have a wide spray pattern at low pressure making them popular with knapsack sprayer operators. They are best suited for defoliants and total weed killers and in situations where multiple nozzle booms are not practical or available. The spray pattern is tapered from the centre to the edge but it is not as uniformly tapered as that of the flat fan. The spray is heavy toward the very edges and coarse throughout the spray pattern. Using this nozzle in a "swinging" pattern across a field will normally result in poor application results. Overlapping by 50 per cent can help eliminate the inherent unevenness in the spray pattern.

Herbicide applications can be made using a single nozzle lance. However, spraying a straight swath with appropriate overlapping is extremely difficult and time consuming. If the single nozzle lance is swung from side to side while walking, the resulting application will have large areas of under-and over-application. Variable pressure, inconsistent speed and poor mixing in the tank can all contribute to non-uniform applications.

Worn Spray tips

Worn out and damaged spray tips lose the ability to properly regulate the spray pattern and should not be used. Worn out tips have a greater output with the spray concentrated beneath the tip. Damaged spray tips have an erratic output, over-applying and under-applying (see the diagram in Plate 5.3). Inspect spray tips and spray patterns at regular intervals replacing worn out and damaged tips as needed.

Multiple boom sprayers

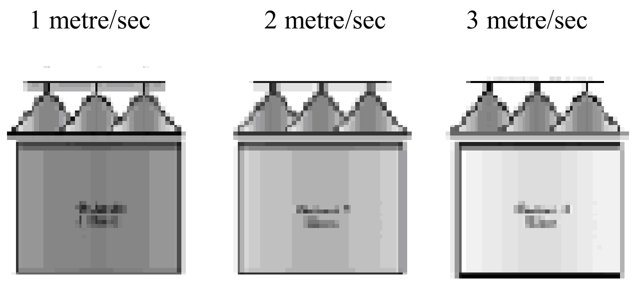
These are the best choice for uniform application of herbicides. They should use flat fan spray tips with 30% overlap of the spray pattern as shown above. This can be obtained by spacing 80 degree spray tips at 50 cm and holding the boom 50 cm above the crop. Using a boom sprayer, compared to swinging a single nozzle, will increase the uniformity of spray applications. Using a three or four nozzle boom will lead to a very uniform herbicide distribution. Spray swaths of three metres or more can be obtained by fitting a knapsack sprayer (preferably a motorized one) with the appropriate nozzles and adjusting the spray pressure of the system to provide adequate output. A simple example of a three nozzle boom suitable for manually operated back pack sprayers is shown in Plate 5.4.

Height above the crop or ground

It is important to maintain the correct height above the crop or ground when using a boom sprayer. If the boom is too low to the ground, the nozzles will not overlap resulting in bands of concentrated spray with little or no spray in between. If the boom is too high, the overlap will be too much resulting in bands of herbicide being applied at high concentrations. 50 cm is a common height for 80 degree spray tips spaced 50cm apart for a boom to get proper overlap.

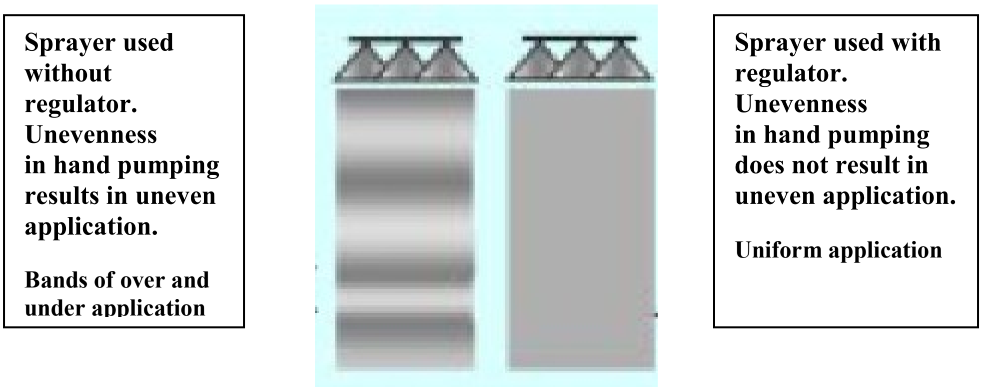
Ground speed

Ground speed **is** another factor responsible for variation in application. Speed is inversely proportional to spray application when boom output is kept constant. As the operator walks faster, less spray is applied to a given area as shown in the next figure. It is essential that the operator walks at a comfortable and consistent pace during application.



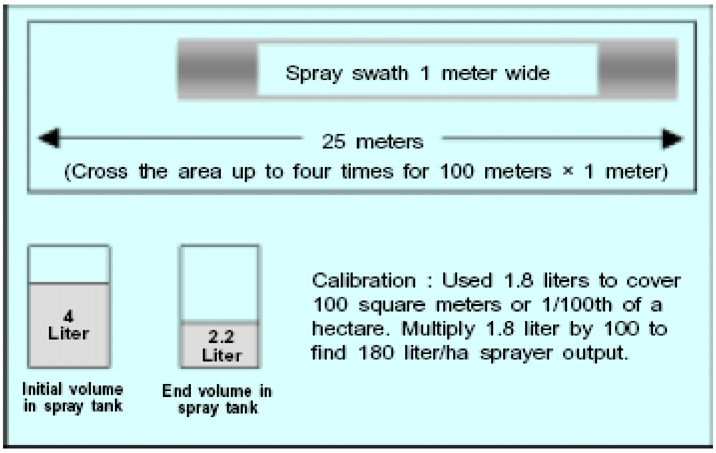
Pressure

Pressure is another key component for herbicide application. It is essential to maintain constant pressure while spraying in order to obtain uniform application. Variable pressure will result in variable output. The pressure on manual sprayers is controlled by the operator pumping the spray chamber. A pressure regulator can be used to advantage to overcome this problem. The regulator keeps the pressure constant whatever pressure is in the tank. Pressure regulates the flow and thus the amount of herbicide applied but also the droplet size. Low pressure results in larger and high pressure in finer droplets. Spray drift is more of a problem with high pressure and fine droplets. In a motorized or tractor operated sprayer the pressure is regulated by engine speed and usually a pressure regulator is included in the system.



Calibration

Calibration is done to determine sprayer output for a given area (i.e. litres per hectare, gallons per acre, or jin per mu). The simplest way to calibrate is to measure the output against a known area:



In this example, a two nozzle boom with 80° nozzles spaced 50 cm apart will be used. An area of 100 square metres (1/100 of a hectare) will be sprayed using a tank filled with a known quantity of water (4 litres). When calibrating, operate the sprayer like it will be done in the field. Walk at a comfortable pace and pump the sprayer in a consistent manner. This sprayer has been found to have an output of 180 litres / hectare. This is only true for the speed and pressure that were used when it was calibrated. With a sprayer output of 180 litres/hectare and an herbicide rate of 100 grams/hectare the calculations for spraying a one hectare field would be:

Wheat field size: **1 hectare**	180 liters / ha x 1 ha = **180 liters** 180 liters / 15 liter per tank = **12 tanks** **(Spray tank capacity of 15 liters)**

Put 100 grams of the herbicide into 12 litres of water and mix well. Pour one litre into each tank, fill with water, mix and spray at the same speed used for calibration. With this boom sprayer, straight passes will be made each metre across the field. It is essential that calibration is done properly for every operator and just before spraying a field.

Pressure regulation

Maintaining a constant pressure can be very difficult with a knapsack sprayer. Without pressure regulation, pressure will tend to fluctuate between the down stroke and the upstroke of the pump. It will also tend to fluctuate as a person spraying becomes tired and finds it more difficult to maintain the initial pressure.

While it is possible to make adequate herbicide applications without a pressure regulator, a regulator will make sprays simpler and more accurate. Most knapsack sprayers do not come equipped with a pressure regulator. A traditional regulator may be far too expensive to justify purchase. Several companies are now manufacturing regulator valves that are intended specifically for knapsack sprayers. They are durable, accurate and relatively inexpensive. These pressure relief valves are attached to a lance or boom line, usually directly before the nozzle. They do not open until their rated pressure is reached. Once the valve does open, excess pressure is managed down to the preset pressure. If pressure should drop below the preset pressure, the valve will shut off flow to the nozzle. Constant pressure regulator valves will help eliminate incorrect application caused by pressure being too high (over-spraying, crop injury) or too low (no weed control). When these valves are correctly matched with nozzles, they will ensure proper nozzle performance. Pressure regulation, of some type, is critical in calibrating a sprayer.

Cleaning

Always clean the sprayer after use or when changing to a new chemical. Rinse the tank with clean water, add fresh water to the tank and spray it through the lance or boom. This should be repeated twice. With most herbicides, extra precaution should be taken to ensure that no chemical is left in the sprayer. Some may contaminate a future spray mixture and cause unwanted crop injury.

Agrochemical safety

Both herbicides and pesticides are chemicals that can cause both short-and long-term health problems with people. While not all agrochemicals have the same level of health risk, they should all be handled carefully. Keep all agrochemicals out of the eyes and mouth. Avoid contact with the skin. If contact occurs with the skin, wash with soap and water immediately. Do not eat, drink or smoke while handling (mixing, spraying or storing) agrochemicals. Wear rubber boots, long water-proof trousers (or wrap plastic sheet securely around legs) and rubber gloves when spraying. Change and wash all clothing after spraying. Never store agrochemicals where children may become accidentally exposed. Do not re-use empty pesticide containers, and do not transfer small quantities of agrochemicals whether diluted or not into drink bottles or cans.

5.5. Common weeds species in central Tibet

The following is a short, incomplete list of weeds found in Tibet. This list needs to be enlarged and accompanied by a set of photos to show each weed species at seedling and adult growth stages:

Latin Name	Common English Name	Chinese/Tibetan Name
Broadleaf weeds: *Chenopodium glaucum* *Chenopodium prostratum* *Cirsium leo* *Convolvulus arvensis* *Equisetum diffusum* *Malva verticillata* *Polygonum aviculare* *Polygonum forrestii* *Rumex nepalensis*	Oak leaved goosefoot Prostrate goosefoot Canada thistle Field bindweed Himalayan horsetail Cluster mallow Prostrate knotweed Knotweed Nepalese dock	Liu tong qian ye shen xue ning
Grassy weeds: *Agropyron repens* *Avena fatua* *Bromus magnus* *Kobresia cuneata* *Pennisetum flaccidum* *Poa annua* *Setaria viridis*	Couch and quack grass Wild oats Brome grass Bog sedge Flaccid grass Annual blue or meadow grass Green foxtail	jie xing song cao

5.6. Integrated weed control in double cropping systems

Weeds and integrated weed control are major issues in proposed double cropping systems in irrigated systems of the Lhasa valley to ensure high productivity of both cereals and the succeeding fodder crop. The following is a logical integrated approach to minimize weed problems.

1) Obtain pure clean seed of all crops used – cereals, fodders, etc. that are free of both variety mixtures and weed seeds.
2) Sow the winter barley on time using either a zero-till or reduced till system by early October at the latest. The reduced till system can use the rotary seeder system, the strip till system or minimal tillage followed by seeding with a seed drill.
3) In the spring, use a herbicide like 2,4-D or one of the sulfonylurea herbicides to control broadleaf weeds at the weed seedling stage only if needed, using the application techniques described above.

4) In relay cropped vetch, if grass weeds are a serious problem after barley harvest, apply a herbicide that controls grasses, or hand weed.

5) For turnip, vetch or other fodders planted after harvest, sow the fodder crop with the zero-till drill and then apply roundup herbicide just after sowing IF weeds are a problem.

6) Remove any obvious weeds by hand from the field **and borders** before they get close to flowering or setting seed. Roundup can also be used to control weeds adjacent to the fields and near the irrigation channels.

7) Maintain as much residue on the surface in the zero-till and strip-till systems as possible to help suppress weeds.

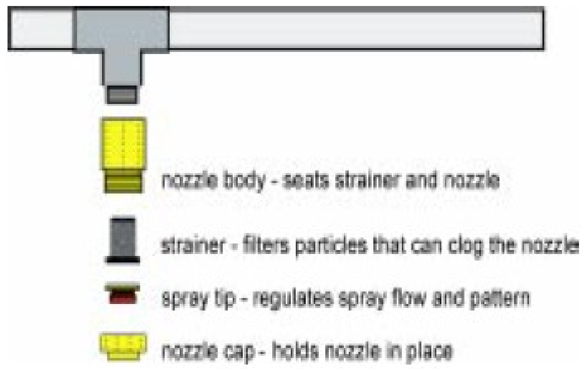
8) Rotate the fields with other crops after the fodder crop is harvested, like spring barley or rapeseed or fall planted winter wheat. Effectively control weeds in these crops, before growing winter barley again.

9) Zero-till or strip-till succeeding crops into the residue left by each preceeding crop after harvest. Control weeds by the integrated methods given above. Do not plough.

Acknowledgements

This chapter has relied on a lot of material that can be found on the rice-wheat consortium web page http://www.rwc.cgiar.org/rwc/publications.asp written by Andrew Miller and Robin Bellinder, Cornell University, Department of Vegetable Crops, Ithaca NY 14853, USA. The diagrams of the various spray parts in particular are borrowed and adapted from this publication.

5.1.1. Knapsack sprayer with 4 nozzle T-boom



5.1.2. Nozzle components

Plate 5.1. Basic components of a crop sprayer

Hollow cone Full cone Flat fan Flood

Plate 5.2. Spray Tips and their Spray Patterns

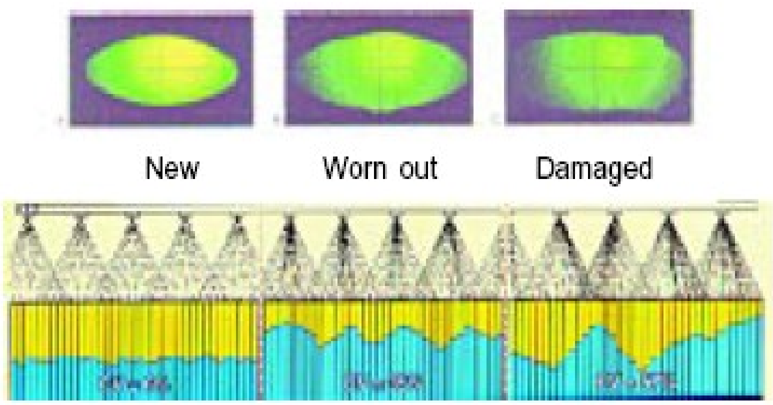


Plate 5.3. Effect of worn out and damaged spray tips on spray pattern

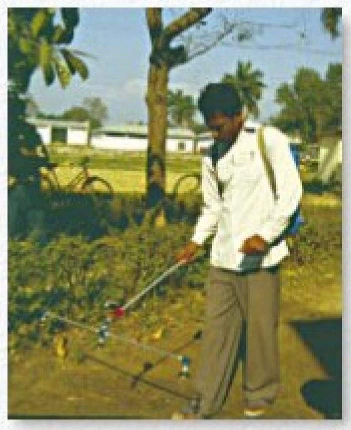


Plate 5.4. Simple knapsack sprayer used with 3 nozzle T-boom

Chapter 6 SEEDERS FOR 2 AND 4-WHEEL TRACTORS

Chapter 6A 2BG-6A ROTARY SEED DRILL FOR THE DONGFENG TWO WHEEL TRACTOR

Peter Hobbs

Chapter 6 SEEDERS FOR 2 AND 4-WHEEL TRACTORS

Seeder equipment was procured for both 2-wheel and 4-wheel tractors to enable the project to plant various small seeded crops (wheat, barley and vetch) by minimum till and zero-till. This chapter outlines the operation, calibration and maintenance of these seed drills. The first part will deal with the 2BG-6A Seed Drill shown attached to the Dongfeng 2-wheel tractor in Plate 6A.1[1]. The zero-till drill for 4-wheel tractors follows in the second part of this chapter.

Chapter 6A 2BG-6A ROTARY SEED DRILL FOR DONGFENG TWO WHEEL TRACTOR

6A.1. Introduction

The 2BG-6A model seed drill is designed to speed soil preparation and planting and reduce the turn around time between the harvest of one crop and planting of the next crop. In Tibet, this could be for planting cereals after the fodder crop is harvested or planting the fodder crop after winter barley harvest. By combining tillage and seeding in one operation crops are planted more timely and yield potential is increased. The 2BG-6A seed drill is attached to a Dongfeng two-wheel tractor (see the separate manual in Chinese on two-wheel tractors). It can be used for sowing many small seeded crops such as wheat and barley, and several fodder crops like vetch, alfalfa and turnips. This can be done either by direct drilling (without ploughing first) or by broadcasting the seed and fertilizer first and then incorporating the seed with the tiller on the seeder. The seeder works in all soil texture types, but it can be broken by large stones. It is best if soil moisture is higher than that normally used for conventional tillage; since the rotary tiller fluffs up the soil so that the soil loses moisture. The issue of moisture is partly resolved by the roller at the back of the seeder. This manual describes the construction, operation, and maintenance of the 2BG-6A seed drill.

6A.2. Construction of the Seed drill

The parts of the 2BG-6A Seed Drill are illustrated and listed in Plate 6A.2.

Overview

The seed drill's primary working parts include the rotovator, seed metering drive system, and a depth control device. When the tractor is in motion, the rotovator tilling blades turn and till the soil. The tilled soil is thrown backward as the tractor moves forward. At the same time, the sprocket mounted on the left drive axle of the tractor drives the seed metering shaft by means of a chain connected to a sprocket on the shaft. As the seed metering shaft and fluted rollers turn, seeds are dropped through the six seed tubes to the six furrow openers. The seeds are distributed into the furrows created by the furrow openers, and then covered by the thrown soil, which is in turn planked by the depth control roller.

Rotovator

The main parts of the rotovator are the tilling shaft, 48 blades, a cover, two supporting brackets, and drive chain housing with a large drive sprocket and a smaller driven sprocket (providing the high RPM necessary for a single pass ploughing). Its main purpose is to provide a vigorous shallow tilling of the soil and throwing it backward to cover the seed. By adjusting the depth control device, the soil can be tilled to depths between 1 and 5 cm.

[1] Courtesy of the National Agricultural Engineering Federation (NAEF) and Scott Justice, an Agricultural Engineer, Kathmandu Nepal

Seed metering system

The fluted roller type seed metering system is made up of a seed box, supporting frame, seed rate adjusting handle, seed metering shaft (which extends from the drive system), seed tube, seed rate adjustment arm, and seed cutoff device. Its purpose is to hold and distribute seeds. If necessary, block some seed tubes to lessen the number of drilling rows and to increase plant spacing. The seeds are dropped into funnels and pass into the soil via the furrow openers. Also adjust these side to side in order to obtain the desired row spacing.

Seed metering drive system

The seed metering drive system includes the transmission, the seed metering shaft, a one-stage drive, two sprockets (Sprocket 1, with 22 teeth and Sprocket 2, with 19 teeth), a splined sleeve, a chain, and a tightening device (Figure 6A.1).

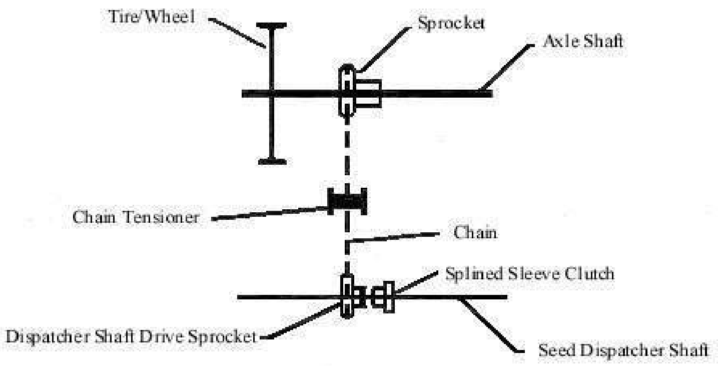


Figure 6A.1. Key features of the seed metering drive system and transmission

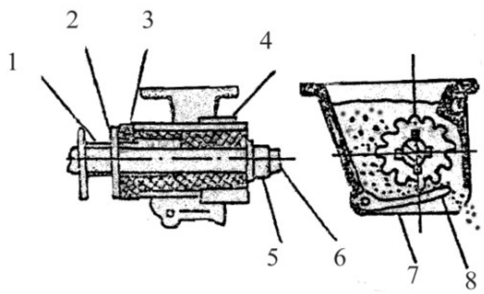


Figure 6A.2. Seed dispatcher mechanism

1. Set screw	4. Adjusting wheel	7. Seed box
2. Sleeve	5. Ring	8. Seed metering tongue
3. Fluted roller	6. Shaft	

When the seed metering system is in use, the seed metering shaft turns the fluted roller, which drops seed from the seed box into the seed tubes. Adjust the length of the fluted roller that extends into the seed box to determine the amount of seed released for any given unit of time (see s*eed rate adjustment, 6A.5*). Adjust the seed meter tongue (Item # 8 in Figure 6A.2) **up** near the fluted roller for fine seeds such as turnip and lucerne, and **down** for larger and rough textured seeds such as vetch to prevent seed breaking. For set spacing of big seeds such as maize, remove the fluted roller meter "rack" and mount another system such as a flat or incline plate system in its place.

Depth Control

Adjust the depth of tillage and seeding via the adjusting plates (Plate 6A.2 # 10). The top hole in the adjusting plate is for road transport and places the seed drill high enough so that the rotary blades do not strike the ground during transport. Once in the field, adjust the plate upwards - remove the large securing pin (held in place with a small cotter pin), lift the depth control roller up, and secure it in any of the six remaining holes. The higher the roller is, the deeper is the tillage. Moving the roller also raises and lowers the furrow openers.

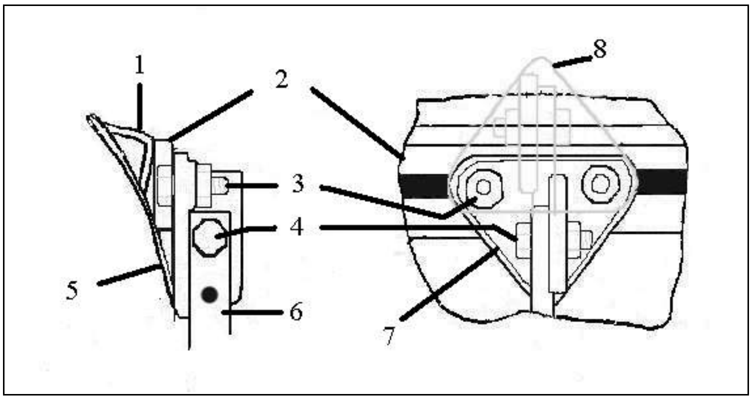


Figure 6A.3 Furrow opener

1. Angle iron mount
2. Furrow opener mounting plate
3. Furrow opener chuck bolts
4. Shank mounting bolt
5. Inner cover
6. Furrow opener shank
7. Furrow opener chuck
8. “Flipped” position for chuck

If the depth of sowing is not satisfactory in relation to the depth of tillage the furrow openers may be adjusted up or down:

1) Move the furrow opener shank (Figure 6A.3 #4) up or down; and / or
2) Flip the furrow opener mounting plate (Figure 6A.3 #2) upwards or downwards as necessary.

The combination of these two methods provides 4 different vertical adjustments and positions for the furrow opener(s).

6A3. Installing the rotary blades

For ease of installation, attach the blades before the seed drill is attached to the tractor. For conventional / normal full tillage fit all 48 blades as shown in Figure 6A.4. If strip or zone till is desired, attain nearly any width of strip by placing more or less blades per strip. Obtain a tilled strip of approximately 10 centimetres by installing the blades as shown in Figure 6A.5.

1) Installing the blades for normal tillage and seeding

For normal full length tillage (1.2 metre width) install all 48 blades as shown in Figure 6A.4. Install blades in pairs with each blade pointing in opposite directions (i.e. the left hand bent blade is installed with the right hand bent blade as its opposite). If blades are not installed properly, they can throw soil into mounds and/or make furrows.

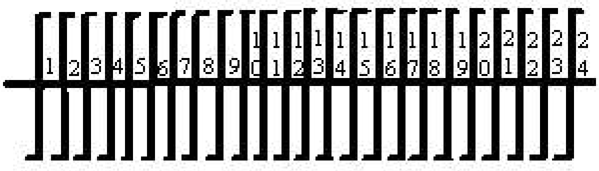


Figure 6A.4. Rotary blade installation for full cutting coverage (normal tillage)

2) Installing blades for strip-tillage seeding

Use strip till seed drilling in fields where weeds are not a problem or where weeding fields is easy (for example where herbicide is used). By strip tilling, better soil structure and residual moisture, increased tilling and drilling speed (more land per hour planted), reduced blade wear and reduced fuel costs per unit of land can be obtained.

For strip till cultivation remove blades according to the spacing and number of rows needed. Various widths can be obtained by having blades facing outwards or inwards as shown in Figure 6A.5. For very narrow strips of 5 cm, two "straightened" blades may be used per strip to obtain a zero till look. Adjust seeding and tilling depth as outlined above. For very narrow strips adjust the furrow opener to be directly behind the blades. Figure 6A.5 on the left shows an arrangement of rotary blades that makes 6 rows of 15 cm strips; on the right it makes 10 cm strips. To make strips 20 cm wide reduce the number of rows to five. And so on.

Figure 6A.5 Power tiller seed drill blades to give 15 cm tilled strips (on left) and 10 cm tilled strips (on right)

3) Installing the blades for inter-row cultivation

The seed drill can be used to cultivate weeds between rows of seedlings (inter-row cultivation). Inter-row cultivation can be used for the first weeding of many line-sown crops when plants are still small since the clearance of the tractor is only 5-10 cm. The setting up of the seed drill for inter-row cultivation is identical to strip tillage with blades removed or configured to give the width of the strip needed.

4) Ridge forming and planting

Adjust the blades as shown in Figure 6A.6 to make ridges and to plant crops on 60 cm beds. Obtain a single wider bed of various widths by starting from the centre of the rotary shaft and working outwards. Drill single and multiple rows of crops at various positions across the beds by adjusting the furrow opener depth accordingly. Alternatively, form beds first and then dibble or transplant crops on to the bed(s) afterwards.

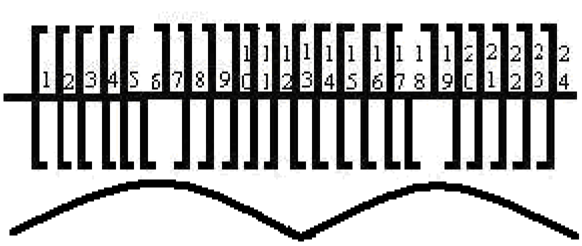


Figure 6A.6. Configuration of blades on 2BG-6A for bed planting

5) Routine maintenance of blades for the seeder

It is very important that the operator check the blades several times a day to ensure they are tightly bolted. The blades tend to come loose after use, and loose blades cause wear on the blade holders and may result in breaking the holders or breaking and loss of blades. Install new blades once blades are worn to the point where tillage of the field is unsatisfactory.

6A.4. Mounting the seed drill to the 2-wheel tractor

To mount the seed drill, first remove the tractor seat and the small wheel below it. Place the tractor's front stand in the up position and then push the front of the tractor downwards to keep the transmission oil from leaking out. Next, remove the large rotovator attachment, taking care to cover the open transmission hole with a plastic bag to keep dirt from getting into the transmission gearbox. Move the seed drill into position and connect it to the transmission box by placing the seed drill mount on to the four bolts of the tractor's rear transmission housing. Make sure the gears are properly aligned / meshed, and take care not to strip the bolt threads. Add the washers and nuts and tighten.

Next attach and adjust the two support arms to the tractor handlebars. Attach the two halves of the seed meter's drive sprocket to the tractor's left axle and align it with the sprocket gear on the seeder. Tighten the nuts on the sprocket gear. (This will drive the seeding mechanism.) Open the chain via its master link and place it over the axle sprocket and through the spring loaded chain tensioner and then connect it to the seeder gear sprocket. Reconnect the chain. If the chain is too big or loose, remove links. Adjust the tensioner's guide pulleys as necessary to obtain the correct chain slack.

Before operating the seed drill, make sure all necessary adjustments have been made. Also make sure the *Preparations for Seed Drilling* and *Operating Notes* are reviewed.

6A.5. Adjustments to the seed drill

Make adjustments to various devices before and during use of the seed drill as necessary. This section describes how to adjust row number, row spacing, ploughing depth, and the quantity of seed disbursed.

Row Spacing Adjustment

To adjust the amount of space between the rows of seeds, loosen the bolts on the furrow opener adjustment plate and move the plate left or right to obtain the proper row spacing, as shown in Figure 6A.3. Tighten the bolts. One or more furrow openers may need to be removed if a wider spacing is needed. To do so, see *Row Number Adjustment* below.

Row Number Adjustment

The number of rows that are planted may need to be adjusted to get even coverage for a plot of a particular size, or because of a change in seed type. To decrease the numbers of rows block the seeds from dropping from individual spouts. The simplest way to do that is to cut a cover from heavy cardboard or even sheet metal and to fit this cover over the top of the seed spout in the seed box. Use an adhesive to hold this cover securely in place.

Tillage Depth Adjustment

Change both the tillage depth of the rotary blades and the depth of seed drilling by adjusting the tillage depth. Adjust the blade depth as desired, but it should not be so deep that the tractor engine is overloaded or so shallow that seed grains are not sown below the ground. Adjust the tillage depth by changing the hole on the depth control adjusting plate (Plate 6A.2. #10) to which the depth control roller/press wheel support arm (Plate 6A.2. #9) is bolted. The holes on the adjusting plate are spaced 10 mm apart. The top hole is the road transport, or walking hole. When the plate is set at this depth, the openers and rotary blades don't penetrate the soil, and the tractor can be moved from place to place. Set the press wheel adjusting plate to the fourth hole to cause the blade to penetrate the soil to a depth of 50 mm, the maximum tillage depth. Use intermediate holes to till at more shallow depths.

After the tillage depth is set, check and re-adjust the seed drilling/placement depth. There are two ways to do this:

1) Change which hole of the shank of the furrow opener is used (upper or lower), as shown in Figure 6A.3 and labeled # 4 and # 6.
2) Spin the furrow opener adjustment plate (# 2) 180^{o}, which moves the bolt holes higher.

The furrow opener can therefore be set at four different depths, each 20 mm deeper than the previous. If too many seeds are being unearthed during planting, lower the furrow opener. If seeds are planted too deeply, raise it.

Seed rate adjustment

Adjust the seeding rate, either to ensure uniformity among the planted rows, or to change the quantity of seeds discharged. To check and adjust the uniformity of seeding, position the seeding rate adjustment handle to "0" on the scale (Figure 6A.7). Make sure that the blocking wheels are all touching the side walls of the seed metering box. If they are not, unscrew the fastening screw of the seed box and shift the seed box left or right as needed so that the blocking wheels are all touching, and retighten the fastening screw. This will ensure that each seed tube delivers approximately the same amount of seed.

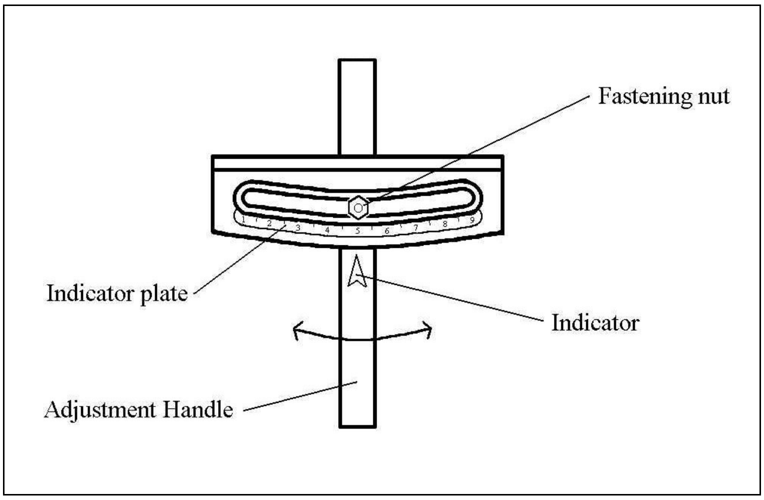


Figure 6A.7. Adjusting the seed metering device

To adjust the seed rate, loosen the seeding rate handle fastening nut and shift it to the left for a lower seeding rate, and to the right for a higher seeding rate. The numbers 1-10 on the indicator's plate are for reference for resetting the meter to earlier known seed rates / settings. Although the manufacturers of this drill claim that each number corresponds to a certain number of kg/hectare for each crop, in practice the loose "play" in the controls and links of this device are so variable that this is not very reliable. The rates also vary between different machines. Also, note that crops vary greatly between varieties in number of seeds per kilogram. After setting the seed rate, re-tighten the fastening nut, as shown in Figure 6A.7. Refer to seed rate recommendations of the varieties and make adjustments to the machine as necessary.

6A.6. Calibrating the quantity of seed delivered by the drill

The seed drill should always be calibrated to ensure the correct quantity of seed is delivered to the field and according to recommended seed rates. This should be done at the beginning of each season, and whenever a different crop or variety is planted. Calibrating the seed drill ensures that the right numbers of seeds are planted to get a good yield. To calibrate the quantity of seed do the following:

1) Measure a length 20 metres long in the field or road and mark each end.

2) Attach a plastic bag to each of the seed tubes to collect the seed while calibrating the seeder. Weigh the seed collected as part of the calibration process and prevent any seed dropping on the ground.
3) Put seed in the seed box.
4) Set the seed rate adjustment handle to just above "2" for the first calibration trial. For wheat we have found that this should give a seed rate of about 120 kg/ha.
5) Run the tractor with the seed drill attached for 20 metres, using the area marked off.
6) Stop and turn off the engine.
7) Remove the plastic bags from the end of the seed tubes, and look at each one to see if they all have approximately the same amount of seed. If they do not, inspect the seed metering mechanism for jams, mis-adjustments or problems.
8) Combine all the seed and weigh it. Weigh each bag separately the first time to ensure that there are not major differences between the various seed rollers. If there are, make adjustments as described above.
9) The area seeded is 20 metre long by 1.2 metre wide = 24 square metres if all 6 seed tubes are used at normal spacing (if the seed tube spacing was changed this value may be different). Multiply the weight of the seed in kilograms by 416, to get the seed rate in kg/ha. (416 times 24 square metres equals one hectare.)
10) If the seed rate is too high or too low, change the setting of the seed rate adjustment handle accordingly, and calibrate again. Seed rate varies from crop to crop, variety by variety and location to location and must be known.
11) Normally, wheat or barley is seeded at 100-120 kg/ha with a seed drill.

6A.7. Preparations before seed drilling

Before operating the seed drill for the first time, read and understand this manual. Become familiar with the drill's mechanism, adjustments, and operating methods. Before each use in the field, review this list to make sure all necessary items are checked and adjusted.

1) Check the condition of the seeder and make any adjustments or repairs necessary. In particular, check the fasteners, blade bolts and check for broken welds and oil leakage before operating. Check the oil level in the chain drive case and fix any oil leaks before operating.
2) Select the proper row spacing, seed quantity, and seed drill depth for the plot and crop in question. (Re-adjust seed rate and drill depth after trial drilling.)
3) Make sure that the seeds to be drilled are clean, and free of soil and rocks. **Do not mix fertilizer with the seeds** when seeding, as this will damage the seed metering device. If fertilizer is to be used, broadcast it before seed drilling.
4) Add the seed to the seed box. Do not fill the seed box more than three quarters full, in order to prevent the box bending under the weight.

6A.8. Operating notes

Before operating the seed drill, review these operating notes:

1) After starting the engine, start the seed drill smoothly. Engage the rotovator handle and the seed metering clutch handle while walking slowly (do not use a foot to engage and disengage the seed metering clutch!). Then, increase throttle speed to the desired operating speed. Always shift the seed metering clutch **gently**, to avoid bending the arm out of shape or damaging the clutch.

2) When tilling and seeding back and forth across the plot, line the seed drill up so the next row is at the desired spacing from the last row just planted. Depending on the row spacing, this may mean there is a slight overlap in the tillage pattern.
3) While operating, pay attention to how much seed is left, and whether the seeds are blocked in the seed tube or in the hole of the furrow opener. If the tractor is backed up while the seed drill is operating, soil will be jammed into the furrow opener and block seeding. If this happens, turn off the engine, and clean the furrow openers and seed tubes as necessary. Restart the engine, raise the implement to back up, and re-drill the area that did not receive seed.
4) Throttle down when approaching the end of the plot. Disengage the seed metering clutch when 2.4 metres away from the end of the plot, raise the handles, and use the steering clutch to turn the tractor. After turning, re-engage the seed metering clutch.
5) Disengage the seed metering clutch transmission and the rotovator transmission when the implement crosses a ridge or is in transport. Lower the roller to raise the blades to the maximum height ("road transport" or "walking" hole) while walking or transporting the tractor on the road.
6) **Stop the engine before fixing a breakdown or adjusting or changing implements**.
7) Be careful not to damage the plastic parts of the seed metering device when assembling and disassembling the seed drill.
8) After operating the seed drill is finished, wash the mud and weeds from the machine, and remove the remaining seeds and any mud in the seed metering device. DO NOT leave seed in the seed box over time since it attracts rodents and can damage the inside of the seed box. Clean and lubricate the chain, and lubricate all moving parts.
9) Install rearward facing lights if there is a need to use the seed drill at night. Lights can be installed on the bolt that connects the supporting arm to the handle so the lamplight can shine between the seed box and seed tube.

6A.9. Seed drill storage

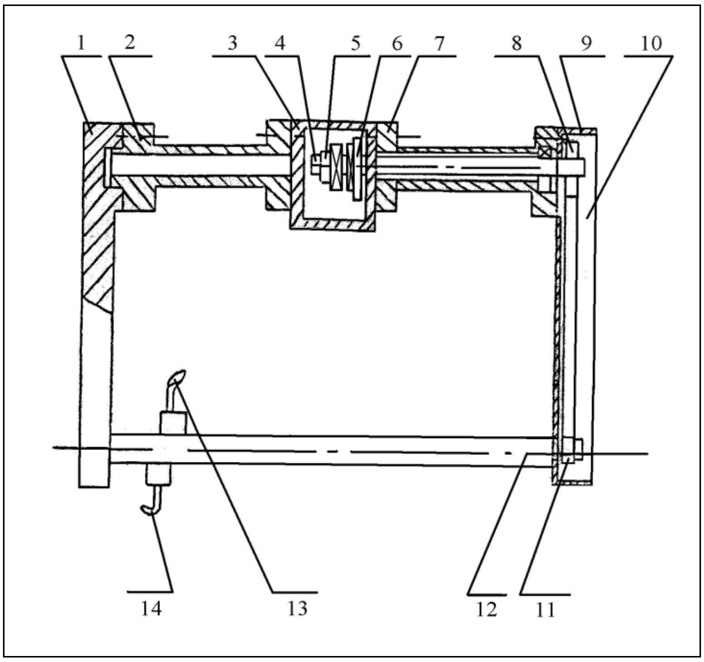
Before storing the seed drill for any length of time, clean each part of the machine, reapply grease to the seed metering clutch, coat each rotary blade with old engine oil or paint, and store the seed drill in a dry, well-ventilated room. Keep the appropriate tools with the machine during storage to ensure that they will be available when needed again.

6A.10. Troubleshooting

Problem	Cause	Remedy
Press wheel is not rotating and causing hilling	1. The scraper angle iron is not sharp enough, or the clearance between the press wheel and angle iron is too large	1. Grind the angle irons, or adjust the clearance. Also, clear away any mud from the roller wheel
	2. Press wheel bearings are locked	2. Remove bearing covers and clean and lubricate with grease. Replace covers
	3. The scraper angle irons are in constant contact with the anti-skid tooth	3. Adjust the position of the anti-skid tooth and then refasten it
	4. Soil moisture is too high	4. Stop drilling until it is drier
Seed is not dropping from furrow opener	1. The seed box is empty	1. Refill the seed box
	2. The furrow opener or seed tube is blocked by soil / mud	2. Clean mud out of the opener and / or seed tubes
	3. The clutch is disengaged	3. Re-engage the clutch, or if that is not possible, repair the seed drill clutch transmission.
Transmission is not engaging properly	1. Clutch gear positioning spring is loose or broken	1. Replace the positioning spring with a new one
	2. The operating handle head is excessively worn	2. Repair the head or replace the handle
	3. The channel in the sleeve of the transmission axle is worn	3. Repair the channel or replace the sleeve

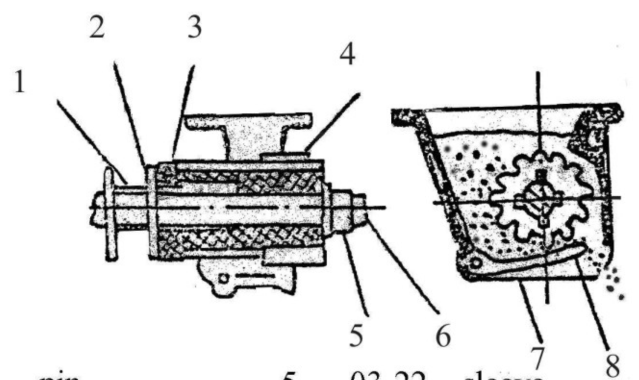
6A.11. Parts List

1) Gear box drive and rotary blade shaft



	Part #	Description		Part #	Description
1	01-01	Shaft supporting arm (left	8	01-12	Sprocket large
2	01-02	Housing shaft supporting arm (left)	9	01-11	Chain drive casing
3	01-03	Housing main drive gear box	10		Chain
4	01-1-	Transmission axle	11	01-19	Sprocket small
5	01-08	Ring shaft	12	01-18	Rotary shaft
6	01-07	Gear, transmission	13	01-1804	Tilling blade (left)
7	01-09	Housing shaft support arm (right)	14	01-1803	Tilling blade (right)

2) Seed Meter



1	03-11	pin	5	03-22	sleeve
2	03-12	fix sleeve	6	03-05	shaft
3	03-16	flutted roller	7	03-13	seedbox
4	03-21	deflector wheel	8	03-19	tongue

6A.12. Main Technical Specifications

Dimension (L x W x H):	720mm x 1320mm x 700mm
Weight (kg):	
With roller:	162 kg
With leveller:	145 kg
Attached tractor:	Power tiller 12 HP Dongfeng hand 2-wheel tractor
Function:	Full or strip till cultivating seed drill
Operating speeds (km/hr):	1.4, 2.5, 4.1 (1st 2nd and 3rd gears)
Maximum walking speed (km/hr):	9.4
Turning speed of shaft (rpm):	512
Diameter of shaft (mm):	300
Tilling width (mm):	1200
Number of rows drilled:	Up to and including six
Row spacing (cm):	15 cm x 6, 20 cm x 5, 23 cm x 4, 30 cm x 3
Maximum tilling depth (mm):	60
Seed drilling depth (mm):	10—50
Maximum volume of seed drilling (kg/ha):	450

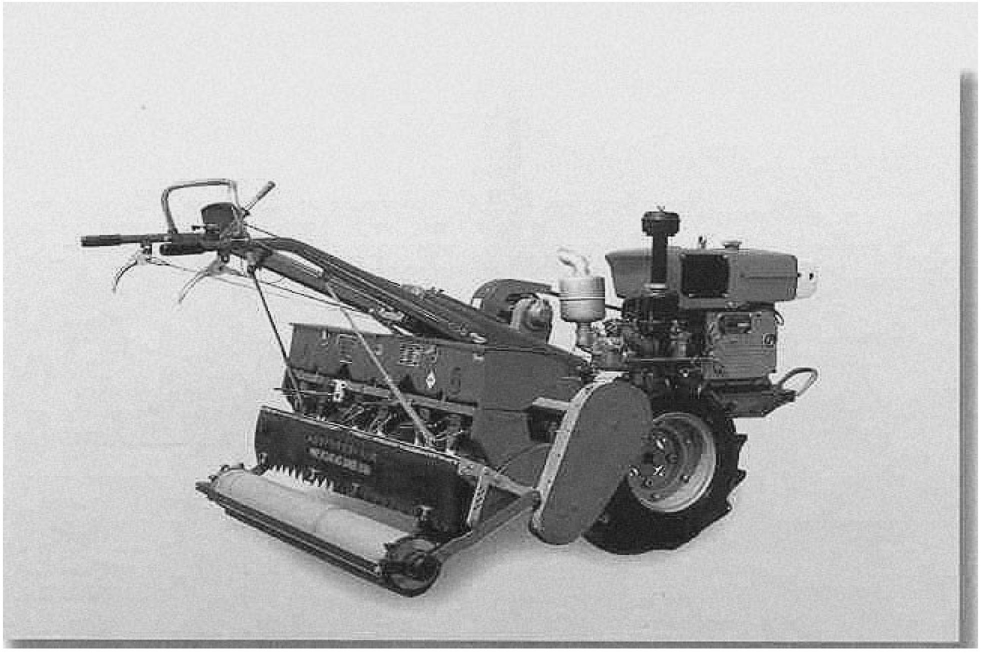


Plate 6A.1. The 2BG-6A rotary seed drill for the two wheel tractor

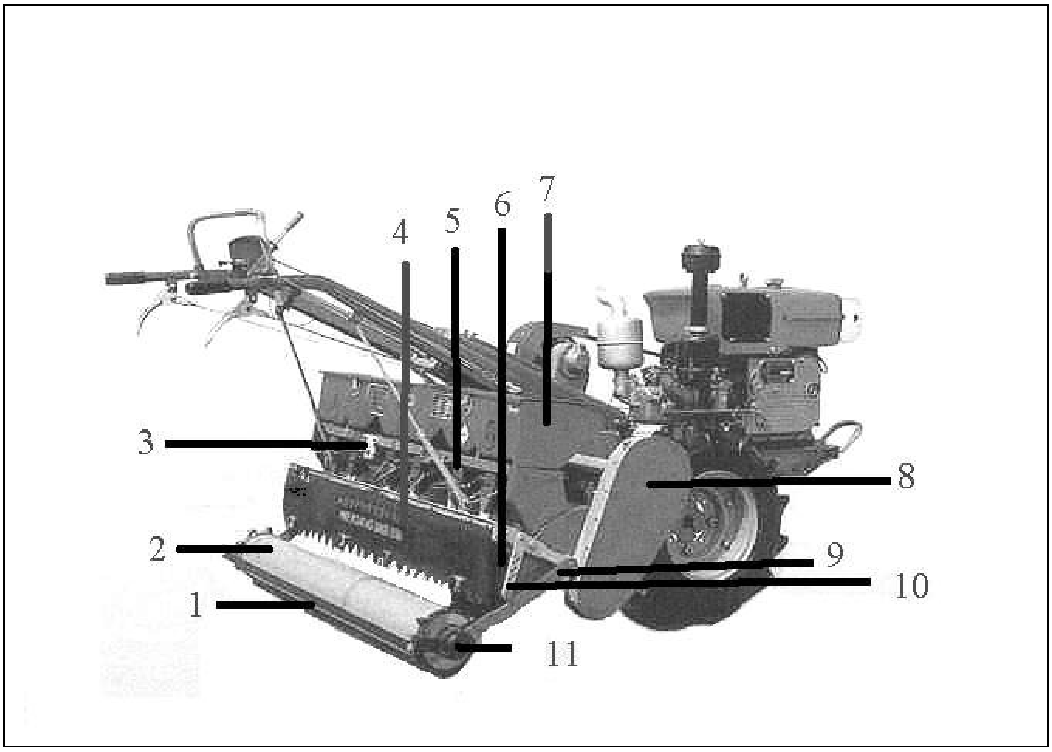


Plate 6A.2. Parts of the Model 2BG-6A Seed Drill

1. Depth control roller and press-wheel scraper blade
2. Depth control roller and press-wheel (plank)
3. Seed rate adjusting handle
4. Rubber curtain / guard
5. Seed meters
6. Furrow openers (6)
7. Seed box
8. Rotovator drive-chain housing
9. Depth control roller/press-wheel support arm
10. Depth control adjusting plate
11. Depth control roller / press-wheel bearing housing

Chapter 6B THE ZERO-TILL DRILL (2BMF-6C-2) FOR 4-WHEEL TRACTORS

Peter Hobbs

1) fertilizer openers. Make sure all parts are dry before using again.

Chapter 6B THE ZERO-TILL DRILL (2BMF-6C-2) FOR 4-WHEEL TRACTORS

6B.1. Construction

The 4-wheel tractor zero-till drill (Plate 6B.1) is similar to the 2-wheel tractor seeder, except that the openers that place the seed in the soil are fixed rather than rotary. Also, this drill is a combination drill and has the ability to place fertilizer as well as to plant small seeded crops like wheat, barley and vetch. There are two bins (Plate 6B.2), the front one for fertilizer and the rear one for seed. The fertilizer and seed tubes are attached to the front and back tubes of the opener (Plate 6B.3), respectively.

The ability of the drill to place the seed and fertilizer improves the efficiency of establishment and fertilizer application over the traditional broadcast system. However, during seeding, the operator must be careful never to allow the drill to move backwards while still inserted in the soil, otherwise the tubes can be blocked with soil that prevents the seed or fertilizer flowing. The operator must lift the drill while moving forward to prevent this blocking problem. The operator should check the tubes at the end of each pass to make sure they are not blocked. Special care is needed when planting small plots for experiments and demonstrations, and it is worth having an assistant employed just to check seed and fertilizer tubes are clear.

Opener spacing and arrangement

The drill can have different opener spacing and arrangements:

1) **Depth**: to control the depth of the openers (Plate 6B.4) move the shaft of the opener up or down. Use holes on the shaft to make sure that the opener is secure.
2) **Spacing**: to adjust spacing between rows loosen the brackets shown in Plate 6B.5 and move the openers closer or further apart - assuming there is space for the drive wheel.
3) **Arrangement**: the drill has six openers that allow seed and/or fertilizer to be placed in the soil. The opener arrangement can have all six openers in one line, or staggered with some openers in the front and others behind. Plate 6B.1 shows 2 openers at the front and 4 openers at the back. There is more chance of loose residue clogging the drill with all six openers in one row. This can be overcome by using the staggered configuration. Note that the openers for the front are of different design compared to those for the back (Plate 6B.6).

Seed and Fertilizer Systems

The seed and fertilizer systems differ mainly in the size of the fluted rollers (Plate 6B.7). The fertilizer flutes are larger than the seed flutes so that sufficient fertilizer can be applied. Plate 6B.8. also shows the mechanism for opening and closing the seed and fertilizer holes. Open the slides during planting, but close them for transport between plots and fields. Open the slides again to remove excess seed and fertilizer, and to clean the bins and seed and fertilizer mechanisms. There is also a black plastic cover shown open in Plate 6B.8 that is held in place with a metal wire clip (Plate 6B.9 and 6B.10). Open this black plastic cover to clean the seed or fertilizer tanks of excess material. The clip shuts the black plastic cover and also holds the green bucket that directs the seed or fertilizer into the tubes.

6B.2. Calibration of seed and fertilizer rates

Both the seed and fertilizer rates need to be calibrated before going to the field. If a new variety or crop is used a new calibration is needed. Calibration is done as follows:

1) Determine the circumference of the drive wheel (Plat 6B.11). The outer circumference is correct. Also check the spacing set for the openers.

2) Make sure that the clip (Plate 6B.10) is in place and the black plastic cover is fully closed and the green bucket in the correct position.

3) Adjust the fertilizer or seed meter (Plate 6B.12) for the test using the wheel on the side of the seeder (Plate 6B.13) - loosen the lock nut and turn the wheel. This wheel slides the seed or fertilizer flutes so that more or less material is dispensed. Use this adjustment to increase or decrease the seed or fertilizer rate until you obtain the correct value. This may take several attempts. Note down the value that is seen on the seed or fertilizer meter for future reference. Tighten locknut after adjustment is finished.

4) Add just sufficient seed or fertilizer for the calibration by placing the material over the openings in the seed or fertilizer bin.

5) Open the metal slide (Plate 6B.10) to the setting that will be used in the field. Opening this slide fully will ensure the maximum flow but it can be partially opened to give an intermediate rate.

6) Place cloth, paper or plastic bags around each tube to collect the seed or fertilizer dispensed. You can calibrate the seed and fertilizer at the same time by placing bags on the 6 seed and 6 fertilizer tubes.

7) Make a mark on the drive wheel or tie a piece of cotton or string in one place on the wheel, so that it is possible to count the number of revolutions.

8) Raise the zero-till drill with the tractor hydraulics and turn the drive wheel by hand 10 full turns. The circumference times 10 will give the length the drill is presumed to have moved.

9) Collect the 6 bags of seed and / or fertilizer from the tubes and note if each has approximately the same quantity. This gives a visual check that the flutes are distributing seed or fertilizer evenly at all 6 openers. Weigh the seed and fertilizer with an accurate balance from the consolidated 6 samples.

Calibration calculations

To determine the area covered when the seed drill moves the length of 10 turns of the drive wheel, multiply the length (10 times the circumference), which for this machine is 15.5 metres, by the width 1.20 metres (6 rows spaced 20 cm apart), which gives an area of 18.60 square metres.

> 10 times circumference (1.55m) of drive wheel is 15.5 m
>
> 6 rows 20 cm apart gives width of 1.2m
>
> Total area = circumference x width = 18.60 m^2

1) In order to get 100 kg seed or fertilizer per hectare, 10 grams of material needs to be dispensed per square metre (100kg x 1000 / 10,000 m^2). Therefore the amount of seed or fertilizer in the 6 bags should equal 18.60 times 10 grams or 186.0 grams. Adjust the seed or fertilizer meter in or out to increase or decrease the flow and re-calibrate again. Repeat until the correct value is obtained.

2) Note for fertilizer, the percent of N in urea is 46 and N and P_2O_5 in DAP is 18 and 46% respectively. In order to get the correct quantity of urea or di-ammonium phosphate you need to divide the N or P_2O_5 value wanted to apply by the percent nutrient to get the amount of product. For example:

    - ♦ To get 100 kg N per hectare divide 100 by 0.46 to get 217 kg of urea or 21.7 grams per square metre.
    - ♦ For P_2O_5 you first calculate the P_2O_5 value needed and then see how much N is also applied. For example to add 50 kg P_2O_5 divide 50 by 0.46 to get 109 kg/ha DAP or 10.9 grams per square square. This also applies 109 times 0.18 or 19.6 kg N per hectare.

6B.3. Planting

Once the drill is calibrated, fill seed and fertilizer boxes with the appropriate quantity of seed for the area to be planted. Don't add too much, otherwise the chore of cleaning out the extra seed and fertilizer will be harder. During the planting, the operator or attendant needs to check the seed and fertilizer boxes to make sure there is sufficient material available over each hole so that missing lines do not occur.

Adjust the pressure of the press wheel (Plate 6B.14) to have the slot made by the opener properly pressed to ensure good seed and soil contact. To adjust the pressure, remove the clip at the top of the spring assembly, tighten the spring, and replace the clip in a lower hole.

The speed with which the tractor moves does not affect the seed rate. If the tractor moves faster, the seed flows faster but applies the same seed or fertilizer per hectare. During the first pass of the tractor check the depth of seeding and fertilizer placement, and adjust as necessary. Make sure that when the end of a pass of the tractor is reached, the seed drill is raised while still moving forward and before the tractor stops. This is to prevent seed and fertilizer dropping and clogging of the tubes. At the end of each row have a person check that the tubes are clear and that the seed and fertilizer are dropping properly.

6B.4. Maintenance of the Zero-Till Drill

Always carry out the following maintenance before and/or after use as appropriate

Before Use

1) Never mix DAP and urea together unless you intend to use immediately. These two compounds tend to deliquesce and form a solid mass if left too long. That will then require a lot of effort to clean the fertilizer box.
2) Maintain the proper chain tension on the drive chain (Plate 6B.11) using the adjustor, and check the chain fits the sprockets properly and that the sprockets are not worn. Replace sprockets and chain if needed.
3) Oil and grease all moving parts, especially bearings and sprockets. If grease nipples are not fitted for bearings, carefully remove bearing caps (without dropping them in the dirt!), pack the bearings with grease, and replace the bearing caps securely.
4) Replace broken parts from a stock of spare parts kept at the workshop. **Replace parts as they break** - do not wait until the whole machine does not work!
5) Tighten all nuts and bolts each morning before use, and after breaks - to make sure they don't come loose and get lost. Make sure that the openers are held tightly and straight. Use a set of spanners that fit the nuts and bolts of the machine - continual use of pliers will round the nuts so that spanners cannot grip them.
6) Make sure the tubes are properly fixed so that they do not come loose during operation. Check before use that tubes are not blocked, and re-check frequently during use. Fit clear plastic tubes so that seed and fertilizer can be seen moving through them during work.

After use

1) Always clean out excess seed from the "seed box" **immediately** after use. It will pick up moisture and start to germinate or go mouldy, and form a solid mass. This can be done by removing the clip that holds the black plastic cover and green cup and pulling the slide out fully (Plate 6B.10).

2) In trial work it is essential that all seeds are cleaned out between plots. Use a soft brush and pan to collect seeds. An easy way is to use a small vacuum cleaner designed for cleaning cars, worked off a 12 volt car battery.

3) Always clean out excess fertilizer from the Fertilizer box **immediately** after use. This can be done by removing the clip that holds the black plastic cover and green cup and pulling the slide out fully (Plate 6B.10). **Never leave fertilizer in the fertilizer box**. It will cake solid and rapidly corrode the metal of the box and metal parts of the metering system.

4) Wash out the last traces of fertilizer with **boiling water**, and use an old tooth brush to remove fertilizer caked on to fertilizer flutes, fertilizer slides, around openings from the fertilizer box, and inside the fertilizer cup. Wash out the plastic fertilizer tubes, and remove fertilizer from the fertilizer openers. Make sure all parts are dry before using again.

Plate 6B.1. Zero-till drill from the front and side, set up for 6 rows – 4 in the rear and two in the front; and for seed (front) and fertilizer (back box).

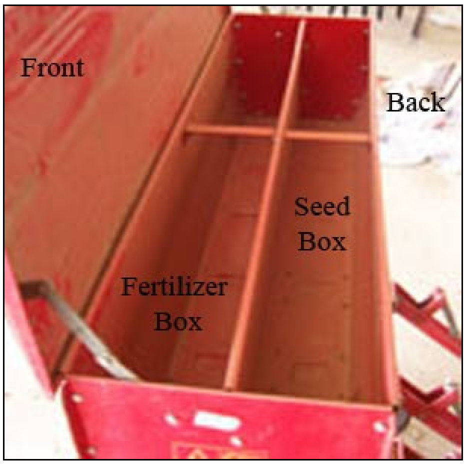


Plate 6B.2. Fertilizer and seed box

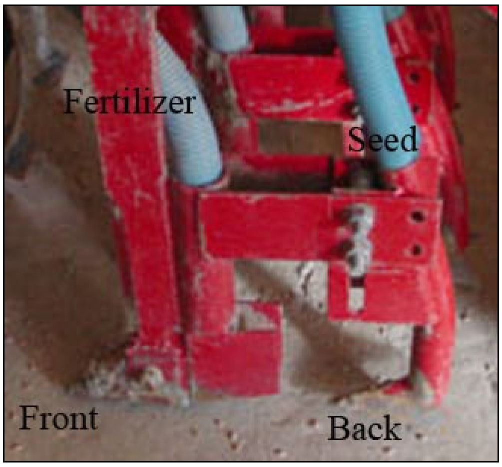


Plate 6B.3. Openers with fertilizer & seed tubes

Plate 6B.4. Shaft of the opener that is raised or lowered to adjust depth of planting.

Photos: Peter Hobbs

Plate 6B.5. Space openers by loosening and moving the brackets to get desired distance between rows

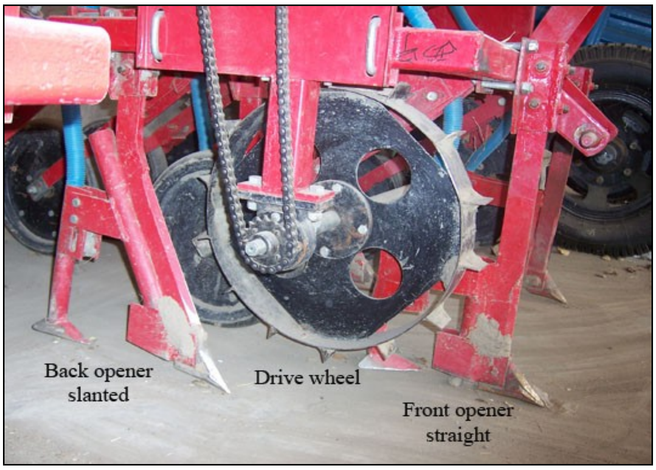


Plate 6B.6. The different type of front and back openers

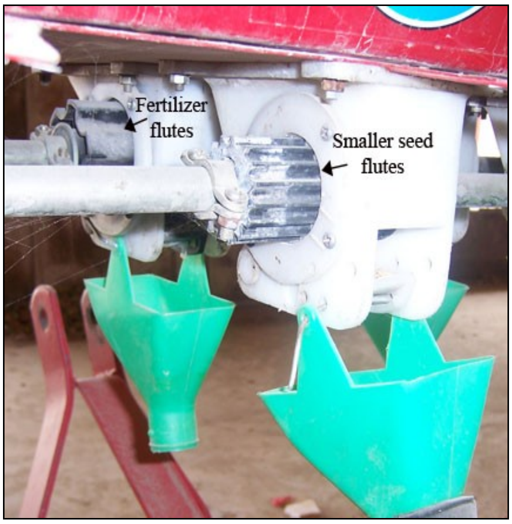


Plate 6B.7. Seed and fertilizer flutes

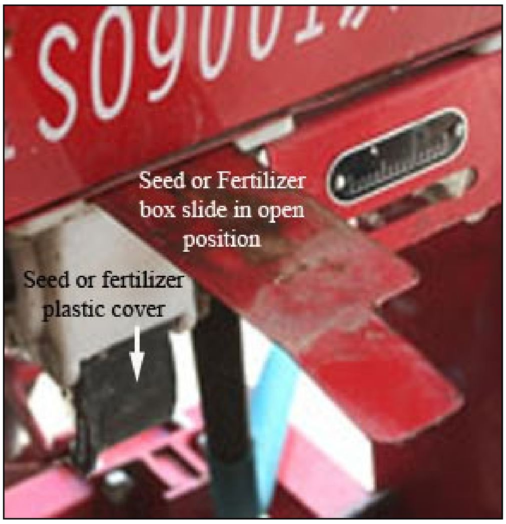


Plate 6B.8. Seed and fertilizer slide and plastic cover shown open

Plate 6B.9. Clip holding plastic cover and the plastic cover

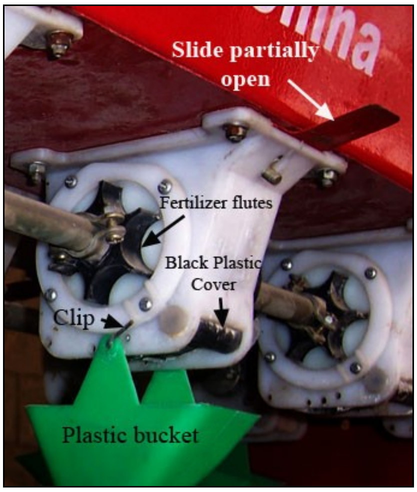


Plate 6B.10. Various components of the fertilizer system

Photos: Peter Hobbs

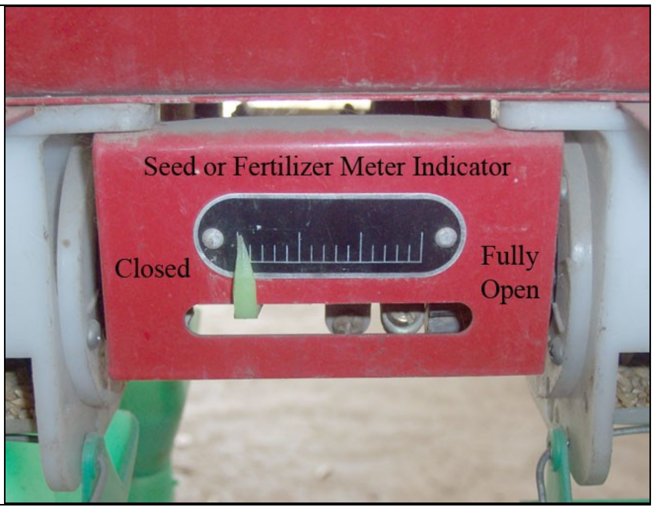


Plate 6B.12. Seed or fertilizer meter indicator set to zero

Plate 6B.11. Zero -Till drive system

Plate 6B.13. Seed or fertilizer adjustment wheel and lock nut

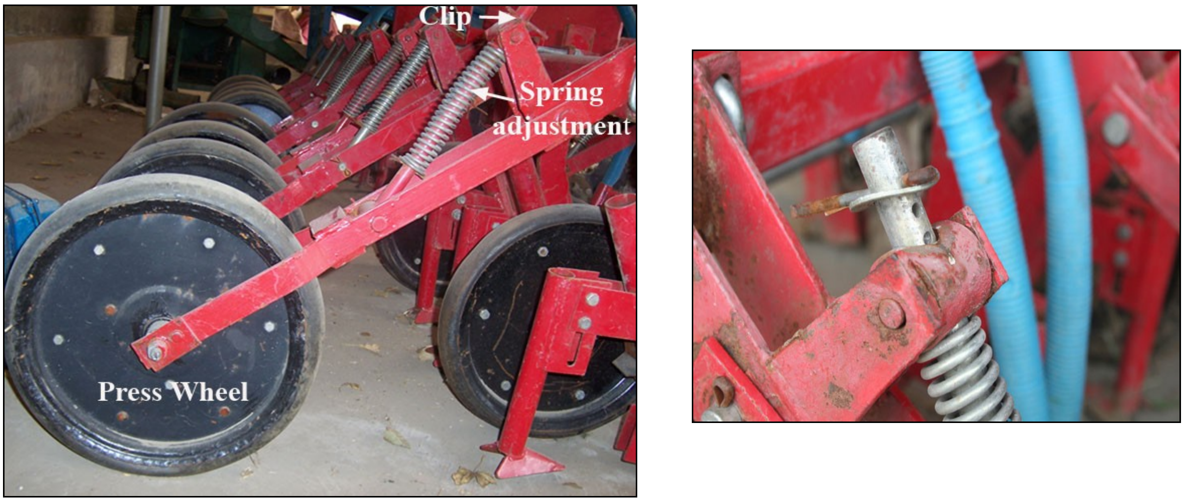


Plate 6B.14. Press wheel assembly and the clip holding the spring adjustment

Photos: Peter Hobbs

Section 3 FODDER PRODUCTION, CONSERVATION & FEEDING

Chapter 7 FODDER CROP OPTIONS

Ian Lane

Section 3 FODDER PRODUCTION, CONSERVATION & FEEDING

Chapter 7 FODDER CROP OPTIONS

7.1. Options for Fodder Crops

There are many options to produce fodder crops in the lower central valleys of Tibet. The government plans to improve the sustainable livelihoods of farmers by production of cash crops and commercial livestock keeping. Where farmers are able to market livestock products, they may in future have the opportunity to grow fodder on all types of land. In this introduction options available to farmers to grow fodder crops are considered, although the main emphasis remains on the production of fodder as a catch crop within double cropping systems. Possible Fodder Crop Systems are shown in Figure 7.1. Different fodder crops are relevant for each system, and for different land resources.

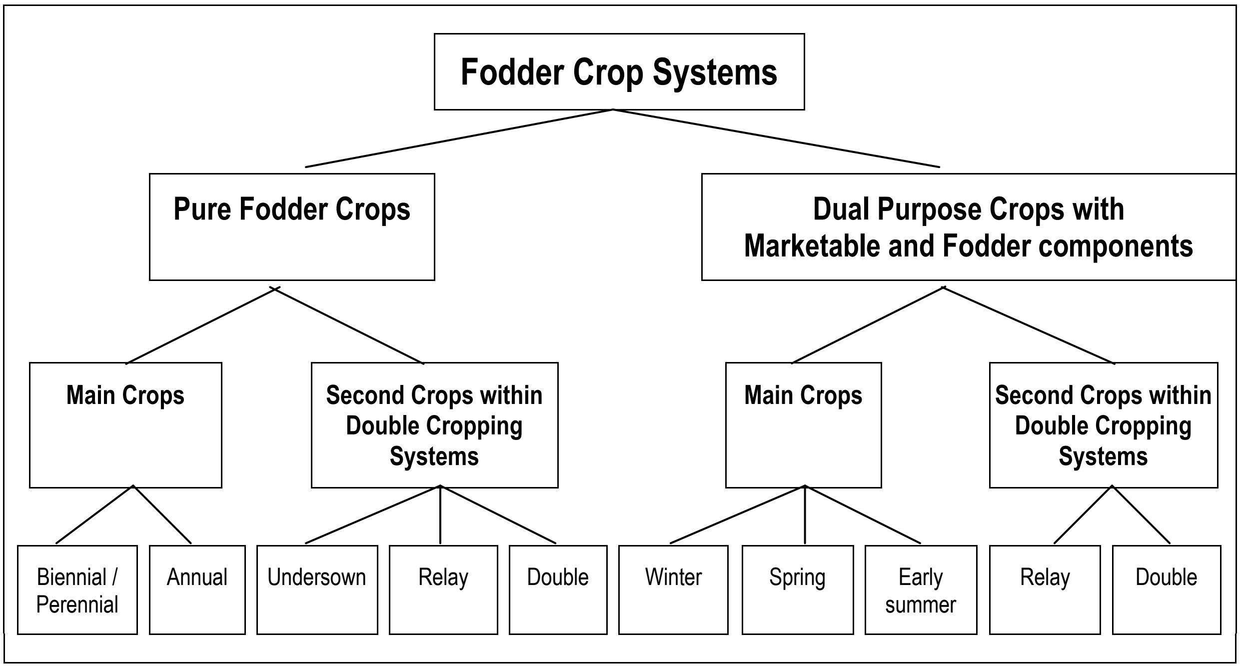


Figure 7.1. Options for Fodder Crops in the lower valleys of central Tibet

First the terms used with respect to fodder crop systems need to be explained:

Fodder Crop System: the complete system which defines the fodder crop to be grown, its place within the annual cropping cycle, and the livestock being fed.

Pure Fodder Crops: fodders which are produced solely for feeding animals, without a product which can be used as food for people.

Dual Purpose Crops: crops grown primarily for human food or as a cash crop, but which also provide by-products which can be fed to animals - such as barley; they also include crops primarily grown as fodder to feed livestock, but which have a product which can be used for human food or marketed - such as turnips.

Main crops: the main crop within the annual cropping cycle that occupies the land for the major part of the growing season - such as winter wheat or spring barley.

Second Crops (SCs): a short duration or "Catch Crop" that is grown following the harvest of the main crop within a "Double Cropping System" in order to fully utilise the land during the possible growing season.

"Early Bite" a short duration pure fodder crop that is sown in autumn to provide green fodder in spring and early summer. It can then be followed by a main crop

	that is normally sown in early summer, or by a pure fodder or dual purpose second crop. Winter cereals, such as wheat and triticale, can also be harvested for fodder as an "Early Bite", before being grown on for a harvest of grain provided they are top dressed with fertilizer after the fodder cut.
Under sown SC:	a second crop that is slow to establish, and is therefore grown under a main crop without affecting the yield of the main crop. After the main crop is harvested, the established second crop can grow quickly. Normally a small seeded biennial or perennial legume is sown under a winter cereal crop by broadcasting or drilling the legume in spring into the established cereal. The exact methods are still being developed for the Project area.
Relay SC:	the second crop is sown into the standing main crop 2-4 weeks before harvest of the main crop. Small seeds of suitable crops may be broadcast, while large seeds must be hand planted into the main crop. This provides additional growing time for the second crop, given that traditional crops of winter wheat (WW) are harvested in early August. Yield of the main crop is not affected.
Double crop SC:	the second crop is planted after the main crop is harvested. Traditionally the land is ploughed, the second crop is broadcast by hand, and the land is then either just left or levelled with a board. The second crop is preferably drilled into a levelled seedbed, which allows lower seed rates to be used.
Sole crop:	where a fodder crop, generally a legume, is grown by itself.
Inter-crop:	where one crop is grown separately to another crop on the same land - for example peas hand sown in spring into the irrigation bunds of a WW crop.
Crop Mixture:	where two or more crops are grown together as mixture. Frequently fodder crops are grown as a mixture of a one or more cereals, and one or more annual legumes. The cereal provides a vertical structure which supports the climbing legume, which otherwise collapses on the ground with reduced yields. In addition the cereal provides the bulk and high energy content, while the legume provides the high protein content.
Bi-Crop:	a Crop Mixture restricted to only two components, usually one cereal and one annual legume.

The land resources available for production of fodder crops can be considered in three major classes. These classes can be sub-divided, and other lands can be developed for forage production.

Irrigated grain lands:	the main land resource for the introduction of double cropping for fodder production, now also possibly available for growing fodder as main crops.
Second class irrigated lands:	previously the only lands available to grow biennial and perennial fodder crops, they remain a major resource. Their use for cereal production is limited by availability of water throughout the growing season, by seasonal flooding, and/or by soil fertility and soil structure. Fodder crops have to be selected that are adapted to the limitations of particular sites.
Rainfed lands:	growth is restricted to the main rainy season, so that the short duration fodder crops used in double cropping must be grown. However no irrigation is available to establish crops before the arrival of the rains, or to extend the growing season after the rains.

Many fodder crops are suitable for more than one system and land class. Fodder crops are therefore listed against systems and land classes for which they are suited in Table 7.1. Brief introductions to the use of each fodder crop are given in the following sections. Plate 7.1 shows the fodder crop observation trial established in July 2005 at TARI field station, Lhasa. Fodder crops and varieties

Table 7.1. Pure Fodder Crops and Dual Purpose Crops suited to Land Classes and Systems

Fodder Crop	Land Class			Fodder Crop System										
				Pure Fodder Crops					Dual Purpose Crops					
				Main Crop		Second Crop			Main Crop			Second Crop		
	Irrigated grain land	Second class irrigated	Rainfed	Biennial / Perennial	Annual	Undersown	Relay	Double	Winter	Spring	Early Summer	Relay	Double
Annual Forage Legumes													
Common Vetch (*Vicia sativa*)	***	***	***		***	*	***	***					
Hairy Vetch (*Vicia villosa*)	***	***	***	*	***	*	***	***					
Forage Peas (*Pisum sativum arvense*)	***	**	*		***			**		**	***		**
Fenugreek = Xuisha (*Trigonella foenum-graecum*)	***	***	***		***			***		***	***		***
Biennial / Perennial Forage Legumes													
Lucerne (*Medicago sativa / M. falcata*)	***	**		***	**	***		**					
Melilotus (*Melilotus officinalis / M. alba*)	***	***	*	***	**	***		*					
Sainfoin (*Onobrychis viciifolia*)	**	**		**	*	*							
Red clover (*Trifolium pratense*)	***	**		***	**	***							
Vegetable / Pulse Legumes													
Peas (green peas in pod) *(Pisum sativum)*	***	*								**	***		**
Peas (pulse crop) (*Pisum sativum*)	***	*								**	***		
Peas (edible pods)(*Pisum sativum axiphium*)	***	*								**	***		**
Broad Beans (*Vicia faba*)	***	*								**	***	**	***
Bush Beans (green pods) (*Phaseolus vulgaris*)	***	*								**	***		***
Bush Beans (pulse crop) (*Phaseolus vulgaris*)	***	*								**	***		
Runner Beans (*Phaseolus coccineus*)	***	*								**	***		*
Root and Leafy Brassica													
Fodder Beet (*Beta vulgaris*)	***				***								
Turnips (*Brassica rapa var. rapa*)	***									*	***	*	***
Stubble Turnips (*Brassica rapa var. rapa*)	***	***	**								***	***	***
Fodder kale (*B. oleraca convar acaphala*)	***	**								**	***		*
Forage Rape (*Brassica napus (partim)*)	***	**	**								***	***	***
Rapeseed (for oil)(*B. napus / B. rapa*)	***	*								***	**	*	**
Cabbage (*Brassica oleraca capitata*)	***	**									***		*
Cereals and Grasses													
Italian ryegrass (*Lolium italicum*)	***	**	**	**	***			***					
Annual Ryegrass (*L. multiflorum* var. Westerwoldicum)	***	**	**		***			***					
Rye (*Secale cereale*)	***	***	**		***			**	***	***			
Oats (*Avena sativa*)	***	***	**		***			**	***	***			
Triticale (T. aestivum x S. cereale)	***	***	**		***			**	***	***			
Wheat (*Triticum aestivum*)	***	**	*		***			*	***	***			
Barley (*Hordeum sp*)	***	***	**		***			*	***	***			
Maize (*Zea mays*)	***	**			***						**		
Cereal / Legume Bi-crops													
Oats / Vetch (Common / Hairy)	***	***	***		***			***					
Oats / Peas	***	***	**		***			**		***			**
Oats / Forage Peas	***	***	**		***			**		**			**
Wheat / Vetch (Common / Hairy)	***	***	***		***			***					
Wheat / Peas	***	***	**		***			**		***			**
Wheat / Forage Peas	***	***	**		***			**		**			**
Minor Crops													
Buckwheat (*Fagopyrum esculentum*)	***	***	*		***			*		***	**		*
Amaranthus (grain and fodder) (*Amaranthus sp*)	***	***	*		***			*		***	**		
Sunflowers (*Helianthus annus*	***	***	*		***			*		***			

Notes: Number of asterisks indicates the relative suitability of that fodder crop for that Land Class or Fodder System compared to other fodder crops within crops were evaluated as second crops in late September / October 2005 (Plate 7.1.1). Growth of biennial / perennial species which survived the winter is shown in Plate 7.1.2, and subsequent early summer growth of these varieties was evaluated in early July 2006 (Plate 7.1.3).

7.2. Annual Forage Legumes

More detail is included in this section than in rest of the chapter, as the project has focussed on cereal / vetch double cropping systems. This has included several experiments at Lhasa and Gongga field stations, on-farm experiments in Qushui and Naidong, plus other demonstrations with farmers.

7.2.1. Common vetch (*Vicia sativa* L.)

Land Class

Common vetch is adapted to a range of soils but not to poorly drained soils, and it will not survive prolonged flooding. Vetch prefers well-drained moderately fertile soils with pH 6.0-8.0. It has strong seedling vigour, but it is susceptible to drought at the early stage of establishment. It responds to fertilization with phosphorous (P), but not to nitrogen (N) except on highly deficient soils. It is therefore well suited to irrigated grain lands, second class lands with fertilization, and will grow on rainfed lands provided sowing is delayed until after the rains have arrived. A reliable response to zero-tillage after winter barley has been found compared to relay cropping. It has a high potential to fix N, but rhizobial inoculation of seed is needed if sown on land where it has not been grown before.

Main Crop

The standard variety of Vetch grown by TARI originated in Japan and is known as Gansu 333. It was the best variety in trials in Tibet several years ago. A second variety has been introduced from Gansu, Xinu 880, which flowers by July when sown in April. This means that seed might be produced locally, which will overcome present shortage of seed in Tibet. Several varieties of vetch have been evaluated as spring sown sole crops at various sites by TLRI.

Vetch has a rapid growth rate and a sprawling growth form, but grows upright when sown as a mixture with a companion cereal (Plate 7.2.2). Oats are commonly used elsewhere, but in Tibet due to farmers' concerns over wild oats it may be more acceptable to farmers to use wheat or triticale. In UK both cereal/vetch bi-crops and arable fodder mixtures including a cereal + vetch + peas are used.

The best system for vetch depends on the location of the individual farm, and the fodder requirements of the farmer. Points to consider include:

- the altitude of the field - lower sites have longer growing periods before and after the rainy season
- the fodder requirements of the farmer - to feed high protein green fodder during early - late summer or to conserve large quantities of high - medium quality fodder as hay
- if grown for making hay, whether the crop can be harvested in hot dry weather before the rains come - or whether the crop has to be grown through the storms of the rainy season in order to harvest in late September when the crop will be mature and hay may be slow to dry
- whether the legume fodder crop is to act as a break crop between continuous cereal crops.

After 6-8 weeks growth vetch is 10 - 15 cm high and can be grazed or cut for green fodder to a stubble height of 3-5 cm. This leaves basal axillary buds from which regrowth occurs, so that more than one cut can be taken. If grown as a sole crop for conservation , the optimum time for harvest is at 50 percent flowering, which occurs after three months active growth. This provides hay yields of 3-5 tons/ha at 25 percent CP. Although yields increase further if the crop grows to early or late pod filling stage, CP declines to 20%. When grown in a mixture with a cereal, the optimum time to cut the mixture is determined by the stage of maturity of the cereal grain - this should be between the milky and soft dough stages, which occurs 4-6 weeks before normal harvest of cereals. At this time the vetch will be in pod, and yield of digestible energy and CP from the mixture will be at a maximum. Yield of hay from bi-crops will be 6-8 tons/ha. The cereal must grow strongly to support the vetch, or else the vetch will dominate and the whole crop will collapse. This means the crop must be on fertile land, or be well fertilized with DAP to encourage the cereal.

Establish a sole crop of vetch in late spring as for a crop of spring barley, by one of various methods. Control weeds at other places in the rotation, such as broadleaved weeds within cereal crops. Calibrate seed drills for vetch seed before use:

1) Use traditional methods to prepare a well cultivated, uniform seed bed, broadcast vetch seed and cover with a board
2) Use traditional methods to prepare a well cultivated, uniform seed bed and drill vetch seed at 3-5 cm depth with good soil cover
3) Zero-till drill vetch into land previously ploughed in the autumn
4) Zero-till drill vetch into residues left from a previous crop for Conservation Agriculture.

Grow vetch-cereal bi-crops for fodder conservation. At upper altitudes use winter cereals to obtain harvest at the milky - soft dough stage in June/July before the rains. Harvest bi-crops with spring cereals in June/July at lower altitudes, or in September at upper altitudes. Several methods are available to establish bi-crops of common vetch and cereal to meet these different objectives:

1) Establish winter cereals as normal, using cold tolerant varieties of wheat, triticale, barley or oats. Since common vetch is not winter hardy in Tibet it can not be sown at this time. Therefore sow the vetch in spring by drilling into the established cereal crop while it is still vegetative. Either use a normal seed drill, or preferably use a zero-till drill, at 3-5 cm depth. Vetch seed can also be broadcast at this time, followed by a light harrow over the cereal crop
2) Mix seed of vetch with seed of spring cereals and establish the crop as for spring cereals by broadcasting, or by drilling or zero-till drilling the seed mixture at the normal depth for cereals. These are the standard methods for sowing spring vetch-cereal mixtures
3) Drill spring cereals and common vetch in separate passes, cereals first, using the appropriate seed depths for each crop. On larger areas the two passes should be diagonal to each other; on narrow strips sow the cereals in straight rows, and weave the vetch rows along their length. With a combination drill split the fertilizer dressing, and apply more N to cereals and more P to vetch.
4) Establish the vetch-cereal bi-crop as an inter-crop. Use a drill with separate compartments in the seed box for each drill coulter, or make separate compartments, and sow alternate rows of vetch and cereal. If possible adjust the sowing depth to 3-5 cm for the vetch coulters. With a combination drill that also places fertilizer, again make separate compartments so that more P is applied to vetch and more N to the cereal.

Seed production is a limiting factor for large scale sowing of vetch for fodder production, as seed yields tend to be 400 - 800 kg/ha, and threshing is difficult. Seed rates for vetch depend on whether it is a sole crop or part of a mixture, and whether seed is broadcast or drilled (Table 7.2). There is considerable flexibility in seed rates, but higher rates of vetch need to be used the poorer the land and the less well cultivated it is. Half the rates shown are used in semi-arid countries such as Australia and USA with extensive agricultural systems.

Table 7.2. Main crop seed rates (kg/ha) for vetch and companion crops according to method of establishment of individual components and the fodder crop system

Fodder Crop	Broadcast and covered			Drilled		
	Sole	Bi-crop	Arable mixture	Sole	Bi-crop	Arable mixture
Vetch	120	75	50	75	50	25
Cereal	-	150	125	-	100	75
Peas	-	-	75	-	-	50

Spring fodder crop demonstrations have been run by nine farmers' Forage Groups on an FAO project in the mountains of Serbia with similar temperatures to the valleys of central Tibet. Yields for various vetch / cereal bi-crops averaged 8.3 - 9.4 t DM/ha in 2004 (Table 7.3). There was, however, major variation in yields between sites, from 4.6 to 15.0 t DM/ha. If data from pea / cereal bi-crops are included (this data is given separately here in the appropriate section) it was found that there were no relationships between yield of fodder and altitude (700 - 1300 m.a.s.l.) or soil pH (5.5 - 7.0) (Figure 7.2). However a Soil Fertility Index accounted for 34 percent of the variation in yield. This Soil Fertility Index is based on simple observations of previous land use, actual or likely application of manure, and known level of fertilizer use for crops at each site. It is expressed on a score of 1 (low) -

Table 7.3. Fodder yields from vetch / cereal spring fodder crop demonstrations in Sandzak region, Serbia, 2004 (t DM/ha)

Spring fodder crop	Mean	Site Number								
		1	2	3	4	5	6	7	8	9
Vetch / oats	9.4	-	-	-	15.0	-	8.6	4.6	9.6	-
Vetch / triticale	8.4	6.4	8.0	6.2	-	13.9	7.2	-	-	-
Vetch / barley	8.3	-	-	-	-	-	-	-	-	8.3

Varieties: Common Vetch: Novi Beograd; Oats: Slavuj; Triticale: KG-20; Barley: Dunavac

(Data from the Report on the Forage Specialist's Sixth mission, 17th - 30th April 2005, Development assistance to livestock farmers in the mountainous areas of the Sandzak region, GCP/FRY/001/NET)

3 (high). It is a minimum expression of soil fertility, and can be easily applied to data from fodder crop demonstration sites in central Tibet. It needs to be refined with results from analysis of soil samples from each demonstration site, and survey data of farmers' actual use of manure and fertilizer. This relationship reinforces the need to apply the same level of manures and fertilizers to legume / cereal fodder main crops as farmers use for their grain cereal crops.

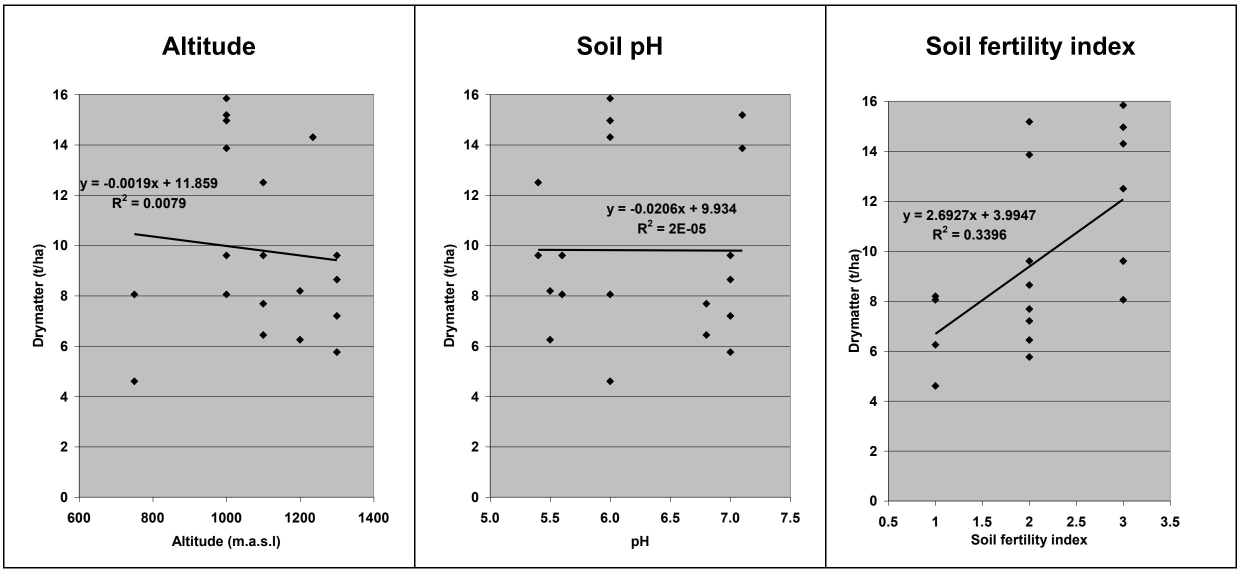


Figure 7.2. Response of dry matter yield of legume-cereal bi-crops to external factors in Sandzak region, Serbia, 2004

(Data from the Report on the Forage Specialist's Sixth mission, 17th - 30th April 2005, Development assistance to livestock farmers in the mountainous areas of the Sandzak region, GCP/FRY/001/NET)

Second Crop

Double cropping with vetch as the second crop has been a major focus of research and development over the past three years at TARI, supported by FAO and ACIAR projects. Varieties sourced from Gansu are under evaluation at the TARI field station specifically for double cropping (Plate 7.2.1).

In 2005 vetch sown in late July had the yields of 5-5-6.0 t/ha air dry fodder (4.9-5.4 t DM/ha) when harvested in early October. The best varieties reached 30-35 cm in height at this time (Table 7.4). Commercial varieties of common vetch, as frost sensitive annuals, do not survive the winter following harvest (Plate 7.1.2). The stubble that remains after harvest of fodder in autumn is well suited to zero-till drilling of a following winter cereal.

Table 7.4. Growth of varieties of common vetch grown in an Observation Trial at TARI field station, sown in late July 2005

Fodder crop and variety	Source	Visual evaluation on 25 September 2005	Height (cm)	Sc[1]	DM yield (kg/ha)
Vetch Lanzhou	Lanzhou	Vigorous, leafy with deep green colour, non-flowering; better than local for nutritive value	35	8	4928
Vetch Gansu 333, Local	TARI	Vigorous, early flowering	30	7	5448

Notes: 1) Score for each fodder species and variety on a range 0 (bad) - 9 (good)

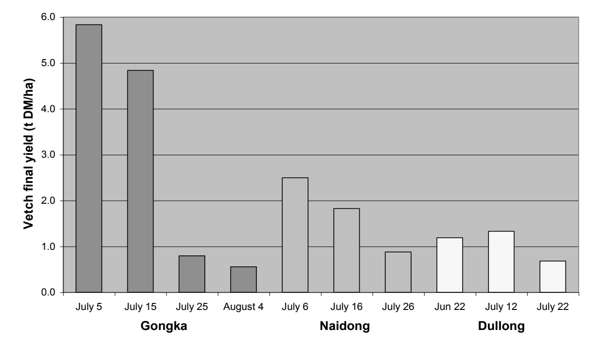
Relay Second Crop

Vetch is a prime candidate for relay cropping (Plate 7.3), and much work has been carried out to define the process and establish the conditions that must be met in order to achieve success. In principle vetch seed is broadcast into the standing cereal crop 2-4 weeks before harvest, and establishes on the soil surface:

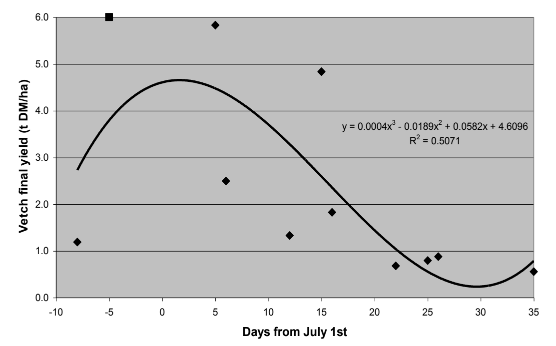
- in the middle of the altitude range, broadcast vetch seed over WB in mid to late June, and over WW in early to mid July
- use a seed rate of 150 kg/ha (10 kg/mu) dry seed
- scarify the vetch seed if sowing before the main rainy season, in order to soften the hard seed coat for quick germination - this is not needed if the rainy season is well established
- to scarify the seed, soak the seed for five minutes in freshly boiled water; drain, then air dry the seed. Sow scarified seed as soon as possible
- broadcast the scarified seed when the soil is moist, at a time when the soil can be kept moist by rain or irrigation - if the seed germinates but then dries out the crop will fail. If the rains have not come and irrigation is not possible, do not scarify or sow the seed
- control seed eaters:
  - scare birds away for at least two weeks - until the crop has germinated
  - control mice and other field rodents
  - control ants, which can steal seed, with insecticides or boiling water
  - plant large areas to reduce losses from seed eaters.

While success has been achieved with relay sowing vetch into WB the risk of crop failure due to late rains is high, since seed is sown earlier than for WW. Good establishment was achieved in the wet year of 2004 with an early sown crop at Gongga on a flood prone site (Plate 7.3.1), leading to fodder yields of 5-6 ton DM/ha. However, in a year with late rains in 2005, good establishment on field trials at Qushui was only obtained on a farmer's plot which had a thin crop of barley, thus reducing moisture stress (Plate 7.3.2). Relay sowing of vetch into WB is weather sensitive, and more work is needed to establish the full conditions required for its success. In addition, due to the soft stems of Winter Barley, farmers do not wish to walk through the semi-mature crop, since this can lead to losses due to lodging.

It is more appropriate to relay sow vetch into WW, since the time of sowing is closer to the start of the rains. In 2004, when rains came early, yields of vetch DM harvested at the end of the growing season from an ACIAR trial on wet fertile land at Gongga were 5 - 6 t/ha when seed was broadcast by mid July, but yields from later sowings were greatly reduced (Figure 7.3.1, Plate 7.3.3). Production of vetch sown into WW on field trials at Naidong and Duilong in 2004 was, however, only 1.3-2.5 t DM/ha (Figure 7.3.1). The site at Naidong was flooded for a long period, and was also infested with weed (*Equisetum* sp). The altitude at Duilong is 3750 m.a.s.l., above the generally accepted upper limit for double cropping of 3650 m.a.s.l. Feimai winter wheat is two weeks later in growth at this site compared to Lhasa city, and is only harvested in late August / early September. This has a major effect on relay sown vetch - as the wheat has full leaf cover later into the season leading to severe competition for light - especially with early sown vetch. The high altitude of the site in general reduces the potential for growth of a second crop, due to lower temperatures and earlier occurrence of frost in autumn. In addition weed density in farmers' crops of WW at Duilong is high, despite late spraying of 2,4-D herbicide against broad leaved weeds.



7.3.1. Effect of time of sowing at each site



7.3.2. Fitted curve for all data from the three sites

1. Data courtesy of ACIAR, 2004
2. The value with a square symbol at -5 days (that is, 25 June) is estimated as the yield for vetch relay sown into winter barley in a plot next to the ACIAR trial at Gongga (6.0 t DM/ha)

Figure 7.3. Effect of sowing time on end of season vetch production for vetch relay sown into WW in three ACIAR trials, 2004

A curve can be fitted to the ACIAR data on the effect of sowing date on the final yield of fodder from relay sowing vetch into WW (Figure 7.3.2). This indicates that fodder yields of 4 t DM/ha can be expected from relay sowing between 25 June to 15 July. However, the curve only accounts for half of the variation in yield. At this stage it is too risky to plan large scale demonstrations of relay sowing vetch into winter cereals.

A large number of small scale demonstration plots should be established for relay sowing vetch into winter wheat throughout the Project area over 2-3 years, organised with county and township agricultural officials:

- *area*: 1 mu for each time of sowing
- *wheat varieties*: Feimai and Bussard
- *times of sowing*: 5, 15 and 25 days after the start of the main rainy season
- *seed rate*: 150 kg/ha dry seed (10 kg/mu)
- *scarification of vetch seed*: soak seed for first sowing date
- *fencing*: needed for all plots to keep out grazing animals
- *supporting records*:
  - wet and dry days - for weather
  - days the site is flooded
  - days/nights of frost
  - yield of the winter cereal crop into which the vetch is sown - competition and fertility effects
  - score for presence of weeds at time of harvest of the wheat.

This will allow the effect of time of relay sowing on final yield of vetch to be established more precisely, so that definite recommendations can be made to farmers with estimates of the probability of success - linked to likely economic returns.

A further problem with relay sowing vetch at present is the high seed rate required in order to ensure successful establishment. Given the losses to birds, rodents and insects, rates of 150 kg seed / ha are needed. Besides the expense, seed supplies are not available for large scale planting at these high rates. Ways must be found to treat the seed with bitter or unpleasant compounds so that the seed is rejected by birds and rodents, but at the same time germination is not affected. In the short term use chili pepper, mixed with the seed after it has been soaked for scarification. Include an insecticide such as derris powder in order to reduce stealing of seed by ants. If these measures are successful it will be possible to reduce seed rates to 100 kg/ha for relay sowing.

Double Crop

It is appropriate to establish vetch after winter barley as a Double Crop, since WB matures and is harvested about one month earlier than current varieties of WW. In order to provide a break between successive cereals, grow vetch as a sole crop rather than as a mixture with cereals. Sow a little rapeseed with the vetch to provide more structure to the crop, even though this practice has not been proven to increase fodder yields. The key factors are to sow the vetch as early as possible, and to minimise the time between harvest of the cereal and the sowing of the vetch. Major points and possible methods include:

1) Grow the short duration WB variety Dongqing # 1, and harvest it manually by the second week of July. Higher yielding WB varieties can be grown, but harvest of all varieties available at present is 2 weeks later. Line up stooks to the side of the plots as is already done when turnips are grown. Then either:
2) Plough the stubble and use a board to level. Broadcast the vetch seed, and either use the board again or use a thornbush brush behind the tractor / animals to lightly cover the seed; or
3) Use traditional methods to prepare a well cultivated, uniform seed bed and drill the vetch seed at 3-5 cm depth with good soil cover; or
4) Zero-till drill vetch directly into the cereal stubble - this is the preferred method for using vetch within Conservation Agriculture
5) This is the classic cropping situation to use zero-tillage (Plate 7.4), although all the possible methods to establish vetch through cultivation have to be considered since only a few zero-till drills are available at present in the Project area. The main benefits of zero-till drilling vetch as a double crop include:
   - *timeliness* - as soon as the cereal crop is harvested the vetch can be sown
   - *establishment* – better germination and establishment, especially by a rota-seeder during dry weather, compared to traditional broadcasting or drilling (as observed in 2006 at Lhasa)
   - *labour* - a single pass with a tractor and drill can establish the fodder crop; this can be carried out by a machinery group or private contractor in the village
   - *capital* - half the seed rates can be used compared to the traditional method of broadcasting and covering the seed - 60 kg/ha compared to 120 kg/ha
   - *land* - due to savings in labour and capital, twice the area can be zero-till drilled compared to standard ploughing and broadcasting
   - *cropping systems* - due to these savings, it can also be worth zero-till drilling vetch into cereal stubbles following WW.

   It is essential, however, that weeds are controlled in the preceding cereal crop, or sprayed off with contact or systemic herbicide (Roundup) prior to drilling.

An alternative cropping system is to harvest an awnless variety of winter wheat for whole-crop cereal silage at the milky - soft dough stage 4-6 weeks earlier than normal grain harvest. This WW can then be followed by double crop vetch.

Large plots of cereal stubble previously grown to WB and of WW were zero-till drilled with Vetch at the TARI field station, Lhasa, in the summer of 2005 (Plate 7.4.1) with the results shown in Table 7.5. Plots were sampled for yield in early October. Both WB and WW crops were harvested two weeks later than normal farmer practice in most of the project area, and this resulted in late drilling of the vetch.

Table 7.5. Evaluation of zero-till drilling of vetch into cereal stubbles, TARI field station, Lhasa, in 2005

Crop	Date of sowing vetch	End of season vetch yields t DM/ha	Evaluation
Winter barley Dongqing #1	July 25	5.0	Zero-till drilled into WB stubbles 1 week after harvest of cereals. Excellent establishment despite late rains, with vigorous growth to 40cm (Plate 7.4.3). An excellent crop for fodder conservation. These plots were to be zero-till drilled into WW.
Winter wheat Feimai	August 28	1.2	Sown as late as possible after WW harvest to see how effective it might be. Excellent establishment, but the crop only reached 10 cm height, due to shorter growing period (9 vs 13 weeks) and growth which occurred late in the season (Plate 7.4.4). Sufficient growth for grazing before zero-till drilling of WB. Nodulation of vetch has occurred after just one month's growth, although nodules are too small to be effective.

In addition, a long term double cropping systems experiment is being carried out at TARI field station, Lhasa. All plots were sown to WB in October 2004. 2,4-D was used in spring to control broadleaved weeds in the barley crop, but no further weed control was carried out. Vetch was established following WB on 10 August by three different methods, with results shown in Table 7.6

Table 7.6. Evaluation of methods of establishment of vetch following winter barley, TARI field station, Lhasa, in 2005 and 2006

Cropping System	Year	End of season vetch yields t DM/ha	Evaluation
Farmer practice: Ploughed, not levelled; vetch broadcast	2005	2.0-3.0	Good establishment in patches, related to uneven land (Plate 7.5.1.) Overall 60 percent establishment with lower plot yield. Strong weed growth between patches of vetch
Improved farmer practice: Ploughed, levelled, vetch sown with drill	2005	3.5-4.0	Good establishment (Plate 7.5.2.) Weeds concentrated along tractor wheel lines.
Zero-tillage – zero-till drill:: Vetch zero-till drilled into cereal stubble	2005	3.5-4.0	Good establishment (Plate 7.5.3.) Weeds scattered through crop.

All crops of WB were harvested later than farmers' normal practice, which delayed establishment of the vetch. In addition irrigation was not available to these plots during this season, so the results represent what might be achieved on second class irrigated land or rainfed land. All methods resulted in useful stands of vetch, with end of season yields of vetch of 2.5 - 4.0 t DM/ha.. Yields would have been higher if plots had been irrigated at the time of sowing, and sowing of vetch had been more timely. However these are still useful yields of fodder for farmers. In 2006 when dry conditions followed planting, zero-tillage by a rota-seeder, which cuts through stubble and creates a mini-seedbed, was clearly better than all other treatments (Plate 7.5). All methods of establishment in this trial involve cultivation, and result in better vetch establishment and end of season fodder yields than can be obtained with relay sowing. Weeds do need to be controlled in the cereal crop, to reduce long term reserves in the weed seed bank. Perennial weeds such as docks can be controlled before cultivation with Glyphosate (Roundup). Vetch is tolerant of several pre-emergence herbicides which are sprayed after drilling, such as linuron and prometryn, if these are available locally.

In conclusion common vetch is a productive pure fodder crop for use in double cropping systems with cereals in the valleys of central Tibet. It can also be used as a main crop, especially when grown with a companion cereal. Seed supply for large scale adoption is a major problem and has to be addressed. This problem will be reduced by emphasis on growing vetch as a double crop with full cultivation and use of seed drills, or with use of zero-tillage. Both systems halve the seed rate compared to relay sowing. Due to the improved soil moisture environment, use of full cultivation or zero-tillage also reduce days to germination from 15 days with relay sowing to 10 days.

7.2.2. Hairy Vetch (*Vicia villosa* Roth.)

Land class

Hairy vetch is similar to common vetch in most respects (7.2.1.1a). It is more tolerant of poorly drained soils than common vetch. It is intolerant of drought at an early stage of establishment, but has medium tolerance thereafter. The chief difference is that Hairy vetch is more cold hardy than common vetch. The indigenous Mao Shaozi survives winter when sown in late July (Plate 7.2.1.1b). Although early production in the following spring is less than lucerne and melilotus, it can yield as much as lucerne in the second year.

Main Crop

The increased cold hardiness means that as a main fodder crop it is possible that hairy vetch can be sown as a mixture with winter cereals in the autumn, instead of having to be sown separately in spring. However, given the extreme cold of Tibetan winters, even in the lower valleys, the cold hardiness of hairy vetch needs to be tested in small plot trials before it is used widely. In a similar environment in the mountains of Serbia, over winter loss of hairy vetch sown with winter oats or triticale was high when temperatures fell to -35°C for five weeks in mid-winter, and there was 1 metre snow cover for five months. If sown with cereals in spring, yields should equal or exceed that from common vetch given current performance at Lhasa, and it should be possible to sow hairy vetch at the same time as spring barley rather than having to wait until severe frosts are over, as with other annual legumes.

Second crop

Hairy vetch is superior to common vetch as a second crop in several ways:

1) Higher flood tolerance for land likely to be flooded either by high rivers or by rain runoff during a wet rainy season.

2) With its increased cold hardiness, hairy vetch sown as a second crop in July can persist into spring of the second year as biennial and perennial species do.

3) The local Mao Shaozi flowers and produces pods much earlier than current varieties of common vetch. It has been observed that seed is produced in the second year in September even when a first harvest has been taken in mid July. Full studies on seed production for Mao Shaozi should be undertaken.

4) In the fodder crop observation trial of 2005 Mao Shaozi equalled common vetch with a yield of >5000 kg DM/ha of very high protein leafy fodder (Table 7.7), (Plate 7.2.1), and survived winter to produce yields equal to lucerne in the second year.

5) Under dry and very weedy conditions for establishment in the evaluation trial of 2006 Mao Shaozi had excellent germination and establishment and consistently produced yields of 2500 kg DM/ha of high value fodder. In contrast establishment of common vetch varieties was poor, with yields from 380-1380 kg/ha. Gansu 333, the local check variety of common vetch yielded 550 kg DM/ha.

Table 7.7. Growth of Mao Shaozi hairy vetch grown in an Observation Trial at TARI field station, sown in late July 2005

Fodder crop and variety	Source	Visual evaluation on 25 September 2005	Height (cm)	Sc[1]	DM yield (kg/ha)
Vetch Mao Shaozi	Lanzhou	Good establishment and dense growth	10	7	5228

Notes: 1) Score for each fodder species and variety on a range 0 (bad) - 9 (good)

It is concluded that hairy vetch combines good survival and adaptability characteristics with high yields and fodder quality, and the potential to be grown on as a high quality sole fodder crop in the following year. While other varieties sourced from Gansu should be evaluated, the local Mao Shaozi currently outperforms all other annual fodder legumes. Urgent steps should be taken for commercial scale seed multiplication of Mao Shaozi, which should be easy compared to seed production of common vetch. Mao Shaozi should immediately be brought into national, county and township extension programmes with farmers. At the same time, further station work is required to optimise cultural requirements as a second crop in its establishment year, and as a sole crop in its second year of production. Methods for commercial scale seed production also need to be optimised in preparation for major extension programmes.

7.2.3. Forage Peas (*Pisum sativum arvense* L. / *Pisum sativum* L. *(partim)*)

Land class

Peas do not tolerate waterlogging, so should not be grown on valley floors liable to flood during the rainy season. They require free draining soils - sandy or medium loam, moderately fertile soils, with a pH of 6.0-7.0. High pH can lead to manganese (Mn) deficiency known as Marsh Spot. Peas are not tolerant of drought. They are therefore most suited to good irrigated soils. However due to their short growing period of 12 weeks or less for fodder, second class lands with some supplemental irrigation may also be used. Fodder crops may also be obtained from rainfed lands in years when rainfall is extended.

Main Crop

The "Black Pea" (*Pisum sativum arvense* L.) grown in the upper valleys of central Tibet (Plate 7.6.1) are well suited as fodder peas. Forage peas have smaller sized grains than vegetable peas, but otherwise are similar. If the period of growth is long enough, pods will form and commence filling, and these can be harvested as a green vegetable, so acting as a dual purpose crop.

Peas have an upright growth form with tangled vegetation, though late maturing types are more prostrate than early flowering types. Most vigorous growth is in spring and early summer from early sown crops. Growth is best between 10^{o}C and 20 ^{o}C. Sow peas in spring when soil temperature has reached 7-8 ^{o}C and risk of severe frost is over. Although there are winter hardy types, they will not survive winters in the valleys of Tibet. Seed rates are variable depending on seed size and cost. The target plant population for sole crops is 70 - 80 plants/m^2.

Peas can be grown as a sole crop, but for forage they are best grown as bi-crops with companion cereals such as spring oats, rye, triticale, wheat and barley. For a full arable mixture, include a small amount of vetch seed. Seed rates are in Table 7.7. For mixtures, mix the seeds of the different crops together, and broadcast or drill the mixture in a single pass.

Peas need a well cultivated but firm seedbed to promote rapid root and plant development. Peas do not like compacted soils, so seeds need to be placed at 7.5 cm depth so that after settlement they will be 3-5 cm deep. Several methods are available to achieve this:

1) Use traditional methods to prepare a well cultivated but open seedbed, broadcast peas with or without companion spring cereals and vetch, and cover seeds with a board

Table 7.8. Main crop seed rates (kg/ha) for Forage peas and companion crops according to method of establishment

Fodder Crop	Broadcast and covered			Drilled		
	Sole	Bi-crop	Arable mixture	Sole	Bi-crop	Arable mixture
Forage peas	150	100	75	100	50	50
Cereal	-	120	120	-	75	75
Vetch	-	-	40	-	-	25

2) Use traditional methods to prepare a well cultivated, uniform seed bed and drill peas with or without companion crops at a depth of 7.5 cm and with a row spacing of 15 - 20 cm
3) Zero-till drill peas with or without companion crops into land previously ploughed in the autumn at a depth of 7.5 cm and a row spacing of 20 cm
4) Zero-till drill peas with or without companion crops into residues left from a previous crop at a depth of 6 cm - to use peas in Conservation Agriculture. Peas in this way might follow rye grown as "Early bite".

Peas are a traditional crop in central Tibet, and farmers know how to grow them. To mix peas with cereals as a companion crop for forage may be new to farmers. As with vetch, the best pea/cereal bi-crops require strong growth of the cereal in order to support the peas and prevent lodging.

Harvest pea and pea/cereal mixtures to feed as green fodder from flowering onwards. Feed up to 10 kg fresh fodder per cross bred cow per day. Peas are a safe legume and have low bloating characteristics. For conservation the optimum combination of forage quality and crop DM yield comes when:

- in sole crops pods are filling, and peas in the pods are at soft dough stage
- in pea/cereal mixtures the cereal grains are at the milky to soft dough stage.

Spring fodder crop demonstrations have been run by nine farmers' Forage Groups on an FAO project in the mountains of Serbia with similar temperatures to the valleys of central Tibet (Plate 7.7). Yields for various Forage Pea / cereal bi-crops averaged 9.7 - 11.3 t DM/ha in 2004 (Table 7.9). There was, however, major variation in yields between sites, from 5.8 to 15.8 t DM/ha. If data from vetch / cereal bi-crops are included (these data are given in the appropriate section) it was found that there were no relationships between yield of fodder and altitude (700 - 1300 m.a.s.l.) or soil pH (5.5 - 7.0) (Figure 7.2). However a Soil Fertility Index accounted for 34 percent of the variation in yield. Well manured and/or fertilized crops gave high yields, and supported prolonged feeding of green fodder in July, and /or good yields of fodder conserved as hay or silage.

Second crop

Inter-crop

Farmers in Qushui were observed to have adopted inter-cropping of the irrigation bunds in winter wheat with strips with Black pea (Plate 7.6.2). Black or white peas are traditionally sown by hand in spring into the irrigation bunds for winter wheat. Flowering occurs in June / July, and the full wheat crop is strong enough to support the peas. This can not be done with winter or spring barley due to their soft straw, since the peas cause the barley to lodge. There is interest in semi-leafless varieties of pea that are more resistant to lodging. Mature peas are harvested at the same time as the wheat for grain, when the pea straw can be either harvested separately or mixed with the wheat straw. More recently farmers are adopting vegetable varieties of peas, and harvesting the green pods for local markets. A major benefit of this practice is that vacant land along the bunds is fully utilised with a high value crop.

Table 7.9. Fodder yields from pea /cereal spring fodder crop demonstrations in Sandzak region, Serbia, 2004 (t DM/ha)

Spring fodder crop	Mean	Site Number								
		1	2	3	4	5	6	7	8	9
Peas / oats	11.3	7.7	-	-	15.8	-	9.6	8.0	12.5	14.3
Peas / triticale	9.7	-	9.6	8.2	-	15.2	5.8	-	-	-

Varieties: Forage Peas: NS Junior Oats: Slavuj; Triticale: KG-20

(Data from the Report on the Forage Specialist's Sixth mission, 17th - 30th April 2005, Development assistance to livestock farmers in the mountainous areas of the Sandzak region, GCP/FRY/001/NET)

Relay

Peas can not be established by broadcasting on the soil surface like vetch. However it is possible to plant forage peas in rows into the main winter wheat crops while the wheat is at the vegetative stage:

- dibble peas in by hand
- drill peas by machine
  - with a jab planter-drill - hand pulled or tractor mounted
  - with a cereal drill
  - with a zero-till drill

Due to the full depth at which peas have to be sown, considerable disturbance will be caused to the wheat crop unless peas are dibbled in by hand. Farmers are generally reluctant to provide the time this requires, although hand/foot operated jab planters can speed up the operation. This means peas have to be drilled before stem elongation, in late April / early May. Sown this early peas will mature at the same time as the main wheat crop, rather than being a second crop. Peas can not be relay sown with barley since this cereal is not strong enough to support peas.

Double Crop

A number of pea varieties are being evaluated for use as second crops at TARI (Plate 7.8). In a preliminary observation trial in 2005, 7 varieties of different maturity date were sown in late July and harvested in early October. Total dry matter yields varied from 1994-3631 kg DM/ha (Table 7.10). In 2006 seven varieties were included in the evaluation trial. Establishment was poor, but individual plants grew well considering the conditions, and corrected total dry matter yields were three times those of common vetch (Table 7.10).

Various pea types can be grown as second crop peas for forage following harvest of short duration winter barley or a whole-crop silage cut of winter wheat:

- true forage peas such as Black peas
- late varieties of vegetable peas that have strong vegetative growth and grow tall, without producing peas in the pod / flowering, such as Zhung Wang #6
- early to medium varieties of vegetable peas that may produce pods and peas depending on the time of planting and growing conditions, such as Zhung Wang #4. In 2005 this variety produced 13% of its dry weight as pods, but in 2006 no pods were present on any variety. Vegetable peas are discussed further under Section 7.4 Vegetable Legumes.

Establish second crop peas as outlined for main crop peas:

- in order to provide a break between main crop cereals establish second crop peas as sole crops
- use high seed rates for sole crops as given in Table 7.7.
- apply medium levels of DAP as it is unlikely that peas will nodulate effectively as a second crop – spread DAP before ploughing or use a combination seed drill to get the phosphate into the root zone

Table 7.10. Total dry matter yields of pea varieties grown as second crops, 2005 and 2006

Variety	Year	
	2005	2006
	kg DM/ha	kg DM/ha
Germany #3	2648	-
Germany #4	3631	-
Pea	-	1720
Pea 33/A	-	1380
White Lanzhou	3059	-
White Local	2130	-
Zhongfrui #6	-	2370
Zhongmu #1	-	2840
Zhongwang #2	3098	-
Zhongwang #4	3254	2880
Zhongwang #6	1994	2760
Mean	**2831**	**2325**

1. Dry matter yields include pods.
2. Due to variable plant establishment, yields are based on average weight/plant corrected to a target plant population of 71 plants/square metre, 710,000 plants/ha

- control weeds effectively – peas do not compete well with weeds
  - during pre-drilling cultivations, including preparation of false seed-beds
  - with the systemic non-selective herbicides Roundup (Glyphosate) immediately after harvest of the cereal – this will kill both grass and broad-leaved weeds
  - for broad-leaved weeds, with selective post emergence herbicide such as MCPB
  - weeds such as docks (Rumex spp) on irrigation channels and bunds with Roundup to prevent transfer to cultivated lands
- harvest and conserve fodder from peas as hay or silage; pea hay is not suitable for fractionation.

As an annual legume peas have a high growth rate, and can produce high yields in combination with cereals as a sole crop, and good yields when grown as a second crop within double cropping systems provided weeds are controlled. It is important that the local Black pea is tested in these systems, since it is grown as a rain fed crop in the upper Lhasa valley, and apparently has wider adaptation to soils and climate than vegetable peas. In addition, as a staple crop currently widely grown, good supplies of seeds are available now.

7.2.4. Fenugreek (*Trigonella foenum-graecum* L.) = Local Legume "Xuisha"

Land class

Xuisha is a local fodder legume grown by farmers in Qushui and Gongga counties, and is also used as a flavouring. It can be grown under irrigation and as a rainfed crop, on a range of well drained soils.

Main Crop

Xuisha can be grown as a main crop with irrigation for green fodder or hay (Plate 7.13.2). It can be broadcast, drilled into a prepared seedbed, or zero-till drilled, either alone or with a cereal companion.

Second Crop

At Gongga Xuisha was grown as a second crop after vegetables. It is a vigorous leafy fodder legume producing a dense stand. This species should be included in formal forage evaluation trials.

7.3. Biennial / Perennial Forage Legumes

7.3.1. Lucerne (*Medicago sativa* L. / *Medicago falcata* and hybrids)

Land class

Lucerne requires fertile well drained soils – the best crop land. It is drought resistant once established, and has long tap roots. It does not withstand flooding. However, as a perennial this does not fit in well with normal annual cropping. It can be used as a long break to restore soil that been over-cropped, and the longer it is grown the more fertility it can restore to the land.

Main Crop

Lucerne was observed being grown on second class crop land at Naidong, where it was successfully used in land restoration, with much better growth than sainfoin. It was also observed growing alone and mixed with melilotus at Shigatse Grassland Institute fodder production station at Amigan. These were vigorous crops grown on irrigated lands (Plate 7.9.1). At Lhasa lucerne yielded 10 ton DM/ha as a first cut in the second year (Plate 7.9.3), with equal regrowth into the autumn, having been sown as a second crop in 2005. It therefore has major potential once good quality crop land is made available for fodder production. A major benefit is that once lucerne is established, cultivation costs are low.

Table 7.11. Dry matter yields of lucerne varieties grown as second crops, 2005 and 2006

Variety	Year	
	2005	2006
	kg DM/ha	kg DM/ha
8920F	-	300
8925	-	450
8925MF	-	180
Canada	1345	-
Debao	-	50
Debao-sunan	-	40
Gannong 1	-	10
King	-	130
Longdong	-	200
Queen	-	280
Runbule	-	20
Shengcunzhe	-	30
Sidi	-	40
Sunan	-	650
WL414	2273	-
WZ525HQ	2400	-
Mean	**2006**	**200**

1. Yields in 2005 are based on observation plots with 2 rows in plots of 0.8 square metres.
2. In 2006 approximately half the data are based on 1 m^2 quadrats from the best portion of 2 x 5 m plots
3. The rest of the data in 2006 are from plots with only a few plants. Yields given are average weight / m^2 for the whole plot.

Second Crop

Inter-crop

The ACIAR legume inter-cropping project has a lot of data on production of both lucerne and wheat and barley when grown as inter-crops. During the establishment year lucerne has been sown in spring, and poor germination has resulted. Lucerne has small seeds, and requires the soil to be kept moist for several weeks until it has established. This does not match the irrigation cycles used for cereals in spring, and many trials have had to be replanted. It appears that there are competition effects on both wheat and lucerne, although the lucerne can grow away quickly once the cereal has been harvested and provide good autumn growth in the first year. In the second year, planting wheat or barley into established lucerne crops leads to major competition effects on the cereals.

Double crop

In the 2005 observation trial held at Lhasa, three lucerne varieties established well with nodulation when sown after the rains had started in late July (Plate 7.9.2), and gave yields of 1345-2400 kg DM / ha, with an average of 2006 kg/ha (Table 7.11). This young fodder is pure leaf with high protein and energy values. The variety Canada was the standard variety used in ACIAR inter-cropping trials, but had only half the dry matter yields of two test varieties. All plots survived the winter, and first harvest yields in 2006 were 10 ton DM/ha as noted above, with equal growth as a second cut in September. Given the success of this establishment, lucerne should be grown as a second crop for establishment. It does have a small seed, however, and is susceptible to weeds as a seedling. In 2006, with a dry seedbed and severe weed competition, establishment and yields of all varieties were low (Table 7.11).

If lucerne is to be grown as a sole crop following cereals, it is sensible to establish it the year before as a second crop following short duration winter barley. Provided weeds are well controlled and a good seedbed is prepared, this will allow the lucerne to become well established before winter, and provide a useful yield of fodder in the establishment year. Further variety evaluation should be carried out, as observations in 2005 indicated a 100% difference in yields between varieties. It is important to include the same check varieties in trials in successive years, to assess year to year variations.

7.3.2. Melilotus (Sweetclovers) (*Melilotus spp)*

According to Frame (2005) several species of melilotus have been cultivated for centuries for grazing, as fodders and as green manures. They are erect annuals or biennials, with a growth habit and form similar to that of lucerne. Sweetclover is grown in northern China for soil improvement and fodder - as an over-wintering catch crop sown after wheat and harvested for fodder in spring, following which it is ploughed in before a summer crop. It may also be undersown to winter wheat or barley, and fodder harvested over one or two years. It is widely used as a pioneer plant in reclaiming degraded grassland on the Loess Plateau, when the plants are cut only when mature and dried at the homestead - the coarse stems are used as fuel and the finer parts are used as fodder. Two of the commonly grown sweetclovers have similar growing conditions and cultural needs: *Melilotus officinalis* (L.) (Yellow Melilotus) and *Melilotus alba* (Medik.) (White Melilotus / White Sweetclover).

Yellow sweetclover (*Melilotus officinalis*) is a yellow flowered biennial. It produces a single well branched stem in the establishment year from seed, but several stems originate from crown buds in the following year. The succulent stems become fibrous with age. It has deep tap roots. Considerable root enlargement together with short rhizomes initiated from the crown takes place in autumn of the establishment year. In contrast annual sweetclovers such as *Melilotus indica* (L), or Yellow Annual Sweetclover, have more aboveground forage and less root development in the year of sowing. Sweetclovers are adapted to temperate climates and can withstand very cold winters - they are grown extensively in Canada and the USA. In central Tibet it appears that the melilotus species that grows wild is the biennial Yellow Sweetclover. It appears to have both yellow and white flowered varieties of the same species (Plate 7.10.1), although mixed populations with White Melilotus may be present.

Land class

Annual and biennial melilotus species tolerate alkaline and saline soils and are therefore suitable for restoration of degraded lands. They respond to high fertility, especially to P and K, with optimum pH of 6.5-7.5. They have a low tolerance to flooding, but Yellow melilotus has a high degree of drought tolerance once established. Both annual and biennial melilotus are therefore suitable for second class crop lands in central Tibet. Suitability of both annual and biennial species for rainfed lands has to be established.

Main Crop

Melilotus was observed planted as a mixture with lucerne at the Shigatse Grassland Institute fodder production station at Amigan (Plate 7.10.1). It is a biennial, and although growth in the first year is not high, it is a big plant that makes rapid growth in the second year. First harvest yield in its second year was 21.5 ton DM/ha at Lhasa in 2006, double that of lucerne (Plate 7.10.2). This was repeated for the second cut. However at this stage the plant is very stemmy, and total quality is low, but it is easy to fractionate the dried crop into stem and leaf. The locally grown melilotus produces a lot of good quality seed in Tibet, which is easy to harvest compared to other legumes. At Shigatse, while lucerne is a perennial that persists up to ten years, it has been found that melilotus will regenerate itself from its own seeds, so that it behaves as a perennial. While melilotus is winter hardy, high utilisation in the autumn of the establishment year can result in winter kill if there has not been sufficient time to rebuild root reserves.

There is a risk of bloat, and melilotus should be cut when the pods are just being formed; if cut earlier the risk of bloat is higher (Gohl, 1981). The feeding of hay or silage spoiled by the development of moulds, due to aeration and heating, produces an anti-coagulant from the coumarin content, which can cause 'bleeding disease'. Low coumarin varieties have been developed, and seed of these should be obtained rather than use seed from wild specimens of unknown origin. In 2005 seed for the observation trial was obtained from Shigatse.

Second Crop

Undersown crop

The project looked at under-sowing winter wheat with melilotus in both autumn and spring. This is an established practice in northern China. However, at Lhasa germination was very slow, and it was only after the wheat harvest that seedlings of melilotus were observed establishing. There is a high content of hard seed in harvested crops, and effective scarification with hot water or abrasion is required – but without cooking or killing the seed respectively.

Double crop

In 2005 excellent plots of melilotus established when sown in late July. Yields were not high, at 1826 kg DM/ha, but this was just leaf of high protein (Plate 7.10.2). These plots went on to yield very highly in the next year. At present sowing melilotus as a second crop appears the best way to establish it. Sources of annual yellow sweet clover should identified, since this has higher first season growth. It will be important to dry the leafy fodder cut in September / October well in order to prevent overheating and formation of anti-nutritive compounds in the hay. Only restricted amounts of this young green fodder should be fed fresh in order to prevent bloat. Further work on use of both annual and biennial melilotus species should be carried out.

7.3.3. Sainfoin (*Onobrychis viciifolia* Scop.)

Land class

Sainfoin requires well drained soils, but is more tolerant of low fertility soils than lucerne. As a perennial species it will need irrigation. However in Naidong it was not growing as well as lucerne in a land restoration project (Plate 7.11.1), although this is likely to be due to requirements for specific rhizobia.

Main Crop

As a perennial, sainfoin has to be considered as a main crop. Production should equal that of lucerne on less fertile land, provided it is inoculated with the appropriate strain of rhizobia.

Second Crop

Sainfoin has not been tested as a second crop.

7.3.4. Red clover (*Trifolium pratense* L.)

Red Clover is a fodder of ancient cultivation. It is an erect short term perennial originating in the temperate and sub-arctic regions of Eurasia. While under cool favourable conditions it can persist for up to seven years, it is generally regarded as a two year crop. It is of upright growth with shoots developing from a crown, and is ideal for cutting for green feeding or conservation. There are two main types of Red Clover, and many cultivars: "Common" has early rapid growth suitable for two or three cuts in a full season but is not so winter hardy; "Late" or "Single-Cut" has later, slower growth suitable for a single heavy cut later in the season, and is more cold tolerant .

Land class

Red clover requires well drained fertile soils.

Main Crop

It should be possible to establish red clover in the spring, but problems with moisture control may occur as with lucerne. As a biennial or short term perennial it has to be considered as a main crop, but it is best established as a second crop in the preceding year.

Second Crop

Undersown crop

Red clover was included in the same under-sowing trial with winter wheat and barley as melilotus, with sowing taking place in autumn after cereal planting, and in spring. Unfortunately no germination occurred due to incorrect scarfication.

Double crop

Red clover was included in the double fodder crop observation trial in 2005, and germination was good. However there appeared to be no nodulation with local rhizobia, and production was small in the first year (Plate 7.11.2). Red clover survived the winter well, and produced 1800 kg DM/ha at the first harvest in 2006. It persisted throughout the year, and produced some flowers in September. Clovers require specific rhizobia *Rhizobium leguminosarum* bv. *trifolii* , and if these can be obtained it is worth keeping red clover in observation trials. It does grow in other parts of China, and inoculant is available (see Chapter 8). Four varieties of red clover were obtained from Beijing, and further variety evaluation should be carried out.

Perennial forage legumes, with their small seeds, have only half the yield of annual forage legumes when grown as a second crop. If perennials such as lucerne are to be grown as sole crops, they should be established as second crops in the preceding year, when small fodder yields can be harvested. Otherwise annual fodder legumes should be grown.

7.4. Vegetable and / or Pulse Legumes

7.4.1. Peas (Green peas in pod) (*Pisum sativum* L.), Peas (Pulse crop for grain) (*Pisum sativum* L.) Peas (Edible pods) (*Pisum sativum axiphium*)

Garden Peas for human consumption have traditionally been long strawed, and have been grown to mature over a long period of time for an extended picking and sale period. Recent selection is for short strawed cultivars that may be semi-leafless, leafless or have narrow leaves that have better standing ability as crops grown in the field, and that mature at a single time for mechanical harvesting either green (Vining Peas) or dry (Combining Peas). Both traditional Garden Peas and Vining peas are suitable for farmers in the Project area to grow for hand picking green crops for marketing. All types produce vines and shelled pods suitable for feeding green or for conservation as hay or silage.

Field peas (*Pisum sativum*) are grown as a pulse crop and harvested dry - either by hand or mechanically. Various varieties are used for human consumption as split peas or Dahl, and for processing canned peas, although the majority are used for feeding livestock. Dry peas are an excellent supplement to straw based diets for milking cows, and as a component of rations for pigs and poultry. Dry peas definitely have a commercial or barter value for farmers in the Project area, while the dry straw retains high nutritive value compared to cereal straws or bean straw.

TARI already has a large collection of Pea cultivars, which have recently been regenerated. However the main collection is of local landraces, which are of tall full leaf traditional Garden Pea type. There is interest to obtain modern short semi-leafless varieties, with better standing ability (Plate 7.8.3).

Land class

Peas are a short duration crop, and may grow through the rains in July / August to produce quality crops in September. However rain during this time can lead to the production of tall crops that are then prone to lodging. Growing peas on lighter soils can reduce the lodging risk, and the crop's tolerance to drought stress allows good yields in low rainfall areas.

Main Crop

Due to their short duration, peas are ideal to sow once the risk of frost is over, and to obtain a crop before the main rains occur. A second fodder crop can be grown after either vegetable or pulse peas.

Second Crop

Inter-crop

Use of peas as an inter-crop on the bunds within fields of winter wheat has been noted (Plate 7.6.2). Varieties to provide peas in the pod and green pods are now being grown.

Double crop

A number of pea varieties are being evaluated for use as second crops at TARI. In a preliminary observation trial in 2005, 7 varieties of different maturity date were sown in late July and harvested in early October. Several varieties flowered and produced pods (Plate 7.8). The highest pod yield was for Zhongwang #4, with a fresh yield of pods of 2405kg/ha, a major marketable production (Table 7.12). This variety also had a high fodder yield of 2822 kg DM/ha without pods. Germany #4 had the highest fodder yield without pods (3449 kg DM/ha) and produced 1408 kg/ha of fresh pods for

Table 7.12. Marketable and fodder yields of peas grown as a dual purpose crop, 2005

Variety	Plant without Pods		Pods		Total plant
	Fresh yield (kg/ha)	DM yield (kg/ha)	Fresh yield (kg/ha)	DM yield (kg/ha)	Corrected DM yield (kg/ha)
White Local	11531	2004	1281	127	2130
White Lanzhou	19933	2805	1760	254	3059
Zhongwang #2	18050	2962	628	136	3098
Zhongwang #4	14606	2822	2405	433	3254
Zhongwang #6	12253	1994	0	0	1994
Germany #3	16168	2636	127	11	2648
Germany #4	22240	3449	1408	182	3631
Mean	**16397**	**2667**	**1087**	**163**	**2831**

1. Due to variable plant establishment, yields are based on average weight/plant corrected to a target plant population of 71 plants/square metre, 710,000 plants/ha. = 20 cm between rows and 7 cm spacing within rows.
2. Dry matter yields are taken as 0.9 Air Dry yields

market. In 2006 due to dry and weedy conditions growth was poor and none of the varieties produced pods; however Zhongwang #4 and #6 had the highest fodder yields of 2880 and 2760 kg/ha respectively.

When peas are grown as a second crop with a good seedbed and weed control and supplemental irrigation as required, early varieties can produce good yields of marketable pods as well as high yields of good quality fodder. Peas are an excellent example of "Dual Purpose" crops for market produce and fodder.

7.4.2. "Broad" or "Faba" Beans (*Vicia faba*)

China is a centre of genetic diversity for Broad Beans, which come in Large, Medium and Small seeded forms. Within each form, larger seeds have been most selected for, with improved palatability and cooking quality - with lower tannin contents and low lectin and protease inhibitor levels. All can be used both for humans and as livestock feeds.

TARI has a collection of large seeded broad beans for human consumption, mainly based on late indeterminate varieties from Gansu, plus a few local varieties. However for double cropping as a second crop following winter barley, short duration day length neutral determinate cultivars of broad bean are required, regardless of seed size.

The following uses of beans for human consumption should be considered in assessing varieties:

i. dry mature and green mature seeds - these require the longest growing period

ii. the whole immature pods as a vegetable (similar to green beans from *Phaseolus vulgaris*)

iii. the tops of the plant as a spinach.

For livestock, crop residues can be used for feeding, or surplus whole plants can be used or conserved before maturity. Broad beans have low dry matter contents and need care in drying or ensiling.

Even if short duration cultivars are identified, Faba Bean suffers from yield instability. At low temperatures and in wet soils Rhizobium symbiosis is not effective; while in cloudy and overcast conditions such as in July/August pod set may be reduced by low levels of bee pollinator activity.

Land class

Broad beans require good quality fertile soils – crop lands. However, being legumes, they have a place in diversified crop rotations. Well drained sunny sites are best, with provision in surrounding areas to encourage bees for pollination.

Main Crop

Broad beans can be grown as main crops in April, and are suitable as a break crop in cereal dominated rotations. During this time sun light and pollinator activity is high.

Second Crop

Relay planting

Large seeded broad beans have successfully been relay planted into winter wheat crops in the project area at the early tillering stage of wheat in March / April, to mature at the same time as the wheat in early August. Labour inputs for planting can be reduced by use of "Jab" planters that simultaneously make a hole in the soil and deposit the seed. However, straw of mature broad beans is of low feeding value due to presence of moulds and mycotoxins, and is best used as a fuel.

Second crop

Broad beans produced high yields of pods at Gongga when planted as a second crop after short duration vegetables (Plate 7.12.3-4). Three broad bean varieties were included in the double crop observation trial in 2005 (Plate 7.12.5), and two in the evaluation trial of 2006 (Table 7.13). While the

Table 7.13. Marketable and fodder yields of broad beans grown as second crops, 2005 and 2006

Variety	Total fresh weight (kg/ha)		Total dry weight (kg DM/ha)		Marketable product (kg fresh/ha)		Residual Fodder (kg DM/ha)	
Year	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**	**2005**	**2006**
French D	13594	16000	1427	2400	6797	8000	714	1200
Linxi 1		12767		2090		6383		1045
Qinghai #9	30423		3014		15212		1507	
Qinghai #10	34067		3237		17034		1619	
Mean	**26028**	**14384**	**2559**	**2245**	**13014**	**7192**	**1280**	**1123**

1. Due to variable plant establishment, yields are based on average weight/plant corrected to a target plant population of 40 plants/m^2, 400,000 plants/ha.
2. Dry matter yields for 2005 are taken as 0.9 Air Dry yields; for 2006 oven dry yields are presented.

beans reached flowering stage in both years, no pods were formed. Germination was poor in both years, and yields were corrected to target plant populations of 40 plants/m^2, or 400,000 plants/ha. This high plant population for beans allows for the short growing period, and is equivalent to planting beans in rows 20 cm apart with 12 cm spacing within the row. In 2005 two German varieties collected from Qinghai yielded 3000 kg DM/ha, double that of the check variety French D. Despite poor germination and growing conditions in 2006, corrected dry matter yields were similar. Although no pods had been formed by harvest time in early October, half the tops could be sold green as spinach, with a marketable product of 6000-17000 kg/ha. This represents a major potential income, although if all farmers were to attempt to sell tops at the same time the market would be glutted. Firstly, tops could be sold over 2-3 months as they became available, to maintain market prices. Secondly ways to preserve the tops by drying or pickling in some way need to be developed. The remaining crop still provides a useful yield of easily harvested fodder, although with low dry matter contents it needs careful drying or ensiling if not fed green.

Points for establishment of broad beans as a second crop include:

- Control weeds in the preceding cereal or other crop, or spray the land with Roundup 2-3 days before ploughing.
- Optimum plant populations depend on the time of sowing and the kind of crop expected:
  - with early sowing when good crops of pods are expected - 20 plants / m^2 or 200,000 plants/ha[1]
  - for standard crops following cereals when tops without pods are expected, aim for double these populations – 40 plants/m^2 or 400,000 plants/ ha.
- Establish broad beans by “ploughing in” – sow bean seeds into the furrow bottom, then plough the next furrow on top of the seeds (Plate 7.12.1):
  - determine seed depth by ploughing depth, which should be shallow at 5-8cm.
  - if the furrow width is 10 – 12 cm, sow seeds into the furrow of every 4th row for crops with pods (45 cm between rows); and every other row for late sowings
  - use 12 cm spacing within rows for both row widths.
- Alternatively, prepare a seedbed by ploughing and planking (Plate 7.12.1-2), and drill seed at 5 cm depth at the same row widths, or use a zero-till drill direct into the stubble of the previous crop. However, most seed drills will only sow small seeded broad beans.
- Spread 100 kg DAP/ha on the stubble before ploughing in the seed, or use a combination drill, to provide phosphate and some N for initial establishment and growth.
- Reduce germination times by soaking the seed for 1 day in cold water, and handle the soaked seed carefully.
- Spray weeds that germinate before beans emerge with 2,4-D for broadleaved weeds, and Roundup if grass weeds are a problem. Hoe between the rows to control weeds after emergence.

[1] Adapted from PGRO (2003)

Broad beans represent a useful second crop that farmers already know. Further work is needed to evaluate varieties to grow as a second crop, and to assess the effect of time of sowing on marketable products – green beans, pods, and spinach from tops; and on fodder yields.

7.4.3. Bush Beans (Green pods) (*Phaseolus vulgaris),* Bush Beans (Pulse crop) (*Phaseolus vulgaris), and* Runner Beans (*Phaseolus coccineus*)

Some Phaseolus beans are already cultivated in the Project area as green beans with pods 30 cm long. A number of outputs are available from Phaseolus beans, and species and cultivars are classified into Types in relation to these outputs:

i. **Edible green pods (Green Beans) (Plate 7.13.1)**

- *P. vulgaris* (single harvest, determinate, erect and bushy growth forms - such as "French Beans")
- *P. coccineus* ("Scarlet Runner Beans" - climbing form - green pods and green seeds that mature over a long period of time)

ii. **Dry seeds as pulse crops:**

- *P. vulgaris* - White Haricot Beans
  - White Navy Beans
  - Red Kidney Beans

Gongga and Qushui are close to Lhasa Airport. Besides marketing fresh green beans (edible pods) in local towns and Lhasa city, they could be shipped by air to the warm lowland city of Chengdu. Residual vines and sub-standard pods provide high value livestock fodder fed either fresh or conserved dry or ensiled.

Phaseolus vulgaris exhibits poor or zero nodulation as a consequence of selection for early maturity and dwarf growth habit. Climbing beans are more effective at N fixation. Day-neutral genotypes do exist for temperate zones, which are of great importance for montane tropical crops growing under temperate conditions. These beans require well drained fertile crop lands with irrigation available as needed. They are vegetable crops, but in UK and in tropical Africa are now grown on a field scale. Given their economic potential, a collection of Phaseolus beans should be developed and evaluated at Lhasa in conjunction with the Vegetable Department of TARI, and field tested with farmers.

7.5. Root crops and Leafy Brassicas

7.5.1. Root crops[2]: Sugar and Fodder Beet (*Beta vulgaris* L.); Turnips (*Brassica rapa* L. var *rapa*); Carrots (*Daucus carota* subsp. *sativa*); and Radish (*Raphanus sativus)*

A number of different root crops can be grown in central Tibet. They vary in length of growing period. Highest yields of roots are obtained from main crops of sugar and fodder beet harvested in autumn. However, good root yields from second crops are only obtained from shorter duration crops such as carrots, turnips, and radish. The proportion of leaf to root in the final product depends on density of the crop; the higher the density, the smaller the individual roots and total root yield, and the higher the proportion of leaf. For high root yields, crops have to be grown as spaced plants, normally within rows to allow for inter-row weeding. Within crops, the earlier crops are sown the higher the potential root yield. High leaf yields are still possible from late sown crops, up to the end of August.

Land class

Main crops of sugar and fodder beet grow best in deep loamy soil. Turnips will grow well on any good soils which do not dry out too quickly. The ideal soil for carrots is a light but deep loam which does not dry out quickly, but will grow reasonably well in most soils with the exception of sticky

[2] The main reference on root crops is Toosey (1972)

clays and very light soils. Radishes prefer light-to-medium, fertile loam, and do not like cold, wet soils. Shallow, stony ground is only suitable for stubble turnips that sit on top of the soil, and round and stump rooted varieties of carrot and radish (Hall, 1978) Root crops are therefore suitable for good crop lands in central Tibet except those liable to flooding, while short duration stubble turnips and stump rooted carrots and radish may be suitable for second class and rainfed lands.

Main crops

Sugar and fodder beets are suitable for sowing in spring with harvest in September / October. heavy yields of roots and tops have been obtained in Panam, as presented in the EU project reports. In addition both stump and long rooted carrots can be sown in spring for an early harvest in July. Turnips and radishes are better sown from early July onwards.

Second crops

A range of root crops are available, and it is possible to grow them for tops (high protein leaf fodder) as well as for roots (high sugar and digestible fibre). Of key interest are the latest possible dates for sowing as second crops, the months of possible harvest, and the likely production of leaves and edible roots. While further evaluation of species and varieties is required in central Tibet, preliminary results are presented in Table 7.14. Many crops are cold hardy, but should be harvested before the ground freezes solid. Tops may be less frost hardy than roots. The dates shown are for Lhasa, later sowing dates are possible at lower altitudes.

Table 7.14. Last sowing dates, and harvest periods for different root crops in central Tibet

Latest possible sowing date	Type of root crop	Product		Months during which the crop is suitable for harvest			Remarks
		Leaf	Root	Aug	Sep	Oct	
1 June	Sugar and fodder beets	(√)	√	-	√	√	For roots, plus leaves
15 July	Carrots	√	√	√	√	-	Stump & round rooted varieties
1 August	Sugar and fodder beets	√	-	-	(√)	√	Leaves only, not frost hardy
1 August	Turnips – hardy frost resistant white and yellow fleshed varieties	(√)	√	-	√	√	Spaced plants for roots, plus leaves
15 August	Radish	(√)	√	-	(√)	√	Red and white Chinese varieties
15 August	Stubble Turnips	√	√	-	(√)	√	Sown at high density for leaves and roots; imported varieties still to be tested
31 August	Turnips	√	(√)	-	-	√	Spaced plants, grown mainly for leaves, roots are small
31 August	Radish	√	(√)	-	-	√	Spaced plants, grown mainly for leaves, roots are small - medium

At present farmers in Qushui county double crop short duration winter barley Dongqing #1 with turnips broadcast on to freshly ploughed land at very high density (Plate 7.14). Depending on availability of seed, green or white turnips with white flesh are used. Crops are grown for both leaves and small roots, and in international terminology these may be considered to be grown as “Stubble Turnips”, compared to spaced turnip plants grown primarily for their roots. The whole plants are harvested in early – mid October, larger roots are chopped, and the whole crop is dried. This is then stored, and can be used as a vegetable within the family, exchanged for barley for family consumption, fed to animals such as high yield milk cows, fattening lambs or pigs, or exchanged for grains or brans as animal feeds. It is estimated farmers obtain yields of stubble turnips of 3000-4000 kg dry matter /ha, which includes both roots and leaves. An economic comparison of the single crop spring barley with the winter barley / stubble turnips double cropping system is given in Chapter 11.

In addition, farmers in central Tibet traditionally cultivate radish with large long red roots with white flesh as a vegetable in or next to their compounds. These are consumed within the family as a salad vegetable, and may be stored into the winter. They are grown on mounds, with 2 – 3 seeds sown at the bottom of 8 cm deep holes in the mounds, later thinned to individual plants. The latest time that seeds are sown appears to be at the beginning of July in Lhasa. This is important, since it shows farmers know the value of both radish as such, and the need to grow spaced plants in order to obtain large individual roots.

A range of root crops including fodder beets, carrots, turnips and winter radishes were grown in an evaluation trial at Lhasa in 2006. Plots were sown at the end of July, but establishment was poor due to dry conditions following sowing and intense weed competition. However some plants grew on most plots, and yields have been corrected to target plant populations for each crop (Table 7.15). While this does tend to overestimate yields, results show the potential of short duration root crops such as turnips and radish to produce high yields of high energy roots when sown late, and other crops such as fodder and sugar beet to produce high yields of leaves (Plate 7.15).

Table 7.15. Total yield (leaves + roots) of root crops at Lhasa grown as spaced plants on 24-25July and harvested on 11 October, 2006

Crop	Variety	Target popn (plant/m^2)	DM %	Yield (kg DM/ha)		Comments
				Variety	Crop	
Fodder beet		8	9	6270	6270	Leaves only
Sugar beet		8	16	2820	2820	Leaves only
Carrot	Local	63	25	1338	1253	Very small roots
	Qitouhong	63	14	1168		
Radish	Beijing Manatanghong	12	12	2950	4640	Plants were not separated into leaves and roots at harvest. Some red and some white varieties had large roots, others had only small roots but large crops of leaves. The largest individual plant (Xiacui) weighed a total of 3.265 kg fresh, and 245g dry.
	Dahongbao	12	11	4270		
	Daliangqing (Dalian Green)	12	9	6430		
	Dingjishengxia (Peak Midsummer)	12	6	5910		
	Guoguang	12	8	5870		
	Huaying	12	7	2920		
	Jiecha	12	6	2670		
	Xiacui (Summer Green)	12	8	8470		
	Xiameinong (Summer Beauty)	12	7	4850		
	Xiliang	12	7	2570		
	Xuyudagen (Spring Snow big root)	12	9	3870		
	Yuan (Snow round)	12	9	4780		
Turnip	Gansu	12	11	3640	4514	Spaced plants
	Tibetan	30	10	5388		Stubble turnips

1. "popn" is an abbreviation for population
2. Actual plant populations were low and variable. Yields were therefore corrected to target plant populations, but this is likely to overestimate yields.
3. High plant populations survived for Tibetan turnips, and actual yield is given.

The economic analysis of the winter barley / stubble turnip double cropping system in Chapter 11 shows that the current system is likely to be less profitable than traditional spring barley for two main reasons:

- the low yield of short duration barley Dongqing #1;

- the high cost of seed for turnips – 22.5 kg/ha at 60 Yuan/kg (3 jin/mu at 30 Yuan/jin).

The following actions can be taken to improve profitability of this double cropping system, in a step by step manner:

1) Reduce seed costs for the stubble turnips by 2/3 either by drilling seed at a lower rate into levelled land with a farmer's drill, or by using a zero-till drill to sow turnips directly into the barley stubble – 7.5 kg/ha at 60 Yuan/kg (1 jin/mu at 30 Yuan/jin). Mix the seed with sand before drilling through a traditional seed drill. Do not mix the seed with fertilizer as this harms germination of the seed.
2) Improve yields of stubble turnips through weed control by spraying Roundup on stubbles 2-3 days before ploughing or zero-till drilling.
3) Replace low yielding short duration Dongqing #1 winter barley with existing varieties of winter barley. These mature two weeks later, but have the same grain and straw yields as spring barley. This will boost income from the cereal, and result in a major improvement in margin over direct costs for the double cropping system. However, a full seed multiplication programme is needed before standard winter barley varieties can be introduced on a large scale; and sowing stubble turnips later will lead to lower yields and a lower proportion of roots.
4) Grow the root crop as spaced plants within rows, at a seed rate of 3.75 kg/ha (0.5 jin/mu). This will result in larger roots, of higher economic value for human food or as marketable crop, even though additional labour will be needed for thinning and weeding. Provided the root crop is sown by the end of July good yields of turnip roots can be obtained.
5) Replace turnips with shorter duration winter radish varieties for good root yields at later sowings. Alternatively, good yields of leaves with some small roots can still be obtained with late sowings of both turnips and radish, although radish leaves are not frost hardy.

Further work is needed to establish potential root and leaf yields for the major root crops when sown at different dates from late June to early September and at different plant densities or row spacing. In addition a further range of turnip varieties grown at Qinghai needs to be evaluated for late sowing in central Tibet. A suitable experimental designs with record sheets for separation of plants into leaves and stem were included by the author of this chapter in his inception report[3]. This station experiment needs to be supplemented with further participatory research and extension with farmers.

7.5.2. Leafy Brassicas[4]: Fodder Kale (*Brassica oleraca* L. *convar. acaphala* (DC.*) Alef. var medullosa),* Cabbage (*Brassica oleraca capitata*), Forage Rape (*Brassica napus* L. *(partim)*), Fodder Radish (*Brassica sp.*)

Leafy brassicas in order of length of growing period include cabbage, fodder kale, fodder rape and fodder raddish. The oilseed crop rapeseed is also a leafy brassica, but is considered in the next section. While fodder kales are normally sown as spring - early summer sole crops for use from late summer onwards, forage rape and fodder radish are rapid growing crops commonly used as catch crops following early harvested cereal crops (Table 7.16).

Land class

Brassicas should grow well in central Tibet as they require neutral to alkaline soils to avoid the root disease clubroot. They require high levels of fertility and are best grown on well drained soils with irrigation as required. It is essential to apply fertilizer for leafy brassicas grown as second crops, as little will be carried over from the main cereal crop. The amount of fertilizer to be applied depends on the length of growing period for the crop, and the crop yield expected. Potash (K_2O) is required in addition to nitrogen and phosphate. It appears that soils in central Tibet have become deficient in

[3] Experiment 8 *"Determination of Yield potential of Double Crop Turnips"*. In Lane, I.R. '*Report on the Inception Mission, 15th May – 5th June 2004*', TCP/CPR/2907. Fodder Production and Double Cropping in Tibet. Beijing: FAO. June, 2004. Annex 11.

[4] The main reference on leafy Brassicas is Toosey (1972).

potash over the past ten years due to intensive cereal cropping, and crop requirements for potash and supplies of potash fertilizers are starting to be addressed.

Table 7.16. Last sowing dates and harvest periods for different leafy fodder brassicas in central Tibet

Latest possible sowing date	Type of Leafy Brassicas	Months during which the crop is suitable for Harvest			Remarks
		Aug	Sep	Oct	
31 May	Cabbages – various types		(√)	√	Sow in a nursery in spring or previous autumn, and transplant in July/August
15 June	Kale - Marrowstem or Maris Kestrel	√	√	√	Main crop. Only sow a limited area when late summer use is required
15 July	Kale - Marrowstem, Maris Kestrel, Thousand Head	-	√	√	Maris Kestrel is the preferred variety
30 July	Kale - light crops only	-	-	√	Forage Rape is preferred for late sowing
7 August	Cabbage – various types		(√)	√	Transplant cabbages grown in a nursery after cereal harvest in July/August
15 August	Forage Rape - large crop	-	√	√	For early sowings Kales give a higher yield
30 August	Fodder Raddish	-	√	√	Fodder Radish is not frost hardy
5 September	Forage Rape - small crop	-	-	√	Forage Rape is susceptible to frost

1. Adapted from Toosey (1972)

Main Crop

There are three main types of fodder kales (Toosey, 1972), although kales can be sown sequentially for a sequence of harvest dates (Table 7.16). Marrowstem kales have thick stems with edible pith (Plate 7.16.2.1), compared to Thousand Head kale in which the leafy tops are edible but the stalk is not eaten. Maris Kestrel bred in UK is an intermediate type with high stem digestibility. Types of kale available in China have still to be established, but may be with the Vegetable Division of TARI.

Various types of cabbage can be grown to feed to livestock, and they provide a high fodder yield from a small area of land. In addition the residues of cabbages grown for human consumption can also be fed to cows, and those normally kept over winter are of most benefit. These provide a high cash income and provide fodder of high feeding value; however it is important to find a market before starting on such cropping. To be grown as a main crop, sow cabbages in a poly tunnel in September, and transplant them to their final position in the field in April / May. This will give maximum yields of cabbage from August onwards, but they will occupy the land throughout the main growing season, so is best suited to cabbages grown as a dual purpose crop.

Second Crop

It should be possible to grow various kale varieties following winter barley, which will give heavier yields of fresh and drymatter than other leafy brassicas. Fodder radish has larger seed than other types and has very rapid growth - early varieties flower 6-8 weeks after sowing, when they should be harvested. It is possible some fodder radish varieties were included in the 2006 evaluation trial detailed in the previous section. Forage rapes also have rapid growth and can be established with little cultivation (Plate 7.16.2.2). Both fodder radish and forage rape should produce useful crops of fodder when sown as catch crops after winter wheat in central Tibet. Leafy forms of stubble turnips can be included in this comparison. It should therefore be possible to have fodder available for feeding green from the start of September through to the end of October - or the fodder can be harvested and dried in September / October, or made into Kaleage - wilted silage made from leafy brassicas. Some kales are frost hardy and it may be possible to leave them in the ground for harvest into November – this has to be tried in practice under the local climate.

To date the only leafy fodder brassicas tested under the project have been two varieties of cabbage, which were included in the 2005 fodder crop observation trial in Lhasa (Plate 7.16.1). These were sown directly in rows as spaced plants, at high target plant populations for cabbages to take account of the short growing period. Germination was poor. Yields corrected to target populations are presented in Table 7.17. Chonggan #11 had initiated heart formation, but plants were small and they could have

Table 7.17. Marketable and fodder yields of cabbages grown as second crops, 2005

Variety	Total fresh weight (kg/ha)	DM %	Total dry weight (kg/ha)	Marketable product (kg fresh/ha)	Residual Fodder (kg DM/ha)
Chonggan #11	54075	9	4886	27038	2443
Qingfeng #1	33472	14	4756	16736	2378
Mean	**43774**	**11**	**4821**	**21887**	**2411**

1. Between row distance 20 cm, within row spacing 10 cm.
2. Due to variable plant establishment, yields are based on average weight/plant corrected to a target plant population of 63 plants/m^2, 630,000 plants/ha.
3. Dry matter yields are taken as 0.9 Air Dry yields.

been established at higher plant density. Qingfeng #1 had not commenced heart formation. Even so, useful total yields of 4821 kg DM/ha were obtained. Moisture contents varied between plots, but at least half of the fresh yields could be marketed with yields of 16000 – 27000 kg fresh/ha, leaving

Table 7.18. Cultural requirements for leafy Brassica crops

Crop	Growing period		Seed rates		Row spacing (cm)	Fertilizer nutrients[1, 6]		
						N	P	K
	Season	Length (days)	Broadcast (kg/ha)	Drilled (kg/ha)		(kg N/ ha)	(kg P_2O_5 / ha)	(kg K_2O / ha)
Cabbage (nursery)	August or April	-	-	1.1	20 - 30	50	75	125
Cabbage (transplant)	May or July - October	165 -120	-	-	150 x 150	200 or 150	75	125
Kale	June-October	135	5.0	3.3	36 - 40	125	75	125
Kale	July-October	105	6.0	4.0	18 - 20	125	40	100
Forage Rape	August - October	90	7.0	4.5	18 - 20	100	40	75
Fodder Radish	August - October	60	12.0	9.0 12.0	36 - 40 18 - 20	100	40	75
Forage Rape	September - October	60	10.0	6.5	18 - 20	75	20	40

1. N: Nitrogen; P: Phosphorous, as phosphate, P_2O_5; K: Potassium, as potash, K_2O
2. Sources: Toosey (1972) and Nix (2003), adapted for central Tibet. Revise data according to local trial results.
3. Use half the seed rates shown for kales of the "Thousand Head" type.
4. Zero-till drilled crops require an extra 25 kg N/ha compared to traditionally cultivated crops.
5. Apply all the P and K to the seedbed or with a combination seed drill. For main crops planted or sown before July, apply half the N to the seedbed, and half as a topdressing in late July. Apply all the N to the seedbed for second crops sown in or after July.
6. Fertilizer rates for P and K allow for good soil reserves of phosphate but low soil reserves for potash.
7. Apply P as DAP (di-ammonium phosphate) ($N:P^2O_5:K_2O$ 18:40:0) and make up the required seedbed N with local N fertilizers such as KAN (calcium ammonium nitrate)(26% N) or urea (46%N). Apply potash as Muriate of Potash (potassium chloride) (60% K_2O).

useful fodder yields of about 2400 kg DM/ha. These yields could be at least doubled if plants were raised in a nursery and planted out; this would also assist hand weeding between rows.

Cultural practices for leafy brassicas are summarised in Table 7.18. Seed of varieties of the main leafy fodder brassicas should be available within China from the seed merchants in Lhasa, Lanzhou and Beijing, and staff of the Vegetable Division at TARI should be able to assist. Most crops can be established by broadcasting on to prepared seedbeds, or drilling in rows using traditional cultivation or zero-tillage. For crops with small seeds and low seed rates, dilute the seed with ‘seed size’ tapioca or clean fine sand. Establish response curves to fertilizer for the different crops and sowing dates.

Rapidly growing short duration leafy brassicas, including fodder radish, are one of the key second crop fodder groups that remain to be evaluated for the cereal / fodder double cropping system in central Tibet. High plant yields have already been obtained for main crop rapeseed as an oil crop. Leafy brassicas as main and second crops have equal potential. Some care is needed in feeding fresh and conserved leaves of brassicas, but they can safely make up to 50 – 66% of the total ration.

7.5.3. Rapeseed / Oil Seed Rape[5] (*Brassica napus, and Brassica rapa* syn *B. campestris*)

Rapeseed grown as a second crop in double cropping systems has several products of interest as fodder and/or feed:

i. locally produced oilseed that yields a high protein oilseed cake or meal after oil extraction which is suitable for feeding to productive cattle and sheep
ii. rapeseed straw and chaff which can be fed to low producing cattle
iii. green fodder from crops that have failed to grow to maturity.

Main crop varieties currently under evaluation at TARI have a wide range of growing periods, with some very short duration varieties. Their performance as second crops need further evaluation, and the latest sowing dates for long and short duration varieties need to be established with respect to seed and fodder yields. Farmers report that animals find green fodder from rapeseed unpalatable. There could be some confusion here between traditional mustard which has toxic mustard oil, and modern varieties of rapeseed now being grown for commercial oil production. However, current rapeseed varieties are ‘single lows’, and still contain high proportions of glucosinolates which are likely to reduce palatability of green fodder.

China is the world's largest producer of rape seed and rape oil, a crop first introduced two thousand years ago. Both *Brassica napus* and *Brassica rapa* belong to the Cruciferae (mustard) family. The mustard family consists of about 3000 species of plants found mainly in cool temperate regions of the northern hemisphere. It has only recently been decided that oilseed rape of the species formerly known as *B. campestris* is in fact the same species as the Turnip species, *B. rapa*; and as the former was named by Linnaeus first (*rapa* being Latin for "root"), oilseed rape of this species should also be known as *B. rapa*. Rapeseed is closely related to other Brassica species such as ‘Brussel sprout’, cabbage, cauliflower (*Brassica oleracea* types), and kale, brown and oriental mustard which provide genetic resources, as well as many wild / weed species.

Rapeseed plants can grow at relatively low temperatures with far less heat units than other oilseed crops, and so can be grown in extreme temperate conditions. The oil expressed from the seeds of rapeseed have high proportions of two fatty acids, eicosenoic and erucic acids (20 - 40%), which are not essential or may be harmful for human health. Plant breeders throughout the temperate world have developed low erucic acid varieties, and the current standard is a maximum of two percent erucic acid. These are known as "Single Low" rapeseed varieties. However, rapeseed also contains glucosinolates, which give the characteristic mustard flavours. These remain in the rapeseed meal following oil extraction, and degrade to further anti-nutritive compounds when the meal is processed into animal feeds - these suppress appetite in animals and reduce animal production. Plant breeders

[5] The main reference for this section is CCC (2003).

therefore worked with animal nutritionists to produce varieties with low erucic acid in the oil (below 2 percent) and low glucosinolates in the meal (less than 30 micromoles per gram of air-dried oil-free meal). Such varieties are known as "Double low" varieties. The latter breeding work was carried out in Canada, and varieties that meet these characteristics can be registered in Canada using the "Canola" trademark. The original selection in 1977 of double lows used a variety of *B. napus*. By the year 2000 the number of Spring *Brassica napus* Canola varieties currently registered was 113, while the number of Spring *Brassica rapa* Canola varieties was 28. This shows that the breeding process for double lows has been successfully transferred to *B. rapa*, although the range of varieties is less extensive.

This is very relevant to Tibet. A new oilseed processing factory has been built at Lhasa, thus stimulating demand for rapeseed to be produced within the Project area, and providing an assured market to farmers for a new cash crop. In addition the government provides rapeseed to family run mills, which sell oilseed meal to farmers (Plate 7.17.2). However according to TARI staff the present cultivars being introduced to farmers to grow are only Single Lows, that is low erucic acid. Given the importance the factory will assume in supplying rapeseed meal to local farmers as a means to improve nutrition and so intensify animal production, it is essential that Double Low varieties are introduced as rapidly as possible. However, the relative merits of the two species of rapeseed do have to be considered.

Yield in rapeseed depends on the amount of leaf produced in the vegetative stage. As a larger plant that takes 7-14 days longer to maturity, *B. napus* varieties tend to yield 20 - 25 percent more seed than *B. rapa* varieties. However this depends on the frost free period being long enough every year to allow the extra growth. A growing period of about 90 days should normally be possible when growing rapeseed as a second crop, although farmers report that they only obtain a seed crop in some years. Field trials in Canada have demonstrated the range in crop duration from seeding to harvest at different research trial locations and years (Table 7.19).

Table 7.19. Crop duration for Brassica rapa and Brassica napus in Canada

Sites	CROP DURATION (Days)					
	Brassica rapa			*Brassica napus*		
	Low	Average	High	Low	Average	High
Short - Guelph	77	79	81	84	86	88
Medium - Scott	83	88	96	97	101	106
Long - Olds	98	104	110	107	113	120

The Canadian data is, however, for rapeseed grown as main crops sown into cold soil in spring. Given the relatively high temperature for sowing a second crop in July in the central Tibet, initial germination and growth should be faster. Central Tibet should therefore resemble the Short - Guelph site in the above table, provided crops can be established quickly following winter cereal harvest.

The two rapeseed species do vary in their temperature tolerance and ability to recover from hail and frost. The optimum growing temperature is 20°C, with a base temperature of 5°C. Growing day degrees are calculated as $((T_{max} + T_{min})/2) - 5$, and accumulated over the potential growing period. These are similar to day degrees needed for cereal production. *Brassica rapa* has an average total requirement of 850 growing day degrees (similar to spring barley), while *Brassica napus* on average requires 1040 growing day degrees (similar to spring wheat). Estimating growing day degrees for Lhasa shows that it is in fact marginal for double cropping rapeseed (Table 7.20).

Emphasis has to be on varieties of *Brassica rapa*, and the growing period needs to be extended by harvesting winter barley as early as possible, or possibly by relay sowing into the standing mature barley crop at the end of June. While harvest can be delayed into October, frost has a particularly severe effect on seed while still maturing. Fortunately due the inherent plasticity of the rapeseed crop, even a high degree of damage by hail can be overcome during the early and mid growth stages in July and early August.

It is reported from Qushui that when farmers obtain a seed crop from rapeseed, yields are about 1125 kg/ha. As a second crop with sub-optimal cultural practices this is a good yield, and indicates total production including straw and chaff of approximately 3000 kg DM/ha. A single variety of rapeseed

Table 7.20. Growing day degrees for double cropping rapeseed in Lhasa

Month	Number of days	Growing degrees (°C)	Total Growing degrees (°C)	Total Growing degrees (°C)
1 - 15 July	15	10.8		162
16 - 31 July	16	10.8	173	
August	31	10.1	313	
September	30	8.6	258	744
1 - 15 October	15	6.2		93
TOTAL				999

1. The shaded portion indicates the main season available for second crops of rapeseed following winter barley Dongqing #1.

was included in the fodder observation trial in 2005, but when sown on 23 July total yield was very low at 469 kg DM/ha. Main objectives are therefore to identify cultivars that will regularly reach maturity; to introduce double low varieties so that the rapeseed meal from the local factory can be fed more safely to livestock; and to identify longer duration varieties with high total dry matter production to join evaluation trials on leafy fodder brassicas.

It is therefore appropriate to evaluate short duration cultivars of *Brassica rapa* under the double cropping programme (Plate 7.17.1). These should include double low varieties with low levels of glucosinolates. Varieties should come from breeding institutes in Northern China, and from high altitude sites around the edge of the Tibet/Qinghai Plateau. Since flower initiation is normally day-length depended, day-neutral cultivars are required to grow rapeseed as a second crop. While suitable material may be available at institutes in Lanzhou and Beijing, assistance may also be sought to obtain suitable Canola varieties from Canada through the CIDA project in Lhasa, in conjunction with the Canola Council of Canada. Locally grown single low varieties can be used as checks.

7.6. Annual / Biennial Grasses and Cereals

7.6.1. Annual / Biennial Grasses: Westerwold Ryegrass (*Lolium multiflorum* Lam. var. Westerwoldicum) and Italian Ryegrass (*Lolium italicum*)

There are a range of short duration ryegrasses that persist for 1-2 years. They respond well to fertility and to fertilizers, and provide safe fodder for feeding green and for conservation as hay or silage. A high proportion of conserved fodder in UK for high yielding milk cows is silage made from short duration ryegrasses cut before or just at ear emergence, when the balance between yield of dry matter and digestibility is optimum, and sugar levels in the crop are high. Several cuts are taken in a year, but nitrogen topdressing is required after each cut, and phosphate and potash levels must be maintained. Ryegrasses are best established as second crops following cereal or rapeseed harvest, and in areas where winter cereals are grown they are hardy enough to survive the winter. Annual ryegrasses will then provide one year's production, while biennial species should continue growth for a second year. Establishment in spring is also possible, either as a sole crop or undersown to barley. Several varieties are available in China, and further evaluation of varieties should be carried out. Ryegrasses can produce large quantities of seed, and the shorter the duration the more seed is produced. Although they can potentially become a weed, they have little ability to establish from surface seeding, and are easily controlled by cultural methods and chemical weed killers compared to perennial stoloniferous and rhizomatous weeds which are already widely present.

Land class

Although short duration ryegrasses grow best on top quality crop lands, they will establish and persist on second class lands provided they receive irrigation and sufficient fertilization. They are more tolerant of flooding and saline/alkaline soils than legumes, since they are not dependent on rhizobia which do not tolerate water-logged or poor quality soils. They should grow on rainfed lands that support a small barley crop, but yields will be related to rainfall and amounts of supplemental irrigation provided, and they may not survive beyond the establishment year.

Main Crop

At Lhasa two varieties of annual ryegrass that were established in the 2005 observation plots persisted well through the winter (Plate 7.18.2), and produced a first cut yield of 10.2 t DM/ha at the seeding stage in early July 2006. Similar yields were produced as a second growth by the end of September, when seeds were ready for harvest. Both yields were produced without fertilization in 2006, and annual production could have been doubled with efficient application of fertilizers. While soil phosphate reserves are generally good in central Tibet, potash reserves are now low. Fodder production from grasses is driven by N fertilization, up to 100 kg N/ha per growth applied in spring when winter cereals are top-dressed, and again after each harvest. Phosphate reserves need to be topped up by application during seedbed preparation. Potash, besides seedbed application, also needs to be replenished after each fodder harvest, in the same quantity of nutrient as applied for N (for example, if 50 kg N/ha was applied at the start of the growing period, 50 kg potash needs to be applied after harvest before the next growing period to make up for the potash removed in the fodder).

Fodder production from fertilized short duration ryegrasses is one of the simplest systems for farmers to introduce. However high yields do require high levels of fertilizer use, with economic and environmental implications. If this is a problem, it is possible to combine the benefits of grasses – high sugar content and ease of conservation as hay or silage, with the benefits of legumes – nitrogen fixation and high protein contents. The grass and legume can be grown as a mixture, so that some of the N fixed by rhizobia and released to the soil following each harvest is picked up by the grass. Grass / legume mixtures can be achieved by mixing seed of the two crops together for broadcasting or drilling, or each crop can be drilled by separate passes of the seed drill, preferably at an angle to each other. Yield of such mixtures will be less than for heavily fertilized grass crops, but similar to grass crops lightly fertilized with N; while the quality of fodder from the mixture will be higher than that from grass alone at low N levels. Suitable mixtures include annual ryegrass / hairy vetch for late summer sowing, annual ryegrass / common vetch for spring sowing, and biennial ryegrass / lucerne sown in late summer for crops to last for two years. Given the success of both common vetch and lucerne in the ACIAR intercropping trials, these mixtures should be most effective.

Second Crop

Annual ryegrasses can be established as a second crop following cereals by broadcasting and covering the seed, or by drilling into a prepared seedbed. Two varieties from Lanzhou were included in the 2005 fodder crop observation trial (Table 7.21) (Plate 7.18.1). Both established and grew vigorously,

Table 7.21. Yields of annual ryegrass varieties grown as second crops, Lhasa, 2005

Variety	Yield (kg DM/ha)	Visual evaluation on 25 September 2005
#1 Lanzhou	3446	Vigorous, some stem elongation, a few ears emerged. Deficient in N, yield would be double if fertilsed.
#2 Hei Mai Cao	2977	Dense stand, excellent growth, still leafy – no stem elongation; while not N deficient, would respond to N.
Mean	**3211**	

1. Sown on 23 July, harvested in early October.
2. Between row distance: 20 cm; plot size: 2m x 0.4 m = $0.8m^2$
3. Dry matter yield is taken as 0.9 Air dry matter yield.

with yields on average of 3200 kg DM/ha of vegetative material. These could be considerably improved through fertilisation with N and with potash, especially as second crops following cereals. This fodder could be cut and fed green, or conserved as hay or silage. With a DM content of 18%, it would need to be wilted before ensiling, but it would have a good sugar content compared to legume fodders. Cultural requirements for establishing ryegrasses as second crops are in Table 7.22.

Table 7.22. Cultural requirements for annual and biennial ryegrasses as second crops

Crop	Growing period		Seed rates		Row spacing (cm)	Fertilizer nutrients[1, 6]		
						N	P	K
	Season	Length (days)	Broadcast (kg/ha)	Drilled (kg/ha)		(kg N/ ha)	(kg P_2O_5 / ha)	(kg K_2O / ha)
Annual ryegrass (Westerwold)	July – October	100	45	30	18 – 20	100	30	100
Biennial ryegrass (Italian)	July – October	100	40	27	18 – 20	100	30	100
Annual ryegrass (Westerwold)	August – October	70	55	37	18 – 20	70	20	70
Biennial ryegrass (Italian)	August – October	70	50	33	18 – 20	70	20	70

1. N: Nitrogen; P: Phosphorous, as phosphate, P_2O_5; K: Potassium, as potash, K_2O
2. Sources: Nix (2003), adapted for central Tibet. Revise data according to local trial results.
3. Use half the seed rates shown if sowing mixtures with vetch or lucerne, and use half the normal seed rates for the legumes. Reduce N to 50 kg/ha, preferably placed with a combination drill under the rows of grass.
4. Zero-till drilled crops require an extra 15 – 25 kg N/ha compared to traditionally cultivated crops.
5. Apply all the fertilizers to the seedbed or with a combination seed drill. Do not mix the seed with fertilizer.
6. Fertilizer rates for P and K allow for good soil reserves of phosphate but low soil reserves for potash.
7. Apply P as DAP (di-ammonium phosphate) ($N:P_2O_5:K_2O$ 18:40:0) and make up the required seedbed N with local N fertilizers such as KAN (calcium ammonium nitrate)(26% N) or urea (46%N). Apply potash as Muriate of Potash (potassium chloride) (60% K_2O).

Well fertilised annual and biennial ryegrasses offer a simple way in which to grow high quality fodder as a second crop. At the same time, this is the best method to establish grass as a main crop for the following year. While fodder produced can be harvested for stall feeding or conservation, the crop can also be grazed under controlled management by cattle and sheep.

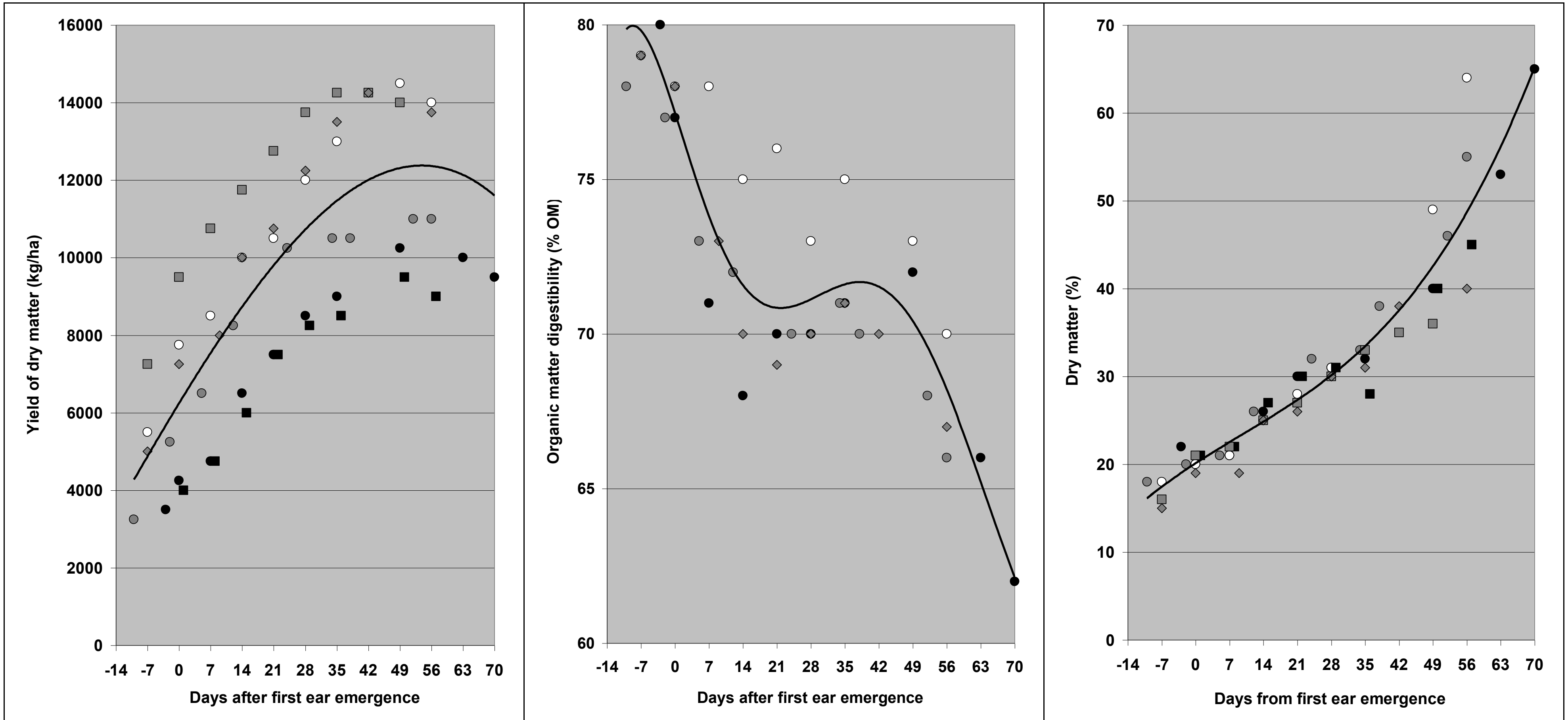
7.6.2. Small-grained cereals[6]: Barley (*Hordeum* sp.); Oats (*Avena sativa*); Rye *(Secale cereale);* Triticale (*Triticum aestivum x Secale cereale*); Wheat (*Triticum aestivum*)

The main interest in growing cereals for fodder production is as main crops for conservation as whole-crop silage or hay, following flowering of the crop (Plate 7.19.1). In addition cereals can be grazed by sheep before or after winter and then grown on for the main grain crop, or an early cut for green fodder can be taken while the crop is still in the vegetative stage – provided the N removed in the crop is replaced by an additional topdressing of fertilizer N. Some cereals, especially rye, are traditionally grown as a winter crop to provide an "early bite" of green fodder at the late vegetative to flowering stage in spring and early summer when green fodder is scarce; this can be followed by summer crops such as maize for silage. Regardless of purpose, it is important that cereal crops are grown well according to normal recommended practice, with full levels of fertilisation and crop protection.

Land class

Cereals for fodder will be grown as normal crops on good quality crop lands. Wheat prefers heavier, moister soils, whereas barley is more suited to well drained lighter soils. Rye and triticale are more

[6] The main reference for this section is Stark and Wilkinson (1992)



7.4.1. Yield of dry matter	*7.4.2. Organic matter digestibility*	*7.4.3. Dry matter content*

1. Data redrawn from Kristensen (1992) in Stark and Wilkinson (1992)
2. Data series are for six experiments at three sites in Denmark in 1980 – 1982. The crop was fertilised with 3 levels of nitrogen (N) and the results shown are mean values for the N levels.
3. Best fit polynomial trend lines fitted to data using Excel.

Figure 7.4. Relationship between days after first ear emergence in whole-crop winter wheat and dry matter yield, organic matter digestibility, and dry matter content

tolerant of lower fertility lands than other crops (Plate 7.19.2). Given the shorter growing period for fodder crops, it is possible to grow cereals for fodder on rainfed lands that would otherwise only provide low yields of grain.

Main Crops

Harvest of whole-crop cereals includes the grains, ears, leaves and stems, to the extent that they have developed at the time of harvest. It is equivalent to the harvest of grain and straw together, and with traditional long strawed varieties can give yields 2-3 times the normal grain yields. In UK maximum yields of winter oats and wheat in the 1970s was about 12 tons of DM/ha at the end of July at a mean DM content of 43%. Spring varieties of barley, oats and wheat had a maximum yield of 10-12 ton DM/ha in early August, at a mean DM content of 44%. By 1989 maximum yields of newer varieties of winter barley, oats, triticale and wheat grown on plots were 12, 15, 18 and 15 ton DM/ha respectively. In a survey of farms growing whole-crop cereals for conservation, the majority grew winter wheat. A key aspect in using winter wheat is the flexibility in cropping that it provides – the decision as to what area of wheat is to be harvested for fodder in any year only needs to be taken after the yield potential of the crop has been established. This is important in central Tibet, where quotas for wheat grain production may be set, beyond which land may be used for fodder production. In Denmark whole-crop silage has become popular feed for cattle, with use of barley alone and mixtures of barley and peas. The use of winter wheat is increasing. The yield potential of winter wheat whole-crop is 9-17 ton DM/ha, and of spring barley is 6-11 ton DM/ha. Spring crops are normally undersown to grass, and 2.0-2.5 ton DM/ha of grass is grazed or harvested in autumn.

The optimum time of harvest of whole-crop winter wheat in Denmark has been related to days from first ear emergence (Figure 7.4). The maximum yield of dry matter in the whole crop was obtained 35-49 days (5-7 weeks) after first ear emergence, and dropped as the crop matured further (Figure 7.4.1). Organic matter digestibility (ODM) generally dropped sharply from first ear emergence until all the ears had emerged (Figure 7.4.2). During the period 14-42 days (2-6 weeks) following first ear emergence ODM tended to increase slightly, after which it fell again. Maximum yield of digestible organic matter was obtained at 42-56 days (6-8 weeks) after the start of heading. The dry matter content increased progressively with increasing growth stage (Figure 7.4.3), and 42 days (6 weeks) after the start of heading, when the yield of dry matter was at a maximum, it was 35-43%. Crude protein content fell sharply from around 150 g/kg DM before heading and levelled off at 60-100 g/kg DM at 35 days (5 weeks) after the start of heading, with lower values for high yielding crops. The content of water soluble carbohydrates remained high at 140-125 g/kg DM until 28-35 days (4-5 weeks) after first ear emergence, after which it fell sharply to almost zero – while the starch content increased rapidly. Similar changes in yield and composition were observed in relation to stage of development in spring barley, except that maximum dry matter yield/ha was obtained at approximately 35% DM.

In summary, the optimum time of harvest for winter wheat based on yield, composition and feeding value, as found in the Danish studies, is 5-6 weeks after first ear emergence, with a dry matter content in the whole-crop of 40% (soft dough stage). For barley the optimum harvest time was 4-5 weeks after first ear emergence, with a dry matter content of around 35% (milky-soft dough stage). Whole-crop cereals, and their mixtures with legumes, of 30-50% DM are easy to ensile without additives. Harvest at these growth stages provides good potential to grow high yields of second crop fodders.

Losses of dry matter during fermentation vary with crop and DM content, but with fine chopping, and good consolidation and sealing they can be reduced to 5- 12 % of the original dry matter (Table 7.23). However the stability of cereal silages when they come to be fed is poor, and aerobic losses due to exposure of the silage to air are high. While silage removed for feeding is consumed by animals within 12 hours, silage remaining in the silo that is exposed to air heats rapidly through the action of bacteria, yeasts and moulds resulting in loss of dry matter and nutrients and formation of toxins. "Plastic Barrel Silage" was developed for use in central Tibet (see Chapter 9), so that only a small amount of silage is exposed at one time during feeding, and unfed silage remains sealed in containers.

Table 7.23. Fermentation and aerobic losses of dry matter in whole-crop cereal silages

Losses	Whole-crop wheat				Whole-crop barley			
	Low DM		High DM		Low DM		High DM	
	DM%	Loss%	DM%	Loss%	DM%	Loss%	DM%	Loss%
Fermentation losses	30	12	47	10	30	7	47	3
Aerobic losses (7 days exposure)	24	10	43	5	27	15	47	4
Aerobic losses (14 days exposure)	24	31	43	30	27	32	47	12

1. Data from Tetlow (1992) in Stark and Wilkinson (1992).

An alternative approach for cereal whole-crop silage has been developed in UK and widely adopted by farmers. In this cereal crops are harvested at maximum dry matter yield 7-9 weeks after first ear emergence at 50% DM (grain medium – hard dough stage). This more mature crop is treated with urea applied at the time of ensiling at 4% of the crop dry matter (about 2% of crop fresh weight). Compared to the highly acidic silages produced by fermentation, urea whole-crop has a high pH, high crude protein content, and high aerobic stability. It is therefore suitable for large scale production of cereal whole-crop in large silos. This method can also be adopted by small scale farmers if dry weather leads to more rapid maturing of the cereal crop than anticipated, or operational delays occur in provision of labour and choppers for harvest of whole-crop cereals. However, time for growth of second crop fodder is reduced.

For making hay, the flowering stage at 21-35 (3-5 weeks) days after the start of heading is best, as the whole plant has high digestibility but there are no grains to be lost.

Fodder oats were introduced to farmers in the mountainous Sandzak region of Serbia, and heavy crops for feeding green and for conservation as hay and silage were produced on fertile land which received high quantities of animal manure and fertilizers (Plate 7.19.4).

Oats as a main crop for disaster relief

Fodder oats are currently grown on a station on the High Plateau that belongs to Dam Zhung County Grassland Bureau, to produce fodder which is dried and then milled for use by Yak herders as emergency relief during snow fall conditions. It is possible that fodder production in the valleys can be linked to this programme provided there is co-ordination between staff of the valleys and high plateau. Oats are also grown for emergency hay production in Shigatse at Amigan (Plate 7.19.3). At present fodder oats would have to be grown as main winter or spring crops, with the potential for a second fodder crop of a different species for use by farmers for their own animals. Importation of oat varieties from New Zealand for evaluation at low and high altitudes is still in progress.

The oat fodder can be harvested with traditional sickles, or tractor mounted reapers, and dried in field or in compound. The oat hay can then be baled with standard rectangular balers available in China, or processed through cubing/pelleting machines specifically manufactured by CAAMS for this kind of operation. TAR / county bureaux can easily arrange backloads to transport the fodder at cost from the valleys to the mountain villages along the main Lhasa / Qinghai highway.

Second Crops

Cereals in general are not included as second fodder crops for sowing after main crop winter cereals due to the potential to build up soil borne pests and diseases and to carry them over from one main cereal crop to the next. It may, however, be possible to grow rye and triticale, which are more resistant to diseases.

Rye has the capacity to make good growth at low temperatures, and so is particularly suited to the provision of really early spring fodder as an "early bite" of green fodder before any other grass or cereal starts to grow (Toosey 1972). In addition rye is not subject to the soil-borne diseases of other cereals, and does not appear to perpetuate them. However the stem develops very quickly in rye and becomes coarse and unpalatable, so fodder needs to be harvested in an early leafy stage. Rye can also be grazed directly in the field at this leafy stage. Special fodder varieties of rye should be grown, which outyield traditional and grain varieties for early bite.

For good early growth in spring, rye must be well established in the autumn. In central Tibet sow in August or early September. Harvest growth made in the autumn in October by grazing with sheep or by plucking leaves by hand to ensure the development of numerous short sturdy tillers. Remove the stock over winter until the early bite is ready. Apply 40 kg/ha of N, P_2O_5 and K_2O to the seedbed, and sow at a high seed rate of 225 kg/ha by standard seed drill or zero-till drill. N topdressing is essential at 50 kg/ha N as KAN, applied from late February to late March according to county. This should be staggered to provide a succession of green fodder through April and May. Following harvest or grazing of rye, a main summer crop such as maize should be cultivated. The exact requirements for growing rye as early bite in central Tibet need to be determined through station and farmers' trials.

It is possible to graze or harvest green fodder from crops of other winter cereals grown for grain (Toosey 1972), and initial trials with wheat and triticale were started at Lhasa in 2006. The amount of fodder available in spring depends on the date of sowing and the temperature during winter and early spring, and yields will vary from 700-1400 kg DM/ha of high quality fodder. Early sowing in September results in a forward crop which is likely to give more spring fodder. The stage of growth is critical, and grazing or harvest of green fodder must be completed before the growing points of the cereal plants start to extend and there is any chance of removing the embryonic ears. Should this occur almost total loss of grain yield will result. In the 2006 trial at Lhasa the fodder harvest was delayed until after stem elongation, and subsequent growth was very small. Examine a few plants before grazing. If the growing point at the centre of the leaf sheaths has not started to elongate, the crop is still fit to graze or to harvest fodder. This should take the form of plucking leaves by hand, rather than cutting with a sickle. Once elongation has started, the embryonic ear is likely to be removed by defoliation, and further grazing or fodder harvest will reduce yield. The date on which this critical stage is reached will vary according to county due to altitude, and from season to season. Crops grazed or harvested for fodder should always be top dressed with 30 – 60 kg N as KAN immediately following defoliation. The exact amount depends on the crop and variety of cereal – more for stronger strawed wheats and less for soft strawed barleys. If the N removed during grazing or fodder harvest is not replaced, subsequent grain yields will be severely reduced.

7.6.3. Maize[7] (*Zea mays*)

Ten years ago maize was frequently grown in the valleys of central Tibet as a sole spring / summer crop. Farmers have not continued to grow it. To date the main interest has been to grow maize as a grain crop. This can only be done in Lhasa with present varieties by using a plastic mulch to warm the soil at planting time. However when grown for fodder conservation as a main crop the growing period is reduced by at least a month, allowing establishment in early summer without plastic. Excellent plots of maize were grown at Lhasa in 2006, and were suitable for harvesting as silage (Plate 7.20). The whole plant with cobs at the cheesy – soft dough stage is chopped, and specific fodder maize varieties are available. However large cobs at this stage are worth up to 1 Yuan each when sold as vegetables, so that it is likely that only small cobs will be ensiled. Grown as a dual purpose crop in this way, it is sensible to consider growing special sweetcorn varieties of maize, which will have higher economic value on the vegetable market, while still providing high yields of fodder for conservation. Maize can also be grown to supply green fodder at a younger stage of growth. When planted in early summer, green fodder can be harvested from June onwards. At the same time, worthwhile crops of green fodder can be obtained from maize planted as second crops following short duration winter cereals, when yield is directly related to the time of planting. The success of both main and second maize crops in 2006 indicates the potential of maize as a fodder crop in central Tibet.

Only a brief summary on crop physiology for forage maize can be given here. As for other cereals growth to various stages of development is related to accumulated temperature. Several methods to

[7] References for this section are Toosey (1972), Bunting *et al.* (1978), Phipps and Wilkinson (1985) and Wilkinson (1998).

estimate day degrees for maize have been developed based on accumulated mean temperature above a specified base level, for example 10°C. However in cool temperate climates the Ontario Unit based on daily maximum and minimum air temperatures (Table 7.24) has been most closely related to observed growth stages in maize, and may be applicable in central Tibet during this exploratory phase of development of the crop.

Table 7.24. Calculation of Ontario system of heat units to related accumulated temperature to maize development

Step	Definition	Comments
1. Estimate the curvilinear contribution (Y_{max}) from T_{max}	$Y_{max} = (3.33 (T_{max}–10)) – (0.084 (T_{max}-10)^2)$ When T_{max} <10, Y_{max} = 0	A maximum value of T_{max} is taken as 30°C
2. Estimate the linear contribution (Y_{min}) from T_{min}	$Y_{min} = 1.8 (T_{min}-4.4)$ When T_{min} <4.4, Y_{min} = 0	
3. Estimate the daily contribution	Ontario Units = 0.5 ($Y_{max} + Y_{min}$)	

1. Adapted from Bunting *et al.* (1978).

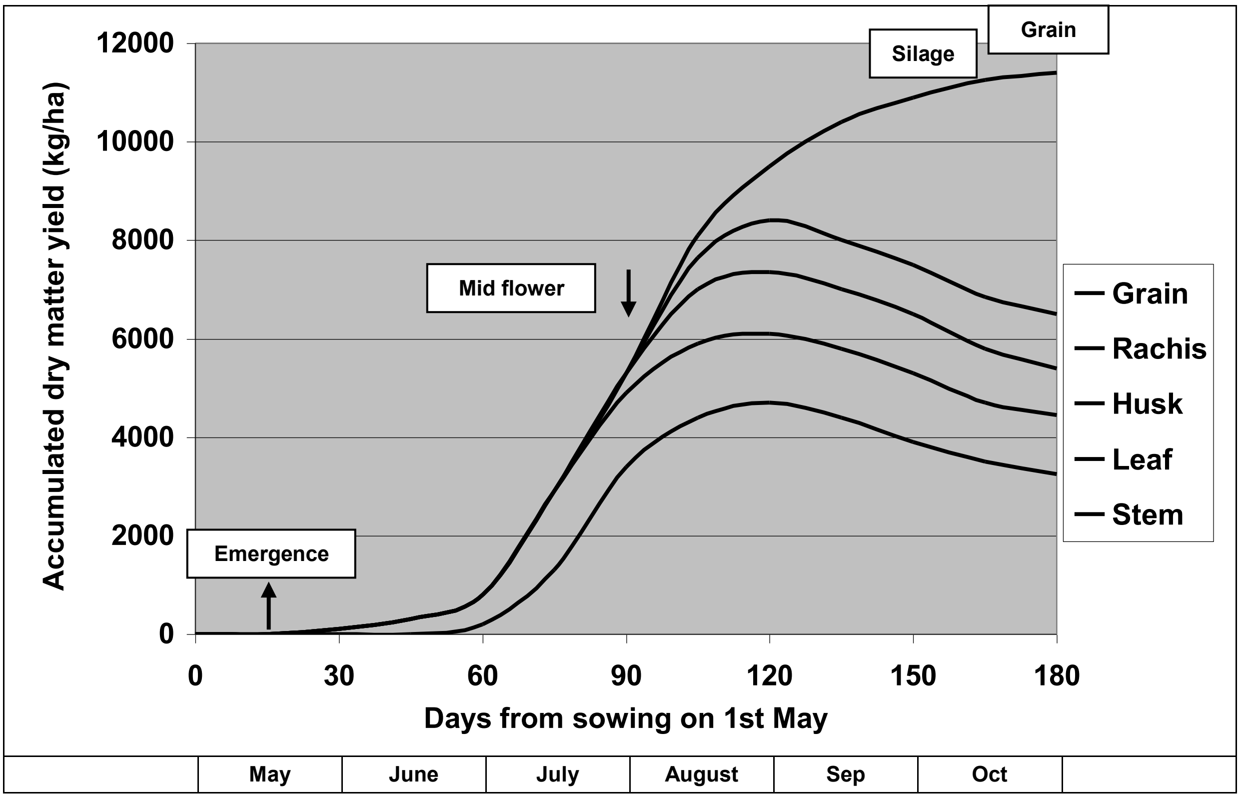
The general pattern of development in short duration maize varieties sown on 1st May in central England at a density of 100,000 plants/ha is shown in Figure 7.5 and is outlined below since it corresponds closely with growth of maize in central Tibet:

1) Following emergence after 14 days growth of seedlings is slow – at this stage maize is particularly vulnerable to weeds which must be effectively controlled by hand or with herbicides.
2) Until six leaves have been initiated by late June the growing point remains at or below ground level.
3) When stem extension does begin it occurs rapidly, plant height increases by 3-5cm/day, and leaf area index increases from 1 to 4 during July. Water stress must be avoided for maximum growth and grain yields.
4) Early short duration varieties flower in late July / early August, with half the plants shedding pollen from the tassels 2-3 days ahead of silk emergence on the cobs. This occurs at around 1400 Ontario heat units. At flowering maize plants reach 75% of maximum fresh weights but only 50% of maximum dry matter yields. The flowering stage is the critical development stage in maize and water demands are highest.
5) 30 days after flowering in late August / early September the crop reaches maximum fresh weight. with around 18% DM content. Cobs and grains are fully formed and grains are at or near milk stage. This is the stage when sweet corn is harvested.
6) After this stage fresh weight of the crop declines but dry weight continues to increase until growth is stopped by autumn frosts. With declining day length current photosynthesis can not meet energy demands of the maturing grains, and sugars are removed from the stem and used to form starch in the grains.
7) By the end of September the crop is within 5% of maximum dry weight, the grain has reached the dough stage of development, and the dry matter content of the whole shoot is 20-30%, and is fit for harvest as silage. Ontario Units are 2300 at this stage.
8) The grains continue to mature, and the crop is ready for grain harvest from mid-October onwards with a grain dry matter above 50%, having required 2550 Ontario Units.

Several factors modify the basic pattern of accumulation and distribution of DM in the maize plant:

Maize variety: a more rapid accumulation of dry matter during the vegetative phase of development is desirable in maize grown for green feed – and for second crops sown too late for flowering and cob development. Differences in early DM yield of 1000 kg DM/ha can occur during the third month after sowing between varieties of similar maturity date.

Sowing date: maize requires a higher temperature for germination than other crops so planting should be later than for spring barley. Soil temperatures climb progressively in spring, and should be 10°C before sowing, when crops will emerge within 10 days and grow vigorously. Maize is also susceptible to frost, so sowing should be delayed until 14 days before the probability of a late severe frost is low. Optimum sowing dates need to be mapped for central Tibet taking these factors into account. Yield of crop dry matter is maintained at or near maximum levels until sowing is delayed more than two weeks beyond the optimum sowing date, as reduction in grain content is offset by increase in plant



1. Redrawn from Bunting et al. (1978)
2. Data are for short duration maize varieties sown on 1st May in central England in 1970s at a density of 100,000 plants/ha

Figure 7.5. Seasonal trends in accumulation and distribution of dry matter in short duration maize hybrids grown in central England in 1970s

height and number of leaves. This is related to increase in day length and higher soil temperatures. As shown in Lhasa, major delays in sowing date results in progressively smaller plants (Plate 7.20.1-4), with reduced proportion of grain in the fodder, until only leaves are produced with maize planted as a second crop in late July.

Plant density: crop dry matter yield increases with plant density up to a maximum then remains constant as density increases further. Yield of grain, however, reaches a maximum at an intermediate level and then declines. Optimum plant densities depend on the objectives in growing the crop, since plant density affects the distribution of dry matter within the plant. Due to high seed costs maximum dry matter yields may be uneconomic. In addition dense crops are susceptible to lodging. Where moisture and plant nutrients are constraints, optimum plant densities will be lower.

Land class

Maize can be grown on a range of soils, but drainage and seedbed preparation must be good. Deep fertile loams are best, while shallow and sandy soils are not suitable. Irrigation facilities must be good, as maize is susceptible to drying out at the tasseling and silking growth stages. Crops for fresh fodder and second crops which are harvested before cob formation can be grown on a wider variety of soils. Maize is not subject to the normal cereal diseases, so can be grown as a break crop between wheat and barley crops. Two successive crops of maize can be grown on the same land.

Main Crop

Short duration (earliness) is the most important factor when selecting varieties for silage in central Tibet. They should be capable of giving a good yield of almost mature grain, and to complete their growth before the first frosts in autumn. It is possible that a range of varieties of various maturities will be available. The earliest maturing varieties , which give a lower yield of dry matter, are suitable for the highest elevations such as Duilong, or for later sowing dates. Medium early varieties suitable for lower elevations will give a good yield of dry matter with a high ear content combined with reasonably early maturity. Work is required on variety evaluation and variety x time of sowing interactions for the range of elevations in central Tibet. A succession of sweetcorn varieties can be grown, since they are harvested at a less mature stage of growth; ear size and yield of ear increases with lateness of maturity. Late varieties and sterile male lines can be evaluated against short duration hybrids for summer green fodder production.

High fertility is required, and high levels of fertilizer should be worked into the seed bed especially when the crop is grown after several cereal crops, and organic manures are not available (Table 7.25). Fertilizer should not be placed through a combination drill as the seed is sensitive to fertilizers. If N has to be top-dressed, it must be placed on the soil surface, or severe leaf scorch will result. Potash fertiliser is required to prevent lodging of the crops, especially when bearing heavy cobs. Lodging leads to soil contamination which greatly reduces fodder quality for ensiling. Reduced fertilizer levels are appropriate for crops grown for green fodder due to the reduced growing period, but good fertilisation is still required.

Table 7.25. Fertilizer requirements for various maize crops

Maize Crop	Fertilizer nutrients[1, 3]		
	N	P	K
	(kg N/ ha)	(kg P_2O_5 / ha)	(kg K_2O / ha)
With fertile soil, with heavy application of manure	100	50	50
With fertile soil, good crop rotation	125	50	75
Maize as a break crop in a run of cereal crops	175	50	100
Maize for green fodder (3 months growth) as break crop	100	30	50
Maize as second crop (2-3 months growth) after cereals	75	25	40

1. N: Nitrogen; P: Phosphorous, as phosphate, P_2O_5; K: Potassium, as potash, K_2O
2. Sources: Toosey (1972), adapted for central Tibet. Revise data according to local soil analysis and trial results.
3. Fertilizer rates for P and K allow for good soil reserves of phosphate but low soil reserves for potash.
4. Apply P as DAP (di-ammonium phosphate) ($N:P_2O_5:K_2O$ 18:40:0) and make up the required seedbed N with local N fertilizers such as KAN (calcium ammonium nitrate) (26% N) or urea (46%N). Apply potash as Muriate of Potash (potassium chloride) (60% K_2O).

The most suitable plant density for maize depends on the purpose for which the crop is required (Table 7.26). With green fodder production the objective is to produce the highest dry matter yield possible regardless of the parts of the plant it comes from. The optimum balance between yield and cost of seed appears to be about 17 plants/m^2 for summer crops. When the ear is important as in high energy maize silage, maximum grain yields are obtained at around 10 plant/m^2, although highest dry matter yields will be obtained at 11 plants/m^2. With sweetcorn only uniform well-filled ears are marketable. Each plant should produce two good ears, achieved by low plant populations of 3 – 5 plants/m^2 for late and early varieties respectively. Corresponding number of plants and seeds required are given in Table 7.26, with weight of seeds/ha for varieties with different seed weights.

With appropriate plant populations and even seed distribution along the row, row widths of 45 – 75 cm have little effect on yields of maize grain, silage or sweetcorn. Mechanical harvesters for maize silage with more than one row are standardised on 75cm row width, and this width has been adopted by CIMMYT as the standard width to evaluate maize varieties. However close row spacing is desirable for green fodder production, such as 35-40cm. Even for silage production, where hand labour is available for weeding, culling and thinning, useful green fodder (1000-2000 kg DM) can be taken from a crop that is established with a high plant population/close row width, and then progressively thinned down to the desired population for silage. This needs to be completed at least two weeks before flowering – at the time cell division occurs in reproductive tissues. Seed should be evenly spaced along the row, and low cost specialist maize drills should be available in Lanzhou and

Table 7.26. Plant densities, approximate number of seeds required/ ha, and seed rates depending on Number of Seeds / Kg for various maize crops

Maize crop	Main objective	Number of plants / m^2	Number of plants / ha	Number of seeds required allowing for 10% failing to produce established plants	Seed rates required (kg/ha) according to Number of Seeds / Kg		
					2600	3300	4000
Sweet Corn – late	Two marketable cobs/plant	3.6	36,000	40,000	15	12	10
Sweet Corn – early	Two marketable cobs/plant	4.8	48,000	53,000	20	16	13
Silage – high energy	Maximum grain production	10	100,000	110,000	42	34	28
Silage – high yield	One good cob/plant + high yield of DM	11	110,000	121,000	47	37	30
Green fodder	Maximum yield of DM	17	170,000	187,000	72	57	47
Second crop	Maximum yield of DM in 2-3 month	20	200,000	220,000	85	67	55

1. Adapted from Toosey (1972)

possibly in Lhasa. There is a risk of seed damage from use of standard cereal drills, unless they are designed to sow maize. Seed depth should be 5cm, which is deep enough to ensure adequate coverage. The seed spacing within the row to meet the required seed populations can be calculated from the following formula:

$$\text{Within row spacing (cm)} = \frac{m^2/\text{ha} \ \text{x} \ cm^2/m^2}{\text{row width (cm)} \ \text{x required seed population}}$$

for example, for high yield silage with 75 cm between row spacing

$$\text{Within row spacing (cm)} = \frac{10{,}000 \ \text{x} \ 10{,}000}{75 \ \text{x} \ 121{,}000} = 11$$

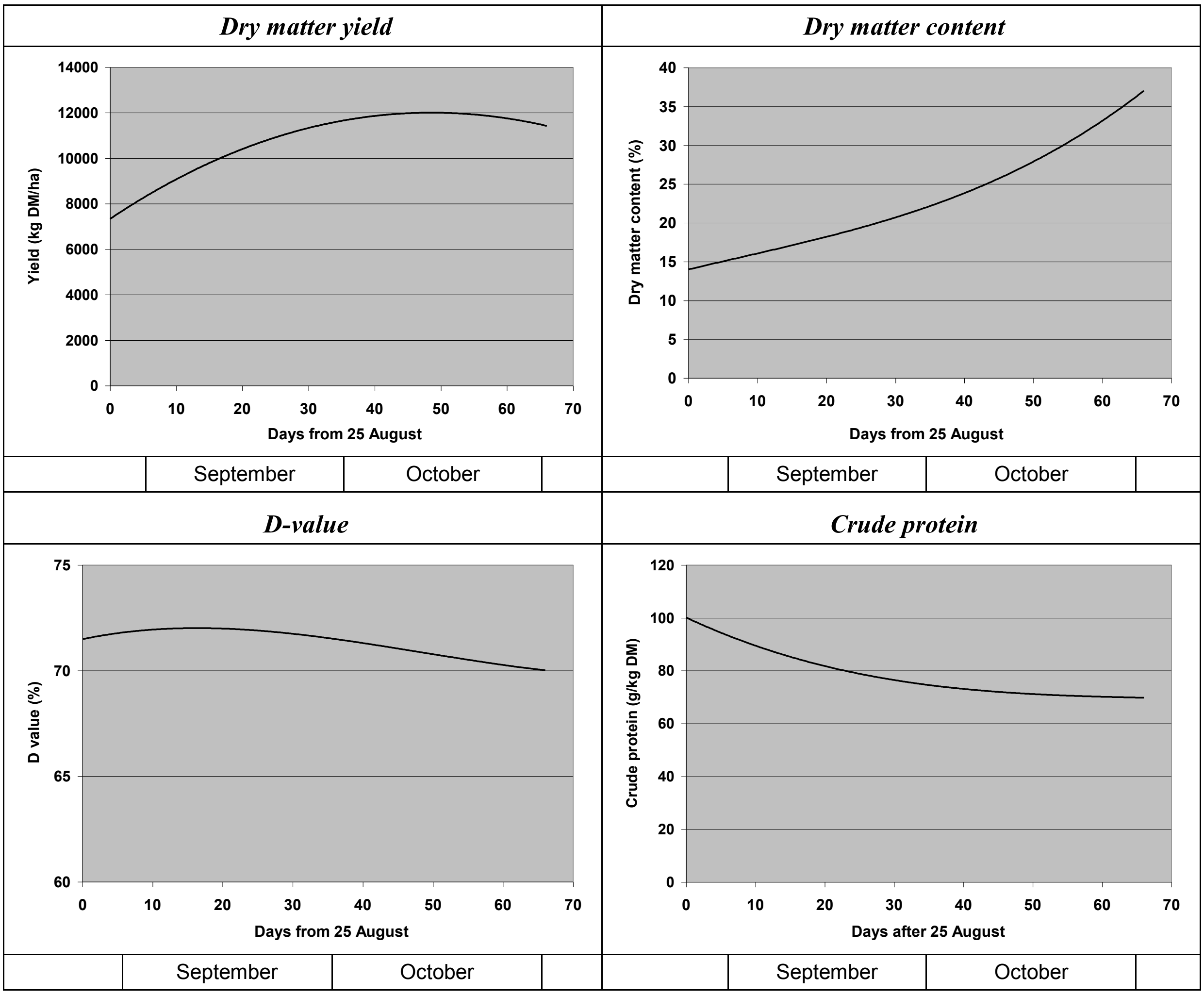
Due to the slow growth of maize seedlings it is essential to have an effective weed control programme (Plate 7.20.5). The late sowing in spring provides a real possibility to use false seedbed techniques to encourage weed seeds to germinate and then to kill them by successive cultivations. If weed control within the crop is by hand or by animal drawn cultivators, rows must be wide enough for easy use of hoes without damage to the young plants. This must be carried out early, and continue until the crop is tall enough to shade the inter-rows. Herbicides can be used in several ways:

1) 2,4-D ester at 1.7-2.3 kg active ingredient (a.i.)/ha pre-emergence, as a supplement to cultivations, to reduce broad-leaved weed competition during the first few weeks of crop growth.
2) 2,4-D amine applied post-emergence before the crop reaches the 4-leaf stage (about 15 cm tall) to check or kill many broad-leaved weeds. Later application in high temperatures cause visual symptoms of damage and a brittleness to the crop which persists for 2-3 weeks and can lead to stem breakage in strong winds. Directed sprays with high dilution rates can be used to control late germinating weeds and thistles.
3) Atrazine, a triazine herbicide, at 1.1-1.7 kg a.i./ha, applied before crop emergence, either before the crop is sown and lightly harrowed in, or as a surface dressing immediately after drilling (moisture is required to activate the herbicide in the soil), to control both broadleaved and grass weeds throughout the growing period. A higher rate of atrazine, at 4.5 kg a.i./ha, is used to control *Agropyron repens*. Atrazine is first adsorbed on to the surface of clay particles, then released slowly over a long period. It is absorbed by plant roots, but maize is highly resistant to its activities. However, due to its persistence in the

environment use of triazine herbicides has now been banned in the EU, and other more costly herbicides with a variety of activities have to be used.

4) Pre-sowing or pre-emergence applications of glyphosate (Roundup) to obtain a sterile seedbed. This is totally inactivated on contact with soil, but will control all annual and perennial broadleaved and grass weeds present at the time of application.

It is essential to control damage by birds at the time of seedling emergence. Some large birds will walk down the row and pull up every seedling to eat the seed below. These birds can be controlled effectively on small areas by stringing heavy duty black nylon thread on sticks or bamboo canes at least 1 metre from the ground. The sticks or canes are placed 15-20 m apart in each direction (allow 70 – 100 sticks or canes/ha). Remove the thread when the maize is 30-45 cm tall. Site maize fields as near the village as possible, and make dawn patrols to scare off birds and use bird scarers such as fire-crackers once crops approach emergence. This must continue until two weeks after crop emergence. Also control mice, rats and other rodents, that can burrow under the soil to steal the seeds.



1. Data redrawn from Toosey (1972), originally supplied by A.J.Heard, Grassland Research Institute, Hurley, UK.
2. D-value is the digestible organic matter in the dry matter, expressed as a percentage

Figure 7.6. Changes in yield of dry matter, D-value, dry matter content and crude protein of short duration maize varieties in UK

The maize crop can be harvested for green fodder at any stage of growth; before flowering dry matter content is low at 15%. As noted above densely sown silage crops can be thinned for green fodder. In addition the tassels can be cut by hand for fodder after flowering, along with old leaves from the bottom of the crop as they start to senesce. Once the ears have been produced further increase in dry matter is mainly due to starch forming in the grains, so that once the grain milky stage has been reached the ear contains half the dry matter of the whole plant. Ears for sweetcorn are harvested at this stage; the outer husk, stem and leaves are still at a high digestibility and crude protein content and constitute good quality fodder as green feed or for silage, possibly with wilting to 25% DM. From this stage total dry matter yield continues to increase as grains fill with starch, but sugars are transferred from the stem so that there is little change in digestibility of the whole plant over 3-4 weeks at around 70% D value (Figure 7.6). Some silage varieties include a cold tolerance 'stay-green' gene that maintains high sugar contents in the stem; besides providing resistance to frosts in autumn, this also improves whole plant digestibility as the stem retains more sugar at maturity. These varieties should be tested in central Tibet as they would lengthen both growing and harvest periods. Dry matter content of the whole crop increases with maturity as cobs fill with starch and stems start to dry out (Figure 7.6). Crude protein of the whole crop initially falls as starch content increases, then stabilises at 60-80 g/kg DM. Optimum stage for harvest for silage is at peak dry matter yield when the whole crop has 20-25% DM and grains are at the cheesy – soft dough stage. Crops for high energy silage should be taken through to the soft-hard dough stage at 25-30%DM of the whole crop. Once frosts occur growth stops and crops should be harvested for silage. Crops grown for maize grain can be left in the field to dry down, harvested and stooked in the field, or cobs picked for drying in cribs while stover is stooked in the stack yard.

For high energy silage to be fed to high producing cows whose milk is sold to the market, chop all ears as well as leaves and stems by hand, or with small electric choppers or large choppers depending on scale of farming. Mix the chopped fodder, and compress it well into the silo (see Chapter 9). Crop will need to be guarded to prevent theft of cobs near harvest. For greatest economic and social returns where milk is not sold, remove well formed ears of sweetcorn for sale, and well formed ears of grain varieties for consumption in the family or for sale, before ensiling small ears with the rest of the crop.

Maize for silage was introduced to farmers in an FAO project in the mountainous Sandzak region in Serbia (Plate 7.21), and short duration varieties produced ears at the milky-cheese stage before growth stopped with the first frosts in early October.

Second Crop

One variety of maize (Maize 308) was included in the fodder evaluation trial in 2006, with reasonable establishment and good growth despite dry conditions following sowing and intense weed competition. Yields given in Table 7.27 are corrected to target plant populations of 17 plants/m^2. These plants were sown on 23 July and reached 20-30 cm height when observed in late September (Plate 7.20.4). While this plant population is suitable for second crops sown in late June / early July, it is likely higher yields of green fodder are possible from later sowings by increasing the plant population even further, providing cheap seed is available. It is essential to evaluate maize varieties for rapid germination and early growth, which may be related to seed size – which has wide variation between varieties and seed lots. Fodder from second crop maize is mainly composed of leaves, and has high feeding value. Plots harvested in 2006 had medium dry matter contents of 23-29%, which should result in well made silage. Maize should be cultivated for second crops as for main crops, apart from specifications for fertilization and seed rates indicated in Tables 7.25 and 7.26.

Table 7.27. Total yield of second crop maize at Lhasa 2006

Variety	Plot	Target popn (plant/m^2)	DM %	Yield (kg DM/ha)		Comments
				Plot	Crop	
308	1	17	24	2720	4250	Yields for Plots 1 & 2 estimated from individual plant weights
	2		29	6440		
	3		23	3600		Yield from best 1m^2 quadrat

1. Plots were sown on 23 July and harvested on 11 October 2006

7.7. Minor crops

Besides fodder production, minor crops may be important as second crops for their role as break crops. Their possible place in rotations with other crops should therefore also be assessed.

7.7.1. Buckwheat (*Fagopyrum esculentum*)

Buckwheat originated in Central and Western China. It is a member of the Polygonaceae and is unrelated to cereals, legumes or brassicas - so it can act as a break crop within rotations. There are minimal related diseases with cereals. A low probability of a damping off and root rot problem exists for one year in relation to legumes and brassicas. Buckwheat is already grown as a second crop for grain in Jiacha county in central Tibet.

Buckwheat is a summer annual with coarse, branched stems and large, broadly arrow-shaped leaves. Flower panicles and leaves arise from the nodes, both on the main stem and branches. Growth habit is indeterminate with flowers opening throughout a comparatively long season, so the crop does not mature at one time. The seed is partially but not entirely enclosed by adhering flower parts during development. Buckwheat is usually only seeded after the ground is warm in early summer. Plants begin blooming about 40 days from seeding and first seeds mature after another 35 days. Harvesting is done when most of the seed is ripe - fields are cut and the plants are stacked to dry before they are threshed.

The seed consists of an outer hull, the seed coat proper, and a starchy endosperm plus the germ. In milling the hull, which makes up 20 percent of the whole grain, is removed. A second milling removes most of the seed coat or "middlings" which comprise 4-18 percent of the whole grain weight depending how much of the seed coat is actually removed. The whole buckwheat grain may be used in poultry mixed grains. The middlings are high in protein and make a good livestock feed. The straw is higher in protein but lower in digestible carbohydrates than cereal straws.

There are two main types of Buckwheat - Japanese, and Silver Hull (Common Gray), plus a couple of minor species. There are ongoing research programmes on Buckwheat at TARI. The cultivars currently available at TARI should be evaluated for their potential role as second crops in double cropping systems in the Project area. These cultivars should be supplemented with additional short duration cultivars from northern China. The susceptibility of Buckwheat to hail and storm needs careful evaluation - although the crop may suffer damage, it should be sufficiently plastic in its growth form to recover from damage.

Land class

Buckwheat is tolerant of low fertility soils, but needs well drained lands. It should produce a grain crop on second class and rainfed lands that support crops of spring barley, and even produce fodder crops in most years without supplemental irrigation.

Main Crop

Grown as a main crop buckwheat would normally be grown through to maturity for grain. Buckwheat straw has similar energy and crude protein values to straw from spring barley, but with a shorter fibre structure it has higher intake characteristics.

Second Crop

Two varieties of buckwheat were grown in the fodder evaluation trial for second crops in 2006 (Plate 7.22.1). Germination and establishment was promising, and plants of the early variety reached flowering on all plots, but yields from these late sown crops with dry conditions after sowing and intense weed competition were low (Table 7.28). Storm damage was not apparent when inspected in late September. Cultural methods are similar to those for wheat, and both N and potash should be applied for second crops. Further work is required to evaluate varieties and growing methods for fodder production as second crops.

Table 7.28. Total yield of second crop buckwheat at Lhasa 2006

Variety	DM %	Total Yield (kg DM/ha)	
		Variety	Crop
Chanyu	24	400	1275
Mirui	24	2150	

1. Plots were sown on 23 July and harvested on 11 October 2006

7.7.2. Amaranthus (Grain and Fodder) (*Amaranthus hypochondriachus, Amaranthus cruentis, Amaranthus caudatus*)

Amaranthus species are short duration high protein grain crops with tiny seeds that are used in human nutrition following toasting or popping. In addition the leaves can be used as a vegetable or fed to animals. Grain Amaranthus has been developed in China since 1982; five cultivars (both grain and forage cultivars) have been officially released, and the current crop extends to 100,000ha[8]. While fodder can be harvested after 25-30 days, grain crops should be ready after 60+ days. Amaranthus species are C4 plants unrelated to local broad-leaved species. Soil disease problems should be restricted to a low probability of damping off and root rot problems if grown within one year of legume and brassica crops.

Land class

Amaranthus species should grow on sheltered sites in the valleys of central Tibet. They are drought resistant, and due to the short duration of growth should grow as a fodder crop on rainfed lands. They tend to be susceptible to lodging due to storms and heavy rainfall, so short stemmed grain cultivars should be selected.

Main Crop

Amaranthus species can be grown as main crops for both green fodder, for example following 'early bite' winter rye, and as short duration seed crops. Prepare a false seedbed in spring to germinate and kill weed seeds, then broadcast seed at low seed rates (2-3 kg/ha) followed by a final levelling with a board once risk of frost is over. Both short and long duration amaranthus varieties should be sown on separate plots to provide a succession of green fodder in June-July.

Second Crop

Amaranthus has been grown in Tibet, but only long duration varieties have been available. Short duration varieties as indicated above should be evaluated for both harvest of fodder in September and seed yield in September/October.

7.7.3. Sunflowers (*Helianthus annus*)

Sunflowers can be grown as a fodder plant where the season is too short and cool for maize[9]. Leaves can be used for green fodder after 6-10 weeks growth. If grown for silage it should be cut when approximately half the heads are flowering. The later the plant is harvested the more fibrous and the less palatable it is. As a main crop it can be taken on to seed production. A large number of sunflower varieties are available in China. Short duration short multi-stemmed varieties with small heads should be selected, since these are more resistant to weather damage. With the possibility of restructuring of crop lands, it may be possible to develop sunflower as a major alternative oilseed crop in the Project area. The residual sunflower meal is a valuable high protein livestock feed, which combines high

[8] Contact Harold Corke, Department of Botany, University of Hong Kong, Pokfulam Road, Hong Kong for seed supplies of cultivars available in China.

[9] Gohl (1981).

protein and energy content with structural fibre. Sunflowers can further diversify the overall crop rotation. However following sunflowers there is a high risk of a disease problem in the form of Sclerotinia rot *(Sclerotinia sclerotiorum)* for following brassica and legume crops for four years, and a low probability for root rot and damping off for one year.

Land class

Sunflowers can be grown on a wide range of well drained soils of varying fertility. They are tolerant of dry conditions but not flooding. They should therefore be suited to most first and second grade crop lands, and rainfed lands for fodder production. Nutrient deficiencies need to be made up with fertilizers in order to obtain high yields.

Main Crop

Good plots of sunflowers for seed production were observed at the TARI station in Panam (Plate 7.22.2) under the EU project, where several varieties have been evaluated. Heavy fodder crops can be produced for feeding green, and if successive crops are sown every two weeks green fodder can be harvested from June – September. Alternatively it should be possible to obtain good fodder yields for silage at 25% DM before the rains in July, or these crops can be taken through for seed production in September. It is essential to dry the whole heads with seeds to a low dry matter content to avoid development of moulds in storage, so varieties and planting dates need to be selected to allow harvest of seed heads when drying conditions are good. Cultural practices are similar to those for maize, but given the large leaf size and horizontal arrangement of leaves lower plant populations and wide spacing between rows may be appropriate.

Second Crop

Sunflowers have not yet been evaluated for fodder production as a second crop in central Tibet. However, given the short duration required to obtain good yields of green fodder it is possible that sunflower may be more productive than maize. In addition its potential to produce fodder crops on rainfed lands needs to be fully assessed. Fodder harvested in the vegetative stage is low in dry matter (15-20%), so second crops need to be wilted before ensiling.

If seed crops of suitable fodder varieties can also be grown in central Tibet, sunflowers offer great potential as a low cost alternative to maize for second crop fodder production.

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7.1.1. 22 September, 2005, before harvest in early October

7.1.2. 29 April, 2006, winter survival of hairy vetch, lucerne, melilotus, red clover and annual ryegrass

7.1.3. 3 July, 2006, flowering, past optimum stage for first harvest of biennials and perennials

Photos in 7.1.1 and 7.1.2 courtesy of Nick Paltridge, 7.1.3 by Ian Lane

Plate 7.1. Observation trial of fodder crops for double cropping at TARI field station, Lhasa, sown 23 July, 2005

a. 1^{st} cut 1^{st} year

b. 1^{st} cut 2^{nd} year

1. Hairy vetch Mao Shaosi

2. Common vetch, Lanzhou

3. Common vetch Gansu 333

7.2.1. Varieties of hairy and common vetch in Fodder Crop Observation Trial, TARI field station, Lhasa, sown on 23 July 2005, observation on September 25, 2005. Hairy vetch 1^{st} cut 2^{nd} year observed on 3 July 2006 at flowering

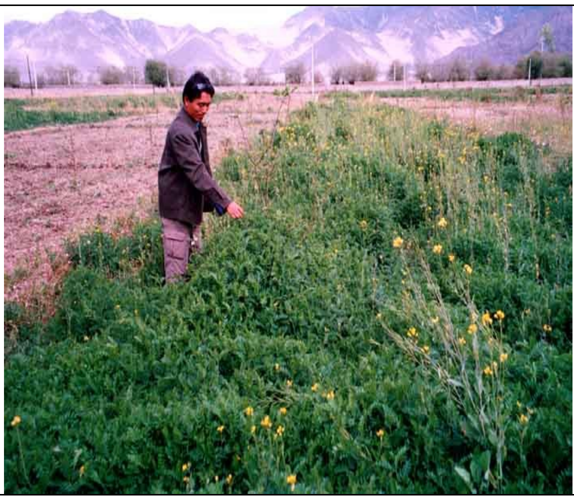
1. Main crop grown on fertile site with good support of vetch by the oats – at optimum stage for cutting

2. Close up of #1 showing vetch pods with seeds at soft dough stage

7.2.2. Vetch-oat mixture as a main pure fodder crop in Serbia grown for summer green fodder and hay

Photos: Ian Lane

Plate 7.2. Vetch in observation trials, and with farmers in Sandzak mountainous region, Serbia, 2004



7.3.1. Vetch relay sown into winter barley at Gongga June 25, 2004, with scattered rapeseed; note extra height of vetch where supported by apple tree seedlings (photo October 4)

7.3.2. Vetch relay sown into winter barley on farmer's field at Qushui on July 2, 2005. Photo on August 23, before plot was grazed following removal of wheat stooks

7.3.3. ACIAR experiment "Date of relay sowing vetch into winter wheat" at Gongga field station (photo 7 October)

3a. July 5

3b. July 15

3c. July 25

3d. August 4

Photo 7.3.2: Nick Paltridge, others: Ian Lane

Plate 7.3. Establishment of vetch by relay sowing into standing cereals

7.4.1. Zero-till drilling vetch into winter wheat stubble with six row drill on August 28, 2005

7.4.2. Close-up of vetch into winter barley ↑ and winter wheat ↓ stubbles

7.4.3. Vetch zero-till drilled into winter barley stubble on July 25

7.4.4. Vetch zero-till drilled into winter wheat stubble on August 28

Photo 7.4.1: Nick Paltridge, others: Ian Lane

Plate 7.4. Establishment of vetch by zero-till drilling into cereal stubbles at TARI field station, Lhasa, 2005. Observations made on September 25, 2005.

7.5.1. Ploughed, not levelled; vetch broadcast

7.5.2. Ploughed, levelled; vetch sown with seed drill

7.5.3. Vetch rota-seeded direct into barley stubble

7.5.4. Vetch zero-till drilled direct into barley stubble

Photos: Ian Lane

Plate 7.5. Methods of establishment of vetch as a second crop following spring barley cut for silage/green fodder at TARI field station, Lhasa. Sown on July 25, observed on September 25, 2006. Conditions were dry for three weeks following sowing.

1. Black peas sown in Tang Jia township in upper Lhasa valley by farmers as a staple food in May 2004

7.6.1. Peas currently grown as sole main crops

7.6.2. Vegetable peas sown as an inter-crop in winter wheat in May along the irrigation bunds, observed early July 2005

7.6.3. Seed multiplication of peas at TARI field station

Photos: Ian Lane

Plate 7.6. Existing uses of peas as dual purpose main crops

		
1. Low fertility - peas dominate	***2. Close-up of #3***	***3. High fertility- oats support peas***
		
4. Height of forage peas	***5. Potential to market pods***	***6. Green peas within pods***
		
7. Peas wilting for hay or silage	***8. Hay made from pea-oat mixture***	***9. Hay is highly palatable to cows***

Photos: Ian Lane

Plate 7.7. Farmer led demonstrations of main crop forage pea - oat mixtures in Sandzak mountainous region, Serbia, 2004



7.8.1. Sample of plots of pea varieties from Second Crop Fodder Observation Trial at TARI Field Station, Lhasa, sown on 23 July and observed on 22 September 2005

1. Red flowers, early with pods

2. White flowers, early with pods

3. White flowers, late, flowers only

7.8.2. Plants from Second Crop Fodder Observation Trial above held to display flowers, pods and stems

1. Late, full leaf – pods flat

2. Medium, full leaf – pods filling

3. Early, full leaf – pods filled

4. Medium, semi-leafless – pods filling

7.8.3. Pea types under seed regeneration and multiplication at TARI, Lhasa, in 2005

Photos: Ian Lane

Plate 7.8. Peas under evaluation as second crop pure fodder and dual purpose crops, TARI, 2005

1. Shigatse fodder production station – for hay making

2. Gongga land reclammation, second class soils

7.9.1. Lucerne grown as main crops by government institutions

1. Canada – standard for ACIAR

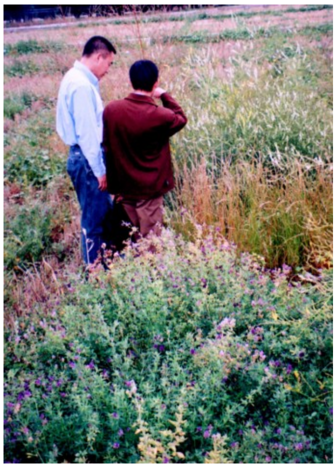
2. Variety WZ 525 HQ (Beijing)

3. Variety WL 414 (Beijing)

7.9.2. Lucerne varieties in Second Crop Fodder Observation Trial at TARI Field Station, Lhasa, sown on 23 July and observed on 22 September 2005

1. Roots of Canada lucerne with nodules, 25 September 2005

2. Canada lucerne, 1st cut 2nd year, 3 July 2006



3. Canada lucerne, 2nd cut 2nd year, 25 September 2006

7.9.3. Further observations on lucerne in the Fodder Crop Observation Trial at TARI Field Station, Lhasa

Photos: Ian Lane

Plate 7.9. Lucerne as a perennial main fodder crop, and established as a second crop

3. Wild white flowered Melilotus at TARI, Lhasa (3 July 06)

1 & 2. Yellow Melilotus as main fodder crop in mixture with lucerne at Shigatse Grassland Institute fodder production station, 8 July 2005 – for hay making. Melilotus self-seeds to continue stand

7.10.1. Melilotus grown at government institutions

1. 1st cut, 1st year (25 September 2005)

2. 1st cut, 2nd year – at flowering (3 July 2006)

3. 2nd cut, 2nd year – at seeding (25 September 2006)

7.10.2. Yellow Melilotus in Second Crop Fodder Observation Trial at TARI Field Station, Lhasa, sown on 23 July 2005

Photos: Ian Lane

Plate 7.10. Melilotus as a biennial fodder crop, and established as a second crop

7.11.1. Sainfoin grown for land reclammation of second class soils in Gongga county, 23 May 2004.

1. General view of sainfoin, above

2. Close-up of sainfoin, right

1. 1^{st} cut, 1^{st} year (25 September 2005)

2. 1^{st} cut, 2^{nd} year – at flowering (3 July 2006)-few flowers

3. 2^{nd} cut, 2^{nd} year – at seeding (25 September 2006)-few seed heads

7.11.2. Red clover in Second Crop Fodder Observation Trial at TARI Field Station, Lhasa, sown on 23 July 2005. Plants did not nodulate with local rhizobia.

Photos: Ian Lane

Plate 7.11. Sainfoin and Red Clover as biennial / perennial legume fodder crops

7.12.1. Shallow ploughing for planting beans

7.12.2. Levelling with a board following ploughing

7.12.3-4. Second crop dual purpose broad beans at TARI field station Gongga following vegetables, sown June and observed 4 October 2004–whole plot, and close-up of edible pods and tops

1. French D, little flowering

2. Qinghai #, flowering, no pods

3. Qinghai #10, flowering, no pods

7.12.5. Plots of broad bean varieties from Second Crop Fodder Observation Trial at TARI Field Station, Lhasa, sown on 23 July and observed on 22 September 2005

Photos: Ian Lane

Plate 7.12. Establishment and evaluation of broad beans (Faba beans) as dual purpose second crops

1. French beans after picking, small pods left to grow

3. Harvest of pods of French bean (left) and Runner beans (right), and residues after food preparation

2. Runner beans supported on bamboo canes after picking, small pods left to grow

7.13.1. French (Bush) and Runner beans grown by the author's wife in their English garden

1. Second crop after vegetables at TARI field station, Gongga, observed on 4 October 2004

2. Farmer's main fodder crop at Qushui – note winter barley Dongqing #1 ready for harvest to left of picture in July 2005

7.13.2. Fenugreek = Local Legume "Xuisha" grown as an annual fodder crop

Photos: Ian Lane

Plate 7.13. French (bush) and runner beans as dual purpose second crops, and annual Fenugreek = Xuisha fodder crop

1. Land ready for cultivation as first rains arrive on 9 July 2005. Note undergrowth of grassy weeds; and sheaves stacked upside down to shed rain.

2. Field stacks of winter barley made on the side of the field, and shallow ploughing already carried out on 9 July 2005. Surrounding crops of winter wheat are awnless varieties – either Feimai or Bussard.

7.14.1. Winter barley Dongqing #1 harvested and stooked ready for cultivation of second crop turnips

1. Farmers harvest the whole crop, chop large bulbs, and dry both leaves and bulbs to store them into the winter

2. A good size plant with healthy leaves and bulb for densely planted turnips

7.14.2. An excellent crop of Stubble turnips observed on 24 September 2005

Photos: Ian Lane

Plate 7.14. Cultivation of high density broadcast second crop turnips (stubble turnips)in Qushui county

7.15.1. Turnip - Gansu

7.15.2. Sugar beet (leaf only)

7.15.3 and 4. White Chinese radish

7.15.5 and 6. Red Chinese radish

Photos: Ian Lane

Plate 7.15. Evaluation of root crops grown as spaced second crops at TARI Field Station, Lhasa, sown on 24-25 July and observed on 25 September 2006

1. Chonggan #11, with initial heart formation

2. Qingfeng #1, no heart formation

Photos: Ian Lane

7.16.1. Dual purpose leafy brassicas: Cabbage varieties directly sown as spaced plants in Second Crop Fodder Observation Trial at TARI Field Station, Lhasa on 23 July and seen on 22 September 2005

1. Grampian Kale, an improved marrow-stem kale bred by Scottish Crops Research Institute

2. Forage Rape. Varieties in UK include Hobson, Interval and Hungry Gap.

Photos: Courtesy of Advanta Seeds UK

7.16.2. Pure fodder leafy brassicas: photos from UK demonstration plots

Plate 7.16. Dual purpose and pure fodder crop leafy brassicas

7.17 .1. Early rapeseed varieties, possibly suitable as second crops, in an evaluation trial at TARI field station, Lhasa, 3 July 2006

7.17.2. Family run oilseed mill in Lhasa city. Purchased rapeseed is being milled, passed through the mill three times. Oil is coarsely filtered to the left of the mill; rapeseed meal/cake is bagged off from the front of the mill after the third pressing.

Photos Ian Lane

Plate 7.17. Evaluation of rapeseed varieties, and oilseed milling

1. Annual ryegrass Lanzhou #1 - vegetative

2. Annual ryegrass Lanzhou #2 - vegetative

7.18.1. Annual ryegrass varieties observed on 23 September 2005

1. Lanzhou #1 1st cut - seeding

2. Lanzhou #1 2nd cut seed ripe

3. Lanzhou #2 1st cut - seeding

7.18.2. Growth of annual ryegrasses in the second year

Photos: Ian Lane

Plate 7.18. Annual ryegrasses in the Observation trial of fodder crops for double cropping at TARI field station, Lhasa, sown 23 July, 2005

1. Winter wheat Feimai

2. Winter barley

7.19.1. Main crop cereals with potential as fodder grown by farmers in Naidong count, 21 May 2004

1. Background – rye. 2. Foreground - wheat

7.19.2. Cereal introductions at TARI field station, Lhasa, 3 July 2006

7.19.3. Main crop fodder oats at the Shigatse Grassland Institute fodder farm – field and close-up - grown to make hay as winter emergency fodder for yak pastoralists

7.19.4. On farm demonstration of main crop fodder oats under high fertility conditions in Sandzak mountainous region, Serbia, being fed as green fodder in summer to pure Simmental cows

Photos: Ian Lane

Plate 7.19. Cereals grown as main crops with potential as fodder, or specifically as fodder crops[1]

[1] see Chapter 9 for conservation of cereals as whole-crop silage

7.20.1. Effect of time of sowing on growth of main crop maize: from back to front sown on 26 May, 10 June and 25 June. Plots in foreground grown as inter-crops. Note plot in background sown as sole crop on 26 May.

7.20.2. Main crop sown on 25 June as an inter-crop. Although height of the crop was only 100cm, plants had produced 1-2 cobs/plant which were at the milky stage – showing major potential for maize as a second crop.

7.20.3. Main crop sown on 26 May at mature height of 200cm with 1-2 cobs/plant at milky–soft dough stage and crop dry matter of 25%

7.20.4. Second crop maize (Maize 308) sown 25 July at 30-45cm height at the start of stem elongation

7.20.5. Reduced yield of main crop maize sown in May due to severe uncontrolled weed competition

7.20.6. Clean seedbed and crop following application of modern residual pre-emergence herbicide (Bayer Cadou Star)

Photos: Ian Lane (Photo in 7.20.6 courtesy of Bayer Crop Science Ltd)

Plate 7.20. Main crop and second crop maize at TARI Field Station, Lhasa, 25 September 2006

7.21.1. Overview of trial site at 1000m above sea level	*7.21.2. Ear at milky-cheese stage*

Photos: Ian Lane

Plate 7.21. Forage maize trial and demonstration on Sjenica plateau, Sandzak region, Serbia. Planted end of May, observed early October 2004

1. Early variety – 'Mirui'	*2. Late variety 'Chanyu'*

7.22.1. Buckwheat second fodder crops at Lhasa, sown on 24-25 July and observed on 25 September 2006

7.22.2. Sunflowers at Baixue research station, Panam, sown in May and observed 8 July 2005

Photos: Ian Lane

Plate 7.22. Other potential second fodder crops in evaluation trials

Chapter 8 NITROGEN FIXATION IN FORAGE LEGUMES

Ian Lane

Chapter 8 NITROGEN FIXATION IN FORAGE LEGUMES[1]

8.1. Introduction

It was known 2000 years ago that legumes can enrich the soil for subsequent crops. The mechanism of N-fixation was discovered in the late 1800s, but rhizobia - the bacteria responsible for the symbiotic relationship with legume plants - were only identified in the mid-1900s. Nitrogen is in the air as di-nitrogen molecules (N_2). The bacteria that fix N_2 belong to the genera *Rhizobium* and *Bradyrhizobium*. These bacteria infect the root hairs of plants of the legume families and induce the formation of benign plant galls which are known as "nodules", and live symbiotically with the host plant.

8.2. Specificity

Rhizobial species are specific to individual host legumes or to cross-inoculation groups of legume species. Among legume species there are great variations in specificity of interaction with rhizobia. Symbiotic requirements in temperate legumes suitable for growing in central Tibet are given in Table 8.1. Distinct strains of *Rhizobium meliloti* are required for different lucerne genotypes.

Table 8.1. Legume / rhizobia specificity

Cross-inoculation group	Legumes included	Rhizobium species
Alfalfa / Lucerne and Melilotus group	Lucerne Yellow Melilotus White Melilotus	*Rhizobium meliloti*
Bean	Beans	*Rhizobium phaseoli*
Clover group III	Red Clover White Clover	*Rhizobium trifolii*
Pea	Vegetable peas Forage peas Common Vetch Hairy Vetch	*Rhizobium leguminosarum*
Sainfoin	Sainfoin	*Rhizobium strain*
Trefoil	Birdsfoot trefoil	*Rhizobium loti*

Amarger (2001), Jennings (2006), Lacefield *et al.* (2006)

8.3. Nodulation

Rhizobia commence infection of the roots of legumes at an early stage of root development, so most mature effective nodules are clustered on the primary root in the upper soil horizons. Nodule size, shape and number vary with the host plant and the *Rhizobium* strain. Red clover has club-shaped and lobed nodules, while lucerne nodules are more branched and longer (Plate 8.1.1). Vetch nodules are oblong to indeterminate in shape (Plate 8.1.2). In some biennial and perennial legume species, such as birdsfoot trefoil, new nodules develop each year in the root hairs; while in others, such as red clover, nodules can fix N_2 for more than one growing season.

Nodules consist of an outer, uninfected, cell zone and an inner, infected zone. When cut open, nodules formed by effective N_2-fixing rhizobial strains are pink or red due to the presence of leghaemoglobin. Nodules formed by ineffective rhizobia are white or yellow. Wait at least two weeks after cutting or close grazing legume crops, to allow time for rhizobia to regenerate before inspecting for effective nodules. Vetch that was zero-till drilled into winter wheat stubble on 28 August had

[1] This section is based on Frame (2005)

developed a full set of nodules by 25 September (Plate 8.1.3), but given their small size it is likely this sowing was too late for them to be effective.

There are often adequate populations of effective rhizobia in fertile soils where a specific legume has been grown before. For example, Vetch has been found to have good nodulation when grown on demonstration sites or farmers' fields in Gongga and Qushui (Plate 8.1.2). However, on infertile soils, or on soils where a legume species is being grown for the first time, inoculation of seed by an effective strain of rhizobial species is necessary. Thus while active growth of vetch and lucerne was obtained at the TARI field station, Lhasa, plots of red clover introduced for the first time established poorly in the first year and grew slowly in the second year (Plate 8.2). Both vetch and lucerne had been infected by active local rhizobial strains. The red clover, which had not been inoculated with specific rhizobia before sowing, had obviously not been infected by effective rhizobia.

It is also necessary to correct any factors that might limit active growth of both the rhizobia and the legume plant. These include essential macro-nutrients such as phosphorous (P), and micro-nutrients such as molybdenum (Mo). Any conditions that affect growth of the legume plant, such as water stress, will reduce the energy supply from the plant to rhizobia, with consequent reduction in N_2 fixation. In extreme cases, such as harvesting the plant by grazing or cutting, nodules are rejected by the plant and break down in the soil. This is one way N_2 is transferred from legumes to other plants, for example in mixed grass / legume pastures. Roots of the legume plants are only re-infected once regrowth following harvest is well underway - since initially energy for this regrowth must come from reserves stored in the roots and the plant crown.

8.4. Seed inoculation and field to field transfer of rhizobia

Effective strains of rhizobia can be introduced to fields where a specific legume has not been grown before by several practical methods:

A. Purchase specific rhizobial inoculant along with the legume seeds

To successfully establish a legume stand, sufficient numbers of the correct rhizobia must be kept alive on the seed for nodule formation. There are many methods of inoculating seeds, but only use those (such as the method below) that provide thousands of bacteria per seed at planting time.

The inoculant generally consists of a suspension of bacteria on powdered peat, which is kept moist and refrigerated. Inoculant is not expensive, but supplies are restricted in China, for example from the China National Seed Group Corporation in Beijing[2]. At present, restrict use of rhizobial inoculants to plant introduction by TARI, with extension to counties through planned demonstrations.

Inoculation Procedure for 10 kg of Seed (adapted from Jennings 2006)**:**

1) Order the correct rhizobial inoculant for the legume group to be sown (Table 8.1). Commercial inoculant manufacturers have selected rhizobial strains for their inoculants which are more competitive with other soil microorganisms, and more efficient in fixing nitrogen than many native strains in soils.
2) Inoculants are cultures of live bacteria - keep them alive and effective for up to 6 months:
   - keep inoculants and inoculated seeds out of the sun at all times
   - keep inoculant refrigerated whenever it is being stored - **but do not freeze inoculants.** If a refrigerator is not available, store the inoculant in a cool, dark place until ready for use

[2] Rhizobial inoculant is available from:
Dr. Xinchun Pu, General Manager of the Beijing SinoSeed Turf and Forage Co.Ltd, (associated with the China National Seed Group Corporation)
Address: Jia 1, 4th Anzhenxili, Chaoyang District, Beijing 100029.
Tel: (+86) 010 - 6443 6699 - 4035; Mob: 13801 028135; email: xcpu@grassonline.com.cn; www.grassonline.com.cn

- for shipping, hand carry using a cool bag - do not send by post to Tibet as it will be held in customs for months!
- check expiry dates on packets of inoculum, and do not use if time is beyond these dates

3) All methods require **thorough mixing** of seed with the appropriate inoculum in a tub or other large container
4) Most forage legume seed is both small and shiny surfaced, which makes it difficult to ensure that large numbers of rhizobia stick to the seed - always use sticking agents to stick the peat based inoculant to the legume seeds (Table 8.2)
5) Prepare a sticking agent as follows:
   - mix 60 g of syrup or molasses with 240 g of water - shake or stir well; **or**
   - mix 1 cup (200 g) sugar with 2 cups (450 g or 450 ml) of water; **or**
   - just use milk

   Do not use cola drinks or other carbonated beverages - their pH is near 2.0 and harmful to bacteria

Table 8.2. Effect of inoculant and use of sticker on soybean root nodulation

Inoculant and sticker treatment	**Nodules per plant**
No inoculant	0.0
Inoculant, no sticker	0.8
Inoculant plus commercial sticker	2.7
Inoculant plus sugar sticker	2.7

University of Kentucky, in Durst and Bosworth (1986)

6) Add about 1/3 bag of fresh peat based inoculant (about 50 g) to about 1 cup (about 200 g) of the sticking agents. Mix to form a black slurry
7) Place 10 kg of seed in a tub or similar container
8) Add the black slurry (about 250 g) to the seed in the tub and thoroughly mix. Be sure to coat every seed
9) Add the remainder of the bag of dry inoculant to coat and dry the seeds. This inoculant rate may be several times the manufacturer's recommended rate of inoculum, but may be necessary in Tibet
10) Allow seeds to dry in the shade. To speed the drying process, add more inoculant or a small amount of baby's talcum powder. **Do not use burnt, hydrated, slaked or builder's lime!**
11) Plant inoculated seed as soon as possible, or keep it in cool, shaded conditions for no longer than one to three days
    - **do not leave the bag of inoculant or inoculated seed in direct sunlight because sunlight kills rhizobia**
    - **do not mix inoculated seed with fertilizer - salts and acids in the fertilizer will kill the rhizobia** - however inoculated seed may be mixed with dry fertilizer if it is sown immediately
12) If molybdenum or fungicides are needed, apply them to seed after inoculation and plant immediately
13) **When planting, always cover seed with soil to speed germination and protect the rhizobia from sunlight. Be careful not to plant alfalfa or clover seed deeper than 6 - 12 mm deep.**

14) If drilling the inoculated seed, re-calibrate the drill for the required seed rate with inoculated seed

B. Transfer soil beneath legumes with effective rhizobia to new sites

Once legumes such as lucerne are growing vigourously with effective strains of rhizobia, large numbers of bacteria are released into the soil. These remain viable, ready to colonise new seedlings.

1) Prepare new fields, such as second class irrigated lands, for sowing
2) Correct both macro- and micro- element deficiencies in the new lands
3) At the time of sowing the legume, take fertile top soil (the top 5 cm of soil) from a field where that legume has been growing vigorously with effective nodulation
   - it is essential that the legume on the donor field is healthy - with no signs of soil borne diseases
   - the field must be weed free - in particular make sure that there are no parasitic weeds (Dodder, *Cuscuta* spp.) - which can severely reduce affected areas of lucerne and will be transferred to the new lands with the soil
4) Finely break down this top soil, and preferably pass it through a screen, so it is easy to spread; at all times keep the top soil moist but not saturated
5) Spread the top soil thinly over the new field - top soil from 0.01 ha will be sufficient for 1 -10 ha of new lands, depending on their fertility.
6) Cultivate the top soil into the surface 2 - 3 cm of soil on the new lands
7) Broadcast and cover, or drill the legume seeds as normal
8) Keep the soil of the new lands moist - it is appropriate to carry out this operation after the rains have started in early - mid July.

C. Emergency inoculation (adapted from Jennings 2006)

If nodulation is inadequate for growth of legumes 3-4 weeks after seedling emergence, use one of the following methods to establish effective nodules **when moisture and temperature are favourable**. Increase rates of inoculant if environmental conditions are not favourable.

1) Mix 0.75 kg (about four small bags) of black peat inoculant with 25 to 50 kg of cottonseed meal, sand, wheat middlings or limestone and broadcast uniformly over 0.4 ha. Unless heavy rainfall is expected within a few days, use a grain drill to put the inoculant into the soil
2) Mix a fine slurry of 0.75 kg of black peat inoculant with 90 litres of water and spray the legume crop at 200 litres/ha. Re-screen the inoculant prior to mixing with water to limit clogging of spray nozzles and valves. It may be possible to obtain a liquid inoculant for spraying. Clean the spray tanks well before adding inoculant so that the bacteria are not killed.

Only apply these treatments immediately before or after rain when the sky is cloudy, as sunlight will kill the bacteria. Use irrigation if necessary.

8.5. The Process of Nitrogen Fixation

There is true symbiosis between the rhizobial bacteria and its host legume plant. The host plant supplies energy via carbohydrate from photosynthesis to the bacteria, while the rhizobia supplies the host plant with nitrogenous compounds such as amino acids and amides from the N_2 fixation process. This process involves conversion of N_2 from air to ammonia (NH_3), in which the rhizobial nitrogenase enzyme plays a major role, followed by metabolism of the ammonia to organic nitrogenous compounds that the host plant can utilise.

Fundamental requirements for nitrogen fixation to take place are:

- *An adequate supply of water* - water restriction depresses N_2 fixation in shallow rooting legumes, such as peas, more than deeper rooting species like lucerne. The symbiotic process can recover when water supply becomes less limiting
- *Certain macro-nutrients*, especially phosphorous (P) and sulphur (S), but also potassium (K) should be adequate. On P deficient soils, legumes respond to fertilization with phosphate in the same way that grasses respond to fertilization with N, mainly through response in N_2 fixation
- *Certain micro-nutrients* (such as molybdenum, iron and cobalt). Rectifying micro-nutrient deficiency can have a dramatic response on growth of legumes, mainly through the benefit to N_2 fixation. Micro-nutrient deficiencies can be identified and quantified by growing the legume of interest in missing element pot trials, using soil taken from the target fields
- *Adequate solar radiation* to produce the plant photosynthate needed by the rhizobia - all second crop legumes planted after the winter cereal can suffer from prolonged cloud in the middle of the rainy season, while relay sown vetch is sensitive to competition from weeds in cereals crops.

Nitrogen fixation is reduced when the soil is rich in available mineral N, whether from:

- the soil reserve
- applied N fertilizers
- organic manures - dung and urine from grazing animals.

In legume monocultures the cause is direct, as the plants take up available N directly from the soil in preference to supplying photosynthate to the rhizobia; as a consequence nodulation and nodule activity is reduced. This effect is observed if vetch fodder crops are heavily fertilized with N; although a small application of N in the seed bed can assist initial establishment of vetch on nutrient poor soils. However, fixed N_2 remains a high proportion of the N harvested in the crop, even at high levels of N fertilization.

With legume/cereal bi-crops, besides the direct effect noted above, the growth of the companion cereal increases as the available mineral N in the soil increases. In the first instance this is positive, since strong cereal growth is required to support climbing legumes such as peas and vetch. Should the cereal dominate, shading will reduce light available to the legume, and N_2 fixation and growth of the legume will be suppressed. This effect is particularly relevant in studies with lucerne/cereal inter-crops.

Factors that depress N_2 fixation include:

- Grazing or cutting legumes depresses N_2 fixation directly by reduction in photosynthate available to the nodules; at the same time, N products accumulate in the nodules and reduce fixation
- Lax grazing or cutting leads to faster recovery in N_2 fixation due to higher levels of carbohydrate reserves in the roots and stubble compared to severe defoliation
- Growing of legumes in shade due to reduced photosynthetically active radiation reaching the crop.
- Root-feeding pests such as nematodes, and organisms that cause root diseases inhibit N_2 fixation directly by damaging root nodules
- Pest attack and disease incidence in the legume plants reduce N_2 fixation indirectly through lowering plant vigour and hence reducing energy supply to the nodules.

In grasses and cereals most available soil mineral N is rapidly taken up by the young vegetative plants, and thereafter is distributed throughout an increasing mass; this results in a low N (and crude protein - CP) content of the mature plant. In contrast, N_2 fixed by rhizobia is available to legumes throughout their growth, which results in the high N and CP contents of the mature legume plant.

During the growth of mixed legume/cereal crops, any N_2 fixed by the legume/rhizobia symbionts is retained by the legume for its own growth. Fixed legume N_2 is transferred to companion cereals and following crops indirectly through legume root decay and legume litter decomposition. Defoliation by grazing or cutting accelerates the rate of turnover of root nodules, while much of the N in grazed forage is returned to the soil in dung and urine. The pattern of nodule growth, decay and shedding is not the same in all legumes. Following cutting, nodules of most legumes are usually shed and new nodules form when root growth is renewed. However, lucerne nodules may remain attached to the roots after forage is harvested. When legume fodder is cut and fed to stall fed animals, however, much of the N is lost to the system - especially if the dung is used as fuel rather than returned as manure to the field.

8.6. Amounts of N_2 fixed

The amount of N_2 fixed by legumes varies markedly according to:

- the individual legume species
- the soil type and fertility
- climatic conditions including temperature and solar radiation
- available moisture
- soil and crop management.

Table 8.3. Median values and ranges for N_2 fixed by well-nodulated forage legumes under favourable field conditions

Legume fodder crop	Median kg N/ha/y	Ranges kg N/ha/y
Lucerne	180	50 - 350
Red clover	170	50 - 200
Birdsfoot trefoil	90	-
Vetch	-	50 - 160
Forage peas	70	50 - 100

Median values from Vance (1997); ranges in values from Jennings (2006) and Lacefield *et al.* (2006)

Median values from the literature cited by Vance (1997) are given in Table 8.3, with ranges provided by Jennings (2006) and Lacefield *et al.* (2006). N_2 fixation by the three perennial species is in line with their relative dry matter productivity. The lower N_2 fixation by annual legume fodder crops relates to their shorter growing periods, which is 12-16 weeks for forage peas. The amount of N_2 fixed by lucerne at 180 kg/ha equals current recommendations for fertilizing mono-culture temperate grass pastures or cereal fodder crops with N fertilizer. It is equivalent to applying 400 kg/ha urea fertilizer (at 46% N) per annum. This allows the economic benefit of growing legume fodders to be appreciated - before the high protein content of the legume fodder is taken into account. When grain legumes are harvested for grain and the residues removed for feeding to animals, the nitrogen balance in the soil is not as favourable as when a fodder or green manure cover crop is grown, since much of the nitrogen is exported in the grain and above ground biomass; only the nitrogen in the roots is left for the soil.

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8.1.1. Effective nodulation of lucerne at TARI field station, Lhasa, with a local strain of rhizobium. Lucerne sown on 28 July 05, photo 25 September 05	***8.1.2. Effective nodulation of vetch (Gansu 333) at GongGa with a local strain of rhizobium. Vetch relay sown into winter wheat on 5 July 04, photo 6 October 04***	***8.1.3. Ineffective nodulation of vetch (Gansu 333) at TARI field station, Lhasa. Vetch zero-till drilled into winter wheat stubble on 28 August 05, photo 25 September 05***

Photos: Ian Lane

These photos illustrate that vetch and lucerne successfully nodulate without artificial inoculation in central Tibet. In each case the plants have only been roughly extracted from the soil, so many nodules have been left behind.

Plate 8.1. Rhizobial nodulation of lucerne and vetch with local strains of rhizobia in Tibet

	
8.2.1. Photo 25 September 05	***8.2.2. Photo 3 July 06***

Photos: Ian Lane

Plate 8.2. Red clover #5 sown on 28 July 05 established without effective nodulation (on left of each photo), compared with lucerne with nodulation (on right of each photo).

Chapter 9 FODDER CONSERVATION

Ian Lane

Chapter 9 FODDER CONSERVATION

9.1. Introduction

A range of fodder crops can be grown as main crops, and as second crops within double cropping systems. The green fodder produced can be utilised in various ways (Figure 9.1).

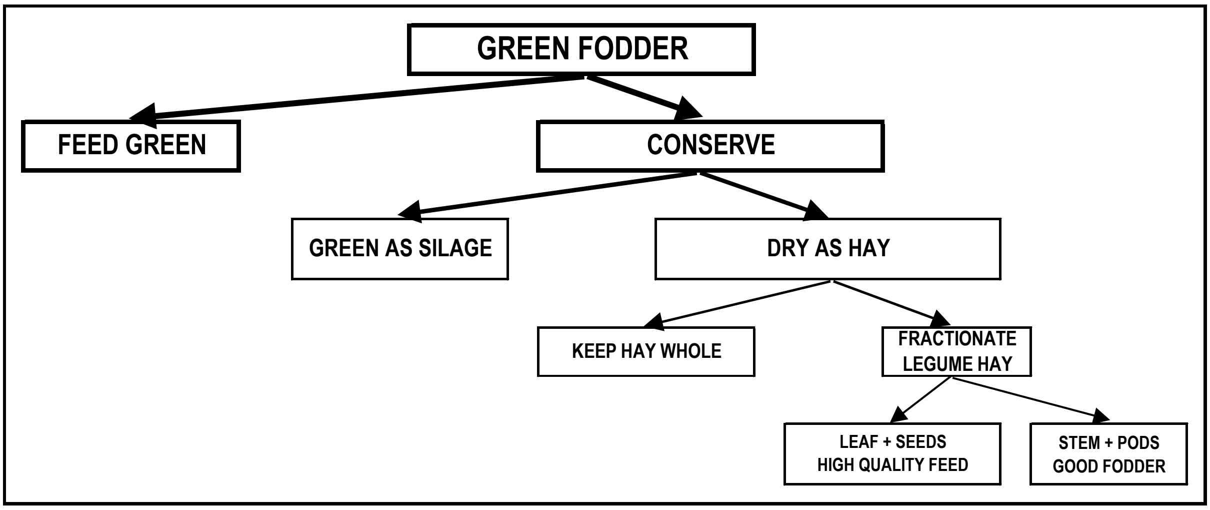


Figure 9.1. Utilisation of green fodder from main and double crops

Fodder can be fed green directly following harvest:

- in May - July
  - from whole-crop winter cereals, and
  - biennial / perennial fodders sown as double crops the previous year;
- in July - September
  - from spring sown main fodder crops, and
  - regrowths of biennial and perennial fodder crops
- in August - early October
  - from second crop pure fodder crops, and
  - second crop dual purpose crops.

Fodder harvested for feeding green replaces grazing, and tends to be harvested at an immature leafy stage of growth. Where time in the growing season permits, the fodder crop is allowed to regrow and second and further cuts can be taken.

Any fodder crop surplus to requirements for feeding green is allowed to grow to a more mature stage to give an optimum balance between yield and quality. In biennial and perennial forage legumes this is at 50 percent flowering. In annual legumes such as vetch and peas the grains and pods make a major contribution to yield and quality, and the optimum stage is at the soft dough stage of the seeds. In fodder cereals and cereal / legume mixtures there is a broad optimum between the flowering and soft dough stages of the cereal. For hay making the crop is cut by the milky stage to avoid loss of immature grains. For silage making it is possible to grow the crop on to the grain soft dough stage.

Traditionally in Tibet fodder for conservation is dried in the sun for hay. In the valleys fodder is carried home to the compound. Long fodder from weeds such as wild oats are plaited into long ropes which are then knotted into loops or rings. These loops are hung on the walls of the compound or on rafters of store sheds or the farmer's house to dry. Short fodder is spread out on the roof of a store or house to dry. Depending on county, additional structures such as hay fences, tripods, or A-frames may be used to support green fodder in order to dry it off the ground - either in the compound, outside by the straw stacks or even in the fields. Such practices are not, however, widespread. Dry fodder is then stacked under cover if hay is made before the rains, or on the roof if the rains have finished.

In this Chapter we introduce new methods of fodder conservation. These are briefly summarised here, and described in detail below. The detailed notes are designed to run demonstrations to introduce farmers to the methods, and also to record data on results achieved. This will allow the methods to be further adapted to fit local conditions.

1) *conservation in the green form as silage*

In silage making the sugars in green fodder are fermented without air by bacteria that produce lactic acid. This acid reduces the pH of the green fodder to below pH 4.5. At this pH bacteria which decompose organic matter can not survive, so that the crop is conserved in a green state. Some farmers in Tibet already use this process to preserve cabbages to feed to pigs in winter.

2) *use of hay fences, tripods, and A-frames for heavy crops in humid conditions*

Heavy crops of fodder exceed the capacity of farmers to dry hay at their compounds, especially under humid conditions during and after the rainy season in July - September. By placing hay on fences, tripods, or A-frames so that air can circulate under as well as over the green fodder, the rate of drying is improved while the crop is prevented from heating and developing mould. These methods are likely to be improvements over the traditional hay rope making technique, and result in faster and more reliable conservation.

3) *fractionation of dry legume fodders*

Well dried hay crops of fodder legumes such as vetch, melilotus and lucerne can be fed whole to milking cows and fattening sheep as part of balanced rations, or fed as green fodder supplements to straw based diets. However their value can be increased if they are separated into leaf and stem and milled to prepare meals. The high protein leaf can be fed to high yielding cows and to pigs and poultry, while the stem is still a good fodder for cattle, sheep and goats.

9.2. Making Silage in Plastic Barrels (Barrel Silage)

Introduction

Benefits of silage making over traditional hay making are:

- high yielding crops of fodder can be conserved at their optimum stage of quality when conditions for drying the crop as hay are poor - such as after the rains have started
- silage making is quick, and fodder can be conserved in a few hours rather than over several days or weeks as for hay
- medium sized plastic barrels can be used as containers for silage, known as “silos”:
    - small quantities of green fodder (25-30 kg) can be made each day
    - small quantities of silage (5-25 kg) can be fed to cows each day without spoilage of the remaining silage - which remains in unopened barrels
    - all work can be done by hand - although motor mowers and powered choppers can be used to reduce labour requirements when large quantities of green fodder are to be conserved

Disadvantages of standard systems of silage making are:

- correct procedures must be followed or the silage can go rotten - with loss of conserved fodder of high feeding value

- the expense of constructing silos such as cement lined pits or silage bunkers
- the expense of choppers for making silage on a large scale
- high losses due to spoilage at the time the silage is fed out if only small amounts are fed to 1 - 2 cows

Provided the correct procedures outlined in this manual are followed, excellent silage can be made in medium sized plastic barrels that overcome the above disadvantages. The cost of silage making can be estimated as follows:

Cost of silage making (Yuan/kg DM)	=	Cost of Barrel / Number of years used (Yuan/year)	/	[Fresh weight of green fodder / barrel (kg)) x Drymatter % / 100]

In the example below, medium sized barrels cost Yuan 25/= and are used again each year for 5 years. They hold 25 kg chopped green fodder at 20 % DM. The cost of silage making is estimated at 1 Yuan per kg DM. This compares with a cost of 2 Yuan/kg for wheat grain, although the costs of growing the fodder have to be included. The price for barrels will be less for large quantities bought directly from the manufacturer, and if larger barrels are used by farmers who keep several cows.

Cost of silage making (Yuan/kg DM)	=	Yuan 25 / 5	/	[25 kg x 20 % / 100]
	=	5	/	5

There are losses of DM during the fermentation process and during feeding out, but well made silage has a higher energy content per unit of DM than the original green fodder. These losses are approximately 20% of the original DM in the green fodder, but are minimised by making silage in plastic barrels.

The essential conditions for successful silage making are:

- fodders with high sugar and/or starch content for fermentation by lactic acid producing bacteria
- complete exclusion of air during storage
- lack of contamination of the green crop by soil - which introduces clostridial bacteria which cause the silage to rot.

Practice silage making with the fodder that is easiest to ferment and that is readily available in central Tibet - that is, whole-crop cereals. These are cereals, harvested between the flowering and soft dough stages, and finely chopped so that the whole plant is conserved. Use awnless varieties of wheat, such as Feimai winter wheat (WW). Do not use awned varieties of wheat since awns in wheat are stiff. Barley has more flexible awns, and can be used in the young stage between flowering and milky stage - although it is grown as the main food crop of farmers. Other cereals can be used, and also cereal / legume mixtures.

Sole crops of fodder legumes are difficult to ensile:

- sugar contents are low - although starch content rises in vetch and pea / bean crops as grains develop in the pods
- protein in the green fodder is always broken down to non-protein nitrogen compounds in silage - these are alkaline, and buffer the lactic acid produced by fermentation. Legumes have high protein contents and high buffering capacity. If the lactic acid is neutralised, secondary fermentation can occur leading to spoilt silage.

Partly dry or "wilt" fodder legumes for one day before ensiling them as for whole-crop cereals. This reduces the amount of lactic acid required to produce a stable fermentation. Alternatively sprinkle sugar or wheat flour over the chopped green fodder at a rate of 0.5 kg / 25 kg green fodder (one barrel of chopped green fodder), and mix well. The lactic acid producing bacteria can use these additives to produce additional lactic acid to preserve the crop.

When silos are opened, air enters and allows other bacteria, yeasts and fungi to spoil the silage. It is therefore necessary to plan a silo which matches the amount of silage to be fed each day. For a farmer with one cow in milk, this might be as little as 5 kg silage a day, to provide a green fodder supplement to a straw based diet. Where a high yielding cross-bred cow is to be fed mainly on good quality fodder, it may be fed 25 - 40 kg of silage. Medium sized plastic barrels hold about 25 kg of chopped green fodder, and can be fed out over 1 - 5 days.

Plan how much fodder to ensile

1) Plan the amount of fodder to be conserved as silage a year ahead, before the autumn planting season. This allows available crop lands to be allocated to:
   - winter wheat - for grain for sale, to be relay sown to vetch
   - winter barley - to be double cropped with vetch, turnip or other dual purpose crop
   - spring barley - for home use
   - spring fodder crop - for harvest as silage in July, followed by a second fodder / dual purpose crop
   - biennial / perennial fodder crop - three harvests for green fodder / conservation

   Awnless winter wheat (Feimai) is flexible, as it can be taken to maturity for grain, or it can be harvested in July for whole-crop cereal silage - and the decision only needs to be taken in July.

2) Calculate approximately the amount of silage from each crop required for the next winter, according to the number of cows, the amount of silage to be fed per cow per day, and the number of days:

Fodder Crop	Quantity of Silage (kg)	=	Number of cows	x	Quantity fed per cow per day (kg)	x	Number of days	=	? kg

In an example to demonstrate silage with two fodder crops:

Whole-crop winter wheat at flowering	Quantity of Silage (kg)	=	1 cow	x	5 kg/cow/day	x	15 days	=	75 kg
2nd crop vetch at leafy stage	Quantity of Silage (kg)	=	2 cows	x	5 kg/cow/day	x	10 days	=	100 kg

Increase the amount of green fodder to conserve by the expected losses during fermentation. For 20% losses:

Amount of whole-crop WW to conserve as silage = 75 kg x [100 / (100-20)] = 94 kg
Amount of vetch to conserve as silage = 100 kg x [100 / (100-20)] = 125 kg

This equals 4 barrels of whole-crop WW each holding 23 kg of green chopped fodder, and 5 barrels of vetch each holding 25 kg.

For larger quantities of silage, plan to use larger barrels - these will also be cheaper per kg of silage DM.

3) Calculate the areas of each fodder crop to be grown, according to the quantity of green fodder required for silage, and the lowest expected yields of fodder at the planned time of harvest:

Fodder Crop	Area to be cut for silage (ha)	=	Green fodder to be cut for silage (kg)	/	Yield of green fodder (kg/ha)	=	? ha ?m^2

In an example to demonstrate silage with two fodder crops:

Whole-crop winter wheat at flowering	Area to be cut for silage (ha)	=	94 kg	/	24,000 kg green fodder / ha	=	0.004ha 40m^2
2nd crop vetch at leafy stage	Area to be cut for silage (ha)	=	125 kg	/	16,000 kg green fodder /ha	=	0.008ha 80m^2

4) Adjust the quantity of green fodder to be made into silage, and the area of fodder crop required, according to the DM content of the green fodder. Preliminary data are given in Table 9.1. Fodders need to be sampled for DM content at different stages of growth to build up a better database.

Table 9.1. Preliminary data on DM content of fodder crops

	Whole-crop winter wheat			Whole-crop spring barley		vetch	
Weeks after Heading	2	3.5	5	2	3.5	N/A	
Crop growth stage	Flowering	Milk	Soft dough	Flowering	Milk	Leafy	Flowering
DM % of green fodder	30	40	50	20	30	20	30

Harvest the fodder crop (Plate 9.1)

1) Sample the plot of fodder for yield of fresh matter and DM content as outlined below, complete the sample record sheet with details of the fodder crop, and send sub-samples to TARI with the record sheet for DM determination
2) Cut green fodder when it is dry on the surface, and preferably after midday when sugar levels in the crop are high
3) Cut the plot of fodder by hand with sickles (Plate 9.1.1), or use a motor mower for large areas:
   - cut at 10 cm to leave a high stubble (Plate 9.1.2):
     - to avoid soil contamination - which will bring Clostridial bacteria to rot the silage
     - not to harvest the lower stem, which is less digestible than the upper stem, leaves, and ears
     - to provide a surface on which to place sheaves without contaminating the cut fodder with soil
     - to provide greater soil cover / mulch for zero-till seeding the next crop into
   - keep sickles and mower blades sharp, so that stems are cut cleanly without pulling plants up by the roots with soil contamination
   - trim off any lower stems and roots to avoid soil contamination
4) Spread out green fodder from forage legumes to dry in the field for 4 - 8 hours
5) Bind the cut green fodder into sheaves (Plate 9.1.3)

6) Clear the complete plot, so that the next crop can be established immediately (Plate 9.1.4)
7) Carry sheaves by hand to the road (Plate 9.1.5); at all times stack the sheaves with the stems pointing in one direction - for easier handling during chopping
8) Take the green fodder back to the compound in a clean trailer to prevent contamination with soil, oil, building materials such as nails and sand, or other obnoxious materials (Plate 9.1.6).

Chop the green fodder (Plate 9.2)

1) Sweep the chopping floor clean to prevent contamination of the chopped fodder with soil, old fodder and feeds, manure, building materials and other obnoxious materials
2) If possible cover the chopping floor with a large tarpaulin to keep the chopped fodder clean
3) Stack the sheaves of long green fodder conveniently for the chopper (Plate 9.2.1), with all stems pointing one way
4) Check the sheaves for any remaining roots, and trim them off to avoid soil contamination - any soil left will be distributed through a large portion of the green fodder during chopping
5) Chop the green fodder by hand with a knife and wooden chopping board, or with a hand guillotine chopper:
   - keep the work space clean, and regularly clear chopped material on to a heap
   - if several people are chopping fodder, make sure the work is organised safely
   - keep knives and choppers sharp for efficient chopping
   - the more mature the fodder, the smaller the chop length required - to ensure efficient compaction in the barrel or other silo

   alternatively:
6) Chop the green fodder by mechanical chopper powered by an electric or petrol motor (Plate 9.2.2; the electric powered chopper shown here is from Hohhote in Inner Mongolia)
   - feed small sheaves one at a time, stems first, continuously into the chopper to present a steady load to the motor - work with at least two people:
     - one person to prepare the small sheaves of fodder
     - the second person to feed the small sheaves into the chopper
   - if the fodder is soft, it will not feed through the feed rollers - carefully wedge the feed rolls of the chopper partly open with a wooden stake (Plate 9.2.3)
   - for safety let the small sheaves feed themselves into the chopper
     - take great care not to trap fingers and hands with the sheaves - they can be dragged through the feed rolls and be chopped off by the cutting cylinder
     - leave the drive belt from the motor to the chopper loose, so that it can slip if the chopper becomes blocked
   - switch the chopper off at the main switch before attempting to clear any blockages
   - keep the area around the chopper clear of fodder
   - sharpen the blades of the cutting cylinder regularly, and adjust the position of the cutting plate as required
7) As the chopped fodder is thrown on to the heap in front of the chopper, it fractionates into light heads (near the chopper), leaves, and heavy pieces of stem (farthest from the chopper) (Plates 9.2.4 and 9.2.5)
8) Only chop enough green fodder to fill one - two barrels at a time. This will prevent some barrels being mainly leaf and others being mainly stem

Mix the chopped green fodder, and fill and seal the barrels (Plate 9.3)

1) Rake up the fodder into a compact heap (Plate 9.3.1), and thoroughly mix the different fractions of ear, leaf and stem together:
   - ears have increasing starch as the grains develop
   - leaves are high in protein and digestible fibre
   - stems are highest in sugars when young, but become fibrous as the crop matures
2) add ordinary sugar or wheat flour to un-wilted leafy legume fodder at a rate of 0.5 kg / 25 kg of green fodder
   - sprinkle the sugar or flour over the heap of chopped green fodder and mix thoroughly with all the fodder in the heap
3) fill the first barrel by hand with chopped green fodder (Plate 9.3.2)
   - fill the barrel in layers of about 5 kg green fodder
   - tread down each layer well
   - sample the green fodder throughout filling as outlined below
4) When the barrel is full to the brim and well compacted, remove a little chopped fodder to allow the inner black plastic liner to fit (Plate 9.3.3)
5) Close and seal the barrel to exclude all air (Plate 9.3.4)
   - cut a thick plastic sheet as an inner seal and fit it over the open barrel
   - fit the inner black plastic liner of the barrel over the plastic sheet
   - firmly screw the outer black plastic lid in place
6) Fermentation will commence:
   - oxygen remaining in air trapped in the barrel will be rapidly converted to carbon dioxide by respiration of the mass of green fodder
   - anaerobic fermentation of sugars in the crop to lactic acid by lactobacilli present on the green crop will then commence, provided the seal remains airtight
   - the pH will be reduced to 4.0 - 4.5 within a few days, depending on the crop and its DM content
   - the silage can be fed to animals after one month
7) Number each barrel and label with fodder crop used and date filled.
8) Chop green fodder and fill the remaining barrels following the same procedures
9) Transport filled and sealed barrels to a safe store:
   - take care the lids of barrels are not accidentally opened during transport or storage
   - prevent damaged by children, livestock, birds, rats and mice, or insects
   - monitor the barrels while in store to check they are not opened or damaged
   - immediately reseal lids if opened, and repair any holes made in the barrels
   - re-use the barrels several times in successive years.

Field Sampling (Plate 9.4.1)

Take samples before cutting the green fodder on experimental plots and farmers' fields, in order to estimate the yields of fresh and dry matter per ha.

1) Cut 1 m^2 quadrats at random throughout the plots or farmers' fields of greed fodder crop
   - quadrats are representative samples of the plot or field
     - do not select quadrats from just the best parts of the plot or field

- cut 2 quadrats for experimental plots
- cut 5 quadrats for large fields
- if there is large variation within plots or fields double these numbers to 4 and 10 quadrats for plots and fields respectively

- cut the quadrats to the same height as used for cutting the whole plot or field for fodder

2) Collect all green fodder from the 1 m^2 quadrat, free of soil contamination, and weigh total green fodder to an accuracy of 10g

3) Take one representative sub-sample weighing 500g from each quadrat with an accuracy of 1g, bind with string as a small sheaf, and label with plot and quadrat numbers (Plate 9.4.1)

4) Complete record forms for each plot, to include fresh weights for each quadrat, and weights of sub-samples

5) Dry green fodder sub-samples in a fan ventilated laboratory oven:
   - if sub-samples are only for DM determination, dry at 100°C for 24 hours, or until all the sample is crisp
   - if sub-samples are to be analysed for nutritive value including fibre, dry at 60 °C for 48 hours, or until all the sample is crisp
   - make sure hot air can circulate easily all around sub-samples in the oven - do not overload the oven

6) Calculate drymatter yield of green fodder as:

Yield of green fodder (kg DM/ha)	=	Weight of fresh green fodder per quadrat (g/m²)	x	Weight of sub-sample dry (g) / Weight of sub-sample wet (g)	x	10,000 / 1000

(10,000 m^2 = 1 ha; 1000 g = 1 kg)

For example, drymatter yield of whole-crop winter wheat at flowering:

DM Yield of green fodder (kg/ha)	=	2400 g/m²	x	100g / 500g	x	10,000 / 1000	=	4800 kg/ha

Sample the green fodder for silage (Plate 9.4)

Take samples of chopped green fodder as barrels or other silos are filled, in order to:

- determine the dry matter content of the green fodder being made into silage
- assess the suitability of the green fodder for fermentation as silage
- determine the nutritive value of the green fodder through laboratory analysis, if this is possible.

Take similar samples at the time the silage is fed out to animals, in order to:

- determine the drymatter content of the silage
- measure losses of drymatter during fermentation
- assess the quality of fermentation and the ensiling process (see below)
- determine the nutritive value of the silage through laboratory analysis, if this is possible.

1) Take one sample from each barrel of silage (Plate 9.4.2)
   - take small sub-samples from each layer as the barrel is filled
   - put these sub-samples into a single strong brown paper bag
   - take care not to lose small pieces of stem

- pick up a small sub-sample with the fingers, then turn the hand over to carry all pieces to the bag
- do **not** shake the sub-sample so that small pieces drop off

2) Label the bag with a unique sample number, the number of the barrel and the type of fodder

3) As soon as possible weigh the fresh sample:
   - the sample is losing moisture all the time; if necessary keep it in a plastic bag or box until it can be weighed
   - use a balance that can weigh to 2000g with an accuracy of 1g
   - place an empty paper sample bag on the balance, and tare the balance to zero
   - place the paper bag with sample of fresh green fodder on the balance, and record the weight of fresh fodder directly

4) Take samples from all the barrels as they are filled with green fodder, and weigh them as above

5) Dry the samples of green fodder in a fan ventilated laboratory oven:
   - if sub-samples are only for DM determination, dry at 100°C for 24 hours, or until all the sample is crisp
   - if sub-samples are to be analysed for nutritive value including fibre, dry at 60 °C for 48 hours, or until all the sample is crisp
   - make small holes in the paper bag with a ball point pen, so that hot air can circulate through the sample and water vapour can escape
   - pack the sample bags in the oven with space between the bags, so that hot air can circulate around the bags
   - if the oven has a variable ventilator:
     - during the first half of the drying period fully open the ventilator - to allow most of the moisture to escape easily
     - during the second half of the drying period half open the ventilator - to allow the oven to operate at the set temperature for efficient extraction of the remaining moisture
   - the laboratory oven is a precision instrument - in order to obtain reliable results use it correctly
   - include an empty bag with the batch of samples, so that it can adjust to the same moisture content as the bags containing the samples

6) Weigh the barrels full of green fodder before storage (Plate 9.4.4)
   - use platform scales with an accuracy of 100g (0.1 kg)
   - weigh an empty barrel, with plastic sheet, inner liner and outer screw lid
   - weigh each sealed barrel full of green fodder
   - calculate the weight of fresh green fodder by difference
   - record all weights against barrel number and fodder type on a record sheet

7) When drying of samples is complete, weigh the dry samples:
   - use a balance that can weigh to 200g with an accuracy of 0.1g
   - place an empty bag that has been dried in the oven on the balance, and tare the balance to zero
   - place each bag with dried sample of fresh green fodder on the balance, and record the weight of the dry sample of fodder directly

8) Calculate the weight of fresh and dry green fodder in each barrel as follows:

Weight of fresh green fodder per barrel (kg)	=	Weight of fresh green fodder plus barrel + lid (kg)	-	Weight of barrel + lid (kg)

Weight of dry green fodder per barrel (kg)	=	Weight of fresh green fodder per barrel (kg)	x	Weight of sub-sample dry (g) / Weight of sub-sample wet (g)

For example, take weights of fresh and dry green fodder for one barrel of whole-crop winter wheat at flowering as follows:

Weight of fresh green fodder per barrel (kg)	=	24.00 kg	-	2.14 kg	=	21.86 kg

Weight of dry green fodder per barrel (kg)	=	21.86 kg	x	99.3g / 331g	=	6.56 kg

Assess Silage Drymatter content, Weight of Drymatter ensiled, and Drymatter Losses during fermentation

1) Before opening each barrel of silage for feeding:
   - weigh the unopened barrel on platform scales and record its weight against barrel number and fodder type
   - to determine the weight of silage in the barrel, subtract the weight of an empty barrel - with plastic sheet, inner liner and outer screw lid
2) Take small sub-samples of silage from different layers down the barrel to prepare a single sample per barrel
   - water is released during fermentation if the DM content of the green fodder is <30%, and will accumulate at the bottom of the barrel
     - this liquid is known as silage effluent
     - mix it with the silage or dry fodder and feed it to ruminants
     - do not allow silage effluent to pollute water courses - it has a high biological oxygen demand (BOD)
   - if feeding at 4 -5 kg of silage per day
     - take sub-samples from each day's silage
     - add sub-samples to a plastic bag and seal the bag after each addition
     - take care to include all parts of the sub-sample - do not lose short pieces of stem
     - store the plastic bag in a refrigerator or freezer until the whole sample is complete
   - if feeding the whole barrel of silage at one time
     - take several sub-samples of silage from different layers as you empty the barrel
     - add sub-samples to a plastic bag
     - take care to include all parts of the sub-sample - do not lose short pieces of stem

- store the plastic bag in a refrigerator or freezer until the whole sample is complete

3) Weigh the fresh silage sample in the plastic bag - tare the balance with an empty plastic bag
4) Transfer the silage sample completely to a brown paper bag, and dry the silage sample as for green fodder at 60 or 100 ^{o}C in a laboratory oven to obtain Oven Drymatter (ODM) %
5) Repeat sampling for each barrel of silage
6) Send dried silage samples for laboratory evaluation if possible
7) Volatile compounds (Volatile Fatty Acids - Lactic, Acetic, Butyric acids, and alcohols) are formed during silage fermentation. These are lost during oven drying. Adjust Oven Drymatter (ODM) as shown below to obtain the Corrected Drymatter (CDM) % content of the silage
8) Calculate the Weight of Drymatter in each barrel, and DM losses in fermentation, using CDM %

Oven Drymatter of Silage (ODM) %	=	Weight of silage sample oven dry (g) / Weight of silage sample wet (g)	x	100

Corrected Drymatter of Silage (CDM) %	=	[Oven Drymatter % x 0.99]	+	1.82

Weight of wet silage per barrel (kg)	=	Weight of wet silage plus barrel + lid (kg)	-	Weight of barrel + lid (kg)

Weight of dry silage per barrel (kg)	=	Weight of wet silage per barrel (kg)	x	Corrected Drymatter of Silage DM (CDM) %	/	100

Drymatter Fermentation losses (kg)	=	Weight of dry green fodder per barrel (kg)	-	Weight of dry silage per barrel (kg)

Drymatter Fermentation losses %	=	Drymatter Fermentation losses (kg)	/	Weight of dry green fodder per barrel (kg)	x	100

For example, weights of silage wet and dry matter, and DM losses, for one barrel of whole-crop winter wheat silage cut at flowering as follows:

Oven Drymatter of Silage (ODM) %	=	90 g / 320 g	x	100	=	28.1 %

Corrected Drymatter of Silage (CDM) %	=	[28.1 % x 0.99]	+	1.82	=	29.7 %

Weight of wet silage per barrel (kg)	=	19.62 kg	-	2.14 kg	=	17.49 kg

Weight of dry silage per barrel (kg)	=	17.49 kg	x	29.7 %	/	100	=	5.19 kg

Drymatter Fermentation losses (kg)	=	6.56 kg	-	5.19 kg	=	1.37 kg

Drymatter Fermentation losses %	=	1.37 kg	/	6.56 kg	x	100	=	20.90 %

Assess Silage Quality by Sight and Smell

1) As the silage is fed out, assess each barrel of silage for effective preservation - against the following criteria:
   - condition of the barrel (undamaged - no holes; small holes; large holes; destroyed)
   - colour of the silage (yellow - straw coloured, green, brown, black, white)
   - smell of the silage (strong acid- lactic; acetic; low acid; alcoholic; rotten)
   - pH of the silage in each barrel, using pH papers for the 3.5 - 5.5 range
   - presence of mould on the silage (no mould; small patches of mould on the surface; large patches of mould on the surface; fungal mycelium through part of the silage; fungal mycelium through the whole barrel; fruiting bodies; other - describe)
   - presence of pests (mice; birds; insects; larvae; other pests)
   - other visible problems - describe.
2) Complete a record sheet on silage quality and send to TARI

Feeding Barrel Silage

The feeding value of silage depends on the fodder crop used, the stage of growth at which it is harvested, and how well the crop was ensiled. This is discussed in Chapter 10.

9.3. Fences, Tripods and A-frames for drying heavy crops of fodder legumes

Introduction

This part is relevant to all legume fodders, but is focussed on vetch since this is the main annual fodder legume for double cropping. Vetch can be grown as a second crop within double cropping systems throughout the project area, and plans have been made for extensive plantings with farmers. It is also being used as a sole crop to reclaim second class crop lands at present unsuitable for grain production in many of the municipalities, as part of a larger state programme to develop fodder production. Under the Project several demonstrations and experiments look at the establishment of vetch and its place within cropping systems.

When vetch is grown by farmers as a sole crop they take two cuts for green fodder during the growing season, and a final large cut in September which they dry as hay. When grown as a second crop within double cropping systems, a single cut is taken for conservation in September. Successful conservation of vetch as hay is not as easy as making hay from natural pastures. Vetch is a legume with high protein content in the leaves. However the leaves are divided into small leaflets. These leaflets dry much more quickly than the stems, and when dry they are easily knocked off and lost on the ground. Farmers who have made hay for a long time from vetch may know how to harvest it successfully, but many farmers are now growing vetch for the first time. These farmers need to be shown how to conserve vetch successfully.

Traditionally in Tibet long fodders including wild oats are plaited into long ropes which are then knotted into a loop and hung on the walls of the compound or on rafters of store sheds or the farmer's house to dry (Plate 9.5). Short fodder is spread out on the roof of a store or house to dry. Depending on county, additional structures such as hay fences, tripods, or A-frames may be used to support green fodder to dry it off the ground - either in the compound, outside by the straw stacks or even in the fields. Such practices are not, however, widespread. Dry fodder is then stacked under cover if hay is made before the rains, or on the roof if the rains have finished.

Harvesting the vetch

1) Cut the vetch crop by hand using the normal long handle sickles. This will usually be done early in the morning, once any dew has dried.
2) Roll the vetch into bundles, so that most of the leaves are protected inside the bundle and cannot fall off.
3) Carry the bundles of vetch to the farmers' compounds.
4) Dry the bundles of vetch.

Drying the vetch

Several methods can be used for drying the green fodder, depending on the weather.

1) Leave the vetch in the bundles, and allow to air dry on platforms or suspended from beams or walls outside; this should take 2-3 days. The bundles should be small, rolled up loosely, and be kept spaced out while drying.
2) Unroll the bundles and sun dry quickly on platforms or on the compound floor.
3) Unroll the bundles and air dry under cover (out of the sun and rain). This will preserve most nutrients in the leaves, but takes longer to clear the whole field.
4) Construct a "Hay Fence" in the compound (Plate 9.6.1) This consists of wooden bars such as Poplar poles set horizontally one above the other in a wooden framework. Metal wires or rope can be used instead of wood. If rain is likely, top the fence off with a small canopy made of tin sheet, or cover the top layer of hay with a plastic sheet.
5) Alternatively, according to local custom, construct wooden tripods (Plate 9.6.2) or A-frames (Plate 9.6.3), which are self-supporting.
6) Hang the green vetch over the bars of a hay fence in thin layers, so that it dries both due to air and to sun. Once hay fences, tripods or A-frames are constructed use them to dry any crop in the compound, at any time of the year - even in the wet season July - August.
7) Alternatively, if all families who farm a block of land grow vetch, build the hay fences, tripods or A-frames on the fields themselves. Suspend the green crop on the supports immediately after cutting. Take care not to lose any leaves and pods when the dry vetch is carried in to the compound.

Once the hay is dry, move it to a safe store - as a high protein hay this is a valuable fodder. At all times keep the hay safe from eating or treading by animals while it is being dried in farmers' compounds or fields.

9.4. Fractionation of legume fodders into leaf and stem

It is possible to fractionate most legume fodders, however it is particularly easy with vetch. Once the vetch crop is safely at the farmer's compound and dry, it is possible to make use of its ability to shed leaves. If beaten with a stick, the leaflets will fall off the stem, and can be collected separately. These leaflets are high in protein and have good digestibility. They can be fed to high yielding milking cows or to pigs and poultry as a protein feed within balanced rations; or fed to milking cows or fattening sheep as a good supplement to straw based rations. The remaining stem is still a better fodder for cattle and sheep than cereal straw.

Fractionation

1) Dry the green vetch until the leaves (leaflets) are dry, but the stems are not yet brittle - this gives best separation of leaves with minimum of stem breakage and dust
2) Beat the bundles or unrolled vetch with sticks - the leaflets will be knocked off easily and accumulated on the threshing floor
3) Sweep up the leaves, taking care not to include any soil from the threshing floor, put them into woven plastic sacks, and keep the sacks in a safe dry store
4) Complete the drying of the stems in one of several ways:
   - keep bundled stems in their bundles and finish drying them as before; or
   - if the stems were unrolled for drying and/or threshing, roll them into bundles again while they are still supple, and finish drying them in bundles; or
   - if the stems were unrolled for drying and/or threshing, complete drying in loose form on a drying platform; or
   - if the whole crop was dried on a Hay fence, re-hang the stems on the fence while they are still supple - alternatively roll the stems into bundles at this stage, and use the Hay fence for another batch of green Vetch from the field
5) Handle the dry stems in one of several ways:
   - store them safely in their bundles
   - beat the stems with sticks to break them into smaller pieces, and store safely in woven plastic sacks
   - pass the stems through a mechanical threshing machine, and store the small pieces safely in woven plastic sacks
   - mill dry stems through a hammer mill with a coarse screen, to prepare a meal. This is the best method for feeding legume stems to fattening sheep.

REFERENCES

Frame, J. 2005. *Forage legumes for temperate grasslands*. Rome: Food and Agriculture Organization of United Nations, and Enfield (NH) USA: Science Publishers. ISBN: 92 5 105043 0 and 1 57808 358 3.

Raymond, F. and Waltham, R. 1996. *Forage conservation and feeding*. Ipswich, UK: Farming Press Books / Miller Freeman Professional. ISBN: 0 85236 350 8.

9.1.1. Cut with a sickle

9.1.2. Leave stubble to avoid soil contamination

9.1.3. Bind green fodder into sheaves

9.1.4. Harvested plot with sheaves waiting collection

9.1.5. Carry sheaves to road

9.1.6. Take green fodder to compound in a clean trailer

Photos Bem Ba / Ian Lane

Plate 9.1. Making "Barrel Silage" from whole-crop cereals (July 5th, 2006; TARI field station, Lhasa). 1. Harvest of Feimai winter wheat at flowering - milky stage

9.2.1. Set chopper up on large tarpaulin to prevent soil contamination, and stack sheaves ready to go

9.2.2. Feed small sheaves into chopper one by one

9.2.3. Wedge feed rolls part open to feed soft fodder

9.2.4. Chop fodder for two barrels at one time - note crop fractionisation

9.2.5. Fractions - from left: heads near chopper, leaf, stem far from chopper

Photos Ian Lane

Plate 9.2. Making Barrel Silage from whole-crop cereals (July 5, 2006; TARI field station, Lhasa) 2. Chopping green fodder - spring barley ZangQing # 690 harvested at milky stage

9.3.1. Rake up and thoroughly mix chopped fodder

9.3.2. Fill barrels with fodder in layers and tread each layer down

9.3.3. Leave space for inner lid

9.3.4. Seal with thick plastic sheet, inner plastic lid and screw cover

9.3.5. Transport to safe store

Photos Ian Lane, and Bem Ba / Ian Lane

Plate 9.3. Making Barrel Silage from whole-crop cereals (July 5th, 2006; TARI field station, Lhasa). 3. Mixing chopped fodder; and filling and sealing barrels

9.4.1. Cut random 1 m^2 quadrats to estimate fresh yields of fodder, and take 500g sub-samples for DM %

9.4.2. Take small sub-samples of chopped green fodder while filling each barrel; do not to lose small pieces

9.4.3. Tare balance for empty bag, and weigh fresh samples to 1g

9.4.4. Weigh barrels empty and full

Photos Ian Lane, and Bem Ba / Ian Lane

Plate 9.4. Making Barrel Silage from Whole Crop Cereals (July 5th, 2006; TARI field station, Lhasa). 4. Field sampling (SB), and sampling chopped green fodder for silage

9.5.1. Plait long green fodder into long ropes

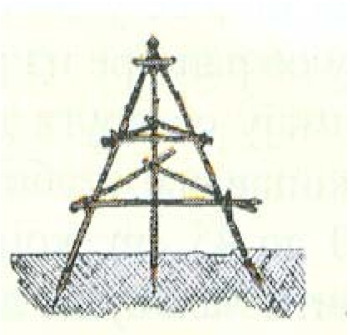
9.5.2. Knot ropes into loops

9.5.3. Hang the rope loops over rafters / beams to dry in the air, sheltered from rain

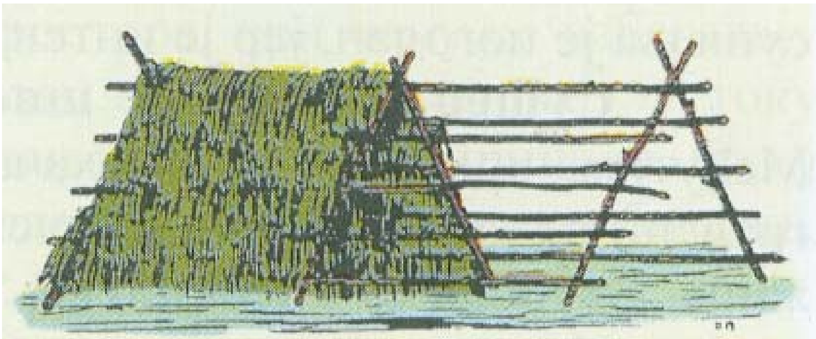
Photos Ian Lane

Plate 9.5. Making "Hay Ropes" from whole-crop cereals (July 5th, 2006; TARI field station, Lhasa) - spring barley at early milk stage

9.6.1. Hay Fences made by farmers in the mountains of Croatia



9.6.2. Hay Tripod



9.6.3. Hay A-Frame

Photos in 1. by Ian Lane

Plate 9.6. Hay Fences, Tripods and A-Frames for drying legume and whole-crop cereal hays

Chapter 10 FEEDING OF FODDER CROPS

Ian Lane

Chapter 10 FEEDING OF FODDER CROPS

10.1. Introduction

There is an old saying "Half the Breeding is in the Feeding", and this is highly relevant in central Tibet where the programme to develop fodder production as second crops is a response to programmes to develop milk production through cross breeding Local cows with highly selected introduced milk breeds that include the Simmental, Holstein and Jersey.

Green fodder from either main or second crops, as fresh feed or conserved green as silage or dry as hay, can be fed as sole feeds, as the green fodder supplement to straw based rations, or as part of balanced rations (Figure 10.1). Leaves from fractionated legume hays can be fed to high yielding cows and pigs and poultry, while stems and pods are still good feeds for cattle and sheep. Root crops can either be chopped and fed whole with tops as well as roots as a balanced feed; or separated at harvest into tops which are a good protein fodder, and roots which are a high energy concentrate.

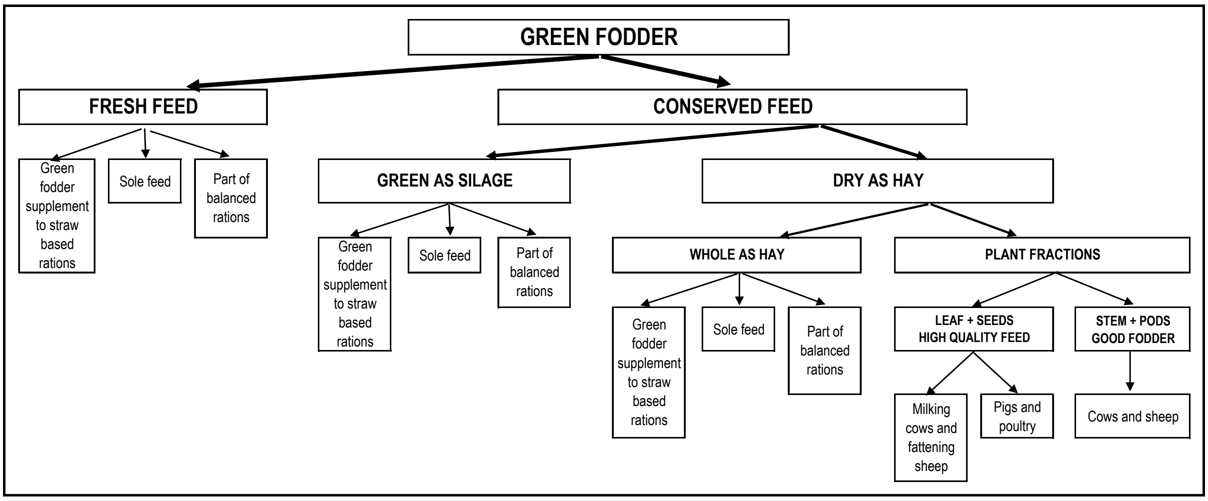


Figure 10.1. Feeding of green fodder from main and double crops

In this chapter factors that determine the feeding value of fodders and feeds are explained. The feed composition and nutritive value of fodders and feeds available in central Tibet are summarised, with comprehensive tables provided as an annex. A brief review of the feeding systems used in Tibet is presented, leading into demonstration of models using the UK Metabolisable Energy and Protein system through RUMNUT ruminant nutrition software and actual composition of UK feeds[1]:

- the influence of fodder quality on the intake of dry matter and nutrients, and on resulting milk yields - for local, crossbred and exotic milk cows;
- replacement of barley straw in straw based rations with whole-crop wheat silage;
- progressive supplementation of straw based rations with various fodders that might be grown as second crops; and
- the relationship between conserved fodder quality and "fodder-to-concentrate ratio" in the diet of milking cows for local, crossbred and exotic milk cows.

Economic responses for these models are given in Chapter 11.

While the feeding of fodder crops to growing and fattening cattle and sheep is important, for simplicity the following discussion is mainly limited to feeding the milking cow.

[1] Key references for this chapter are "*Energy allowances and feeding systems for ruminants*" by MAFF (1984), "*Feeding the Dairy Cow*" by Chamberlain and Wilkinson (1996), and "*Animal Nutrition*" by McDonald *et al.* (2002)

10.2. Feeding Value

The Feeding Value of individual fodders and feeds is expressed as follows:

Feeding Value (Milk yield, litres/day)	=	**Intake** (kg DM/day)	x	**Digestion** (proportion)	x	**Utilisation** (proportion)

The Feeding Value of a fodder or feed is expressed in terms of the animal production it can produce, such as litres of milk in dairy cows. It involves the following components:

10.2.1. Voluntary Feed Intake (Dry Matter Intake, Appetite)

Feed intake is the major component that determines the amount of milk that a cow will produce. It is, however, affected by many different factors, and is therefore difficult to predict precisely. These include both animal factors and properties of the fodder and feeds, as presented in Tables 10.1 and 10.2 respectively. Since fodder and feeds can be fed in fresh or in conserved wet or dry forms, it is convenient to work with feed intake in terms of dry matter. However, when preparing rations on farm it is necessary to convert back to the fresh weights of the feeds that farmers actually have available.

Table 10.1. Animal Factors that determine voluntary feed intake in milking cows

<table>
<tr><th>Factor</th><th>Description</th></tr>
<tr><td>Liveweight
(Bodyweight)</td><td>A simple rule for use on farm for all types of milk cows is that dry matter intake is 3 percent of liveweight:
$DMI = 0.03\ W$
where DMI = dry matter intake, kg/day
W = liveweight, kg
<table>
<tr><th colspan="4">Predicted dry matter intake of cows in mid and late lactation (kg/day)</th></tr>
<tr><td>Type</td><td>Local</td><td>Crossbred</td><td>Exotic</td></tr>
<tr><td>W (kg)</td><td>200</td><td>400</td><td>600</td></tr>
<tr><td>DMI (kg/day)</td><td>6.0</td><td>12.0</td><td>18.0</td></tr>
</table></td></tr>
<tr><td>Milk yield</td><td>At similar liveweights, cows with high milk yields eat more than cows with low milk yields – intake is led by the higher milk yield. A two factor equation is generally accepted to account for both liveweight and milk yield (MAFF, 1984), and is used in RUMNUT:
$DMI = 0.025\ W + 0.1\ Y$
where DMI = dry matter intake, kg/day
W = liveweight, kg
Y = milk yield, kg/day (litres/day can be used)
<table>
<tr><th colspan="9">Predicted dry matter intake of cows in mid and late lactation (kg/day)</th></tr>
<tr><td>Liveweight</td><td colspan="8">Milk yield , Y (kg/day or litres/day)</td></tr>
<tr><td>W (kg)</td><td>0</td><td>4</td><td>8</td><td>12</td><td>16</td><td>20</td><td>24</td><td>28</td></tr>
<tr><td>200</td><td>5.0</td><td>5.4</td><td>5.8</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>400</td><td>10.0</td><td>10.4</td><td>10.8</td><td>11.2</td><td>11.6</td><td>12.0</td><td></td><td></td></tr>
<tr><td>600</td><td>15.0</td><td>15.4</td><td>15.8</td><td>16.2</td><td>16.6</td><td>17.0</td><td>17.4</td><td>17.8</td></tr>
</table></td></tr>
<tr><td>Body Condition</td><td>At the same liveweight, thin cows tend to eat 25-30 percent more per unit of liveweight than fat cows, since fat animals will use fat reserves to meet energy requirements. When assessing liveweight in order to estimate DMI, it is therefore important to estimate what the cow would weigh at body condition score 2.5 (on a scale of 1 = thin to 5 = fat) rather than her exact weight. Alternatively, use a weighband to measure actual liveweight, and correct estimates of DMI according to condition score as below[2].</td></tr>
</table>

[2] Estimated from Forbes (1983) as given in Chamberlain and Wilkinson (1996)

<table>
<tr><td rowspan="4">Body condition (continued)</td><td colspan="5">Correction factors for Body condition score</td></tr>
<tr><td>Condition</td><td>Thin</td><td>Optimum</td><td>Fat</td><td>Very fat</td></tr>
<tr><td>Condition Score</td><td>1</td><td>2.5</td><td>4</td><td>5</td></tr>
<tr><td>Correction factor</td><td>1.15</td><td>1.00</td><td>0.85</td><td>0.8</td></tr>
</table>

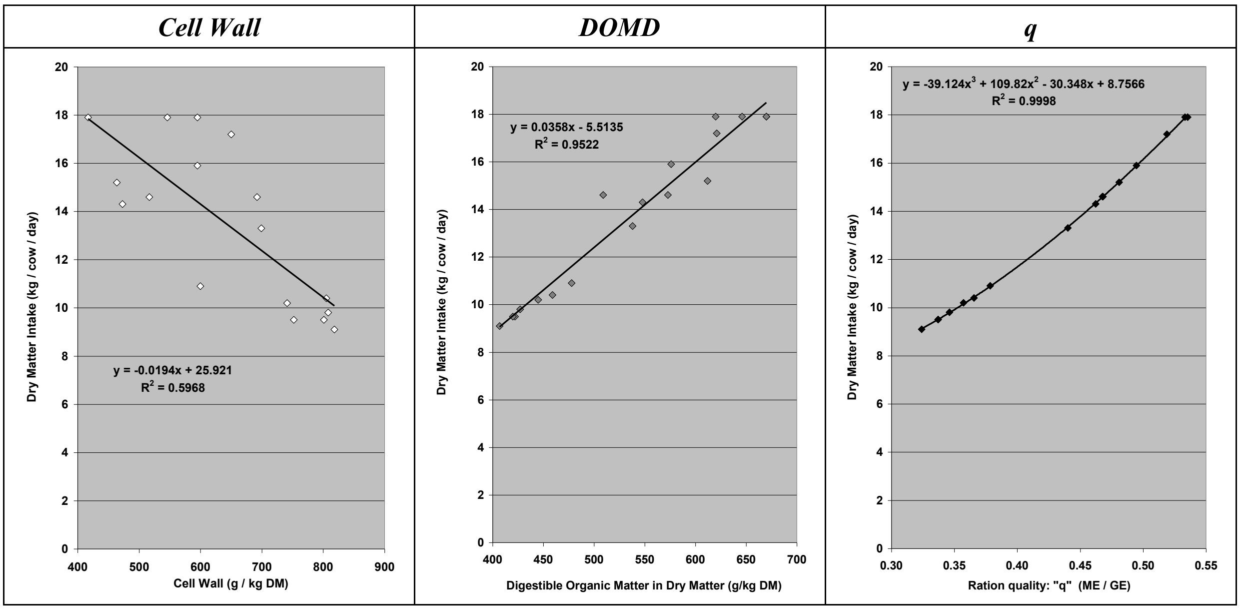
<table>
<tr><td rowspan="4">Stage of lactation</td><td colspan="8">Freshly calved cows do not eat as much as predicted from their liveweight and milk yields.
1). The rumen takes several days to expand into the space previously occupied by the uterus and foetus
2). Both the rumen wall and the microbial population need time to adjust to a diet with high nutritive value following calving
3). Cows draw on their body reserves following calving, reducing their appetite
4). Intake lags behind milk yield by 4-6 weeks, so that if peak yield is reached in the 6-8th week of lactation, peak intake results in the 10-12th week.
For Friesian cows MAFF (1984) states that feed intakes should be reduced by 2-3 kg DMI per day in the first six weeks. Chamberlain and Wilkinson use the following correction factors in RUMNUT, adapted from Vladiveloo and Holmes (1979). These can be used to correct predicted DMI for cows of all types and sizes:</td></tr>
<tr><td colspan="8">Correction factors for stage of lactation</td></tr>
<tr><td>Lactation week</td><td>1</td><td>2</td><td>4</td><td>6</td><td>8</td><td>10</td><td>12</td></tr>
<tr><td>Correction factor</td><td>0.67</td><td>0.78</td><td>0.88</td><td>0.93</td><td>0.96</td><td>0.98</td><td>1.00</td></tr>
<tr><td>Stage of pregnancy</td><td colspan="8">In late pregnancy the uterus enlarges and reduces the rumen volume, so that feed intake is depressed compared to predicted values. Throughout the last month voluntary intake may be only 1.5-1.75 % of liveweight.</td></tr>
<tr><td>Pregnancy number</td><td colspan="8">First calvers (heifers in their first lactation) have a reduced feed intake due to a lower gut capacity per kg liveweight compared to mature cows. Apply a correction factor of 0.90 – 0.95 to predicted DMI.</td></tr>
<tr><td>Breed</td><td colspan="8">The MAFF (1984) prediction equation was based largely on the British Friesian breed. Modern Holsteins have a larger frame and gut size, and potential feed intakes have increased by 10 – 20%. If imported Holstein semen is used, apply a correction factor of 1.10 – 1.20 to predicted DMI for purebred cows, and 1.05 – 1.10 to predicted DMI for F1 crossbred cows.</td></tr>
</table>

It is apparent that the major animal factor determining voluntary feed intake is the body size or liveweight of the cow. This is the main reason that Holstein and Simmental cows and their crosses give more milk than local cows in Tibet – they are bigger, and can therefore eat more food. In fact there are two main options:

- larger cows can eat more of the same food and produce more milk, or
- larger cows can eat more food of lower quality and produce the same amount of milk.

Simmentals and their crosses tend to produce milk of similar quality as Local cows. Holstein cows and their crosses tend to produce milk of lower fat content, so that at the same energy intake as Simmentals they will produce more milk – although their fat corrected milk yields will be similar. However because Holstein cows have been highly selected for milk yield, their lactation curves have a high peak at 8 – 10 weeks of lactation. Due to reduced feed intake following calving it is difficult to feed purebred Holstein cows sufficient energy at this time. Genetically they must produce milk, and are prone to acute metabolic diseases such as hypocalcaemia immediately post-calving, and ketosis if weight loss continues at more than 1 kg/day. Prolonged underfeeding in early lactation also results in premature peak milk yields, rapid decline of milk yields from peak yields to a low plateau that equates energy intake and output, and poor conception rates. On the other hand, Simmentals are dual purpose milk and meat cows and have been subject to less intense selection for peak milk yield. They have a lower, flatter, milk production curve, and are better adapted to underfeeding in early lactation. Farmers in Tibet have found it difficult to cope with the high quantity of feed required by Holstein and Simmental cows, so the Jersey breed with a mature liveweight of 350 kg has been introduced because it is intermediate in size. However, this action immediately removes the benefit of using a large breed for crossbreeding with Local cows, in that the Jersey and its crosses need higher quality fodder for both maintenance and milk production than either the Simmental or Holstein and their crosses. From a nutritional viewpoint, the Simmental is the best breed for crossing with local cattle in Tibet at the present early stage of fodder and feed development.

While on the subject of the size of cows, although it is claimed that many Simmental and Holstein cross cows are present in Central Tibet, few are noticeable compared to Local cows. It appears that crossbred cows are the same size as Local cows, while they should be intermediate in weight – 400kg compared to 200 kg for Local cows. This is undoubtedly due to crossbred calves being fed the same rations as local calves, so that they grow at the same rate and end up being mature at the same weight as Local cows. This will mean that they can only have the same feed intake as Local cows, as shown in Table 10.1, and only be able to produce the same amount of milk as Local cows. It is essential that crossbred calves are fed according to their potential growth rates, so that they can reach their correct weight for first calving at 2 – 3 years old. This means feeding them with 2 – 4 times the amount of food compared to that normally given to Local calves, and this should be of sufficient quality to allow them to achieve the necessary growth rates.



1. Data are from Annex 10.2. and cover the range of fodders from spring wheat straw to good quality hay;
2. Cell wall is taken from neutral detergent fibre (NDF); "q", the Metabolisability of the ration, is estimated as the ratio of ME / GE;
3. Values for DMI were estimated using RUMNUT, which uses "q" to determine DMI; this relationship fits the cubic relationship shown;
4. Relationships are for a mature local Holstein cow of 600 kg liveweight with milk yield of 30 litres / day, zero weight change, condition score 2.5 / 5.0, 12 weeks post calving, 0 weeks pregnant.
5. These figures are only to demonstrate the theoretical effect of fodder quality on DMI. At low fodder quality the intake of ME is well below requirements, and the milk yield stated is not sustainable.

Figure 10.2. The relationship of Voluntary Feed Intake to Ration Quality as indicated by Cell Wall content, Digestible Organic Matter in the Dry matter (DOMD), and the Metabolisability of the ration (q), over the range of ration quality where intake is controlled by physical factors

Table 10.2. Properties of fodder and feeds, and feeding systems, which affect dry matter intake

Property	Description
Quality of the ration	In fibrous fodders and feeds the proportion of soluble cell contents is low, and that of cell wall is high. The more mature the plant, the higher the degree of lignification of the cell wall, and the slower it will be digested by microbes in the rumen. Long fibres such as those of grasses and cereal straws stay longer in the rumen than short fibres such as those of forage legumes and concentrate feeds. The longer the cell walls remain in the rumen, the less new feed can be eaten by the animal, so that the bulk of the ration provides a physical control on feed intake. Such fibrous feeds have a low concentration of Metabolisable energy (ME).

Quality of the ration (continued)

In younger fodders the proportion of rapidly fermentable cell contents is higher. At the same time the extent of lignification of the cell walls is less, so that they are digested more quickly and to a greater extent in the rumen. As a result the dry matter disappearance rate of young fodders is greater, and the animal can readily eat more feed to replace that digested and lost from the rumen. Such feeds have medium to high levels of Metabolisable energy, and as the quality of the diet increases the animal can eat more dry matter.

However a changeover point is reached when the diet can meet the energy requirements of the animal. Beyond this point voluntary intake is not limited by rate of digestion, and the cow eats to meet her energy requirement. The animal's physiology or metabolism takes over control of intake, and further increase in energy concentration results in a decrease in dry matter intake. The point at which this changeover occurs is subject to animal factors such liveweight, milk yield and body condition. The higher the energy requirement of the cow, the better the quality of the ration before the changeover point is reached.

The quality of the ration may be assessed in terms of cell wall measured as neutral detergent fibre, but due to variability in cell wall structure the relationship with intake is not precise (r^2 = 0.60). Digestibility, as Digestible Organic Matter in the Dry matter (DOMD) is well related to intake (r^2 = 0.95). However, since cows tend to eat to meet their requirements for energy, it is convenient to use the ratio of Metabolisable energy[3] to Gross energy (ME/GE) known as "q" (the "Metabolisability" of the ration), since both ME and GE are estimated for feeds during ration formulation. These relationships are demonstrated in Figure 10.2. for various feeds in the DOMD range 400 – 670 g/kg DM equivalent to spring wheat straw to good quality grass or vetch hay, for a local Holstein cow of 600 kg liveweight and milk yield of 30 litres / day. It is over this range in ration quality that the physical bulk of the ration controls intake. With higher quality fodders and feeds physiological control takes over. Intakes of various fodders for cows of different liveweights are given below. Note that only good quality fodder allows the intakes predicted from animal characteristics in Table 10.1 to be achieved.

Rations based on cereal straws alone will be deficient in fermentable protein. This will reduce fermentation in the rumen, and intakes will be less than those predicted from q. Apply correction factors of 0.7 – 0.9 to predicted intakes for ration CP levels <70 g/kg DM.

Effect of ration quality on physical control of feed intake

Liveweight (kg)			200	400	600
Milk yield (litres)			6	18	30
	DOMD (g/kg DM)	q	Dry Matter Intake (kg / cow / day)		
Winter wheat straw	420	0.34	2.6	6.2	9.5
Fresh lucerne	548	0.46	3.9	9.3	14.3
Whole-crop Wheat Silage	670	0.53	4.9	11.7	17.9

1. These figures are only to demonstrate the theoretical effect of fodder quality on DMI. At low fodder quality the intake of ME is well below requirements, and milk yields shown are not sustainable.

Processing

Chopping fresh and dried fodders allows cows to consume them more easily than fodder in the long form. Chopping also reduces the scope for selection of leaves and stem pieces of higher digestibility and protein content, which is useful if fodder is limited and the farmer wishes to reduce waste. The shorter the chop length the higher the intake, with a target of 5 cm, and lead to increased intake of 5–15%. Responses in intake of silage have been reported to chopping as short as 7 mm particle length. Predicted intakes need to be adjusted according to intakes observed in practice, by applying Correction factors of 1.05 – 1.15. However, if fodder is plentiful animals can improve the quality of their own diet by selection, leading to increased intake – chopping fodder will reduce the animal's ability to select.

Fine milling of fibrous feeds such as straws and low quality hays can lead to a 10-20% increase in feed intake. This is related to a faster rate of passage through the gut, so that digestion of the whole feed is reduced, particularly in large cattle. However, the animal will still digest the soluble cell contents – sugars, starches and soluble nitrogenous compounds, plus the more quickly fermented cell wall components which are made more available by the milling process. Net intake of nutrients will therefore tend to be increased. Apply correction

[3] The ME system will be outlined in a later section.

Processing (continued)	factors of 1.10 – 1.20 to predicted intakes for cows. Fine milling of fibrous feeds is most beneficial for sheep, especially fattening lambs. Fine milling does, however, reduce the scratch factor required to stimulate saliva flow and rumination – if the straw is to provide the fibre component in a concentrate based diet for cows, it should only be chopped or coarsely milled. Treatment of straws with alkalis such as ammonia generated from urea, or with biological treatment, breaks down the structure of cell walls and improves digestibility. This increases potential feed intake compared to the untreated straws. Chemically treated straws are listed as separate feeds compared to the untreated straws (see Annex Table 10. 3).
Method of conservation	Conserved fodder can only be as good as the green fodder from which it is made, and losses in nutrients invariably occur during conservation as hay or silage. Properties discussed under "Quality of the ration" therefore apply to conserved fodders as well as fresh. However additional factors can reduce the intake of hay and silage in relation to the effectiveness of the conservation process, which act in addition to possible losses of nutrients: ***Hay***: 1. Prolonged drying because of bad weather conditions with activity by plant enzymes, bacteria and fungi – leading to blackening of the hay due to mould, and the presence of mycotoxins and actinomycetes; 2. Heat damage during curing in store due to Maillard-type reactions between proteins in the presence of sugars, leading to a dark brown colour and tobacco smell; and 3. Overheating in field stack or in store with formation of white spores from thermophilic bacteria. The impact of mould on intake depends on how bad the hay is, and may result in either total rejection of hay, or the health risk including danger of abortion being so severe that the hay should not be fed. Correction factors (CF) should therefore be applied to predicted intake from 0.9 (little mould) to 0.0 (total rejection). Hay with CF of <0.7 should not be fed to cows at all. Heat damaged brown hay may have a sweet smell and be palatable to stock – they will eat it, but the efficiency of utilisation of nutrients is reduced. In this case, apply a correction factor of 0.3 to reduce the amount fed in order to prevent digestive problems.
	Silage The voluntary feed intake of silage can not be accurately predicted due to the variable extent and pattern of fermentation and its assessment, and the effect of feeding with other fodders and concentrates. Actual intakes of silage if fed as the main fodder are estimated on farm. In well-preserved naturally fermented unwilted silages, commonly made from grasses and whole crop cereals, lactic acid bacteria have dominated the fermentation. They have low pH values of 3.7 – 4.2 and contain a high concentration of lactic acid, and low soluble carbohydrates, with dry matter contents of 18-25%. In well-preserved silages wilted to 28-32% DM, lactic acid contents are half those of unwilted silage, with higher sugar contents. Badly preserved silages where clostridia and/or enterobacteria have dominated fermentation are frequently produced from crops which: 1. are ensiled at too high a moisture content 2. contain low levels of water-soluble carbohydrates 3. are deficient in lactic acid bacteria 4. have high protein levels such as legume fodders Such silages have a high pH of 5.0 - 7.0, with fermentation acids dominated by butyric or acetic. Lactic acid and sugar concentrations are low. Ammonia-N levels at >200 g/kg total N are more than double the levels in well preserved silages (70-100 g/kg total N), are derived from catabolism of amino acids, and are accompanied by other degradation products. Even well preserved unwilted silage may reduce intake if fed as the main feed: 1. It is acidic, and being chopped and easily consumed does not stimulate the cow to produce enough saliva to neutralise the acidity in the rumen; and 2. Low dry matter silages contain water within the plant cells, so that intakes are reduced due to excessive wetness. The optimal dry matter content of the whole diet is 40 - 55%. Apply correction factors of 0.7 – 0.9 to predicted intakes of poorly preserved silages, depending on the attributes of individual silages and their proportion in the total diet. A "Cluster Index" of factors that determine silage quality can be prepared, but this should be based on easily recognisable factors for use on farm. Silage that is spoilt by mould or has turned black due to aerobic deterioration is toxic and should never be fed to animals.

Feeding systems

Ad-libitum versus restricted

Feeding of any fodder or feed to appetite implies that there is more food on offer than an animal can eat – normally 5 – 20% surplus depending on the variability of the fodder. While concentrate feeds, which are relatively expensive, tend to be fed in measured amounts, fodders, or at least the main fodder, are fed so that the animal can eat as much as it can and be satisfied. Normally some parts of fodder are highly fibrous and unpalatable, and forcing the animal to eat these parts so that it leaves a clean trough will reduce the total amount of feed it eats. Apply a correction factor of 0.95 – 0.80 to predicted intakes depending on the variability of the fodder if animals are required to eat all feed presented. It has been observed in central Tibet that farmers tend to restrict the amount of straw offered to cattle in the feed trough during the day – yet surplus straw is applied as bedding to animal houses.

Feed intake can also be depressed by competition between cows if there is inadequate trough space. While less space is needed when complete diets are fed 24 hours per day, there are periods of the day when most cows want to eat at the same time.

Width of feed face (trough space) (m) for cows by liveweight and feeding system

Liveweight (kg)	Cows feeding simultaneously[1]	Complete diets 24 h access[2]
200	0.40	0.27
400	0.55	0.39
600	0.67	0.45

1. Defra / ADAS (2006). 2. Chamberlain and Wilkinson (1996)

Complete diets vs. separate feeds

Traditionally concentrate feeds are fed to cows at milking 2 times a day, and fodders are fed after milking for the rest of the day. Since concentrates contain high amounts of energy which are rapidly fermented to Volatile Fatty Acids (VFAs), this leads to wide fluctuations in rumen pH. Microorganisms which digest cell walls need a pH >6.0; below this pH they stop digesting cellulose. With low – medium levels of concentrate feeds the rumen is too acidic for cellulosic digestion for 1 - 4 hours after each milking. This can be overcome by splitting the concentrate feeds, so that half are given at milking, and half are given between milkings at midday and at midnight. Distribution of fresh food in itself also stimulates renewed eating.

Alternatively, fodders can be chopped, and all feeds can be mixed and fed as a “Complete Diet” or “Total Mixed Ration (TMR)”. This has added benefits in that wet and dry feeds can be mixed together, with reduced dustiness of hays, straws and grains; and increased palatability. This can be done equally by hand or with hand operated equipment, as well as by large scale machinery, depending on the number of cows to be fed and overall levels of farm mechanisation. When complete diets are fed, each mouthful that the cow eats contains a mix of fibrous and concentrate feeds, so that the rumen is maintained at a pH above 6.0 and fibre digestion is continuous. In addition supply of fermentable metabolisable energy (FME) and degradable protein (ERDP) to the rumen microbial population occurs at the same time, compared to separate feeding of concentrates and fodders.

If high levels of concentrates are fed as two meals, the rumen remains too acidic for cellulose digestion for several hours after each feed, and can result in rumen acidosis, rumen stasis when the rumen stops contractions, and bloat. Again it is essential that high levels of concentrates are fed as many small feeds – up to six or eight per day. If high levels of concentrates are included in mixed diets, it is essential that some fodders are fed in long form to stimulate rumination and saliva production, and so maintain rumen pH above 6.0.

Feeding concentrates as multiple feeds can improve total feed intakes by 10 – 15%, so apply correction factors of 1.10 – 1.15 to predicted intakes. Feeding complete diets leads to improved digestion of the total ration, and improved intakes of 20 – 30 percent, so apply correction factors of 1.20 – 1.30 to predicted intakes depending on the quality of the original diets. These are significant improvements when extended to the impact on intake of net energy for lactation, and explains why lactation yields above 5000 - 7000 litres are now expected for Simmental and Holstein cows.

Fodders only versus fodders plus concentrates

In rations based only on fodder, feed intake is solely related to the quality of the fodder as noted above. However, for high yielding cows conserved fodders are usually supplemented with concentrates as a means of improving ration quality. Here, dry matter intake is more closely related to the quantity of concentrates fed that to the quality of the fodder, since this both determines ration Metabolisability (q), and the proportion of the diet that is composed of

<table>
<tr>
<td>Feeding systems
(continued)</td>
<td>
“fine” or milled feeds compared to “coarse” fodders. Vladiveloo and Holmes (1979) prepared an equation to predict dry matter intake based on traditional Holstein type cows that includes major animal factors and covers diets based on hays, straw and well made silage where concentrates are fed separately, as well as diets where forages and concentrates are given together as complete diets:
$$DMI = 0.076 + 0.404C + 0.013W - 0.129n + 4.12\log10(n) + 0.14Y$$
where DMI = dry matter intake, kg/day
W = liveweight, kg
Y = milk yield, kg/day (litres/day can be used)
C = concentrate DM (kg/day)
n = the week of lactation
Forage intake can be calculated by deducting the concentrate dry matter from the total DMI predicted by the equation. This equation does not include factors for the quality of the fodder, and so is easy to apply without laboratory analysis.
Sole fodder versus mixed fodder
At the same ration quality, intake of feed is stimulated by providing a variety of different fodders, rather than just a single fodder:
• legume hays in addition to grass hays or cereal straws
• green fodders or silages in addition to dry hays or straws
• maize silage with cobs made at the dough stage, in addition to grass or whole-crop cereal silage.
Apply a correction factor of 1.05 to take account of feeding mixtures of fodders.
Ration palatability
Cows show a preference for sweet feeds. Addition of straight sugar (sucrose) at 1.5% of a complete diet increased feed intake by 13% over the control diet. Swedes and radish have high sugar contents, and should be chopped and mixed with the rest of the ration. The added sugar and moisture from roots can increase intake of diets of the same quality by 10% - apply a correction factor of 1.05 – 1.10 to predicted dry matter intakes.
</td>
</tr>
</table>

For manual application predict dry matter intake from the tables in Annex Table 10.1, taking account of cow liveweight, milk yield, and ration quality q (M/D, DOMD and TDN are also provided). These tables have been generated using RUMNUT ration formulation software with fodders of appropriate quality; they have been expanded compared to other published tables of DMI to take account of the size of Local, crossbred and pure Holstein and Simmental cows, and cover the range 175 – 700 kg liveweight and milk yields up to 40 litres in exotic cows. Apply correction factors to these predicted intakes for animal and feed modifying factors as noted in Tables 10.1 and 10.2 above. These tables give predicted dry matter intakes, but these do not necessarily support requirements for maintenance and the milk yields indicated. Shaded portions of the tables show where intake of Metabolisable energy will be less than requirements – leading to liveweight loss and reduction in milk yield. Note that rations with $q < 0.45$ (M/D 8.3 MJ ME / kg DM, TDN < 55%) will not provide sufficient energy for maintenance, especially in small cows. If large quantities of concentrate feeds are fed, check both total and fodder intake potential using the equation of Vladiveloo and Holmes (1979) in Table 10.2.

10.2.2. Digestion

The digestibility of a feed is the proportion that is not excreted in the faeces and so is assumed to be absorbed by the animal. It is expressed in terms of dry matter and as a proportion (or coefficient) or percentage. For example, if 12 kg of hay at 83% dry matter is fed to a cow, it will consume 10 kg of dry matter (Figure 10.3). If all the faeces are collected and dried and weigh 4 kg, the cow will have digested 6 kg of dry matter. The digestibility of the hay dry matter is:

$$(10 - 4) / 10 = 6 / 10 = 0.60 \quad \text{as a proportion or coefficient, or}$$

$$((10 - 4) / 10) \times 100 = (6 / 10) \times 100 = 60.0 \quad \text{as a percentage}$$

This is the “apparent digestibility”, as substances excreted by the animal into the gut are ignored.

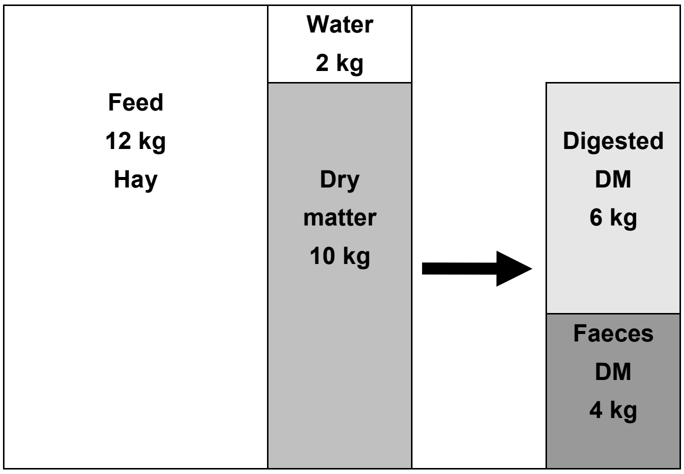


Figure 10.3. Illustration of dry matter digestibility for hay

Digestibility coefficients can be calculated in the same way for each nutrient in a feed, by analysing each nutrient in both the feed and the faeces, and expressing the amount digested as a proportion of that consumed:

Digestibility = (Nutrient consumed – Nutrient in faeces) / Nutrient consumed

= Nutrient digested / Nutrient consumed

While the simplest measure of digestibility is for dry matter, this contains a variable amount of ash which does not contribute to the energy nutrition of the animal. Simple organic matter digestibility can be used, by subtracting ash contents from both feed and faeces:

Organic matter digestibility (OMD) = (OM in Feed - OM in faeces) / OM in Feed

However, for feed rationing on farm it is easier to express this digestibility in terms of dry matter, using the Digestible Organic Matter in the Dry matter (DOMD), also know as the "D" value[4]:

DOMD (g/kg DM) = (OM in Feed - OM in faeces) / DM in feed

In Tibet the quality of fodder and feeds is traditionally expressed as Total Digestible Nutrients (TDN) expressed as percent of dry matter. This takes account of the additional energy in oil bearing feeds such as oil seed cakes, and is obtained by summing the digestible nutrients digestible crude protein (DCP), digestible crude fibre (DCF), digestible nitrogen free extract (DNFE) based on the Weende Proximate Analysis and giving extra weight to digestible ether extract (DEE) (fat):

TDN (% of DM) = DCP + DCF + DNFE + 2.25EE

Since most fodders have low oil contents, values of DOMD and TDN are similar, since both remove the effect of ash from estimates of dry matter digestibility.

Digestibility feeding trials[5]

Either cattle or sheep can be used to estimate digestibility in ruminants, know as "*in vivo*", that is in the live animal. *In vivo* digestibility is the gold standard against which all other determinations are judged. Cattle tend to give slightly lower digestibility values compared to sheep; it is likely that yak will give slightly higher values for low quality fodders due to their adjustment to low quality diets. While it is best to use the species to which the fodders are to be fed, sheep tend to be used due to ease of management and lower quantities of feed required. Male or castrate animals tend to be used, since it is easier to separate faeces and urine. To collect the faeces, animals can be kept in a fixed position within a digestibility crate so that faeces are collected on a screen, free of urine. Alternatively, animals can be kept loose in a pen or tied in a stall, and faeces are caught in a collection bag made of

[4] 'D' value is DOMD expressed as a percentage of DM
[5] See Schneider and Flatt (1975)

canvas strapped on to the animal's rear. At its simplest, it is possible to use cows tied in a stall or cowshed, and to scoop up each dung pat as it is deposited day and night. Due to variability between animals, it is essential that at least three animals are used for each determination.

In digestibility trials animals are fed to provide energy for maintenance, which implies some prior knowledge of the likely digestibility of the fodder or feed. As feed levels increase above maintenance, outflow rates from the rumen increase with reduction in digestibility. This means that use of digestibility data in feed rationing needs to take account of level of feeding – this is done in the Metabolisable Energy system.

Fodders are chopped so that no selection can occur, and animals should eat all of the feed presented. Each trial consists of a preliminary period of 14 – 20 days for the animal to adjust to the new feed, and a collection period of 7 – 10 days when all faeces are collected.

In the example in Figure 10.3, a good hay is fed as the sole diet. However concentrate feeds can not be fed alone without upsetting the digestion of the animal, while poor quality feeds can not provide maintenance. Digestibilities of both types of feed can be determined by feeding them in combination with a fodder of known digestibility. Estimation of the test feeds is demonstrated in Table 10.3:

Table 10.3. Examples of estimation of digestibilities of high and low quality feeds

Feed	Quantity fed (kg)	Feed DM (kg)	Faeces DM (kg)	Digested DM (kg)	Digestibility of test feeds
Basal feed - Hay	12.0	10.00	4.00		
Wheat grain	1.0	0.90	4.20 – 4.00 = 0.20	0.90 – 0.20 = 0.70	0.70 / 0.90 = **0.78**
Totals			4.20		
Basal feed - Hay	12.0	10.00	4.00		
Barley straw	1.0	0.90	4.54 – 4.00 = 0.54	0.90 – 0.54 = 0.36	0.36 / 0.90 = **0.40**
Totals			4.54		

The general equation for any nutrient to be determined in a test feed (concentrate or coarse fodder) is:

$$\text{Digestibility of test feed} = \frac{\text{Nutrient in test feed} - (\text{Total nutrient in faeces} - \text{Nutrient in faeces from basal feed})}{\text{Nutrient in test feed}}$$

Laboratory estimation of digestibility

Digestibility trials require a number of stall fed sheep or cattle with supporting staff and facilities, and comparatively large quantities of a fodder at a constant quality. There are a number of laboratory methods from which digestibility can be estimated for small samples of just a few grams – 25-100g is usually sufficient. Thus it is possible to assess samples of fodder from both observation trials when many varieties are being evaluated, and for advisory purposes fodders harvested by individual farmers. These methods vary from reproducing digestion in the ruminant animal, to purely chemical analysis. For fodders, samples of known high and low *in vivo* or *in vitro* digestibility are included as standards, and laboratory determinations are corrected to these - since variation between runs can be high especially when using rumen fluid for incubation. These methods are given in Table 10.4.

While the Weende system of Proximate Analysis tends to be no longer used, since crude fibre and nitrogen free extracts are not well related to biological components such as cell wall, world wide there is a large amount of such data available. Crude protein as N x 6.25 is retained as the benchmark for protein content, and Total Ash (TA) is used both to derive Organic Matter (OM) content, and to identify soil contamination in silages and root crops. Proximate Analysis have been carried out on feeds and faeces of many digestibility trials with cattle and sheep, so TDN can now be estimated approximately from feeds alone (Gohl, 1981):

Fresh grasses[6]: $\text{TDN (\% of DM)} = 54.6 + 3.66 \,\text{Log}_e\, \text{CP\%} - 0.26\, \text{CF\%} + 6.85\, \text{Log}_e\, \text{EE\%}$

Hays: $\text{TDN (\% of DM)} = 51.78 + 6.44\, \text{Log}_e\, \text{CP}$

Table 10.4. Laboratory methods for the estimation of dry matter digestibility of fodders

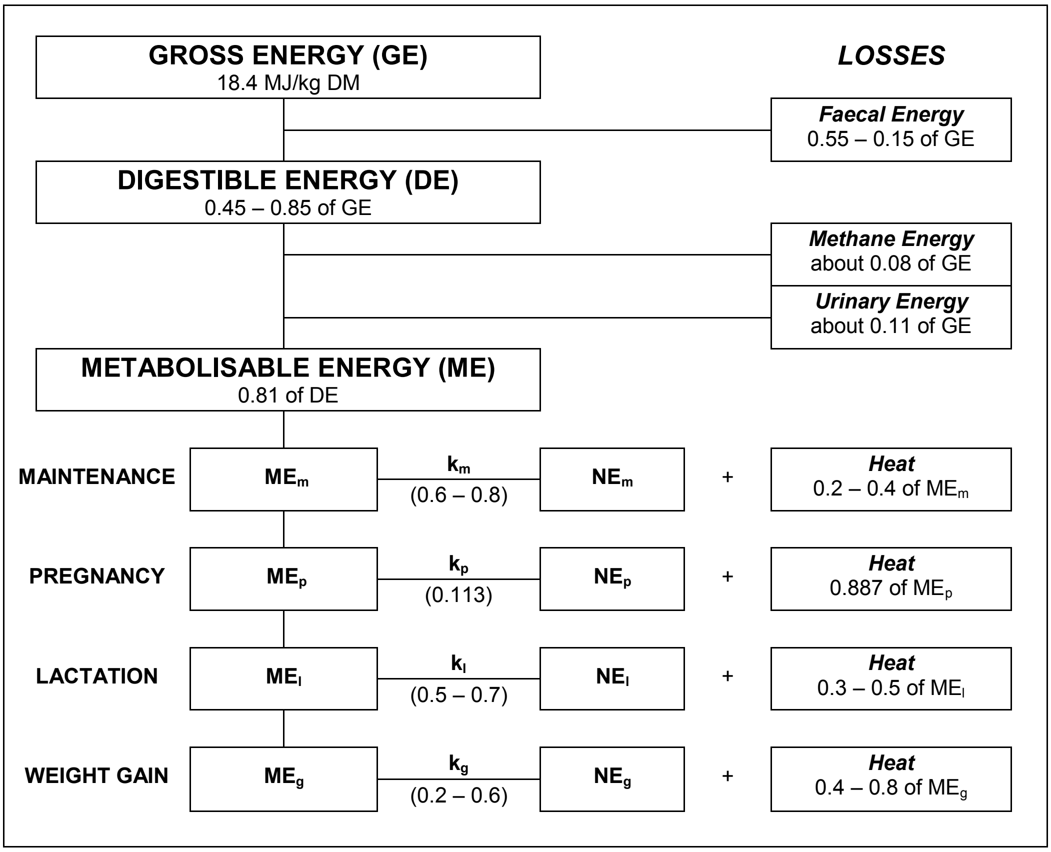
<table>
<tr><th>Method</th><th>Comments</th></tr>
<tr><td>a. Two-stage incubation in rumen liquor followed by digestion with pepsin (in vitro digestibility)</td><td>Closest in method to in vivo digestibility, with two 48 hour stages, using 1g samples. The acid pepsin dissolves the microbial protein formed in the first stage. Uniform results for a wide range of fodders, with values only slightly less than in vivo Dry Matter Digestibility (DMD). If the residue is ashed, Organic Matter Digestibility (OMD) can be estimated, leading to DOMD. This method requires cannulated cattle or sheep to provide rumen liquor.</td></tr>
<tr><td>b. Nylon Bag (in sacco or in situ digestibility)[1]</td><td>3 – 5g samples are placed in small porous nylon bags which are inserted into the rumen through a cannula, and incubated there for 24 – 48 hours. After each bag is withdrawn and washed the residue is the undigested portion of the feed. Use of standards and a constant incubation time of 24 hours provides a straight forward if laborious way to estimate DMD and nutrient digestibilities. By withdrawing samples of the same feed from the rumen at intervals over 48 hours, the rate of degradation can be estimated as well as total digestibility. Protein degradability parameters are required for the Metabolisable Protein system discussed below.</td></tr>
<tr><td>c. Gas production</td><td>The proportion of food digested is estimated indirectly from the volume of gas produced by fermentation with rumen liquor. Using a standard 24 hour fermentation and standards, digestibility can be estimated for a large number of samples with simple equipment. The method can be simplified by using flexible plastic or rigid glass bottles, and withdrawal of the gas produced with disposable syringes; rumen fluid can be replaced by buffered diluted cattle or horse faeces (from healthy animals), removing the need for cannulated sheep or cattle. Gas production has also been extensively used to assess dry matter degradation curves and parameters.</td></tr>
<tr><td>d. Digestion with pepsin then with cellulase</td><td>Fermentation with rumen liquor in the two stage in vitro digestibility technique is replace by fungal cellulase. Results are more variable, and due to different fibre structures separate prediction equations are required for grasses and legumes.</td></tr>
<tr><td>e. Goering and Van Soest detergent fibre system[2]</td><td>It is possible to break down fodder dry matter into biologically meaningful components through boiling with a series of detergent solutions of different strengths:
<table>
<tr><th>Start</th><th>Chemical and process</th><th colspan="3">Resulting determination</th></tr>
<tr><td rowspan="2">DM</td><td>Neutral detergent solution</td><td rowspan="2">Neutral Detergent Fibre (NDF)</td><td rowspan="2">=</td><td rowspan="2">Cell Wall</td></tr>
<tr><td>(dissolves soluble cell contents)</td></tr>
<tr><td rowspan="2">NDF</td><td>Acid detergent solution</td><td rowspan="2">Acid Detergent Fibre (ADF)</td><td rowspan="2">=</td><td rowspan="2">Cellulose + Lignin</td></tr>
<tr><td>(dissolves hemicellulose)</td></tr>
<tr><td rowspan="2">ADF</td><td>72% Sulphuric Acid</td><td rowspan="2">Acid Lignin</td><td rowspan="2">+</td><td rowspan="2">Cellulose</td></tr>
<tr><td>(dissolves cellulose)</td></tr>
<tr><td rowspan="2">or ADF</td><td>Potassium permanganate</td><td rowspan="2">Cellulose</td><td rowspan="2">+</td><td rowspan="2">Permanganate Lignin</td></tr>
<tr><td>(dissolves lignin)</td></tr>
</table>
For the full procedure, dry matter digestibility equals soluble cell contents plus the cell wall digested according to the extent of lignification of the cellulose.
Variations include a 2 h digestion with ADF solution to give Modified Acid Detergent Fibre (MADF), which is used to predict DOMD.</td></tr>
<tr><td>f. Neutral detergent cellulase digestibility (NCD)</td><td>Digestion with NDF solution followed by cellulase incubation for 48 h. This directly estimates DOMD, generally with better precision than MADF.</td></tr>
<tr><td>g. Neutral detergent cellulase + gammanase digestibility (NCDG)</td><td>Digestion with NDF solution followed by incubation with cellulase + gammanase for 48 h. This directly estimates DOMD and is the standard method for concentrate feeds.</td></tr>
</table>

1. Шrskov and Mehrez,1977. 2. Goering and Van Soest (1970)

[6] Where Log_e is the natural logarithm

10.2.3. Utilisation

Digested nutrients are utilised by the cow with varying efficiencies for maintenance, activity (walking, climbing, draught), lactation, weight gain and pregnancy. In evaluating fodders and using them to feed productive animals, the primary concern is with the utilisation of energy and protein. Pathways of energy digestion and utilisation in milking cows are summarised in Figure 10.4 based on the UK Metabolisable Energy system. A variable amount of the gross energy in feeds passes out in the faeces, and the proportion that is digested is the Digestible Energy (DE). This can be determined directly through *in vivo* digestibility trials by determining the gross energy in both feeds and faeces by bomb calorimetry. It varies from 40-45% of gross energy in straws to over 85% in concentrate feeds such as cereal grains. The digestible energy less losses of energy as methane produced in the rumen through anaerobic fermentation, and energy contained in waste products in the urine which is unavailable for use by the animal, is the Metabolisable Energy (ME) and is about 81% of the DE.



1. Adapted from Chamberlain and Wilkinson (1996)

Figure 10.4. Pathways of energy digestion and utilisation in milking cows

ME is the energy available to the animal for various functions, but energy is lost as heat as the products of digestion are transformed into forms that the body tissues can use. The amount of energy actually available for bodily functions is the Net Energy (NE). The efficiency of conversion of ME to NE is different for each function, and is denoted by k, with a letter added to show the function, such a k_m for maintenance. On good forage diets ME is used for maintenance with k_m of about 0.72; energy for lactation with k_l of about 0.62, for growth with k_g of about 0.47, and for pregnancy with k_p of about 0.11. The efficiencies are low with poor quality diets and increase with improving quality of the diet, with the greatest range in efficiencies for growth. For example straw needs more chewing and rumination, and results in production of more acetic acid in the rumen which is used with low efficiency – especially for growth. In contrast high quality fodders and concentrates are easily digested, and lead to more propionic acid in the rumen which is used efficiently in the tissues and for growth. Note that liveweight gain in lactating cows relating to improved body condition has the same efficiency as lactation, even on lower quality diets; this efficiency is lost once the cow becomes dry.

Requirements of protein for milk production are high relative to maintenance, so that protein is the third limiting factor in feeding milking cows after feed intake and energy. True protein contains 16% N, so the protein content of feeds is estimated from laboratory analysis of N as Crude Protein (CP).

$$CP\ (\%\ of\ DM) = N \times 6.25$$

However not all CP is digestible, so Digestible Crude Protein has been used, which is related to diet quality. This can be estimated in digestibility trials from amounts of CP in feed and faeces. If this is not possible, it can be estimated directly from CP using equations. A general equation[7] for cattle is:

$$DCP\ (\%\ of\ DM) = -3.143 + 0.8950\ CP\%$$

However use of DCP does not adequately describe efficiency of utilisation of non-protein nitrogen sources such as urea. In addition to NPN, some true protein is degraded in the rumen to ammonia and amino acids which are used by microbes for protein synthesis. On the other hand, some protein feeds are less fermented in the rumen but are digested in the abomasum, and these have become known as "Bypass Protein". This led to the development of protein systems for ruminants that split crude protein into Rumen Degradable Protein (RDP) and Undegradable Dietary Protein (UDP).

These systems have been further refined in the UK Metabolisable Protein system[8] for protein digestion and metabolism in ruminants (Figure 10.5), which is integrated with the supply of Fermentable Metabolisable Energy (FME) in the rumen. Metabolisable Protein (MP) is defined as the total digestible true protein (amino acids) available to the animal for metabolism after digestion and absorption of the feed in the animal's digestive tract. It has two components, Digestible Microbial True Protein (DMTP) and Digestible Undegraded feed Protein (DUP). About 0.25 of Microbial Crude Protein is made up of nucleic acids which can not be used by the ruminant, so the Microbial True Protein (MTP) is 0.75 of MCP. MTP is 0.85 digestible in the intestines, so that:

$$DMTP\ (g/day) = 0.75 \times 0.85 \times MCP = 0.64\ MCP\ (g/day)$$

DUP is the protein that is not degraded in the rumen (UDP), but is sufficiently digestible to be absorbed in the lower intestines of the animal. The proportion of DUP in UDP varies from 0.0-0.9, and depends on the feed, its composition and pretreatment. Digestibility of UDP is predicted from the Acid Detergent Insoluble Nitrogen (ADIN) content of the feed. Metabolisable Protein is therefore:

$$MP\ (g/day) = 0.64MCP + DUP$$

The absorbed amino acids are converted to tissue protein for various uses. The conversion efficiency is high for maintenance where a wide range of amino acids are required, but progressively lower for pregnancy, lactation, weight gain and fibre production as more specific amino acids are required as Net Protein (NP) for the particular function.

Key parameters of the MP systems - Quickly Degradable Protein (QDP), Slowly Degradable Protein (SDP), and DUP - are derived from rates of degradation of feed proteins suspended in porous nylon bags in the rumen for various lengths of time (Шrskov and Mehrez, 1977). The proportion of protein degraded is plotted against time, and an exponential function is fitted:

$$Degradation\ (dg) = a + b\{1 - e^{(-ct)}\}$$

where *t = time in hours in the rumen*

a = water soluble N extracted by cold water rinsing of samples without rumen fermentation

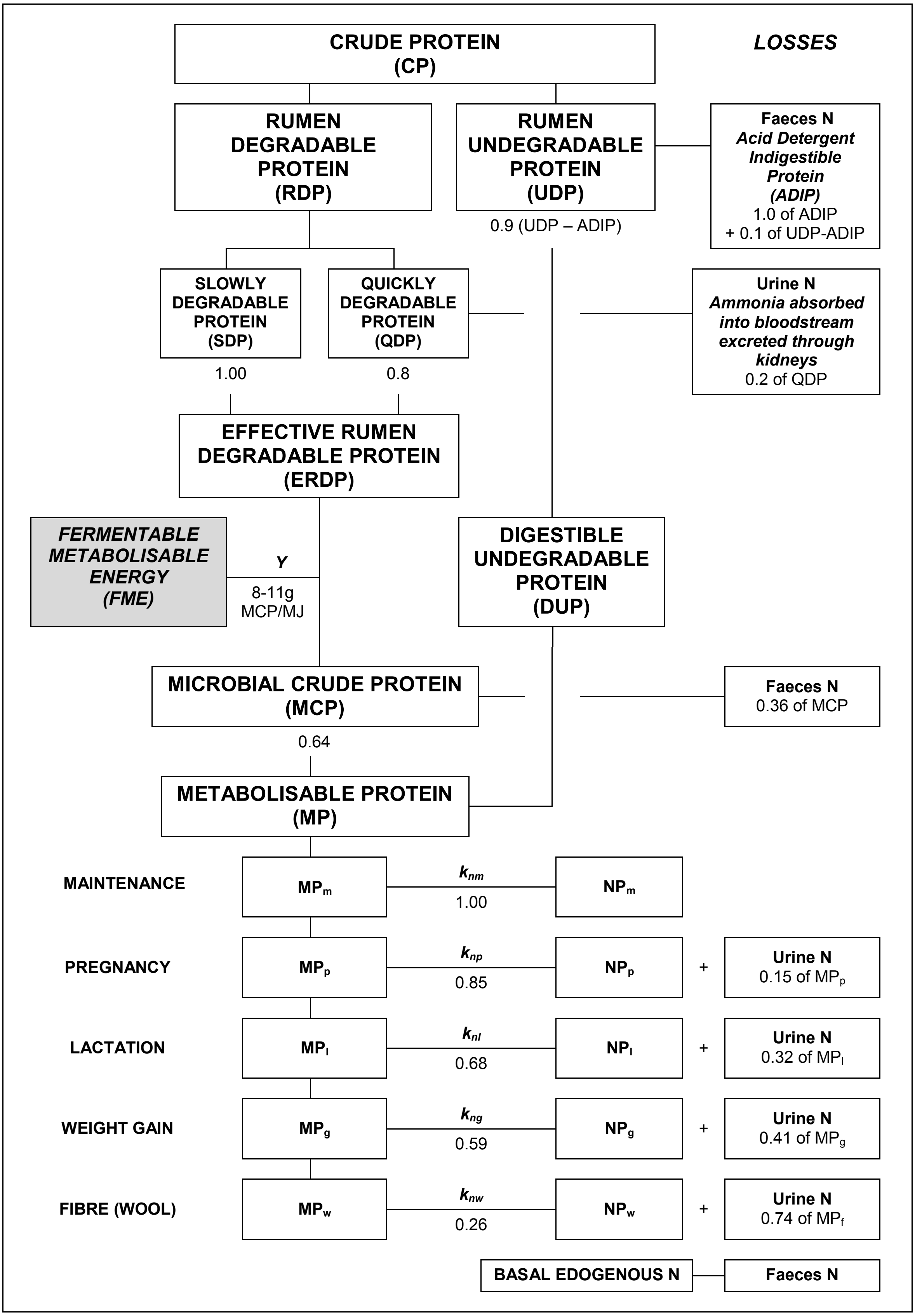
b = potentially degradable N, other than water soluble N (the asymptote of the degradation curve)

c = fractional rate of degradation of feed N per hour

The fractional rate relates to how rapidly feed protein is degraded, and is high for silages and cereals, and low for hays and heat treated protein concentrates.

[7] Derived from equations of Wardeh (1981) given in Fonnesbeck *et al.* (1984).

[8] See AFRC (1993) and Chamberlain and Wilkinson (1996) for a full description of the MP system.



1. Adapted from AFRC (1993) and Chamberlain and Wilkinson (1996)

Figure 10.5. Pathways of protein digestion and utilisation in milking cows

QDP is released quickly, so only 80% is available to microbes. While QDP is not affected by intake of the animal, with increasing animal production level (APL)[9] dry matter intake increases, rumen outflow rate increases, and retention time for SDP is reduced. This reduces ERDP, but increases the dietary protein that passes undegraded to the abomasum (UDP). Total protein available to microbes is known as Effective Rumen Degradable Protein (ERDP):

$$ERDP = 0.8\ QDP + SDP$$

The amount of Microbial Crude Protein (MCP) produced in the rumen depends on both the supply of degradable protein and the supply of Fermentable Metabolisable Energy (FME) estimated from the ME system. If either ERDP or FME is limiting, microbial protein synthesis will be reduced to the level of the limiting supply. If ERDP is limiting:

$$MCP_{(protein\ limited)} = ERDP$$

If energy is limiting, the amount of MCP produced depends on the supply of FME and the yield of MCP per MJ of FME. The energy in fat, and in the lactic acid and volatile fatty acids in silages, can not be used for microbial synthesis. FME is therefore estimated as:

$$FME = Total\ ME - ME_{fat\ (ether\ extract)} - ME_{fermentation}$$

Microbial Yield (Y) depends on the Animal Production Level (APL) and varies from 8.8 ($APL \leq 1.0$) to 11.8 ($APL \geq 4.5$) g MCP/MJ FME. If energy is limiting:

$$MCP_{(energy\ limited)} = FME \times Y$$

The smaller estimate of MCP production is taken. This is a key principle of the MP system, and emphasizes the importance of balancing degradable protein (ERDP) with fermentable energy (FME) in the rumen. Ammonia remaining from surplus protein will be absorbed into the blood stream and excreted through the kidneys in the urine. Surplus FME can lead to acidosis and depressed butterfat. It is important to balance both the total amount of FME and ERDP fed in a day, and as noted for feed intake, the distribution of FME and ERDP within the day. As near as possible these should be synchronous, so that FME is available when ERDP is released, or protein will be wasted.

The UK and MP systems can be calculated manually, and full equations and examples are given in AFRC (1993) and Chamberlain and Wilkinson (1996). However, given that MP supply depends on the animal factors, it is easier to use computer software such as RUMNUT to estimate supplies for given milk yields. Different feeds are easily combined to meet animal requirements while matching FME and ERDP supplies for optimum microbial protein synthesis. Detailed composition of a range of feeds relevant to Tibet that include degradation rates for use in the UK ME/MP system are given in Annex Table 10.2. Some of these feeds have been used in the preparation of the feeding models.

Ironically, despite its complexity, in practice it has been found that the UK ME/MP system consistently underestimates MP requirements in milking cows by about 10%. For Tibet it is proposed that the UK ME/MP still be used through adoption of RUMNUT software, but that rations are formulated to provide a minimum surplus of 10% MP above predicted requirements. Many workers in fact consider that the content of crude protein in the total diet dry matter is a realistic guide to MP supply and milk production response, and recommended contents of CP are given in Table 10.5.

Table 10.5. Recommended crude protein levels in diets for cows of 600 kg live weight

Milk yield (litres / day)	Crude protein in total diet (g/kg DM)	Milk yield (litres / day)	Crude protein in total diet (g/kg DM)
0	135 - 140	20	155 - 160
5	140 - 145	25	160 - 165
10	145 - 150	30	165 - 170
15	150 - 155	35	175 - 180

1. Adapted from Chamberlain and Wilkinson (1996).

[9] APL = Total ME requirement for maintenance and production / ME requirement for maintenance.

10.3. Feed composition and nutritive value of fodders and feeds available in central Tibet

Staff of the Tibet Livestock Research Institute (TLRI) have carried out extensive sampling of natural pastures in Tibet with analysis of their nutritive value, in relation to nutrition of the yak. However no data has been available to the current project on the nutritive value of fodders and feeds from crop lands in central Tibet available for feeding to milking cows, although this may be addressed by ongoing ACIAR project. Accordingly, besides the detailed nutritional data provided for fodders and feeds from UK used for RUMNUT models (Annex Table 10.2), comprehensive tables of feed composition and nutritive value relevant to central Tibet have been sourced for key nutrients from world wide data sources (Gohl, 1981; Fonnesbeck *et al*. (1984); MAFF, 1990; and Chamberlain and Wilkinson, 1996) and are presented as Annex Table 10.3. Nutrients in this table include Dry matter (DM), Metabolisable Energy (ME), Total Digestible Nutrients (TDN), Crude Protein (CP), Fat (from ether extract), Neutral Detergent Fibre (NDF) = Cell wall, Sugars, Starch, and mineral Calcium (Ca), Magnesium (Mg) and Phosphorous (P). ME in Annex Table 10.3 has been calculated using a variety of equations depending on source; where values for ME have been provided for cattle and for sheep (IFI, 1984), those for cattle have been taken. TDN has been estimated from the resulting ME values:

$$\text{TDN \%} = 6.6098 \text{ ME (MJ/kg DM)}$$

Feeds from the following classes are included in Annex Table 10.3: straw, straws - treated, hays, leaf meals, fresh forages, silages, energy feeds – dry, energy feeds – fresh roots, protein feeds, other byproducts, minerals, and buffers. Series that cover a range of maturities for the same fodder have been selected for hays, fresh fodders and silages. However, due to the nature of the tables in the original sources, successive values in these series are not necessarily from the same crops. Considerable variation exists for any one feed, for example wheat straw, and multiple entries are included for some feeds.

1) Straws

Cereal straws from spring barley and winter wheat comprise the main fodder resources for traditional livestock in central Tibet. Straw of both spring and winter varieties of naked barley grown in Tibet appears softer than straw of hulled barleys grown elsewhere. This relates to lower lignification of cell walls, and would lead to higher digestibilities and ME contents than given in Annex Tables 10.2 and 10.3, and lead to higher dry matter intakes. However, without analytical data, book values are used for RUMNUT models. Wheat straw is stronger than barley straw, tends to be more lignified, and of lower ME, digestibility and intake. CP is low in all cereal straws as N is transferred to the grains.

Simple ways to improve the feeding value of cereal straws include:

- feed to appetite (a surplus of 10%), so cows are not forced to eat everything that is fed to them
- make sure straw is always available to cows, feed frequently in small amounts, and remove coarse uneaten straw before each feed
- feed sufficient straw to allow cows to select just leaves, which are much more digestible than stem:

Proportion of leaves in straw	0.5	0.4	0.3	0.2
Weight of straw for cows to select 1 kg of leaves (kg)	2.0	2.5	3.3	5.0

- after threshing sheaves, cut the threshed sheaves in two: save the top part for feeding to appetite, and the lower part for fuel
- when harvesting barley and wheat in the field, leave a long stubble. This will be the least digestible part of the plant
- chop the straw to be fed to about 3 cm, and mix with succulent feeds such as fresh fodders, chopped roots and silage
- finely mill the straw to be fed, and mix with concentrate feeds
- supplement with minerals, nitrogen, and green fodder (see below).

Longer term ways to improve the feeding value of straws include:

- treatment of straws with urea / ammonia to improve both digestibility and N content (see next section)
- use of crop growth regulators to shorten the length of barley and wheat straws; this reduces the length of stem internodes, but leaves the same number of leaves. As a result, there is a higher proportion of leaf in the straw. In Tibet a major reason for low barley yields, especially in Dongqing #1, is that the stems are too weak to support heavy grain yields, so that N fertilizer input has to be low. Shortened straw is stronger so that higher N fertilizer can be used, resulting in higher grain yield, the same total quantity of straw, a higher proportion of leaf in the straw, and possibly higher N content of the straw. Use of regulators can be tested and extended now, while a breeding programme for early high yielding winter barley varieties will take another 6 – 12 years.
- selection of crops with straw of high nutritive value. Maize straw, especially from high sugar cold tolerant varieties, is higher in ME than other cereal straws; while straws from peas and beans have both higher ME and CP contents.

2) Straws - treated

a. Microbial treatment

Use of microbial fermentation to improve the nutritive value of cereal straws has already been introduced to farmers in central Tibet, but quantitative data on its benefits was not available and farmers do not appear to have adopted the practice. A major problem is that the microbes, whether fungi or bacteria, make use of released soluble carbohydrates for their own growth, losing carbon dioxide through respiration, so that actual benefits may not match the expense and labour required for treatment. In addition inoculants for the process require careful storage.

b. Urea / ammonia treatment

Benefits to ammonia treatment of straw are shown below using saturated ammonia solution, and this is translated into increased intakes which can double:

Cereal	Untreated		Ammonia treated	
	ME (MJ/kg DM)	CP (g/kg DM)	ME (MJ/kg DM)	CP (g/kg DM)
Winter Barley	6.3	38	7.5	68
Winter Wheat	6.1	38	7.4	69

1. Data from Chamberlain and Wilkinson (1996)

Treatment of straw with ammonia is not practical for smallholders. However urea in solution breaks down to ammonia, and is a practical way to treat straws on farm that has been widely introduced in China. Local methods should be followed.

Alternatively the following method has been used by the author of this chapter in Pakistan[10, 11]:

Item	Amount (kg)	Comments
Cereal straw	100	Treat straw following threshing in July – August. Wheat straw is preferable as it has less wax on the leaf and stem so penetration of ammonia is better.
Boiling Water	10	As hot as possible
Cold water	25	
Urea	5	Fertilizer grade can be used, as preservatives are broken down by use of manure to liberate ammonia
Fresh cow manure	10	Any disease organisms will be killed by the ammonia

10 Following guidelines from the Pakistan Agricultural Research Centre (PARC)

11 Note discussion on urea/ammonia treatment and feeding of treated straws in Preston and Leng (1987)

i. Place a long thick plastic sheet on a flat piece of ground. If the sheet comes as a tube, tie one end and fill it as a large tube. Alternatively use existing straw treatment pits or silage pits.

ii. Dissolve the urea in the boiling water with vigorous stirring, add to the remaining water, and stir in the fresh cow manure which will provide bacteria to break the urea down and release ammonia.

iii. Spread 20 kg of straw on one end of the plastic sheet, and sprinkle $1/5^{th}$ of the urea solution over the straw.

iv. Repeat adding straw and sprinkling urea solution until both are used up and there is a heap of straw at one end of the sheet.

v. Use the remainder of the sheet to fully wrap over the heap of treated straw, and weigh the edges of the sheet down to make the heap of straw gas tight and weather proof.

vi. After two months (August - September) the straw should be treated. Remove the plastic carefully to use again. Dry the treated straw, and store in a safe place.

Treated straw by itself can provide maintenance and a small amount of milk, but should be fed as part of a balanced ration at a maximum inclusion rate of 50% of the diet.

3) Hays

Hays can be divided into grass hays such as perennial meadow grasses including ryegrass; whole-crop cereals conserved as hay; and legume fodders. Factors that affect the quality of hays include:

- the stage of growth at which they were harvested, from early vegetative through to post ripe (Figure 10.6)
- the efficiency of conservation, especially the extent to which high quality leaves have been retained
- bleaching by sun on green hay, and blackening by mould on dry hay

Prairie grass hay represents hays from natural pastures and mountain rangelands in which many species of grass and forbs are present, so that new species emerge in vegetative and flowering stages over several months during the summer, maintaining energy levels even though protein may fall. Although hay from individual species of cultivated grass declines steadily in ME and CP with maturity, in the late vegetative to early bloom stage these values at around 10 MJ/kg DM and 100-120 g / kg DM respectively are roughly double those of cereal straws.

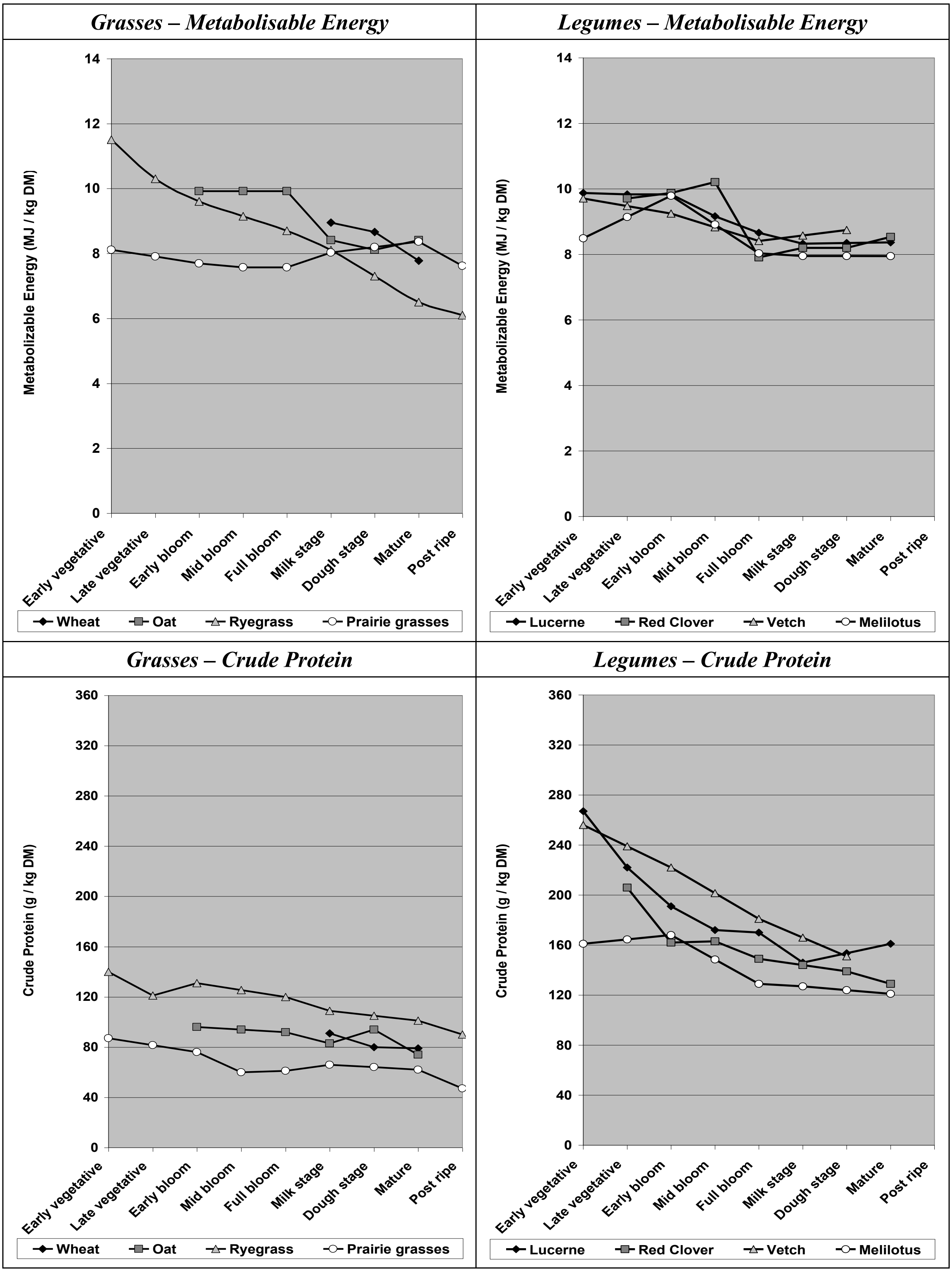
Hays from small grain cereals tend to have higher energy but lower protein contents than grasses, as the grains reach milky to dough stage and play a greater part in whole-crop digestibility. In vegetative stages, though not shown here, they would more closely represent other annual grasses. Both cereal and grass hays need to come from well fertilized crops in order to have high protein contents.

Legume hays have double the crude protein content compared to grass and cereal hays, even though there is a large range of CP values among species, and large falls in CP do occur with stage of growth. The high protein levels (>200 g/kg) good ME contents (9.5 – 10 MJ/ kg DM) in vegetative vetch and lucerne are most important for double crop fodders, provided such young fodders can be effectively dried in October.

4) Leaf meals

The more mature legumes are allowed to grow, the greater the difference in nutritive value, especially protein, between their leaves which remain of high value, and their stems which become lignified:

Legume	Stem meal		Leaf meal	
	ME (MJ/kg DM)	CP (g/kg DM)	ME (MJ/kg DM)	CP (g/kg DM)
Lucerne	7.8	121	10.6	281
Melilotus, Yellow	7.2	106	9.7	280



1. Data from Annex Table 10.3, sourced from Fonnesbeck *et al.* (1984) and Chamberlain and Wilkinson (1996). Data points for a fodder crop may include different samples leading to variation. Some intermediate data points have been interpolated.

Figure 10.6. Effect of stage of growth of fodder plants on their Metabolisable Energy and Crude Protein contents – Hays

This should be considered for vetch, given the large quantities that may be grown through double cropping. In addition lucerne and melilotus can be established as a second crop following winter barley, and grown on as perennial / biennial crops for a second year. The leaf meal is of high enough quality to be fed to pigs and poultry, while the stems are medium quality fodder for ruminants.

5) Fresh forages

The higher values for fresh fodders shown in Figure 10.7 compared to hays illustrate the problems in efficient conservation, especially that of preserving the high protein content of legume fodders during hay making.

In grasses there is a lag phase during the vegetative stage before energy and protein levels start to fall, which can be exploited by grazing animals and the green feeding of young vegetation. The contrast between the steady fall in plant quality from flowering onward in grasses, and the constant or increased energy content of cereals such as oats and rye as they enter the milky to dough stages is clear.

Fodder legumes do have very high protein levels during the vegetative stages. Care must be taken to avoid bloat in ruminants when feeding leafy legumes, and such fodder should be used as a green fodder supplement rather than as a main fodder. In addition legumes can cause infertility due to high levels of oestrogens, though this is more of a problem with clovers than the species being grown in Tibet.

Other fresh forages to note in Annex Table 10.3 include:

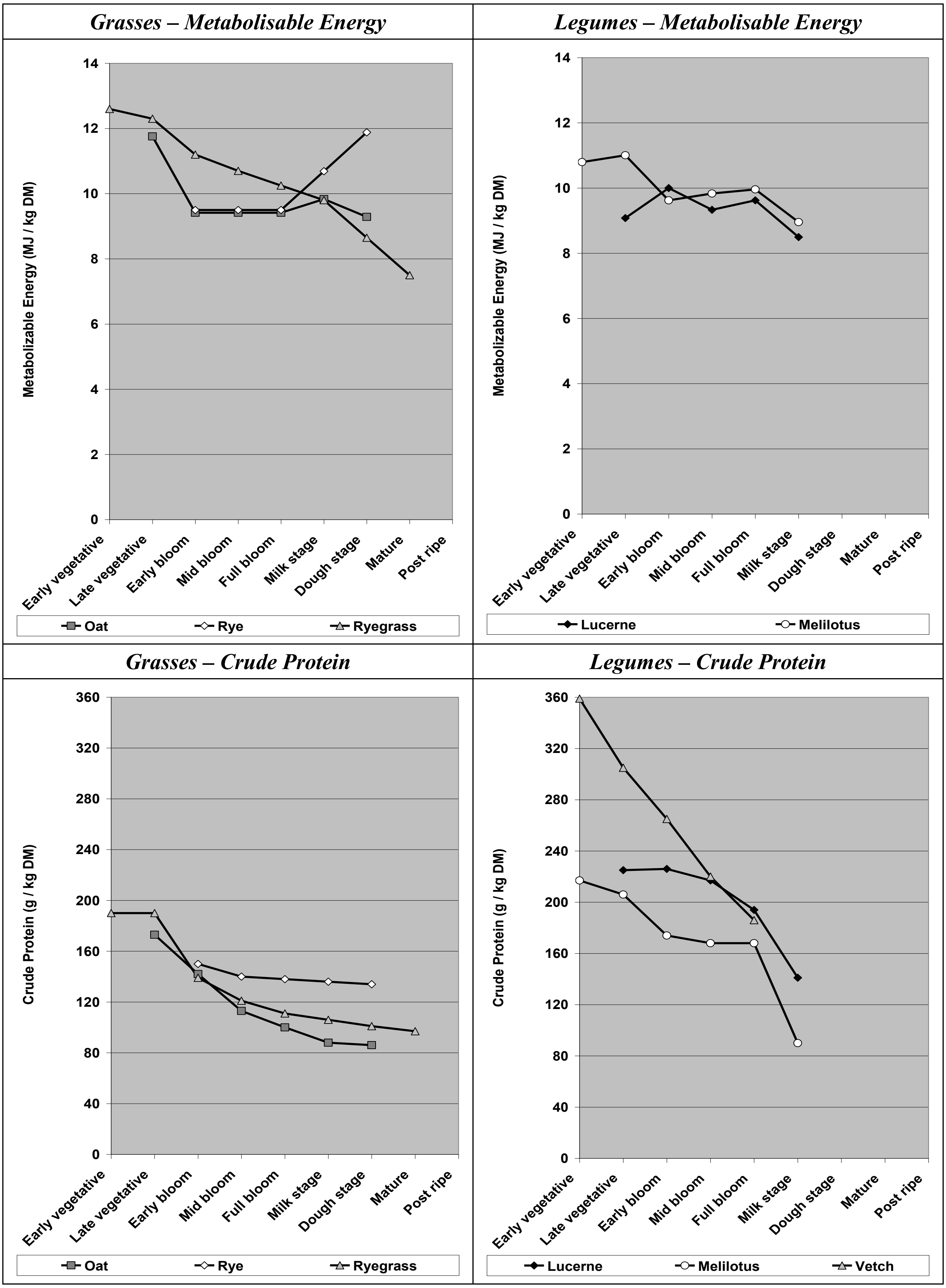
- rye which can be grown as a winter cereal and harvested in early summer in the vegetative to early bloom stage as a green fodder supplement
- fresh maize plants up to the milky stage, and residues from sweet corn and baby corn that are useful fodder for feeding green
- young sunflowers, which can be grown as an early planted second crop like maize
- the tops of root crops such as carrot, sugar beet, turnip which have good ME and CP values
- kale (Brassica) with high ME and CP, which is cold tolerant and can be harvested for fresh fodder to the end of October in central Tibet
- cabbage, with high ME and CP, which is also cold tolerant and can grow to the end of October. It can still provides excellent fodder from discarded outer leaves after the inner heart is used for human consumption. Cabbages are easily stored into the winter, and are fed to pigs in Tibet.

6) Silages

The general comment about silage is “Rubbish in, rubbish out!”. Just as for hays, the major factor determining the quality of silage is the stage of growth at which the fodder crop is harvested (Figure 10.8). Careful examination of Figures 10.6, 7 and 8 shows that the quality of the same fodders conserved as silage tends to be better than for hay when harvested at the same stage of growth. This does not tell the whole story, however, since heavy crops of young leafy materials can be conserved successfully as silage during periods of wet or humid weather when it would not be possible to make hay. As a result, most crops are harvested at an earlier stage of maturity for silage than they would be cut for hay, so that provided the necessary steps are taken to ensure good fermentation, better quality conserved fodder results. Requirements for good silage making have already been outlined in Table 10.2. Note:

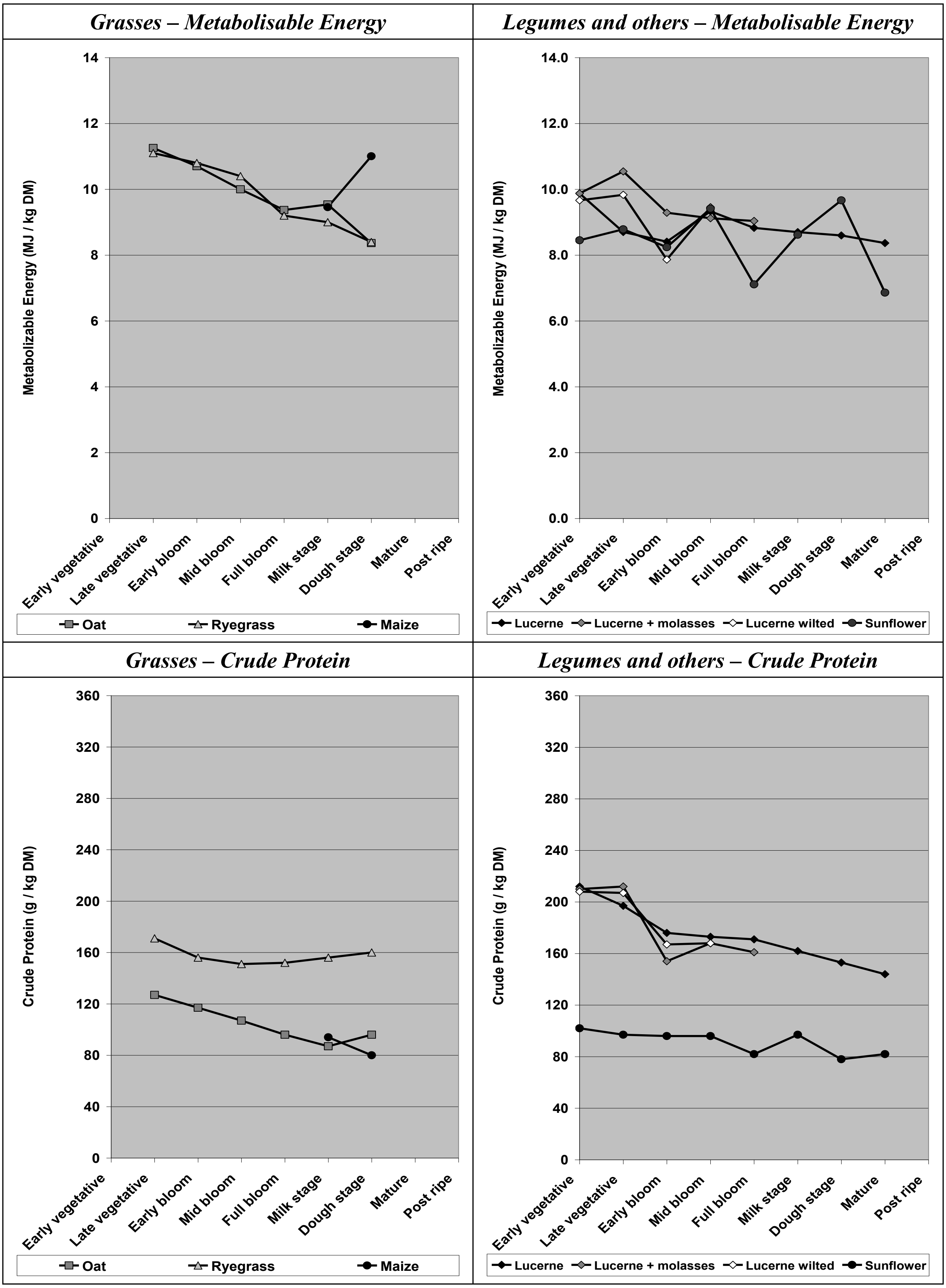
- the major increase in ME but decrease in CP for maize silage as cobs progress from the milk to the dough stage
- major fluctuations in energy content of sunflower silage with stage of growth, and its persistent low protein content (it is placed with legume silages for convenience).

The composition of the grass and legume silages used for the RUMNUT models and listed in Annex Table 10.2 are given in Table 10.6, to include pH, Lactic and Volatile Fatty Acids (VFAs), and ammonia as a percent of total N. The generally lower ME but higher CP of legume silages is seen.



1. Data from Annex Table 10.3, sourced from Fonnesbeck *et al.* (1984) and Chamberlain and Wilkinson (1996). Data points for a fodder crop may include different samples leading to variation. Some intermediate data points have been interpolated.

Figure 10.7. Effect of stage of growth of fodder plants on their Metabolisable Energy and Crude Protein contents – Fresh fodders



1. Data from Annex Table 10.3, sourced from Fonnesbeck *et al.* (1984) and Chamberlain and Wilkinson (1996). Data points for a fodder crop may include different samples leading to variation. Some intermediate data points have been interpolated.

Figure 10.8 . Effect of stage of growth of fodder plants on their Metabolisable Energy and Crude Protein contents – Silages

Table 10.6. Composition of grass and legume silages including pH, Lactic and Volatile Fatty Acids, and Ammonia

Feed, Species and Type	Source	DM %	ME MJ	TDN % DM	CP g	Sugars g	Starch g	pH	Volatile Fatty Acids (VFAs)(g/kg ODM) Lactic	Formic	Acetic	Propionic	Butyric	NH3N/TN g/kg
Barley *[Hordeum vulgare]*														
Silage, whole crop	MAFF	41	11.5	76	90	33	234	5.9	21	1	12	0	2	110
Bean, Faba (Broad) *[Vicia faba]*														
Silage, whole crop	MAFF	24	8.2	54	172	30	2	3.7	14	10	28	4	24	145
Clover, mixed *[Trifolium spp]*														
Silage	MAFF	24	10.3	68	233	20	2	4.2	80	25	30	4	6	97
Lucerne (Alfalfa) *[Medicago sativa]*														
Silage	CW	34	8.0	53	194	12	4	4.3	50	22	18	5	17	98
Maize *[Zea mays]*														
Silage	CW	30	11.5	76	88	5	206	3.8	69	5	33	3	4	92
Pea *[Pisum sativum]*														
Silage, whole crop	MAFF	28	11.1	73	179	72	6	4.2	49	8	33	14	18	126
Ryegrass *[Lolium spp]*														
Silage, Big Bale	MAFF	37	10.1	67	159	42	4	4.9	45	3	12	4	5	106
Silage, Clamp	MAFF	27	10.0	66	170	18	8	4.1	79	10	32	6	12	117

1. All analyses per kg DM, except DM which is percent fresh weight, and TDN which is percent DM.
2. Definition of terms:

DM	Dry Matter (percent of fresh weight)	ODM	Oven Dry Matter	ME	Metabolisable Energy (MJ / kg DM)	NH3N	Ammonia nitrogen
MJ	Megajoules (One million joules)	TDN	Total Digestible Nutrients (% of DM)	CP	Crude Protein (g/kg DM) = N x 6.25	TN	Total nitrogen

3. Sources:

CW	**Chamberlain, A.T. and Wilkinson, J.M**. 1996. *Feeding the dairy cow*. Lincoln, UK: Chalcombe Publications. ISBN0948 617 32 2	*Values are means of several samples*
MAFF	**MAFF**. 1990. *UK Tables of nutritive value and chemical composition of feedstuffs*. Ministry of Agriculture, Fisheries and Food. Aberdeen, UK: Rowett Research Services.	*Values are means of several samples*

With respect to fermentation characteristics, note:

- the higher the dry matter, the higher the pH (Figure 10.9). R^2 for the silages shown is 0.93[12]; however most of these silages have been wilted and treated with formic acid additive to reduce pH rapidly and so improve fermentation. The relationship over a wider range of silages extends to a pH of 3.5 at a DM of 15-18, provided sufficient sugars are available for fermentation.
- maize and barley crops have a higher DM when harvested; lucerne and big-bale ryegrass silage are cut and wilted (partially dried) before being picked up and chopped.
- the high levels of butyric acid and ammonia as a percent of total N in legume silages.
- the benefit of formic acid additive on restricting butyric acid formation (R^2 = 0.59) and ammonia as a percent of total N (R^2 = 0.81) in legume silages (Figure 10.10).
- a cluster analysis is required in order to provide an integrated assessment of silage quality.

The data in Table 10.6 show the importance of using an additive for effective preservation of silage made from legume fodders. On a small scale farmers should wilt legume fodders to 30 % dry matter, and add sugar or wheat flour at 0.4 kg / 10 kg chopped green fodder. A cluster index for silage quality that includes intake potential is given in Table 10.7. To use this, score the silage for each criteria and take the average. In the laboratory, levels of lactic, formic and VFAs for cluster analysis can be determined by titration (Offer *et al.*, 1993).

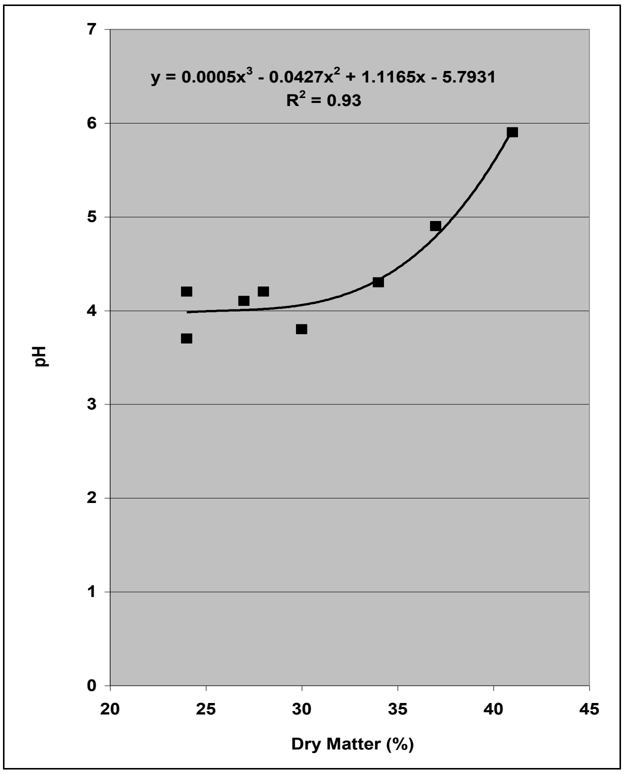
Table 10.7. General Cluster index for silage quality

Criteria	**Cluster Index**				**Comments**
	Bad	**Medium**	**Good**	**Very good**	
	1	**2**	**3**	**4**	
Stage of maturity	Mature	Seeding	Flowering	Vegetative	Interaction between yield and quality
Dry Matter	<20	20-25	25-30	>30	Depends on DM of green fodder; wilt until no water can be wrung out
Fermentation	Bad	Moderate	Good	V. good	Judged by factors below
Butyric acid	High	Medium	Low	V. low	Butyric has bad smell, bright green colour and slimy texture
Lactic acid	Low	High	High	Low	A clean acid smell, straw colour
pH	>4.5	3.5-4.0	4.0-4.5	>4.5	Good pH varies with DM; determine on farm by taste or with pH papers
Residual sugar and starch	Zero	Low	Medium	High	From laboratory analysis
Crude protein	Low	Medium	High	V. high	Provided fermentation is good – v. good

1. Adapted from Offer *et al.* (1993), in Chamberlain and Wilkinson (1996).

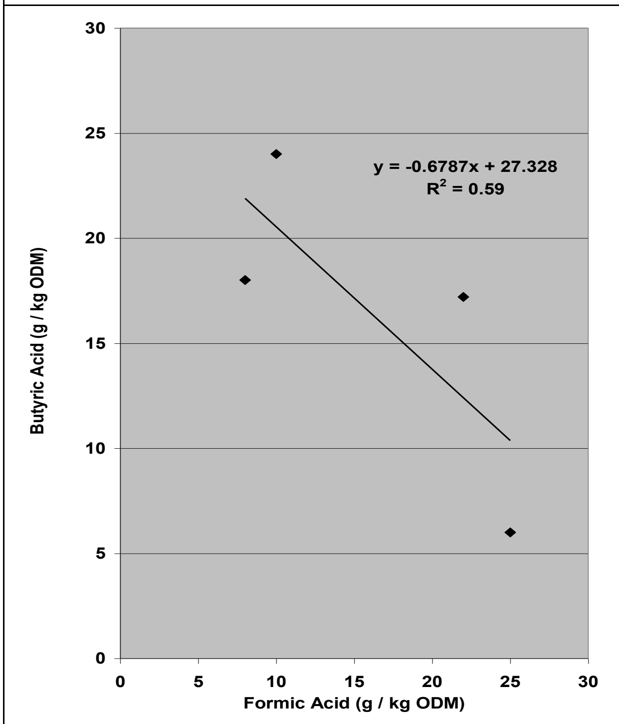
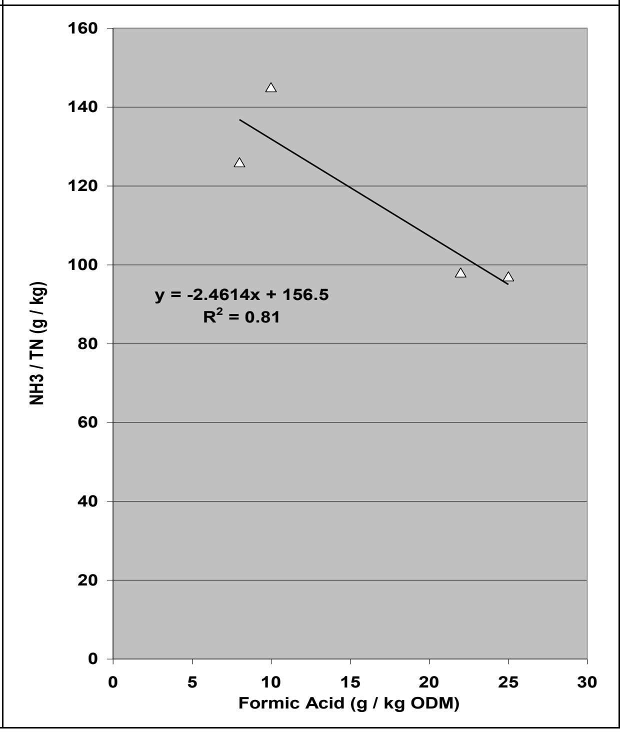
In addition, note from Annex Table 10.3. the possibilities for vetch / cereal mixtures which balance energy and protein levels in silage; and the possibility of preserving more mature whole-crop cereals at 50-60 % DM by ensiling with the addition of 3% of fresh weight as urea.

[12] R^2 measures the proportion of the total variation that is accounted for by a relationship, where 1.0 indicates a perfect relationship where all the variation is accounted for, and 0.0 indicates that there is no relationship.



1. Data from Table 10.6 .

Figure 10.9 . Relationship between silage dry matter and pH in silages with controlled fermentation

Butyric Acid	***Ammonia N / Total N***
	

1. Data from Table 10.6 .
2. ODM: Oven Dry Matter

Figure 10.10 Effect of formic acid application to legume silages on reduction in butyric acid concentration and ammonia N as a percent of total N

7) Energy feeds - dry

To obtain high milk yields from conserved fodders and most fresh fodders, rations need to include concentrates with a high proportion of energy feeds. Unfortunately the range of feeds in central Tibet is limited, although more will become available with improved transport links. Most supplementary feeds have restrictions on their use, which are listed in Annex Table 10.4. These restrictions can be entered into RUMNUT for ease of use on farm. All energy feeds should be fed with caution. They need to be introduced to animals over a period of three weeks, and should be fed to animals in several small feeds throughout the day, to prevent bloat and acidosis in the rumen. Energy feeds can be split into several sub-classes:

a. Grains

All grains need to be coarsely milled, cracked or rolled before feeding to cows, so that rumen microbes can get past the seed coat. Otherwise they will pass through the animal undigested. Wheat and related small grains should not be finely milled, as they can form dough in the rumen and stop rumen function.

Barley – types with hulls are a traditional feed for cattle in Europe, since the hull provides fibre that keeps the rumen contents open. However although the naked barley grown in Tibet would be an excellent feed for cows, it is the main staple for the local people and used solely for humans.

Buckwheat – lower energy content than cereal grains, but good protein content. Could be grown as an animal feed on marginal lands with restricted irrigation.

Maize – widely grown as a commercial grain crop in northern China, maize is or will be available as a feed grain in Tibet. It has a higher energy but lower protein content than wheat. Maize starch is less degraded in the rumen than other cereals, so is available for digestion in the small intestines and absorbed as glucose.

Oats – grains have a high proportion of hulls which reduce energy and increase fibre. Grains should be stored for several months before use to prevent bloat.

Rye and Triticale – these cereals should be grown on poor quality crop lands for grain production, since yields will equal or surpass wheat, while the grains are higher in protein.

Wheat – now that Tibet is self-sufficient in wheat, surplus and poor quality grain can be used for feeding high yielding milk cows. Levels need to be restricted to prevent poor rumen function.

b. Brans

Brans are variable feeds both between and within cereal crops. They are generally available from flour mills for use as animal feeds. They lie between being energy and protein concentrates, but have high levels of fibre part of which does act as structural fibre. They tend to be high in minerals, especially phosphate, but this is largely in the phytate form which can not be used by the animal and interferes with Ca and P uptake.

Maize bran – an excellent energy feed that has ME and CP similar to maize, but a high fibre content.

Wheat bran – highly palatable with energy as digestible fibre rather than starch (196 g/kg). Its CP content is above 170 g/kg DM, so that it is classed as a protein concentrate in Tibet. Its ME is less than that of wheat, while fibre content is less than that of maize bran. Its high phosphorous content may affect mineral nutrition if fed at high levels.

8) Energy feeds – roots

Roots are listed in Annex Table 10.3. in their “fresh” state, although this includes roots stored into the winter. Values for roots are given in the table for the bulb, after the leaves or tops have been removed. In Tibet roots may also be chopped and dried for storage. Great care must be taken to clean the roots before storage and feeding, or high levels of soil contamination will result.

Roots are an excellent source of energy, with high ME coming from very high levels of sugars in brassicas and beets, or starch in potatoes. In addition the fibre present is not lignified, so it contributes to ME. Protein contents are generally less than for cereal grains. Roots are low in dry matter, but if chopped and mixed with dry feeds provide moisture to the whole ration. Roots are degraded very rapidly in the rumen, so must be fed with great caution or animals will bloat. Roots of turnips and other brassicas have a strong flavour, and this can cause a taint in the milk. For this reason intake should be restricted to 0.6, 1.2 and 2.0 kg per day for 200, 400 and 600 kg cows. Higher levels can be fed to growing cattle and fattening sheep.

Sugar beet pulp is an excellent energy concentrate based on the digestible fibre of roots left after sugar is extracted from sugar beet. Sugar factories dry the pulp with or without added molasses, and sell it in either loose or pelleted forms. This has energy and protein contents only slightly less than cereal grains, but much of the energy comes from digestible fibre. As a slowly fermented but degradable energy source this has good fermentation characteristics in the rumen, maintains rumen pH, and does not suppress the fibre degradation of fodders to the same extent as cereals. However, at present it does not appear to be available in Tibet.

9) Protein feeds

The range of protein concentrates available in Tibet appears limited at present. It is desirable to feed a range of protein feeds to high yielding cows if possible, since the CP content is variable between different batches of feed and feeding mixtures tends to even this out. In addition each protein source tends to have its own constraint, so that the cheaper feeds should only be fed in limited amounts. Sub-classes include:

a. Oilseed cakes

The residues from extraction of oil from oilseeds, either mechanically or using solvents. Mechanical processing can be small scale, as in shops in Lhasa; or carried out by large mills as in the new rapeseed oil mill. Solvent extracted meals have higher protein content but lower energy as more oil is removed. The nutrient content of oilseed cakes and meals also depends on whether seed hulls are included during extraction (undecorticated), or removed before extraction (decorticated). Removal of hulls increases contents of both protein and energy, and reduces fibre content. A high fibre content can be useful if a high proportion of the diet is concentrates, when fibre becomes limiting. Due to the heat treatment degradation rates of the protein in oil seed cakes and meals are reduced compared to that in the original seeds and in pulse crops (grain legumes).

Cotton seed meal – an excellent protein supplement for cattle. Although it contains an anti-nutritive compound called gossypol, this has little effect on adult cattle. The meal should be available in China and possibly in Tibet at a cost competitive with other protein sources. It has variable protein and energy levels which depend on the presence of hulls and processing method.

Peanut (Groundnut) meal – mouldy groundnuts support the mould *Aspergillus flavus* which produces the toxin aflatoxin, which is harmful to cows and is passed to humans through milk. The fungus grows in temperatures 30-35^{o}C when the nuts are above 9% and the cake is above 15% moisture content (Gohl, 1981). This can be prevented by quick drying of the nuts and storage of nuts and meal under dry condition. Peanut meal has a good protein balance and can be fed without restriction – subject to low aflatoxin levels.

Rapeseed meal – oilseed meal from crops of local mustard seed contains residual mustard oil and must not be fed. Rapeseed is now being cultivated in Tibet, and government also sells seed to local oil millers for oil extraction, so good quality locally produced rapeseed meal is becoming available. This may still contain toxic factors derived from glycosides, but should be suitable for ruminants. 0.3-0.5, 0.6-1.0, and 1.0-1.5 kg per day can be fed to adult cattle of 200, 400 and 600 kg liveweight respectively without adverse effects on total dry matter intake or milk flavour.

Soya bean meal: this is the gold standard of oil seed meals with protein of ideal amino acid composition. It can be fed to pigs and poultry, but due to its cost will only be fed to milk cows for the highest yields.

Sunflower meal: the composition varies widely depending on the type of seeds and the method of processing. The cakes are hard and need milling before feeding. Decorticated meal is a high value protein feed, while undecorticated meals provide useful fibre for high concentrate diets. Since they can only be used by ruminants costs should be less per unit of protein.

b. Legume seeds

A number of grain legumes are already grown in Tibet for sale for human consumption as dry seeds used for "popping" as snacks, and as boiled dishes. There is considerable scope to expand legume seed production for use whole as protein feeds for high yielding cows. ME contents are higher than for most cereals due to higher fat contents, while protein contents of good biological value are 250-350 g/kg DM. Phosphorous contents are high. Protein degradation rates are high in the rumen, so that legume seeds are a good source of Effective Rumen Degradable Protein to supplement fodders with low protein : energy levels such as cereal straws and whole-crop cereal silages including maize silage. However, they may contain tannins which reduce digestibility.

Beans – Faba (Broad): these are the most widely used home grown protein in UK. A diverse range of bean varieties are grown in central Tibet, and seeds should be analysed for use as animal feed.

Peas – 'Black peas' are widely grown in the upper Lhasa valley, and although used for human consumption should be readily available. Again, these need to be analysed. Other types could be grown in the future as feed peas.

c. Non-protein nitrogen (NPN)

Allowance is made in the UK MP system for the rapid release of ammonia in the rumen from NPN sources. Urea is the most widely used commercial NPN additive. Its use as a source of ammonia to treat cereal straws has been described. Urea is also used as a supplement to straw based rations. It is a crystalline chemical, with a crude protein content of 2875 g/kg DM – that is ten times the CP content of a normal protein supplement. For high yielding milk cows its main use is to top up CP levels to meet requirements without exceeding desirable concentrate : fodder ratios. However it has to be used with great care to avoid acute ammonia toxicity, and is best fed mixed in complete rations or mixed with molasses as a supplementary feed block.

10) Other products

A wide range of agricultural by-products and food processing wastes are available in central Tibet and are use to feed milk cows. A detailed survey of feeds fed and milk yield responses has been made in four counties under an ACIAR project, but information was not available at the time of writing.

Brewer's grains – it is likely various brewery and distillery by-products are available in central Tibet, based on a range of cereals including rice. These can be fed fresh, ensiled wet, or dried by the factory. Brewer's grains have medium energy and protein levels, and high digestible fibre. They are highly palatable , and can be fed to milking cows are high inclusion rates.

Winery pomace – residues of stalk, skin and/or seeds after pressing juice from grapes. Pomace is highly fibrous, low in energy and low-medium in protein.

11) Minerals

Mineral contents of fodders and feeds are too low for high yielding milk cows. Mineral requirements for maintenance, pregnancy, lactation and body gain can be calculated as for ME and MP, and mineral supplements fed to meet requirements. The major requirements are for salt (NaCl), calcium (Ca), magnesium (Mg), and Phosphorous (P). Requirements for minor minerals in central Tibet are currently being assessed under an ACIAR project. A range of natural products and manufactured chemicals are available to meet requirements for major minerals.

12) Buffers

High concentrate : fodder ratios are required to meet nutrient requirements of high yielding cows. These lead to low levels of chewing and rumination with reduced saliva, rapid fermentation, high rates of acid production, lowered pH and reduced fibre digestion. Supplementation of such rations with rumen buffers to some extent counteracts these effects, and leads to increased feed intake and higher milk yields.

Sodium bicarbonate is the buffer most commonly fed on a commercial basis, at 10 and 20 g/kg of the total ration and the concentrate portion respectively.

10.4. Feeding systems and models[13]

The main fodders available to farmers in central Tibet are spring and winter barley straws and winter wheat straw. As seen these are high in fibre, and low in metabolisable energy and crude protein. It is suggested that there are three main ways to develop the feeding of cows to support improved milk production, with many possibilities to combine these methods:

i. improvement of fodder quality, by harvest of fresh or conserved forages at increasingly immature stages of growth, or by replacement of straws by high quality fodder
ii. supplementation of cereal straws, to improve their digestibility and intake – but keeping straw as the basal ration
iii. estimation of the nutrient requirements of high yielding cows for metabolisable energy and protein (and minerals), and formulating rations using the available fodders and feedstuffs that meet these requirements within the predicted dry matter intake.

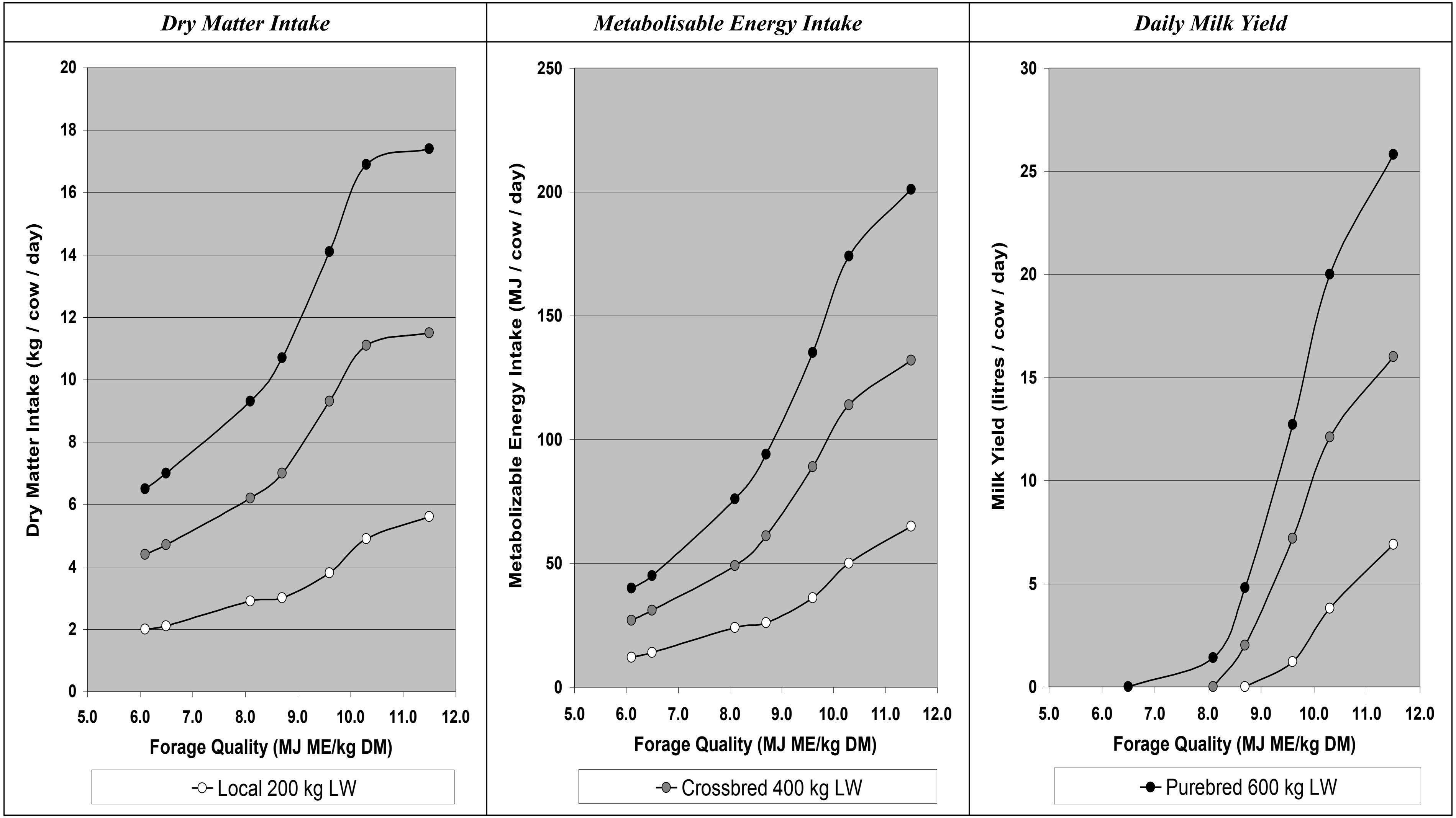
10.4.1. Improvement of fodder quality

a. Progressive improvement in the quality of a single fodder – grass hays

The effect of improvement of forage quality on dry matter intake, ME intake, and resulting daily milk yield is demonstrated through RUMNUT models in Figure 10.11. These show the effect of ME concentration (6.1 – 11.5 MJ/kg DM) in a series of grass hays (perennial ryegrass) harvested sequentially at a range of maturities from early vegetative to over mature (post ripe). The poorest hay has a similar ME to cereal straws. Each chart includes curves for high yielding local, crossbred and pure bred exotic milk cows with liveweights of 200, 400 and 600 kg respectively. Only ME concentration is considered in this set of models; rumen energy (FME) and degradable protein (ERDP) were not balanced, and requirements for MP and minerals were not met – so the predicted intakes and milk yields may not be reached in practice. The models show:

- dry matter intake increases by almost three fold over the range in fodder quality from 6.1 – 10.3 MJ ME/kg DM, with a greater rate of improvement as fodder quality improves. However there is little further increase in DM intake as quality increases above 10.5 MJ ME/kg DM when physiological control takes over from physical control of intake (this is built into the RUMNUT model as one of the animal intake factors);
- ME intake increases in relation to both dry matter intake, and the increase in MJ of ME for each kg DM consumed. This results in a four fold increase in ME intake over the range 6.1 – 10.3 MJ ME/kg DM, which again is curvilinear, with further increase in ME intake with the highest quality of hay.
- The ME intake has to support both maintenance and milk production. The animals used for the models were taken to be in week 12 of lactation, with no weight change and condition score 2.5/5.0, and non-pregnant.

[13] Detailed feed composition and nutritive value for the feeds used in the models is given in Annex Table 10.2



1. Legends apply to all charts.
2. Intakes of Dry Matter and Metabolizable Energy for the grass hays, and the resulting milk yields, were estimated using RUMNUT ruminant nutrition rationing software based on the UK Metabolizable Energy system (Chamberlain, 2004). These charts illustrate the effect of forage quality with respect to ME content. The hays were not balanced for protein or other nutrients, so that the intakes and milk yields shown here may not be achieved in practice.

Figure 10.11 . Effect of Forage Quality of grass hays and of Cow Type on Dry Matter Intake and Metabolisable Energy Intake, and Milk Yield

- Lower quality hays can only support maintenance and some milk in the larger cows, due to their relatively higher intakes of DM and ME. Small and medium sized cows will lose weight on fodders below 8.6 and 8.0 MJ ME/kg DM respectively, while large cows can maintain their weight on good quality straws at 6.5 MJ/kg DM.
- Predicted milk yield (4 per cent butterfat) increases linearly over the middle range of fodder quality with potential yields of 4, 12 and 20 litres with forage quality of 10.3 MJ ME/kg DM for small, medium and large cows respectively. The rate of yield increase slows with higher quality fodder, so that predicted milk yield reaches 6, 16 and 26 litres respectively with best quality hay.

This series of models demonstrates that high milk yields are potentially possible from high quality conserved fodders provided they are available in sufficient quantity. Such fodders will need some supplementation for these yields to be attained. In addition, hays tend to have high levels of fermentable ME, while much of the digestible protein is undegradable in the rumen. This leads to a mis-match of FME and ERDP in the rumen with high quality hay made from grasses, even though CP levels appear sufficient and production of MP meets requirements. This can be alleviated by feeding some fodder as silage, which has low FME and high ERDP; and/or feeding some fresh green fodders or legume hays which have high ERDP. Mineral requirements need to be met separately.

The economic consequence of improving the quality of fodders is examined in Chapter 11.

b. Replacement of straws by high quality fodder

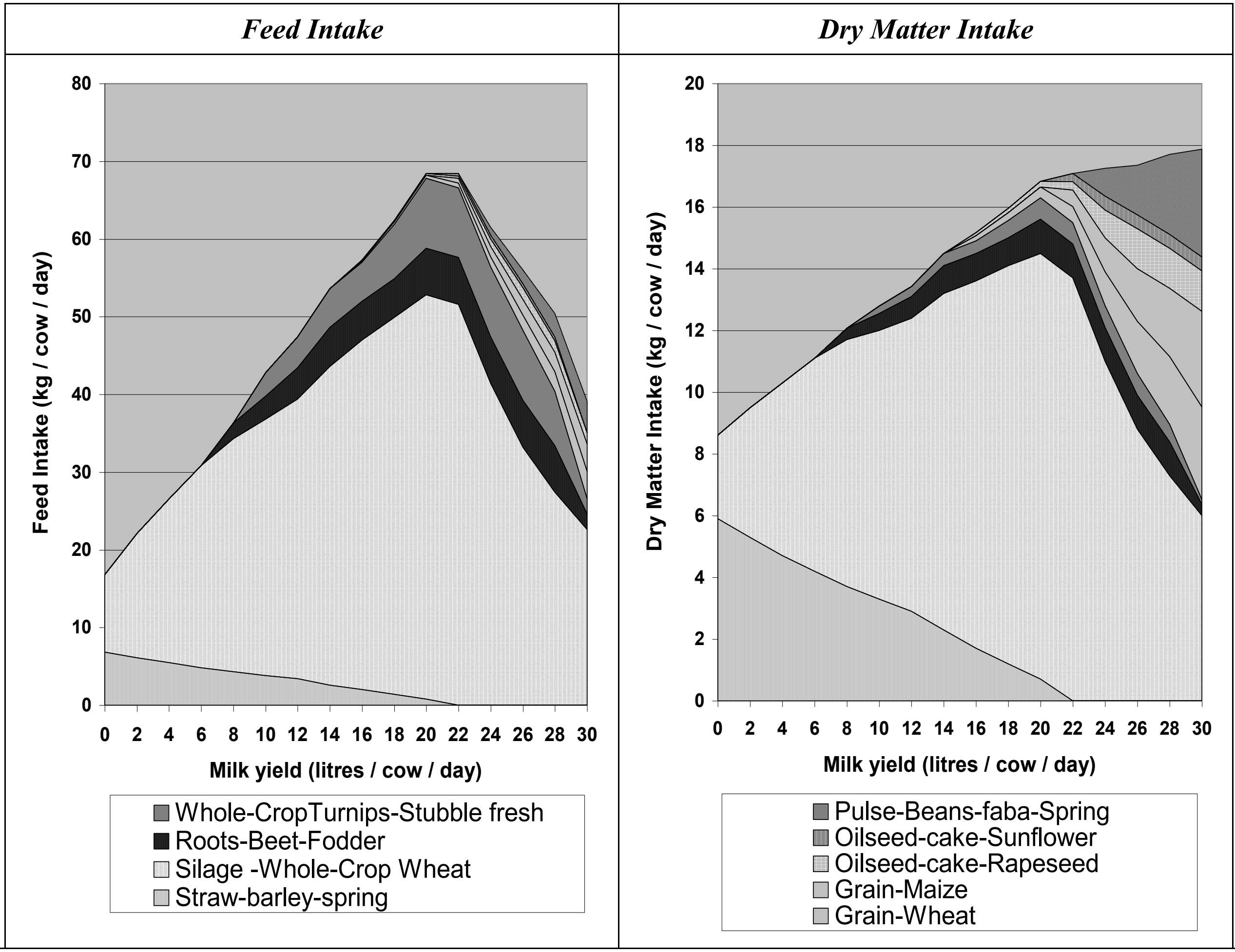
Two examples are explored in which spring barley straw is progressively replaced by high quality fodders. These models have been developed using RUMNUT based on the UK ME/MP system (Chamberlain, 2004). Rumen FME / ERDP ratios have been optimised, and protein requirements have been met, but minerals have not been considered and need to be supplemented. Both models have been developed just for purebred exotic cows of 600 kg liveweight, in week 12 of lactation, with no weight change and condition score 2.5/5.0, and non-pregnant. These cows should be at their peak milk yield with near maximum feed intake. The models take spring barley straw as the starting feed, and record the additional fodders and concentrate feeds required to move the cow from maintenance to a high level of production. The X axis is therefore milk yield in litres/cow/day. At high yields a rumen buffer such as sodium bicarbonate fed at 1% of the total ration may be needed to balance excess sugars and starch when high levels of roots and concentrates are fed. Economic responses are in Chapter 11.

i. Replacement of spring barley straw by Whole-Crop Wheat Silage (WCWS)[14] harvested at the early milk stage, and concentrate feeds

Intakes of fresh feeds and dry matter for this model are shown in Figure 10.12.1, and intakes of ME, CP and effective fibre are in Figure 10.12.2. Note the following points:

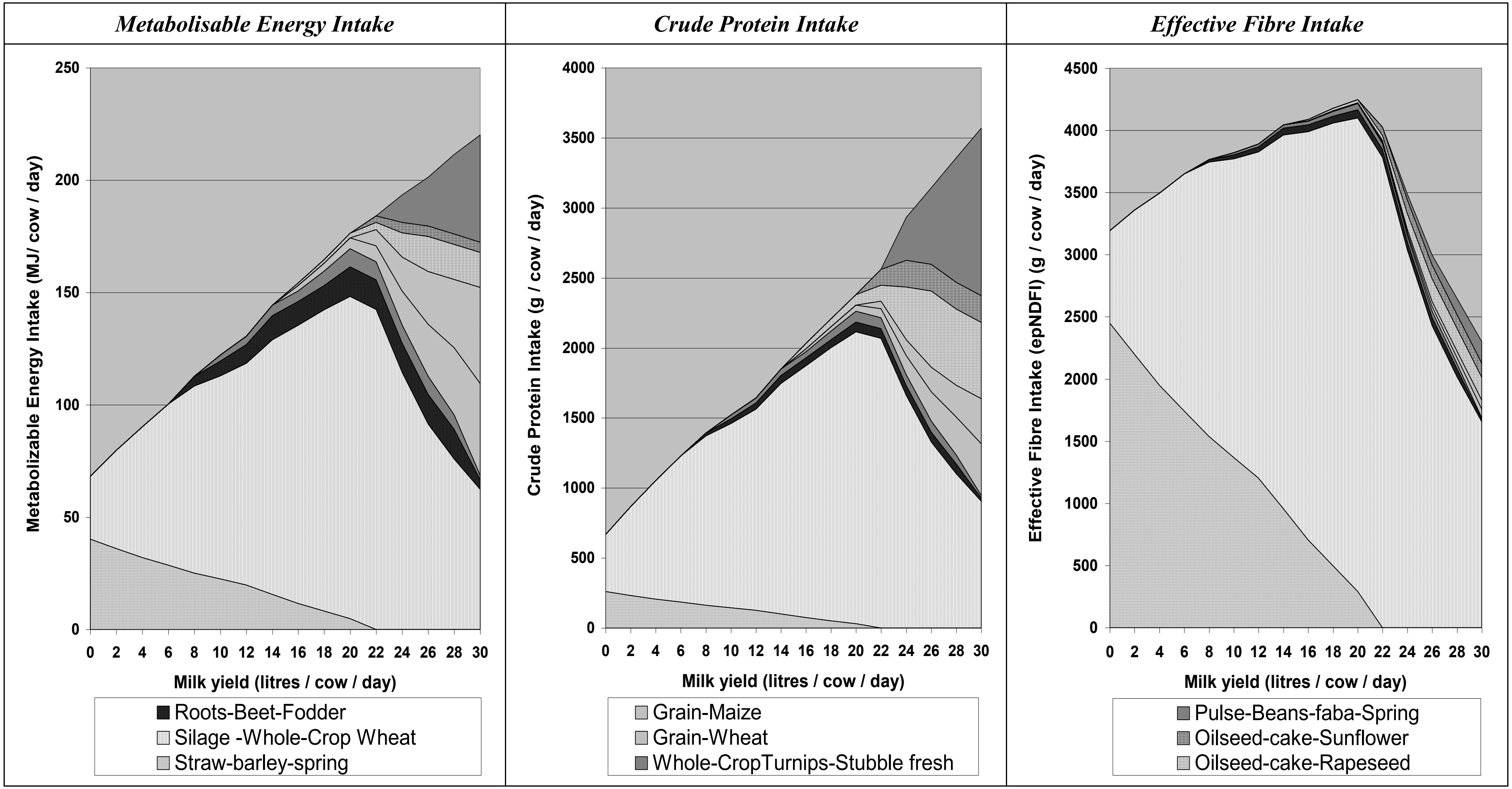
- Straw alone can not support maintenance, even with large cows. A quarter of dry matter and almost half of ME has to come from WCWS just for maintenance.
- Total dry matter intake increases linearly up to a milk yield (4% butterfat) of 20 litres / day, after which DM intake remains almost constant as the quality of the ration has to be raised by feeding concentrates (fine feeds).
- With increasing milk yield WCWS progressively replaces barley straw up to a milk yield of 22 litres. The two fodders can supply all nutrients up to 6 litres, when additional energy is required and met by feeding fodder beet and whole-crop stubble turnips. These high energy root crops replace WCWS that would otherwise have been fed.
- The energy in both root crops is in the form of sugars, which is rapidly fermented in the rumen and can lead to acidosis. In addition high levels can cause taint in milk. Levels were therefore limited to a total roots of 2 kg DM/day.

[14] Feed composition for Whole-Crop Wheat Silage was not available, so values for average quality grass silage were used for this model



1. Legends apply to all charts.
2. Rations were formulated using RUMNUT ruminant nutrition rationing software based on the UK Metabolizable Energy and Protein systems (Chamberlain, 2004).
3. A rumen buffer such as sodium bicarbonate may be needed at 1% of the total ration DM to balance excess sugars and starch when high levels of roots and concentrate feeds are fed for high milk yields.
4. Rations are not balanced for minerals; Ca and P supplements are needed.
5. Quantities shown are for feeds and DM consumed. Amounts of straw and silage actually fed should be increased by 5-10% to allow for rejection and wastage.

Figure 10.12.1. Replacement of Spring Barley Straw by Whole-Crop Wheat Silage (Early milk stage) and concentrate feeds for Milk production with Purebred cows (600 kg LW) – Feed and Dry Matter Intakes



1. Legends apply to all charts.
2. Rations were formulated using RUMNUT ruminant nutrition rationing software based on the UK Metabolizable Energy and Protein systems (Chamberlain, 2004).
3. A rumen buffer such as sodium bicarbonate may be needed at 1% of the total ration DM to balance excess sugars and starch when high levels of roots and concentrate feeds are fed for high milk yields.
4. Rations are not balanced for minerals; Ca and P supplements are needed.
5. Quantities shown are for feeds and DM consumed. Amounts of straw and silage actually fed should be increased by 5-10% to allow for rejection and wastage.

Figure 10.12.2. Replacement of Spring Barley Straw by Whole-Crop Wheat Silage (Early milk stage) and concentrate feeds for Milk production with Purebred cows (600 kg LW) – Metabolisable Energy, Crude Protein and Effective Fibre Intakes

- Further energy is therefore supplied by equal portions of wheat and maize grains, plus energy from protein concentrates.
- Up to 14 litres of milk, WCWS can supply all the protein required; above this milk yield protein concentrates are required, initially as small amounts of rapeseed meal.
- Above 20 litres milk yield, increase in dry matter intake of concentrate feeds has to be met by an equal reduction in dry matter intake of WCWS – known as the replacement effect of concentrates. This rapid decline in fodder intake also reduces the ME and CP intake from WCWS, which have to be met by increasing amounts of concentrates.
- Since the cereals grains are low in CP, additional protein concentrates have to be fed for high milk yields. The amount of rapeseed cake is limited for palatability reasons, so is supplemented with sunflower cake (undecorticated) and finally beans. If available, a mix of different oilseed cakes would be used for high yields including soya bean meal, since the amount of beans should be restricted due to their tannin content. The energy from these protein concentrates does make a significant contribution to ME supply.
- As concentrates replace fodder at high milk yields, intake of effective fibre rapidly declines and becomes limiting at 30 litres. Low levels of fibre reduce the amount of chewing and rumination, so release of saliva which acts as a rumen buffer is reduced. Levels of starch and sugars are high in the rumen, so the risk of acidosis is high.
- Measures to alleviate this situation include:
  - use of energy concentrates with high contents of digestible fibre rather than starch, such as sugar beet pulp if available,
  - use of protein concentrates with high fibre contents, such as wheat bran (digestible fibre) and undecorticated oil seed cakes such as sunflower meal (indigestible fibre)
  - feeding a buffer such as sodium bicarbonate at 1% of the diet
  - feeding concentrate feeds as many small feeds through the day
  - feeding all feeds mixed as complete diets

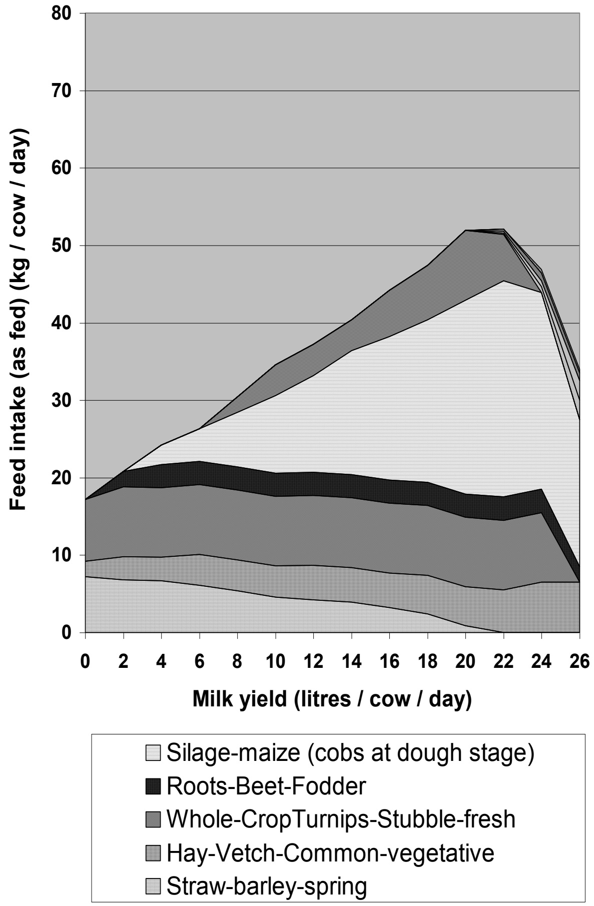
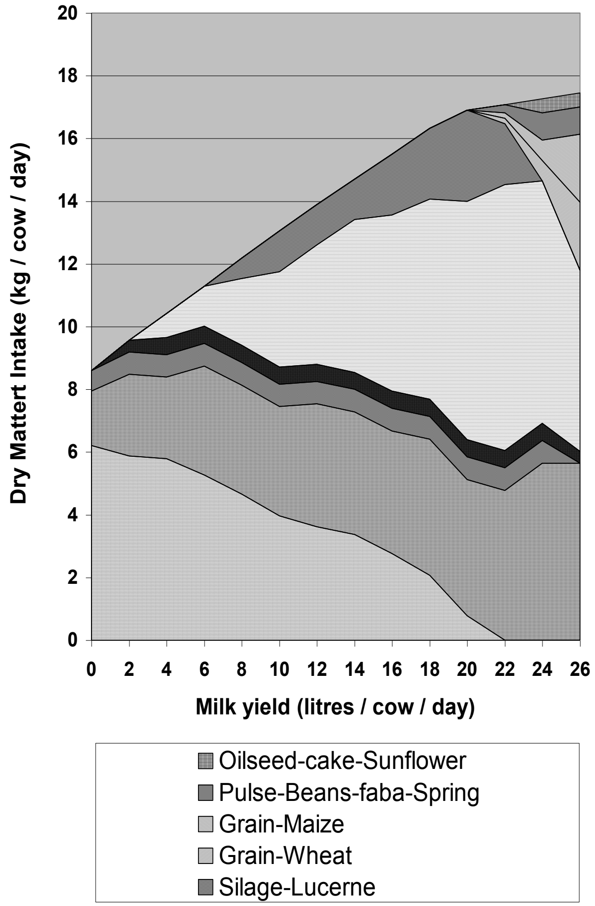
  The last two methods will also allow the animal to have higher dry matter intakes so that higher proportions of high quality fodder can be fed.

In practice it is likely that a range of fodders will be fed, so that more of the protein can come from fodders and so reduce the need for high amounts of concentrates. This is the basis of the second model.

ii. Supplementation of spring barley straw with fodder crops

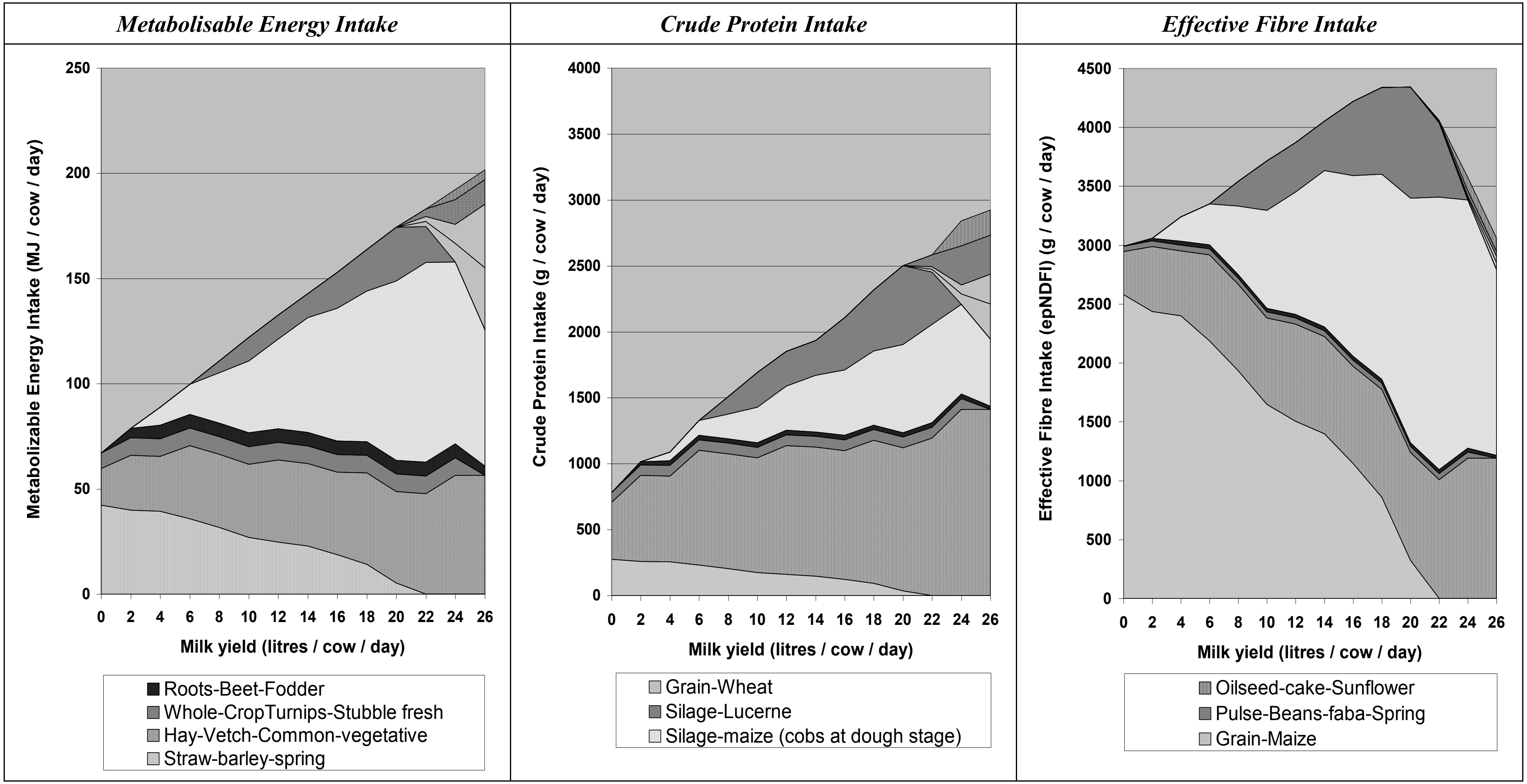
Intakes of fresh feeds and dry matter for this model are shown in Figure 10.13.1, and intakes of ME, CP and effective fibre are in Figure 10.13.2. Note the following points:

- The model is only extended to a milk yield of 26 litres since above this yield concentrate feeding again dominates.
- The range of fodder crops used for the model includes, in order of inclusion, the basal spring barley straw (low ME and CP); high quality hay from vetch cut at the vegetative stage (medium ME and high CP); whole-crop stubble turnips (high ME) – taken as fresh, but in practice in Tibet these are likely to be dried; fodder beet roots (high ME); maize silage with cobs harvested at the dough stage (high ME); and lucerne silage (high CP).
- Using a range of fodders it is possible to feed large cows for 20 litres entirely from fodders grown as annual crops. Some of the fodders used are from double crops, others are from main crops.
- Few fodders provide a perfect match for milk production across the range of milk yields from maintenance to 20 litres. Different fodders as shown provide more or less ME and CP, quickly and slowly fermented energy and degradable protein, and non-degradable starch and DUP.
- The high sugar levels in hays and roots, and the low ERDP in hays, are balanced by the low sugar levels and high ERDP in silages.

Feed Intake	***Dry Matter Intake***
	

1. Legends apply to all charts.
2. Rations were formulated using RUMNUT ruminant nutrition rationing software based on the UK Metabolizable Energy and Protein systems (Chamberlain, 2004).
3. A rumen buffer such as sodium bicarbonate may be needed at 1% of the total ration DM to balance excess sugars and starch when high levels of roots and concentrate feeds are fed for high milk yields.
4. Rations are not balanced for minerals; Ca and P supplements are needed.
5. Quantities shown are for feeds and DM consumed. Amounts of straw, hay and silages actually fed should be increased by 5-10% to allow for rejection and wastage.

Figure 10.13.1. Supplementation of Spring Barley Straw with Fodder Crops for Milk production with Purebred cows (600 kg LW) – Feed and Dry Matter Intakes



1. Legends apply to all charts.
2. Rations were formulated using RUMNUT ruminant nutrition rationing software based on the UK Metabolizable Energy and Protein systems (Chamberlain, 2004).
3. A rumen buffer such as sodium bicarbonate may be needed at 1% of the total ration DM to balance excess sugars and starch when high levels of roots and concentrate feeds are fed for high milk yields.
4. Rations are not balanced for minerals; Ca and P supplements are needed.
5. Quantities shown are for feeds and DM consumed. Amounts of straw, hay and silages actually fed should be increased by 5-10% to allow for rejection and wastage.

Figure 10.13.2. Supplementation of Spring Barley Straw with Fodder Crops for Milk production with Purebred cows (600 kg LW) – Metabolisable Energy, Crude Protein and Effective Fibre Intakes

- In practice, by feeding a mix of fodders, animals have a higher interest in their food, and will increase their dry matter intakes by 5 percent. In the present model this would have been sufficient to allow production of 25 litres of milk from fodders.
- Wheat bran would be a good concentrate feed to start supplementation, since its high digestible fibre level and low starch content would supplement fodders well.

Fodders should always be fed with an allowance of 5 – 10 percent so that animals can reject inedible parts and meet their predicted feed intakes.

10.4.2. Supplementation of cereal straws

Within government programmes it is important to include policies that can benefit all farmers, even though emphasis is given to special projects that will transform more able subsistence farmers into commercial livestock producers. Preston and Leng (1987) go back to the basic principles of animal nutrition to propose ways in which the feeding of available feed stuffs can be improved to increase the production of ruminant animals for all farmers. Their basic approach is to ask a series of questions as set out in Table 10.8, many of which have been discussed above.

Table 10.8. Development of available feed resources: questions and answers for central Tibet

Questions	**Answers for central Tibet**
What are the basic fodder resources?	Barley and wheat straws
How can these dry fodders be treated to improve their feeding values?	Fractionation of straws into stem and leaf or by feeding surplus straws for animal selection Treatment with urea or bacterial fermentation
How can fermentation of the basal fodders in the rumen be improved by fermentable supplements to provide fibre digesting bacteria with their minimum requirements for growth?	Supplementation with: ▪ nitrogen ▪ minerals ▪ a green fodder supplement
What Bypass supplements can be fed to stimulate the animal's metabolism and improve feed intake?	Bypass supplements for: ▪ protein ▪ starch ▪ oils

The idea is to take the basic fodders, and make the best use of them. This will not support high milk production from crossbred and purebred exotic cows, but it can help all farmers obtain more milk from their existing cows in an economic way.

Straw treatment: this has already been discussed, including fractionation and ammoniation with urea.

Fermentable supplements:

- *nitrogen*: urea is an economic source of non-protein nitrogen. The problem is to develop a local way to feed it safely. Urea can be dissolved in water and sprinkled on to straws before feeding. However it is rapidly degraded to ammonia in the rumen, so a rapidly fermentable carbohydrate such as sugar must be available at the same time. Traditionally urea is mixed with molasses, and the mixture sprinkled on to straws which also increases their palatability. However molasses is unlikely to be available in central Tibet. An alternative would be to chop turnips or radish finely, mix urea in small quantities with the chopped turnip, and then mix the chopped turnip well with chopped straw.

  Urea is also mixed with molasses and fed as a liquid supplement through a special feeder which allows animals to lick just a small amount at a time; or it is made into a solid urea molasses block. If molasses is not available, there are various recipes to make urea blocks from wheat or rice bran, possibly using cement as a binder. These blocks can also contain the necessary minerals.

- *minerals*: straws need to be supplemented with both major and minor minerals for active fermentation by rumen microbes. The minerals required will be identified by the ACIAR project. Minerals can be fed to cows mixed with the concentrate portion of the ration which ensures all animals consume the required amount. Alternatively, they can be prepared as a dry mixture with salt, and be made available for animals to help themselves – free choice. Again, for convenience and to reduce wastage, they can be made into solid blocks. As with urea blocks, this is an activity that can be organised by county staff working with farmers and suppliers.
- *green fodder supplement*: when cows are fed solely on cereal straws, fibrolytic bacteria are the main bacteria in the rumen, and due to the slow rate of digestion of straws most are attached to plant fibres. This means that the rumen fluid has few bacteria in it, and when a mouthful of straw enters the rumen it can be 24 hours before it is fully colonised. This reduces the rate of rumen fermentation, outflow rates and feed intake. If a small quantity of digestible green fodder is fed, bacteria have a place on which they can multiply rapidly, and as the green fodder is digested the bacteria are returned to the rumen fluid. As a result, when a mouthful of straw enters the rumen it is rapidly colonised, with higher rumen fermentation of straw, outflow rate of straw and straw intake. It is the first 5 – 10 percent of dry matter intake as green fodder that makes the major difference – and this can be eaten in addition to the full amount of straw. Beyond this level, the green fodder starts to replace straw intake as shown previously – although straw digestion will continue to be improved.

  In central Tibet, the green fodders grown as second crops such as vetch and radish tops can all be used; and fodders conserved as hay or silage are as effective as green fodder supplements as fresh fodders. If legume fodders are fed, they can also act as supplements for N and minerals. The best would be leaf meals prepared from fractionation of legume fodders such as vetch, lucerne and melilotus, which have high levels of fermentable N and minerals, but will have low replacement rates for the basal straws in the rumen.

Bypass supplements:

- *protein*: digestible but undegradable protein feeds depend on heat treatment or tannin content to reduce degradation of protein in the rumen. Supplements for bypass protein therefore includes all oilseed cakes, plus pea and bean grains. Protein in hays is less degradable than in fresh or ensiled fodder. Some legumes have high tannin contents in their fodder as well as their seeds, and this includes broad beans, peas and sainfoin. It would appear that hays or leaf meals prepared from second crop legume fodders are very suitable as bypass protein supplements for use by most farmers .
- *starch*: starch in maize grain is less degradable than in wheat. Finely milled maize flour passes quickly through the rumen and part escapes undegraded. This is transformed to glucose and absorbed in the small intestines for various metabolic processes. Similarly rice polishings which include many broken grains can provide bypass starch as well as bypass protein.
- *oil*: the lipids in most oil bearing feeds including rice polishings will pass through the rumen undigested, although they will be hydrogenated to hard fats in the rumen. Quantities fed must be limited as lipids tend to coat the surface of fibres, thus protecting the fibres from degradation by rumen microbes.

It therefore appears that leaf meals and hays from forage legumes are multipurpose supplements to straw based ration. They provide fermentable N and minerals, act as a green fodder supplement with low replacement rate, and provide bypass protein (DUP) to stimulate the animal's metabolism. Finely milled maize flour may be fed for bypass starch and oil.

10.4.3. Estimation of nutrient requirements and ration formulation to meet those requirements

The standard ways in which feeding systems for milk production are used are:

a. to estimate the cow's requirements for energy and protein (and minerals) given her liveweight, stage of lactation / target live weight change, body condition, stage of pregnancy and target yield of milk of desired composition; and

b. to design a ration using available feeds that will meet those requirements.

Various feeding systems have already been discussed, ending with the UK ME/MP system:

- The UK ME/MP system has been outlined in detail with respect to estimation of the metabolisable energy and protein that a given fodder or feed will supply.
- Estimation of the requirements of animals for ME and MP is straightforward by assessment of the requirements for each component (maintenance, activity, pregnancy, weight change, lactation) using simple equations, and summing them.
- Ration design then entails assembling fodders and concentrate feeds that together meet the requirements, but at the same time maintain optimum rumen conditions by matching fermentable energy and degradable protein in the rumen – within the limits of voluntary feed intake.
- Feed requirements can then be expressed as required ME and CP concentrations in the ration DM.

This can be done manually according to equations and tables in MAFF (1984) and AFRC (1993), or by computer using software such as RUMNUT (Chamberlain, 2004) as described in Chamberlain and Wilkinson (1996). A teaching version of the RUMNUT Dairy module is available free. The ME/MP systems can be developed as a spreadsheet, again for teaching rather than for on-farm use.

10.4.4. The relationship between conserved fodder quality and the 'Fodder to Concentrate Ratio' in the diet of milking cows

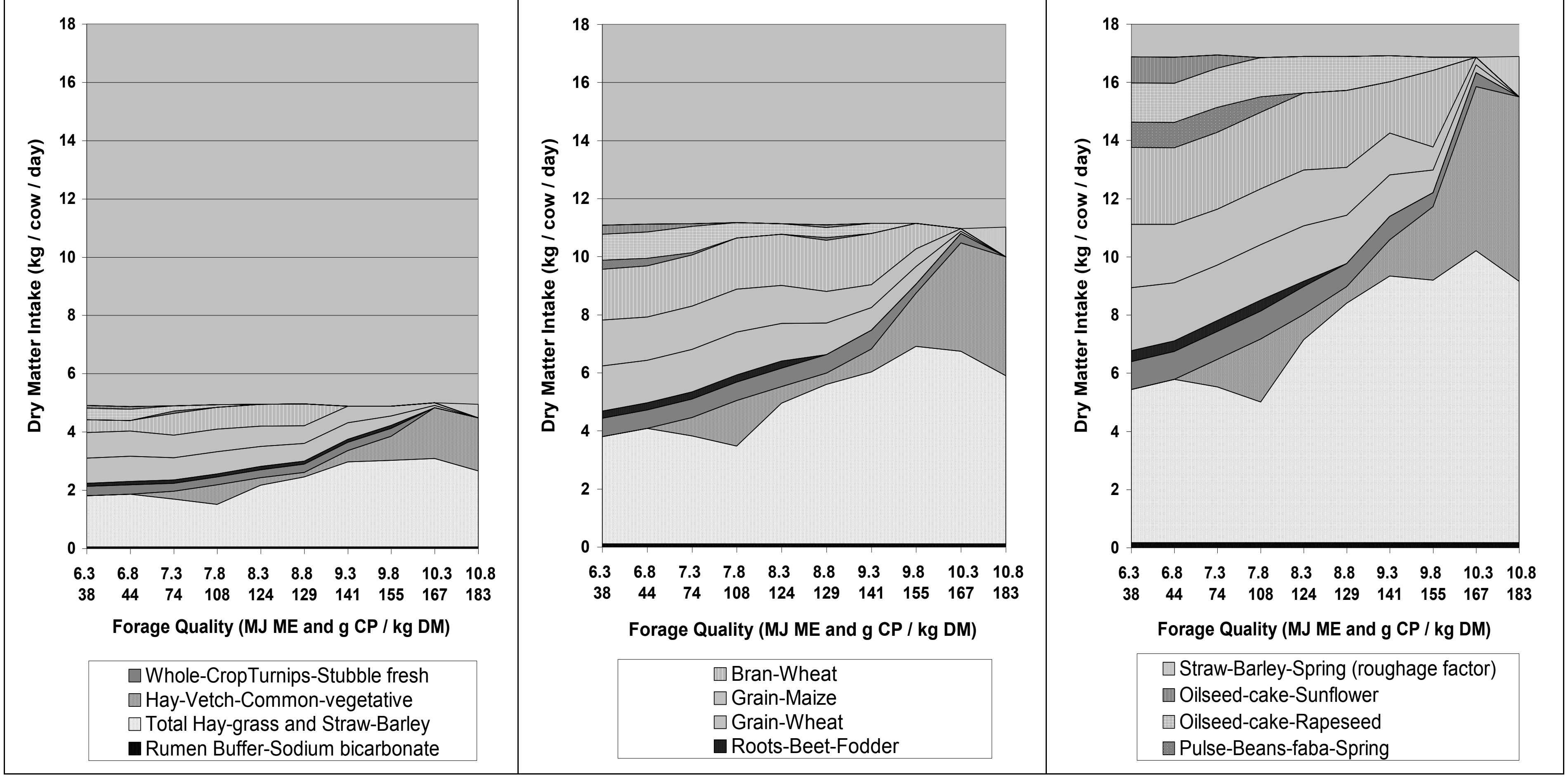
The estimation of nutrient requirements and ration formulation approach is used here to demonstrate the relationship between the quality of conserved fodder, and the fodder to concentrate ratio necessary to meet the feed requirements of small, medium and large cows with the animal factors in Table 10.9.

Table 10.9. Animal factors for demonstration of the relationship between the quality of conserved fodder and the fodder to concentrate ratio in the diet of milking cows

Animal factor \ Cow type	**Local**	**Crossbred**	**Pure exotic**
Liveweight (kg)	200	400	600
Milk yield (litres/day)	4	12	20
with Butterfat (%)	4.0	4.0	4.0
Lactation stage (weeks)	12	12	12
Weight change (kg/day)	0.0	0.0	0.0
Condition score (out of 5.0)	2.5	2.5	2.5
Pregnancy (weeks)	0.0	0.0	0.0
Feed requirement (kg DM/day)	4.9	11.1	16.9
with ME (MJ/kg DM)	10.4	10.3	10.3
and CP (g/kg DM)	>120	>135	>150

Models have been produced using RUMNUT and are given in Figures 10.14.1 showing individual feeds, and in Figure 10.14.2 showing feeds grouped into feed classes. Detailed composition and nutritive values for the fodders and feeds are in Annex Table 10.2. In developing rations for each level of fodder quality, rumen FME and ERDP were balanced and rations met ME and CP requirements; MP was in surplus. Details on the models are as follows:

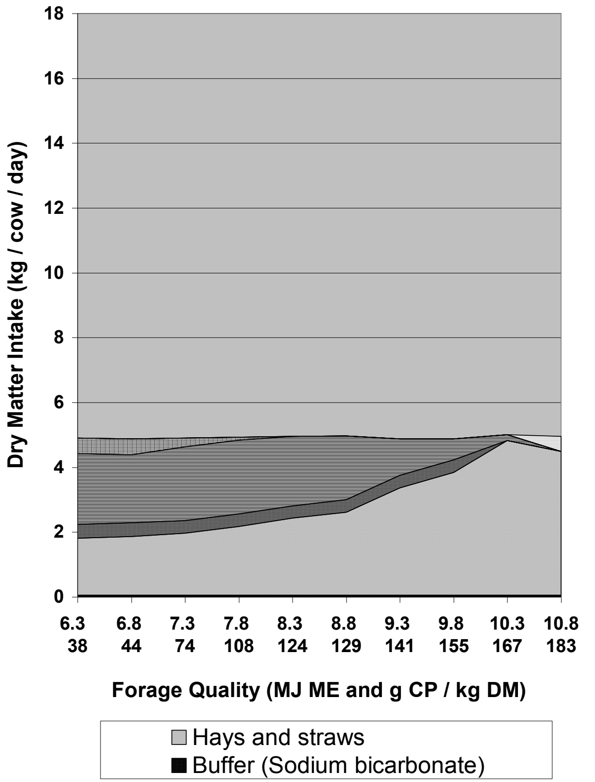
Local cow (200 kg LW) Milk yield of 4 litres / day Feed Requirement: 4.9 kg DM / day with 10.4 MJ ME and at least 120 g CP / kg DM	**Crossbred cow (400 kg LW)** Milk yield of 12 litres / day Feed Requirement: 11.1 kg DM / day with 10.3 MJ ME and at least 135 g CP / kg DM	**Simmental or Holstein cow (600 kg LW)** Milk yield 20 litres / day Feed Requirement: 16.9 kg DM / day with 10.3 MJ ME and at least 150 g CP / Kg DM

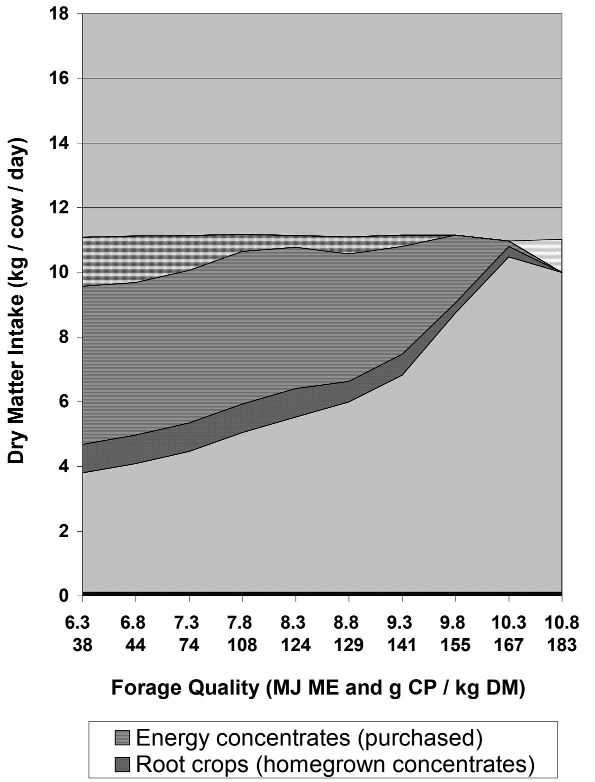


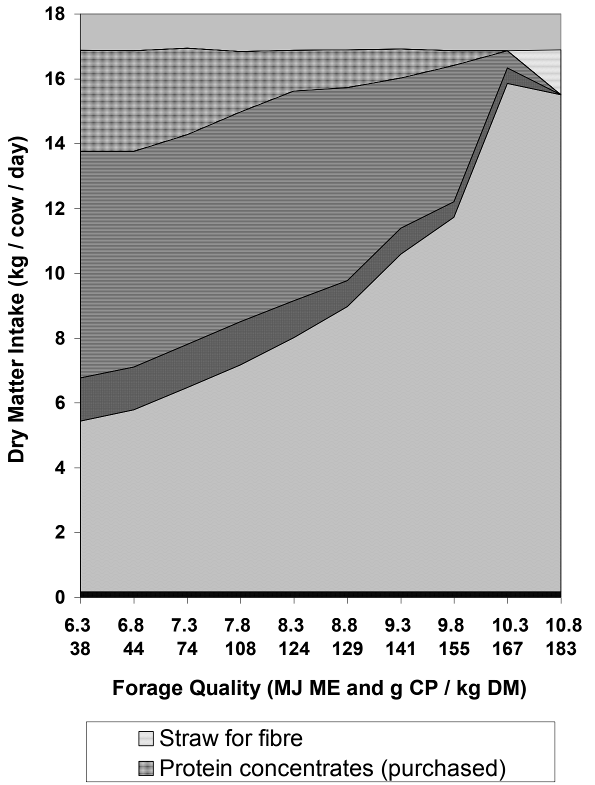
1. Legends apply to all charts.
2. Rations were formulated using RUMNUT ruminant nutrition rationing software based on the UK Metabolisable Energy and Protein systems (Chamberlain, 2004) (see notes for Figure 10.14.2).

Figure 10.14.1. Relationship between Conserved Forage Quality and Forage to Concentrate Ratio in the diet of milking cows. Individual feeds

Local cow (200 kg LW) Milk yield of 4 litres / day Feed Requirement: 4.9 kg DM / day with 10.4 MJ ME and at least 120 g CP / kg DM	**Crossbred cow (400 kg LW)** Milk yield of 12 litres / day Feed Requirement: 11.1 kg DM / day with 10.3 MJ ME and at least 135 g CP / kg DM	**Simmental or Holstein cow (600 kg LW)** Milk yield 20 litres / day Feed Requirement: 16.9 kg DM / day with 10.3 MJ ME and at least 150 g CP / Kg DM







1. Legends apply to all charts.
2. Rations were formulated using RUMNUT ruminant nutrition rationing software based on the UK Metabolizable Energy and Protein systems (Chamberlain, 2004).
3. Firstly, mixtures of barley straw, grass hays and vetch hay were formulated to provide the forage quality indicated. Secondly home-grown energy feeds in the form of roots were added up to a maximum inclusion rate. Thirdly, purchased energy and protein feeds were added while maintaining optimum levels of Fermentable Metabolizable Energy and Effective Rumen Degradable Protein, to meet the target ME and CP concentrations in the DM for the given milk yields. Finally a buffer in the form of sodium bicarbonate was added at 1% of total DM to balance excess starch and sugars in cereals and hays respectively.
4. Rations are not balanced for minerals; Ca and P supplementation is needed to balance high Mg in wheat bran and P deficiencies induced by phytate forms of P in cereals and bran.
5. Quantities shown are for DM consumed. Amounts of straws and hays actually fed should be increased by 5-10% to allow for rejection and wastage.

Figure 10.14.2. Relationship between Conserved Forage Quality and Forage to Concentrate Ratio in the diet of milking cows. Feed classes

- Animal requirements:
    - ME requirements as MJ/kg DM remain constant for different sized cows as ME intake drives milk production; the requirement for 200 kg cows is slightly raised due to intake limits.
    - CP requirement as g/kg DM is less for small and medium sized cows with lower milk yields due to the relatively high CP requirements for milk production.
- Forage quality is shown on the horizontal X axis in terms of ME (MJ/kg DM) and CP (g/kg DM), ranging from high to low values of 10.8 – 6.3 MJ ME/kg DM and 183 – 38 g/kg CP.
- Fodders include grass hays with a range of maturities from late vegetative (high quality), to mature (low quality); barley straw at the lowest levels of forage quality; and vetch hay at the vegetative stage to provide additional protein from fodder at high levels of fodder quality.
- Top quality fodder meets ME and CP requirements alone; some barley straw is added to the ration to satisfy the cows' appetite and provide additional long fibre for rumen function.
- As fodder quality declines, increasing amounts of energy and protein concentrates are required until they contribute two thirds of the ration.
- A limited quantity of roots are fed as home-grown energy concentrates with the lower quality fodders, in the form of whole-crop stubble turnips and fodder beet. Their use is restricted with high quality hays since the proportion of sugars is already too high in the total ration.
- In order to meet target milk yields, an increasing proportion of purchased energy concentrates have to be fed as fodder quality declines:
    - In these models wheat bran is included as an energy concentrate, although it is often regarded as a protein feed. Its digestible fibre and low starch contents contribute to maintaining rumen function at high concentrate levels. The amount of wheat bran has been limited since it has a high phosphate content, but it is possible that higher levels can be fed.
    - Wheat and maize grains are included in equal proportions.
    - Total energy concentrates make up almost half the ration with poor quality fodders.
    - If available, sugar beet pulp comprised of digestible fibre should replace some cereal grains.
- Inclusion of vetch hay greatly reduces the amount of purchased protein concentrates required with high quality fodders.
- Rapeseed cake is included to meet protein requirements with medium to low quality fodders, up to its maximum inclusion rate. Broad beans are included to provide extra protein with poor quality fodders, and to help balance higher cereal levels. Beans could be replaced by peas. At the lowest levels of fodder quality, where barley straw with low CP replaces hay, sunflower cake is introduced. Other oilseed cakes can be used, and the selection depends on availability and price. However, undecorticated sunflower seed cake has higher levels of structural fibre which is needed with high concentrate levels.
- Lower amounts of protein concentrates and wheat bran are required for small and medium sized cows due to their lower protein requirements.
- High quality hays have above recommended levels of sugars, which can cause acidosis due to rapid fermentation in the rumen. With low quality hays and straws, the high levels of cereal based concentrates provide an excess of starch. Sodium bicarbonate has therefore been included as a rumen buffer at 1% of the total ration, for all qualities of fodder.
- The quantities of hays and straws shown are for DM consumed. Amounts actually fed should be increased by 5-10% to allow for rejection and wastage and so meet dry matter intake predictions.

These models demonstrate that high yields of milk are possible from home grown fodders alone. However, if only low to medium quality fodders are available, it is still possible to attain target milk yields and meet nutritional requirements using home grown roots and purchased energy and protein concentrate feeds that should be available in central Tibet. What is clear from the models is that keeping three small cows requires almost as much fodder and feed as one large cow – but three small cows only produce 12 litres of milk per day compared to 20 litres for one large cow. Medium sized cows such as crossbreds, and pure Jersey cows, are intermediate in efficiency. Economic responses are reported in Chapter 11.

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Annex Table 10.1. Predicted dry matter intakes of lactating cows (kg DM / day)

Output from RUMNUT, based on ARC (1980) and MAFF (1975)

Ration q = 0.35
M/D = 6.4 MJ ME / kg DM
DOMD = 427 g / kg DM
TDN = 42.3%

Cow Weight (kg)	Milk yield (kg/day or litres/day): 0	2	4	6	8	10
175	1.7					
200	2.0					
225	2.4					
250	2.7					
275	3.0					
300	3.3					
325	3.6					
350	4.0					
375	4.2					
400	4.5					
425	4.8					
450	5.1					
475	5.4					
500	5.7					
525	5.9					
550	6.2					
575	6.5					
600	6.7					
625	7.0					
650	7.3					
675	7.5					
700	7.8					

Ration q = 0.40
M/D = 7.4 MJ ME / kg DM
DOMD = 493 g / kg DM
TDN = 48.9%

Cow Weight (kg)	Milk yield (kg/day or litres/day): 0	2	4	6	8	10
175	2.0					
200	2.4					
225	2.8					
250	3.2					
275	3.6					
300	3.9					
325	4.3					
350	4.7					
375	5.0					
400	5.4	5.6				
425	5.7	6.0				
450	6.1	6.3				
475	6.4	6.6				
500	6.7	6.9				
525	7.1	7.3				
550	7.4	7.6				
575	7.7	7.9				
600	8.0	8.2				
625	8.3	8.5				
650	8.6	8.8				
675	8.9	9.1				
700	9.2	9.4				

Ration q = 0.45
M/D = 8.3 MJ ME / kg DM
DOMD = 553 g / kg DM
TDN = 54.9%

Cow Weight (kg)	Milk yield (kg/day or litres/day): 0	2	4	6	8	10
175	2.4	2.6				
200	2.8	3.1				
225	3.3	3.6				
250	3.8	4.1				
275	4.2	4.5				
300	4.7	5.0	5.2			
325	5.1	5.4	5.7			
350	5.5	5.8	6.1			
375	5.9	6.2	6.5			
400	6.4	6.6	6.9	7.2		
425	6.8	7.0	7.3	7.6		
450	7.2	7.4	7.7	8.0		
475	7.5	7.8	8.1	8.4		
500	7.9	8.2	8.5	8.8	9.1	
525	8.3	8.6	8.9	9.2	9.5	
550	8.7	9.0	9.3	9.5	9.8	
575	9.1	9.3	9.6	9.9	10.2	
600	9.4	9.7	10.0	10.3	10.6	10.9
625	9.8	10.1	10.4	10.6	10.9	11.2
650	10.2	10.4	10.7	11.0	11.3	11.6
675	10.5	10.8	11.1	11.4	11.6	11.9
700	10.9	11.1	11.4	11.7	12.0	12.3

1. Ration q = Metabolisability of the ration = Metabolisable Energy (ME) / Gross Energy (GE) (both as MJ / kg DM)
2. Dry matter intakes are predicted for the cow liveweights, milk yields and ration Metabolisability (q) indicated. They do not necessarily contain sufficient energy and other nutrients to support the maintenance and milk yields shown – in which case animals will lose weight and /or milk yields will fall.
3. Dry matter intakes for the shaded parts of the tables do not meet total Metabolisable Energy requirements for maintenance and milk production for the yield indicated. Dr matter intakes can be estimated for higher milk yields than those shown
4. Apply correction factors for animal and feed modifying factors as outlined in Tables 10.1 and 10.2. to these predicted dry matter intakes.

Ration q	**=**	**0.50**
M/D	**=**	**9.2 MJ ME / kg DM**
DOMD	**=**	**613 g / kg DM**
TDN	**=**	**60.8%**

Cow	**Milk yield (kg / day or litres / day**										
Weight (kg)	**0**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
175	2.8	3.1	3.4	3.8							
200	3.3	3.7	4.0	4.3	4.7						
225	3.9	4.2	4.6	4.9	5.2						
250	4.4	4.8	5.1	5.4	5.8						
275	5.0	5.3	5.6	6.0	6.3	6.6					
300	5.5	5.8	6.1	6.5	6.8	7.2					
325	6.0	6.3	6.7	7.0	7.3	7.7					
350	6.5	6.8	7.1	7.5	7.8	8.2	8.5				
375	7.0	7.3	7.6	8.0	8.3	8.6	9.0				
400	7.5	7.8	8.1	8.5	8.8	9.1	9.5				
425	7.9	8.2	8.6	8.9	9.3	9.6	9.9				
450	8.4	8.7	9.1	9.4	9.7	10.1	10.4	10.7			
475	8.8	9.2	9.5	9.8	10.2	10.5	10.9	11.2			
500	9.3	9.6	10.0	10.3	10.6	11.0	11.3	11.6			
525	9.8	10.1	10.4	10.7	11.1	11.4	11.8	12.1			
550	10.2	10.5	10.8	11.2	11.5	11.9	12.2	12.5	12.9		
575	10.6	10.9	11.3	11.6	12.0	12.3	12.6	13.0	13.3		
600	11.0	11.4	11.7	12.1	12.4	12.7	13.1	13.4	13.7		
625	11.5	11.8	12.2	12.5	12.8	13.1	13.5	13.8	14.2	14.5	
650	11.9	12.2	12.6	12.9	13.2	13.6	13.9	14.2	14.6	14.9	
675	12.3	12.6	13.0	13.3	13.7	14.0	14.3	14.7	15.0	15.3	
700	12.7	13.1	13.4	13.7	14.1	14.4	14.7	15.1	15.4	15.7	

5. The following animal factors were used to prepare these tables:

Animal weight:	as indicated	Weight change:	0.00 kg/day	Milk composition	
Milk yield:	as indicated	Weeks post-calving:	12	Butterfat:	4.00 %
Activity level:	low	Weeks pregnant:	0	Protein:	3.40 %
DMI correction:	1.0 (none)	Condition score:	2.5 / 5.0	Lactose:	4.60 %

Ration q = 0.55
M/D = 10.1 MJ ME / kg DM
DOMD = 673 g / kg DM
TDN = 66.8%

Cow	Milk yield (kg / day or litres / day														
Weight (kg)	**0**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**
175	3.3	3.7	4.1	4.5	4.9	5.2										
200	3.9	4.3	4.7	5.1	5.5	5.9										
225	4.6	5.0	5.4	5.8	6.2	6.6	6.7									
250	5.2	5.6	6.0	6.4	6.8	7.2	7.4									
275	5.9	6.3	6.7	7.1	7.4	7.8	8.0	8.2								
300	6.5	6.9	7.3	7.7	8.1	8.4	8.6	8.8	8.9							
325	7.1	7.5	7.9	8.3	8.7	9.1	9.3	9.5	9.6							
350	7.7	8.1	8.4	8.8	9.2	9.6	9.9	10.1	10.3	10.4						
375	8.2	8.6	9.0	9.4	9.8	10.2	10.5	10.7	10.9	11.1						
400	8.8	9.2	9.6	10.0	10.4	10.8	11.1	11.3	11.5	11.7						
425	9.4	9.7	10.1	10.5	10.9	11.3	11.7	11.9	12.1	12.3	12.5					
450	9.9	10.3	10.7	11.1	11.5	11.9	12.3	12.6	12.8	12.9	13.1	13.3				
475	10.4	10.8	11.2	11.6	12.0	12.4	12.8	13.2	13.4	13.6	13.8	14.0				
500	11.0	11.4	11.8	12.2	12.6	13.0	13.4	13.7	14.0	14.2	14.4	14.6				
525	11.5	11.9	12.3	12.7	13.1	13.5	13.9	14.3	14.6	14.8	15.0	15.2	15.4			
550	12.0	12.4	12.8	13.2	13.6	14.0	14.4	14.8	15.2	15.4	15.6	15.8	16.0			
575	12.5	12.9	13.3	13.7	14.1	14.5	14.9	15.3	15.7	16.0	16.2	16.4	16.6	16.8		
600	13.0	13.4	13.8	14.2	14.6	15.0	15.4	15.8	16.2	16.6	16.9	17.1	17.3	17.5		
625	13.6	13.9	14.3	14.7	15.1	15.5	15.9	16.3	16.7	17.1	17.5	17.7	17.9	18.1	18.3	
650	14.1	14.5	14.8	15.2	15.6	16.0	16.4	16.8	17.2	17.6	18.0	18.3	18.5	18.7	18.9	
675	14.6	15.0	15.4	15.7	16.1	16.5	16.9	17.3	17.7	18.1	18.5	18.9	19.1	19.3	19.5	19.7
700	15.0	15.4	15.8	16.2	16.6	17.0	17.4	17.8	18.2	18.6	19.0	19.4	19.7	19.9	20.1	20.3

6. The following fodders were used in preparation of these tables

q = 0.35	1.00 Winter barley straw (q = 0.35)	q = 0.50	0.40 Grass hay 550-600 DOMD (q = 0.47) + 0.60 Grass hay 600-650 DOMD (q = 0.52)
q = 0.40	0.50 Grass hay 450-500 DOMD (q = 0.36) + 0.50 Grass hay 500-550 DOMD (q = 0.44)	q = 0.55	0.25 Grass hay 600-650 DOMD (q = 0.52) + 0.75 Grass hay 650-700 DOMD (q = 0.56)
q = 0.45	0.66 Grass hay 500-550 DOMD (q = 0.44) + 0.33 Grass hay 550-600 DOMD (q = 0.47)	q ≥ 0.60	1.00 Grass hay >700 (q = 0.62)

Ration q	**≥**	**0.60**
M/D	**≥**	**11.1 MJ ME / kg DM**
DOMD	**≥**	**733 g / kg DM**
TDN	**≥**	**72.7%**

Cow	**Milk yield (kg/day or litres/day)**																				
Weight (kg)	**0**	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**	**36**	**38**	**40**
175	4.1	4.5	4.7	4.9	5.1	5.2	5.2	5.2													
200	4.9	5.2	5.4	5.6	5.8	6.0	6.0	6.0													
225	5.6	5.8	6.0	6.2	6.4	6.6	6.7	6.7	6.7												
250	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.4	7.5	7.5											
275	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2	8.2	8.2											
300	7.4	7.6	7.8	8.0	8.2	8.4	8.6	8.8	8.9	8.9	8.9										
325	8.1	8.3	8.5	8.7	8.9	9.1	9.3	9.5	9.6	9.7	9.7	9.7									
350	8.7	8.9	9.1	9.3	9.5	9.7	9.9	10.1	10.3	10.4	10.4	10.4									
375	9.3	9.5	9.7	9.9	10.1	10.3	10.5	10.7	10.9	11.1	11.2	11.2	11.2								
400	9.7	10.1	10.3	10.5	10.7	10.9	11.1	11.3	11.5	11.7	11.9	11.9	11.9								
425	10.5	10.7	10.9	11.1	11.3	11.5	11.7	11.9	12.1	12.3	12.5	12.7	12.7	12.7							
450	11.2	11.4	11.6	11.8	12.0	12.2	12.4	12.6	12.8	12.9	13.1	13.3	13.4	13.4	13.4						
475	11.8	12.0	12.2	12.4	12.6	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.1	14.1	14.1						
500	12.4	12.6	12.8	13.0	13.2	13.4	13.6	13.8	14.0	14.2	14.4	14.6	14.8	14.9	14.9	14.9					
525	13.0	13.2	13.4	13.6	13.8	14.0	14.2	14.4	14.6	14.8	15.0	15.2	15.4	15.6	15.6	15.6					
550	13.6	13.8	14.0	14.2	14.4	14.6	14.8	15.0	15.2	15.4	15.6	15.8	16.0	16.2	16.4	16.4	16.4				
575	14.3	14.5	14.7	14.9	15.1	15.3	15.5	15.7	15.9	16.0	16.2	16.4	16.6	16.8	17.0	17.1	17.1	17.1			
600	14.9	15.1	15.3	15.5	15.7	15.9	16.1	16.3	16.5	16.7	16.9	17.1	17.3	17.5	17.7	17.9	17.9	17.9			
625	15.5	15.7	15.9	16.1	16.3	16.5	16.7	16.9	17.1	17.3	17.5	17.7	17.9	18.1	18.3	18.5	18.6	18.6	18.6		
650	16.1	16.3	16.5	16.7	16.9	17.1	17.3	17.5	17.7	17.9	18.1	18.3	18.5	18.7	18.9	19.1	19.3	19.3	19.3		
675	16.7	16.9	17.1	17.3	17.5	17.7	17.9	18.1	18.3	18.5	18.7	18.9	19.1	19.3	19.5	19.7	19.9	20.1	20.1	20.1	
700	17.4	17.6	17.8	18.0	18.2	18.4	18.6	18.8	19.0	19.1	19.3	19.5	19.7	19.9	20.1	20.3	20.5	20.7	20.8	20.8	20.8

Annex Table 10.2. Feeds relevant for central Tibet used in RUMNUT models: I. Chemical composition

	DM	TA	CP	EE	CF	NFE	Sugar	Starch	RRS	NDF	epNDF	ADF	Lignin	MADF
	%	g/kg	g/kg	g/kg	g/kg	g/kg	g/kg	g/kg	g/kg	g/kg	g/kg	g/kg	g/kg	g/kg
Hays & Straws														
Hay DOMD<450	87.0	*80*	90	14	*433*	*383*	38	*2*	0	752	*368*	*516*	*97*	*510*
Hay DOMD450-500	85.0	*80*	101	12	*418*	*389*	38	*2*	0	741	*362*	*499*	*93*	*491*
Hay DOMD500-550	85.0	*80*	109	16	*356*	*439*	68	*2*	0	699	*335*	*434*	*76*	*412*
Hay DOMD550-600	85.7	*80*	120	16	*333*	*451*	59	2	0	692	*331*	*409*	*70*	*383*
Hay DOMD600-650	85.7	80	131	18	297	*474*	93	1	0	650	294	364	57	337
Hay DOMD650-700	87.1	78	121	22	263	*516*	153	2	1	595	270	334	50	295
Hay DOMD>700	86.3	86	140	21	235	*518*	167	1	0	560	253	313	47	265
Straw-Barley-Spring	86.3	58	44	15	426	*457*	13	18	2	805	415	505	95	494
Straw-Barley-Winter	87.8	59	38	13	439	*451*	35	2	0	808	392	526	102	508
Straw-Wheat-Spring	88.3	68	37	14	434	*447*	10	12	1	818	736	535	95	516
Straw-Wheat-Winter	87.2	77	38	13	414	*458*	11	2	0	801	402	486	95	517
Straw-Pea	86.0	80	63	11	406	*440*	3	3	1	600	200	500	100	450
Hay-Vetch-Common-veg	86.9	108	250	28	236	*378*	56	13	2	417	211	306	99	284
Fodders-fresh														
Cabbage	10.6	113	207	17	96	*567*	316	5	0	586	234	129	-	140
Forage Pea (empty pod)	25.9	154	208	40	298	*300*	33	1	0	517	264	450	-	-
Beet-Sugar-Tops	16.0	212	125	31	100	*532*								
Pasture-mixed, veg	19.6	64	162	18	227	*529*	207	7	1	566	509	283	-	242
Lucerne-fresh	20.0	107	192	32	268	*401*	56	13	2	473	240	347	99	322
Silages														
Grass-silage-poor	38.4	96	152	27	306	*419*	32	5	0	595	279	363	73	343
Grass-silage-av=WCWS	26.5	88	151	35	293	*433*	17	1	1	546	276	332	60	333
Lucerne-silage	32.3	102	205	23	307	*363*	12	3	0	464	325	409	68	357
Maize-silage	30.4	49	88	30	172	*661*	5	250	100	390	273	231	23	215
Roots														
Carrots	13.0	69	92	15	108	*716*	-	-	-	200	-	-	-	-
Beet-Fodder-roots	18.3	76	63	3	53	*805*	649	1	0	127	-	68	21	83
Turnips-Stubble-whole	8.0	60	112	15	162	*651*	587	100	-	140	-	125	14	114
Energy feeds														
Maize-grain	87.3	15	104	39	20	*822*	18	700	210	117	23	28	6	28
Wheat-bran	88.0	68	178	46	107	*601*	64	196	59	496	86	151	45	140
Wheat-grain	86.8	24	123	19	20	*814*	58	660	198	166	29	32	11	28
Protein feeds														
Beans-faba-spring	86.6	38	342	13	74	*533*	50	360	50	195	-	123	15	111
Rapeseed-meal	89.9	77	418	23	108	*374*	103	40	3	279	141	198	87	187
Sunflower-cake	90.0	72	423	31	181	*293*	66	3	1	350	250	328	75	293

1. All analyses are on a per kg DM basis except DM which is per cent of fresh weight, and TDN as per cent DM
2. Values in italics have been estimated from the remaining data in this table

Annex Table 10.2. Feeds relevant for Central Tibet used in RUMNUT models: II. Nutritive Value - ME, DM digestibilities,& variables for estimation of MP

	DM	GE	DE	ME	FME	q	DOMD	TDN	NCD	CP	ADIN	Point dg	N-a	N-b	N-c
	%	MJ/kg	MJ/kg	MJ/kg	MJ/kg	ME/GE	g/kg	g/kg	g/kg	g/kg	g/kg	g/g	g/g	g/g	g/g
Hays & Straws															
Hay DOMD<450	87.0	18.1	7.5	6.1	5.6	0.34	422	368	*342*	90	*0.79*	*0.19*	*0.252*	*0.557*	0.101
Hay DOMD450-500	85.0	18.2	8.0	6.5	6.1	0.36	445	392	*369*	101	*0.81*	*0.25*	*0.243*	*0.569*	0.096
Hay DOMD500-550	85.0	18.4	10.0	8.1	7.5	0.44	538	488	*480*	109	*0.83*	*0.47*	*0.235*	*0.578*	0.093
Hay DOMD550-600	85.7	18.6	10.7	8.7	8.1	0.47	573	525	*521*	120	*0.85*	*0.56*	*0.225*	*0.590*	0.089
Hay DOMD600-650	85.7	18.5	11.9	9.6	9.0	0.52	621	579	574	131	*0.88*	*0.67*	*0.216*	*0.602*	0.084
Hay DOMD650-700	87.1	18.4	12.6	10.3	9.5	0.56	670	681	650	121	*0.86*	*0.79*	*0.225*	*0.591*	0.088
Hay DOMD>700	86.3	18.6	14.0	11.5	10.8	0.62	724	760	688	140	*0.90*	*0.92*	*0.207*	*0.612*	0.081
Straw-Barley-Spring	86.3	18.6	8.3	6.8	6.3	0.37	459	449	375	44	*0.69*	*0.28*	*0.294*	*0.507*	0.119
Straw-Barley-Winter	87.8	18.2	7.8	6.3	5.8	0.35	427	380	274	38	*0.68*	*0.21*	*0.299*	*0.500*	0.122
Straw-Wheat-Spring	88.3	17.9	7.2	5.8	5.3	0.32	407	350	355	37	*0.68*	*0.16*	*0.300*	*0.499*	0.122
Straw-Wheat-Winter	87.2	18.1	7.5	6.1	5.6	0.34	420	368	355	38	*0.68*	*0.19*	*0.299*	*0.500*	0.122
Straw-Pea	86.0	17.7	8.3	6.7	6.3	0.38	478	404	450	63	*0.73*	*0.33*	0.300	0.600	0.100
Hay-Vetch-Common-veg	86.9	18.6	12.3	10.0	9.0	0.54	646	601	718	250	1.40	0.60	0.560	0.380	0.040
Fodders-fresh															
Cabbage	10.6	17.6	16.9	13.7	13.1	0.78	816	826	-	207	0.80	0.60	0.114	0.597	0.035
Forage Pea (empty pod)	25.9	18.8	10.9	8.8	7.4	0.47	509	531	-	208	0.70	0.60	0.595	0.434	0.159
Beet-Sugar-Tops	16.0	15.4	12.2	9.9	8.8	0.64	620	597	-	125	1.60	0.60			
Pasture-mixed, veg	19.6	18.4	14.4	11.7	11.1	0.64	754	706	739	162	0.70	0.60	0.322	0.710	0.210
Lucerne-fresh	20.0	18.6	11.0	8.6	7.5	0.46	548	519	609	192	1.40	0.60	0.560	0.380	0.040
Silages															
Grass-silage-poor	38.4	18.6	11.4	9.2	7.3	0.49	576	555	563	152	0.70	0.80	0.453	0.534	0.030
Grass-silage-av=WCWS	26.5	19.5	12.8	10.4	8.1	0.53	670	627	618	151	0.80	0.60	0.630	0.260	0.070
Lucerne-silage	32.3	18.3	10.9	8.8	7.1	0.48	612	531	546	205	0.80	0.80	0.663	0.252	0.166
Maize-silage	30.4	18.5	13.8	11.2	9.0	0.61	700	675	700	88	0.70	0.80	0.693	0.163	0.054
Roots															
Carrots	13.0	17.4	15.8	12.8	12.3	0.74	810	772	-	92	1.00	0.80	-	-	-
Beet-Fodder-roots	18.3	16.2	14.7	11.9	11.8	0.73	822	718	874	63	0.50	0.80	0.250	0.650	0.440
Turnips-Stubble-whole	8.0	18.4	14.3	11.6	11.1	0.63	740	699	-	112	0.60	0.80	0.250	0.650	0.340
Energy feeds															
Maize-grain	87.3	18.9	17.0	13.8	12.6	0.73	879	832	927	104	0.30	0.60	0.260	0.690	0.100
Wheat-bran	88.0	18.9	13.3	10.8	9.2	0.57	693	651	800	178	1.00	0.60	0.130	0.800	0.130
Wheat-grain	86.8	18.2	16.8	13.6	12.9	0.75	884	820	927	123	0.24	0.80	0.450	0.510	0.380
Protein feeds															
Beans-faba-spring	86.6	18.6	16.8	13.6	13.1	0.73	880	820	-	342	0.50	0.40	0.420	0.560	0.160
Rapeseed-meal	89.9	19.5	14.8	12.0	11.2	0.62	724	724	766	418	1.00	0.60	0.320	0.610	0.160
Sunflower-cake	90.0	19.0	12.7	10.3	9.2	0.54	423	621	633	423	1.30	0.60	0.300	0.650	0.170

1. All analyses are on a per kg DM basis except DM which is per cent of fresh weight, and TDN as per cent DM
2. Values in italics have been estimated from the remaining data in this table

Annex Table 10.2. Feeds relevant for Central Tibet used in RUMNUT models

ADF	Acid detergent fibre	**References:**
ADIN	Acid Detergent Insoluble Nitrogen	
CF	Crude Fibre	**Agriculture and Food Research Council.** 1993. *Energy and protein requirements of ruminants*.
CP	Crude Protein	An advisory manual prepared by the AFRC Technical Committee on Responses to Nutrients.
DE	Digestible Energy	Wallingford, UK: CAB International.
DM	Dry Matter	
DM-a	DM degradation constant a = water soluble DM extracted by cold water rinsing	**Chamberlain, A.T. and Wilkinson, J.M**. 1996. *Feeding the Dairy Cow*. Lincoln, UK:
DM-b	DM degradation constant b = potentially degradable DM, other than water soluble DM	Chalcombe Publications.
DM-c	DM degradation constant c = fractional rate of degradation of feed DM per hour	
DOMD	Digestible Organic Matter in the Dry Matter	**Ministry of Agriculture, Fisheries and Food**. 1992. *UK Tables of Feed Composition and Nutritive Value*
EE	Ether Extract = Fats and oil	*for Ruminants.* Second edition. Canterbury, UK: Chalcombe Publications.
epNDF	effective Neutral Detergent Fibre = structural fibre	
FME	Fermentable Metabolisable Energy	**Ministry of Agriculture, Fisheries and Food. 1986.** *Feed Composition: UK Tables of Feed Composition*
GE	Gross Energy	*and Nutritive Value for Ruminants*. Marlow, UK: Chalcombe Publications.
Lignin	Lignin	
MADF	Modified Acid Detergent Fibre	
ME	Metabolisable Energy	
N-a	N degradation constant a = water soluble N extracted by cold water rinsing	
N-b	N degradation constant b = potentially degradable N, other than water soluble N	
N-c	N degradation constant c = fractional rate of degradation of feed N per hour	
NCD	Neutral detergent Cellulase Digestibility	
NDF	Neutral Detergen Fibre	
NFE	Nitrogen Free Extract = DM - TA - CP - EE - CF	
Point dg	Point degradability	
q	Metabolisability = ME/GE	
RRS	Rumen Resistant Starch	
Starch	Starch	
Sugar	Sugar	
TA	Total Ash	
TDN	Total Digestible Nutrients (%)	

Annex Table 10.3. Tables of Feed Composition and Nutritive Value for fodders and feedstuffs available in the Central region of Tibet

Feed, Species and Type	Source	DM %	ME MJ	TDN % DM	CP g	Fat g	NDF g	Sugars g	Starch g	Ca g	Mg g	P g
STRAWS												
Barley *[Hordeum vulgare]*												
Straw, Kenya	G	90	6.8	45	60	-	-	-	-	-	-	-
Straw, Iraq	G	92	6.5	43	25	-	-	-	-	-	-	-
Barley, Spring *[Hordeum vulgare]*												
Straw	CW	86	6.8	45	44	15	805	13	5	4.8	0.8	1.0
Barley, Winter *[Hordeum vulgare]*												
Straw	CW	88	6.3	42	38	13	808	35	-	4.0	1.0	0.8
Bean, French (Dwarf) *[Phaseolus vulgaris]*												
Haulm, Chile	G	89	-	-	63	-	-	-	-	11.5	-	0.9
Buckwheat, Common *[Fagopyrum sagittatum]*												
Straw	IFI	88	6.7	44	46	11	-	-	-	14.1	-	1.2
Maize, Dent, Yellow *[Zea mays indentata]*												
Straw, sun-cured, without ears and husks	IFI	87	7.6	50	49	13	809	-	-	5.4	3.8	1.0
Millet, Bulrush (Pearl) *[Pennisetum glaucum]*												
Straw, Tanzania	G	90	7.0	46	43	-	-	-	-	-	-	-
Oat *[Avena sativa]*												
Straw	IFI	91	7.8	51	44	22	708	-	-	2.4	1.7	0.7
Straw, Kenya	G	87	5.8	38	53	-	-	-	-	-	-	-
Oat, Winter *[Avena sativa]*												
Straw	CW	86	7.0	46	37	14	735	19	1	3.6	0.8	0.9
Pea *[Pisum sativum]*												
Haulm, Israel (after green pea harvest)	G	84	7.4	49	84	-	-	-	-	11.8	-	3.4
Haulm, sun-cured (after green pea harvest)	IFI	87	9.3	61	149	28	-	-	-	17.2	-	1.9
Straw	CW	86	6.7	44	63	11	-	-	-	-	-	-
Straw	IFI	88	8.8	58	109	20	-	-	-	-	-	-
Wheat *[Triticum aestivum]*												
Straw	IFI	91	7.1	47	38	19	786	-	-	2.2	1.3	0.5
Straw, Iraq	G	92	5.4	36	31	-	-	-	-	-	-	-
Wheat, Winter *[Triticum aestivum]*												
Straw	CW	87	6.1	40	38	13	801	11	-	3.7	0.9	0.8
STRAWS - TREATED												
Barley *[Hordeum vulgare]*												
Straw, NH_3 treated	CW	87	7.5	50	68	16	786	17	-	4.6	0.6	0.8
Wheat *[Triticum aestivum]*												
Straw, NH_3 treated	CW	87	7.4	49	69	14	770	13	-	4.0	0.7	0.8

1. All analyses per kg DM, except DM which is percent fresh weight, and TDN which is percent DM.
2. Definition of terms:

DM	Dry Matter (percent of fresh weight)	MJ	Megajoules (One million joules)
ME	Metabolisable Energy (MJ/kg DM)	NDF	Neutral Detergent Fibre (g/kg DM) = Cell Wall
TDN	Total Digestible Nutrients (percent of DM)	Ca	Calcium (g/kg DM)
CP	Crude Protein (g/kg DM) = N x 6.25	Mg	Magnesium (g/kg DM)
Fat	Fat (g/kg DM) = Ether Extract	P	Phosphorous (g/kg DM)

3. Sources:

CW	**Chamberlain, A.T. and Wilkinson, J.M**. 1996. *Feeding the dairy cow*. Lincoln, UK: Chalcombe Publications. ISBN0948 617 32 2	*Values are means of many samples*
G	**Gohl, B**. 1981. *Tropical feeds: feed information summaries and nutritive values*. Rome: Food and Agriculture Organization of United Nations.92-5-100463-3	*Values are from individual samples*
IFI	**Fonnesbeck, P. V., Lloyd, H., Obray, R. and Romesburg, S.** 1984. *IFI tables of feed composition*. Logan, Utah USA: International Feedstuffs Institute, Utah State University	*Values are means of many samples*
MAFF	**MAFF**. 1990. UK Tables of nutritive value and chemical composition of feedstuffs. Ministry of Agriculture, Fisheries and Food. Aberdeen, UK: Rowett Research Services.	*Values are means of many samples*

Feed, Species and Type	Source	DM %	ME MJ	TDN % DM	CP g	Fat g	NDF g	Sugars g	Starch g	Ca g	Mg g	P g
HAYS												
Clover, Red *[Trifolium pratense]*												
Hay, average, Chile	G	90	-	-	98	-	-	-	-	9.8	-	1.3
Hay, sun-cured, late vegetative	IFI	89	9.7	64	206	30	-	-	-	16.7	4.6	3.8
Hay, sun-cured, early bloom	IFI	88	9.9	65	162	26	-	-	-	14.4	4.1	3.2
Hay, sun-cured, mid bloom	IFI	88	10.2	67	163	45	-	-	-	17.2	-	3.1
Hay, sun-cured, full bloom	IFI	87	7.9	52	149	26	-	-	-	14.7	3.9	2.6
Hay, sun-cured, mature	IFI	91	8.5	56	129	24	-	-	-	11.8	3.5	2.1
Lucerne (Alfalfa) *[Medicago sativa]*												
Hay, pre bloom, South Africa	G	90	9.2	61	187	-	-	-	-	12.6	-	1.8
Hay, early bloom, South Africa	G	90	8.9	59	170	-	-	-	-	12.0	-	1.8
Hay, mid bloom, South Africa	G	90	8.8	58	154	-	-	-	-	10.9	-	1.6
Hay, sun-cured, early vegetative	IFI	90	9.9	65	267	43	377	-	-	16.1	2.0	3.7
Hay, sun-cured, late vegetative	IFI	90	9.8	65	222	32	419	-	-	15.2	2.1	2.9
Hay, sun-cured, early bloom	IFI	91	9.8	65	191	29	391	-	-	16.3	3.4	2.2
Hay, sun-cured, mid bloom	IFI	90	9.2	61	172	31	467	-	-	16.3	3.5	2.6
Hay, sun-cured, full bloom	IFI	90	8.7	57	170	33	496	-	-	12.1	2.7	2.4
Hay, sun-cured, milk stage	IFI	91	8.3	55	146	23	542	-	-	12.5	1.3	2.3
Hay, sun-cured, mature	IFI	92	8.4	55	161	29	550	-	-	12.4	3.5	2.1
Hay, UK	MAFF	87	8.5	56	183	13	493	-	-	-	-	-
Lupin (Lupine) *[Lupinus spp]*												
Hay, sun-cured	IFI	90	9.5	63	195	34	-	-	-	10.5	-	2.0
Maize *[Zea mays]*												
Hay, South Africa	G	86	9.1	60	70	-	-	-	-	-	-	-
Melilotus, Yellow *[Melilotus officinalis]*												
Hay, sun-cured, early vegetative	IFI	86	8.5	56	161	20	-	-	-	14.9	2.5	2.7
Hay, sun-cured, early bloom	IFI	83	9.8	65	168	14	-	-	-	-	-	-
Hay, sun-cured, full bloom	IFI	89	8.0	53	129	20	-	-	-	-	-	-
Hay, sun-cured, mature	IFI	92	7.9	53	121	11	-	-	-	10.7	6.2	1.8
Oat *[Avena sativa]*												
Hay, milk stage, Zimbabwe	G	83	8.4	56	108	-	-	-	-	-	-	-
Hay, sun-cured, early bloom	IFI	93	9.9	66	96	34	595	-	-	-	-	-
Hay, sun-cured, full bloom	IFI	87	9.9	66	92	23	-	-	-	3.0	14.8	3.5
Hay, sun-cured, milk stage	IFI	88	8.4	56	83	28	-	-	-	2.5	-	2.0
Hay, sun-cured, dough stage	IFI	92	8.1	54	94	32	66	-	-	2.4	1.8	2.2
Hay, sun-cured, mature	IFI	91	8.4	56	74	33	-	-	-	3.5	-	2.3
Pea *[Pisum sativum]*												
Hay, Israel	G	89	9.5	63	149	-	-	-	-	-	-	-
Haulm with pods, sun-cured	IFI	91	10.2	67	208	26	-	-	-	7.4	-	3.8
Hay, sun-cured	IFI	87	8.9	59	127	26	-	-	-	-	-	-
Pea, Forage (Field) *[Pisum sativum arvense]*												
Hay, sun-cured	IFI	90	9.5	63	172	36	-	-	-	13.9	3.3	2.7
Pea / Oat mixture *[Pisum spp / Avena sativa]*												
Hay, sun-cured	IFI	88	8.9	59	133	34	-	-	-	8.1	-	2.5
Prairie plants, USA mid-west [Mixed grasses and forbs]												
Hay, sun-cured, early vegetative	IFI	90	8.1	54	87	26	-	-	-	5.7	2.4	1.9
Hay, sun-cured, early bloom	IFI	91	7.7	51	76	31	-	-	-	4.3	-	1.4
Hay, sun-cured, mid bloom	IFI	94	7.6	50	60	22	-	-	-	-	-	-
Hay, sun-cured, full bloom	IFI	89	7.6	50	61	24	-	-	-	3.8	2.4	1.4
Hay, sun-cured, milk stage	IFI	90	8.0	53	66	27	-	-	-	5.2	3.9	0.8
Hay, sun-cured, mature	IFI	90	8.4	55	62	39	-	-	-	4.5		0.9
Hay, sun-cured, post ripe	IFI	93	7.6	50	47	26	-	-	-	4.6	2.8	1.8
Quackgrass (Couch, Twitch) *[Agropyron repens]*												
Hay, sun-cured, early vegetative	IFI	86	9.5	63	164	35	-	-	-	3.3	-	1.2
Hay, sun-cured, full bloom	IFI	92	9.0	59	108	27	-	-	-	3.9	-	1.8
Rye *[Secale cereale]*												
Hay, sun-cured, dough stage	IFI	93	8.3	55	105	23	-	-	-	3.3	1.3	1.9
Hay, sun-cured, mature	IFI	91	7.8	52	81	22	-	-	-	3.3	1.3	1.9
Ryegrass *[Lolium spp]*												
Hay DOMD >700	CW	86	11.5	76	140	21	560	167	1	5.0	1.3	3.1
Hay DOMD 650-700	CW	87	10.3	68	121	22	595	153	2	5.3	1.4	2.8
Hay DOMD 600-650	CW	86	9.6	63	131	18	650	93	1	6.3	1.6	3.0
Hay DOMD 550-600	CW	85	8.7	58	120	16	692	59	2	5.2	1.4	2.6
Hay DOMD 500-550	CW	85	8.1	54	109	16	699	68	2	5.0	1.5	2.7
Hay DOMD 450-500	CW	85	6.5	43	101	12	741	38	-	4.9	1.5	2.8
Hay DOMD <450	CW	87	6.1	40	90	14	752	38	-	3.7	1.6	2.0
Hay, barn cured, ME >10	MAFF	85	10.7	71	150	18	604	-	-	-	-	-
Hay, barn cured, ME 8 - 10	MAFF	86	9.0	59	113	16	672	-	-	-	-	-
Hay, barn cured, ME < 8	MAFF	87	7.3	48	68	17	644	-	-	-	-	-
Hay, sun cured, ME > 10	MAFF	87	10.1	67	114	13	650	-	-	-	-	-
Hay, sun cured, ME 8 - 10	MAFF	87	9.0	59	95	16	676	-	-	-	-	-
Hay, sun cured, ME < 8	MAFF	86	7.4	49	84	14	709	-	-	-	-	-

Feed, Species and Type	Source	DM %	ME MJ	TDN % DM	CP g	Fat g	NDF g	Sugars g	Starch g	Ca g	Mg g	P g
HAYS (Continued)												
Sainfoin, Common *[Onobrychis viciifolia]*												
Hay, sun-cured, early bloom	IFI	88	10.2	67	226	38	-	-	-	7.8	3.9	2.9
Hay, sun-cured, full bloom	IFI	90	8.3	55	123	16	453	-	-	7.8	3.9	2.9
Turnip *[Brassica rapa var. rapa]*												
Hay, sun-cured, aerial part	IFI	88	8.8	58	151	16	-	-	-	-	-	-
Vetch *[Vicia spp]*												
Hay, sun-cured, early vegetative	IFI	92	10.6	70	211	52	387	-	-	-	-	-
Hay, sun-cured, late vegetative	IFI	92	-	-	196	-	432	-	-	-	-	-
Hay, sun-cured, mid bloom	IFI	91	10.3	68	226	48	517	-	-	-	-	-
Hay, sun-cured, full bloom	IFI	87	8.4	56	160	19	-	-	-	10.2	2.2	2.8
Hay, sun-cured, late bloom	IFI	92	-	-	100	-	577	-	-	-	-	-
Hay, sun-cured, milk stage	IFI	93	-	-	100	-	629	-	-	-	-	-
Hay, sun-cured, dough stage	IFI	91	8.0	53	118	21	695	-	-	-	-	-
Hay, sun-cured, mature	IFI	92	-	-	106	-	723	-	-	-	-	-
Vetch, Common *[Vicia sativa]*												
Hay, sun-cured, early vegetative	IFI	87	9.7	64	256	28	-	-	-	-	-	-
Hay, sun-cured, early bloom	IFI	85	9.2	61	222	28	-	-	-	7.4	1.9	3.6
Hay, sun-cured, full bloom	IFI	87	8.4	56	181	19	350	-	-	-	-	-
Hay, sun-cured, dough stage	IFI	89	8.7	58	151	25	-	-	-	-	-	-
Hay, Israel	G	89	9.6	64	190	-	-	-	-	11.1	-	3.0
Vetch, Hairy *[Vicia villosa]*												
Hay, sun-cured, early vegetative	IFI	89	9.4	62	226	-	-	-	-	12.3	2.3	3.6
Vetch / Oats mixture *[Vicia spp / Avena sativa]*												
Hay, sun-cured	IFI	87	8.0	53	92	29	-	-	-	7.2	-	2.8
Vetch / Wheat mixture *[Vicia spp / Triticum aestivum]*												
Hay, sun-cured	IFI	90	8.8	58	171	24	-	-	-	-	-	-
Wheat *[Triticum aestivum]*												
Hay, sun-cured, milk stage	IFI	84	9.0	59	91	19	-	-	-	1.5	1.2	2.1
Hay, sun-cured, dough stage	IFI	83	8.7	57	80	23	-	-	-	-	-	-
Hay, sun-cured, mature	IFI	89	7.8	51	79	17	632	-	-	1.4	-	2.0
LEAF MEALS												
Beet, Sugar *[Beta vulgaris altissima]*												
Dried tops, (leaves plus crown), Israel	G	80	11.0	72	164	-	-	-	-	-	-	-
Lucerne (Alfalfa) *[Medicago sativa]*												
Leaf meal, South Africa	G	90	9.5	63	217	-	-	-	-	14.4	2.0	-
Leaves, meal	IFI	91	10.2	67	234	37	-	-	-	17.5	3.8	2.7
Leaves, sun-cured	IFI	89	10.6	70	281	38	-	-	-	25.5	4.1	2.8
Stems, sun-cured	IFI	89	7.8	51	121	16	-	-	-	9.3	2.9	1.6
Melilotus, Yellow *[Melilotus officinalis]*												
Leaves, sun-cured	IFI	91	9.7	64	280	35	-	-	-	31.2	-	3.2
Stems, sun-cured	IFI	92	7.2	48	106	12	-	-	-	6.2	-	3.3
Potato *[Solanum tuberosum]*												
Leaf meal, India	G	91	-	-	175	-	-	-	-	13.9	1.4	-
FRESH FORAGE												
Barley *[Hordeum vulgare]*												
Fresh, Whole crop	CW	25	10.0	66	162	16	-	-	-	4.9	1.5	2.5
Fresh, 7 weeks, South Africa	G	18	11.9	79	227	-	-	-	-	-	-	-
Fresh, 8 weeks, South Africa	G	19	11.6	77	204	-	-	-	-	-	-	-
Fresh, 9 weeks, South Africa	G	21	11.4	75	172	-	-	-	-	-	-	-
Fresh, 10 weeks, South Africa	G	21	11.6	77	148	-	-	-	-	-	-	-
Fresh, 11 weeks, South Africa	G	22	11.6	77	117	-	-	-	-	-	-	-
Fresh, 12 weeks, South Africa	G	22	11.5	76	113	-	-	-	-	-	-	-
Fresh, 13 weeks, South Africa	G	23	11.5	76	104	-	-	-	-	-	-	-
Beet, Sugar *[Beta vulgaris altissima]*												
Fresh, Tops	CW	16	9.9	65	125	31	-	-	-	8.6	-	2.8
Fresh, leaves, Chile	G	13			179	-	-	-	-	19.6	-	4.0
Fresh, tops (leaves plus crown), Israel	G	25	11.3	74	91	-	-	-	-	-	-	-
Cabbage *[Brassica oleracea capitata]*												
Fresh	CW	11	13.7	91	207	17	244	316	4	8.3	1.5	1.9
Fresh, aerial part	IFI	9	10.9	72	209	31	-	-	-	5.9	2.1	3.7
Fresh, outside leaves	IFI	12	10.0	66	180	34	-	-	-	8.7	3.4	2.1
Carrot *[Daucus spp]*												
Fresh, aerial part	G	16	10.2	67	121	-	-	-	-	-	-	-

Feed, Species and Type	Source	DM %	ME MJ	TDN % DM	CP g	Fat g	NDF g	Sugars g	Starch g	Ca g	Mg g	P g
FRESH FORAGE (Continued)												
Clover, Red *[Trifolium pratense]*												
Fresh, immature, USSR	G	21	11.8	78	280	-	-	-	-	-	-	-
Fresh, mid bloom, USSR	G	25	10.7	71	161	-	-	-	-	-	-	-
Fresh, post bloom, USSR	G	40	9.5	63	98	-	-	-	-	-	-	-
Kale *[Brassica oleraca convar.acaphala var.medullosa]*												
Fresh	CW	13	11.8	78	164	-	-	-	-	12.5	1.5	3.9
Lucerne (Alfalfa) *[Medicago sativa]*												
Fresh, pre bloom, Israel	G	17	10.3	68	253	-	-	-	-	25.6	-	3.1
Fresh, early bloom, Israel	G	23	9.9	65	229	-	-	-	-	17.6	-	2.4
Fresh, mid bloom, Israel	G	29	8.4	56	190	-	-	-	-	14.4	-	2.0
Fresh, late vegetative	IFI	23	9.1	60	225	28	343	-	-	15.6	3.0	3.0
Fresh, early bloom	IFI	24	10.0	66	226	31	369	-	-	16.3	4.6	2.7
Fresh, mid bloom	IFI	26	9.3	62	217	26	433	-	-	15.9	4.1	3.0
Fresh, full bloom	IFI	28	9.6	64	194	21	462	-	-	16.7	3.7	2.4
Fresh, milk stage	IFI	30	8.5	56	141	28	516	-	-	12.3	-	2.0
Lupin (Lupine) *[Lupinus spp]*												
Fresh	IFI	16	9.7	64	200	31	-	-	-	12.8	-	2.5
Maize *[Zea mays]*												
Fresh, 8 weeks, Israel	G	16	9.9	66	89	-	-	-	-	-	-	-
Fresh, 10 weeks, Israel	G	22	9.3	61	100	-	-	-	-	-	-	-
Fresh, mid bloom, fertilized	G	24	9.7	64	95	-	-	-	-	-	-	-
Fresh, milk stage, 200cm, Tanzania	G	17	9.8	65	88	-	-	-	-	-	-	-
Maize, Dent, Yellow *[Zea mays indentata]*												
Fresh, milk stage	IFI	18	10.1	67	93	23	-	-	-	2.9	5.3	2.1
Maize, Sweetcorn *[Zea mays saccharata]*												
Fresh, aerial part without ears and husks	IFI	22	10.0	66	73	18	-	-	-	-	-	-
Fresh, mature	IFI	18	10.5	69	117	30	-	-	-	-	-	2.0
Melilotus indica *[Melilotus indica]*												
Fresh, aerial part, India	G	22	9.7	64	153	-	-	-	-	-	-	-
Melilotus, Yellow *[Melilotus officinalis]*												
Fresh, early vegetative	IFI	20	10.8	71	217	32	-	-	-	17.3	3.0	4.4
Fresh, late vegetative	IFI	19	11.0	73	206	34	-	-	-	16.4	-	4.0
Fresh, early bloom	IFI	21	9.6	64	174	27	-	-	-	-	-	-
Fresh, mid bloom	IFI	29	9.8	65	168	27	-	-	-	12.3	3.4	2.4
Fresh, full bloom	IFI	33	10.0	66	168	25	-	-	-	13.0	3.4	2.2
Fresh, milk stage	IFI	39	9.0	59	90	21	-	-	-	-	-	-
Oat *[Avena sativa]*												
Fresh, 2 month, Israel	G	11	9.1	60	182	-	-	-	-	-	-	-
Fresh, 3-4 month, Israel	G	14	9.0	60	128	-	-	-	-	-	-	-
Fresh, early bloom, Israel	G	23	8.7	58	79	-	-	-	-	-	-	-
Fresh, late vegetative	IFI	20	11.8	78	173	36	472	-	-	2.8	4.3	3.8
Fresh, early bloom	IFI	25	9.4	62	142	31	552	-	-	3.4	-	3.4
Fresh, milk stage	IFI	29	9.8	65	88	35	645	-	-	5.1	1.0	1.4
Fresh, dough stage	IFI	31	9.3	61	86	31	580	-	-	3.2	2.0	2.3
Pea *[Pisum sativum]*												
Fresh, late vegetative, Israel	G	13	10.4	69	172	-	-	-	-	18.7	-	3.7
Fresh, mid bloom, Israel	G	15	10.1	67	145	-	-	-	-	18.4	-	4.0
Pea, Forage (Field) *[Pisum sativum arvense]*												
Fresh	CW	26	8.8	58	208	40	517	33	1	12.7	2.0	4.4
Potato *[Solanum tuberosum]*												
Haulm	G	23	6.6	44	175	-	-	-	-	-	-	-
Quackgrass (Couch, Twitch) *[Agropyron repens]*												
Fresh, early bloom	IFI	32	9.2	61	72	28	-	-	-	2.8	-	2.2
Fresh, mature	IFI	32	9.2	61	70	27	-	-	-	2.8	-	2.2
Rape *[Brassica napus]*												
Fresh	CW	14	9.5	63	200	57	-	-	-	9.3	2.1	4.2
Fresh, early vegetative	IFI	32	11.1	73	164	40	-	-	-	14.4	6.0	4.2
Rye *[Secale cereale]*												
Fresh, Forage	CW	23	9.5	63	126	39	-	-	-	-	-	-
Fresh, early bloom	IFI	21	9.5	63	150	44	-	-	-	5.1	3.1	3.4
Fresh, dough stage	IFI	33	11.9	79	134	35	-	-	-	2.8	-	3.0
Ryegrass *[Lolium spp]*												
Fresh DOMD >800	CW	21	12.6	83	190	24	488	248	-	5.3	1.3	2.5
Fresh DOMD 750-800	CW	22	12.3	81	190	25	531	187	3	5.2	1.5	3.2
Fresh DOMD 700-750	CW	21	11.2	74	139	22	576	174	3	4.9	1.4	2.9
Fresh DOMD 650-700	CW	21	10.7	71	121	20	610	161	3	4.6	1.4	2.7
Fresh DOMD 600-650	CW	23	9.8	65	106	19	629	154	3	4.4	1.4	2.5
Fresh DOMD 550-600	CW	20	7.5	50	97	16	664	126	3	4.8	1.2	2.8

Feed, Species and Type	Source	DM %	ME MJ	TDN % DM	CP g	Fat g	NDF g	Sugars g	Starch g	Ca g	Mg g	P g
FRESH FORAGE (Continued)												
Ryegrass, Italian *[Lolium multiflorum]*												
Fresh	CW	22	11.4	75	128	22	534	232	-	4.7	1.3	2.9
Sainfoin, Common *[Onobrychis viciifolia]*												
Fresh	IFI	24	10.1	67	141	27	522	-	-	16.8	3.7	2.3
Sunflower *[Helianthus annus]*												
Fresh, 7 weeks, Israel	G	11	9.8	65	130	-	-	-	-	16.7	-	3.7
Fresh, 10 weeks, Israel	G	15			103							
Turnip *[Brassica rapa var. rapa]*												
Fresh, aerial part	IFI	13	10.5	69	207	29	-	-	-	29.3	5.4	3.9
Vetch *[Vicia spp]*												
Fresh, late vegetative	IFI	24	9.8	65	210	22	-	-	-	-	-	-
Vetch, Common *[Vicia sativa]*												
Fresh, early vegetative, Kenya	G	-	-	-	359	-	-	-	-	4.9	-	6.1
Fresh, early bloom, Kenya	G	-	-	-	265	-	-	-	-	9.7	-	4.2
Fresh, full bloom, Kenya	G	-	-	-	186	-	-	-	-	12.8	-	2.6
Fresh, 10 weeks, Israel	G	17	10.0	66	229	-	-	-	-	9.6	-	3.0
Fresh	IFI	20	10.0	66	189	29	-	-	-	15.6	2.0	3.1
Vetch, Hairy *[Vicia villosa]*												
Fresh	IFI	18	10.2	67	238	35	-	-	-	11.0	-	3.3
Vetch / Oats mixture *[Vicia spp / Avena sativa]*												
Fresh	IFI	25	9.2	61	100	43	-	-	-	6.3	2.3	2.8
Vetch / Wheat mixture *[Vicia spp / Triticum aestivum]*												
Fresh	IFI	19	10.0	66	137	-	-	-	-	-	-	-
Wheat *[Triticum aestivum]*												
Fresh, 16 weeks, South Africa	G	30	12.6	83	181	-	-	-	-	-	-	-
Fresh, 19 weeks, South Africa	G	31	12.5	82	123	-	-	-	-	-	-	-
Fresh, 20 weeks, South Africa	G	34	12.1	80	108	-	-	-	-	-	-	-
Fresh, 21 weeks, South Africa	G	35	11.9	79	104	-	-	-	-	-	-	-
Fresh, 22 weeks, South Africa	G	35	11.6	77	85	-	-	-	-	-	-	-
Fresh, 23 weeks, South Africa	G	34	11.7	77	86	-	-	-	-	-	-	-
Fresh	IFI	27	12.9	85	132	30	-	-	-	3.7	-	3.1
Fresh, early vegetative	IFI	22	12.7	84	261	39	462	-	-	4.2	2.1	4.0
SILAGES												
Barley *[Hordeum vulgare]*												
Silage, whole crop	MAFF	41	11.5	76	90	20	575	33	234	2.4	0.8	2.3
Bean, Faba (Broad) *[Vicia faba]*												
Silage, whole crop	MAFF	24	8.2	54	172	12	566	30	2	6.5	1.7	3.4
Silage, whole crop	IFI	32	9.1	60	189	-	481	-	-	8.7	-	2.8
Silage, whole crop, dough stage	IFI	37	-	-	202	-	-	-	-	9.0	-	2.5
Beet, Sugar *[Beta vulgaris altissima]*												
Silage, tops (leaves plus crown)	MAFF	21	10.3	68	174	38	-	-	-	15.7	6.7	2.0
Silage, tops (leaves plus crown), Chile	G	22	9.2	61	106	-	-	-	-	-	-	-
Clover, mixed *[Trifolium spp]*												
Silage	MAFF	24	10.3	68	233	36	440	20	2	16.7	2.3	3.1
Clover, Red *[Trifolium pratense]*												
Silage, Chile	G	23	-	-	142	-	-	-	-	-	-	-
Silage	IFI	27	10.4	69	140	39	507	-	-	-	-	-
Silage, early bloom	IFI	25	8.7	57	165	34	-	-	-	-	-	-
Lucerne (Alfalfa) *[Medicago sativa]*												
Silage	CW	34	8.0	53	194	25	495	12	4	17.6	1.8	3.0
Silage, early vegetative	IFI	32	9.9	65	212	38	-	-	-	19.5	2.6	4.0
Silage, late vegetative	IFI	22	8.7	58	197	42	-	-	-	-	-	-
Silage, early bloom	IFI	28	8.4	56	176	32	-	-	-	14.9	3.0	2.7
Silage, mid bloom	IFI	34	9.3	62	173	34	-	-	-	12.8	3.5	2.0
Silage, full bloom	IFI	26	8.8	58	171	33	-	-	-	-	-	-
Silage, mature	IFI	32	8.4	55	144	31	-	-	-	18.4	3.5	1.7
Silage, molasses added, early vegetative	IFI	32	9.9	65	210	40	-	-	-	-	-	-
Silage, molasses added, late vegetative	IFI	25	10.5	70	212	43	-	-	-	-	-	-
Silage, molasses added, early bloom	IFI	30	9.3	61	154	47	-	-	-	-	-	-
Silage, molasses added, mid bloom	IFI	31	9.1	60	168	31	-	-	-	-	-	-
Silage, molasses added, full bloom	IFI	28	9.0	60	161	30	-	-	-	-	-	-
Silage, wilted, early vegetative	IFI	37	9.7	64	208	38	-	-	-	-	-	-
Silage, wilted, late vegetative	IFI	35	9.8	65	207	40	-	-	-	-	-	-
Silage, wilted, early bloom	IFI	35	7.9	52	167	32	-	-	-	-	-	-
Silage, wilted, mid bloom	IFI	38	9.5	63	168	31	-	-	-	-	-	-
Silage wilted, molasses added, late vegetative	IFI	39	9.7	64	210	37	-	-	-	-	-	-

Feed, Species and Type	Source	DM %	ME MJ	TDN % DM	CP g	Fat g	NDF g	Sugars g	Starch g	Ca g	Mg g	P g
SILAGES (Continued)												
Maize *[Zea mays]*												
Silage	CW	30	11.5	76	88	30	390	5	206	3.9	2.4	1.8
Maize, Dent, Yellow *[Zea mays indentata]*												
Silage, few ears	IFI	29	9.0	60	84	30	550	-	-	3.4	2.3	1.9
Silage, well eared	IFI	29	10.0	66	82	29	480	-	-	3.1	2.0	2.3
Silage, milk stage	IFI	22	9.5	63	94	28	584	-	-	4.5	2.3	2.4
Silage, dough stage	IFI	30	11.0	73	80	32	595	-	-	4.1	1.0	1.8
Silage, aerial part less ears less husks, mature	IFI	25	8.6	57	66	25	-	-	-	3.4	-	4.2
Maize, Sweetcorn *[Zea mays saccharata]*												
Silage	IFI	22	10.1	67	104	43	-	-	-	2.8	2.1	2.4
Oat *[Avena sativa]*												
Silage, UK	G	24	8.4	56	80	25	-	-	-	-	-	-
Silage, late vegetative	IFI	23	11.3	74	127	25	-	-	-	-	-	0.1
Silage, full bloom, wilted	IFI	58	9.4	62	96	32	-	-	-	-	-	-
Silage, milk stage	IFI	29	9.5	63	87	28	-	-	-	-	-	-
Silage, dough stage	IFI	35	8.4	55	96	41	511	-	-	4.7	-	3.3
Pea *[Pisum sativum]*												
Silage, whole crop	MAFF	28	11.1	73	179	35	280	72	6	12.6	2.2	3.0
Silage, empty pods	G	28	11.0	73	127	-	-	-	-	-	-	-
Silage, haulm (vines)	G	24	9.2	61	148	-	-	-	-	-	-	-
Silage, haulm with pods	IFI	25	8.5	56	131	33	-	-	-	13.1	3.9	2.4
Pea, Forage (Field) *[Pisum sativum arvense]*												
Silage	IFI	27	9.7	64	141	16	244	-	-	13.6	3.9	2.9
Pea / Oat mixture *[Pisum spp / Avena sativa]*												
Silage	IFI	26	8.6	57	109	34	-	-	-	-	-	-
Potato *[Solanum tuberosum]*												
Silage, haulm	G	25	6.5	43	128	-	-	-	-	-	-	-
Ryegrass *[Lolium spp]*												
Silage, Big Bale	MAFF	37	10.1	67	159	31	605	42	4	6.3	1.9	3.1
Silage, Clamp	MAFF	27	10.0	66	170	44	578	18	8	6.4	1.7	3.2
Silage very good	CW	21	11.1	73	171	51	483	19	-	6.0	1.5	3.0
Silage good	CW	27	10.8	71	156	37	523	21	10	5.8	1.6	3.1
Silage average	CW	27	10.4	69	151	35	546	17	7	6.8	1.3	2.9
Silage poor	CW	38	9.2	61	152	27	595	32	5	6.3	2.1	2.7
Silage very poor	CW	32	8.4	56	160	31	603	15	-	8.4	1.7	3.2
Sorghum, dual purpose *[Sorghum bicolor]*												
Silage, dough stage, USA	G	24	9.5	63	73	-	-	-	-	-	-	-
Sorghum, grain variety *[Sorghum bicolor]*												
Silage, mature, USA	G	30	9.9	66	80	-	-	-	-	-	-	-
Sorghum, sweet hybrid *[Sorghum bicolor x Sorghum sudanense]*												
Silage, dough stage, USA	G	27	9.4	62	75	-	-	-	-	-	-	-
Sunflower *[Helianthus annus]*												
Silage, mid bloom, Canada	G	24	8.5	56	141	-	-	-	-	-	-	-
Silage, late vegetative	IFI	26	8.5	56	102	28	-	-	-	-	-	-
Silage, early bloom	IFI	21	8.8	58	97	25	-	-	-	-	-	-
Silage, mid bloom	IFI	21	8.2	54	96	48	-	-	-	-	-	-
Silage, full bloom	IFI	16	9.4	62	96	31	-	-	-	-	-	-
Silage, late bloom	IFI	26	7.1	47	82	21	-	-	-	-	-	-
Silage, milk stage	IFI	21	8.6	57	97	59	-	-	-	-	-	-
Silage, dough stage	IFI	22	9.7	64	78	79	-	-	-	16.6	5.9	2.3
Silage, mature	IFI	25	6.9	45	82	43	-	-	-	15.4	-	1.8
Turnip *[Brassica rapa var. rapa]*												
Silage, aerial part	IFI	14	10.5	69	148	31	-	-	-	28.7	4.7	5.8
Vetch / Oats mixture *[Vicia spp / Avena sativa]*												
Silage	IFI	27	9.2	61	100	43	-	-	-	10.5	-	2.5
Wheat *[Triticum aestivum]*												
Silage	IFI	31	9.3	61	109	34	-	-	-	3.2	1.0	2.6
Silage, early vegetative	IFI	30	9.3	61	117	34	520	-	-	2.7	6.2	2.7
Urea whole-crop	CW	55	10.4	69	230	15	500	20	216	2.0	1.0	2.5

Feed, Species and Type	Source	DM %	ME MJ	TDN % DM	CP g	Fat g	NDF g	Sugars g	Starch g	Ca g	Mg g	P g
ENERGY FEEDS - Dry												
Barley *[Hordeum vulgare]*												
Bran, Israel	G	89	11.5	76	134	-	-	-	-	3.3	-	6.7
Grain	CW	87	13.3	88	129	16	201	37	562	0.9	1.2	4.0
Grain, Israel	G	90	12.8	85	120	-	-	-	-	0.6	-	4.2
Barley, Spring [*Hordeum vulgare*]												
Grain	MAFF	87	12.8	85	128	14	207	28	572	0.7	1.1	4.0
Barley, Winter *[Hordeum vulgare]*												
Grain	MAFF	86	12.9	85	130	18	178	14	585	0.8	1.2	3.9
Beet, Sugar *[Beta vulgaris altissima]*												
Pulp, extracted, dry, molassed	CW	86	12.5	83	129	4	294	296	5	5.9	1.0	0.7
Pulp, extracted, dry,un-molassed	CW	86	12.9	85	77	7	372	79	3	7.6	1.8	0.8
Buckwheat, Common *[Fagopyrum sagittatum]*												
Grain	IFI	88	11.2	74	127	26	-	-	-	1.1	1.2	3.7
Groats	IFI	89	13.0	86	154	35	-	-	-	0.4	4.4	4.5
Maize *[Zea mays]*												
Bran	CW	88	13.4	89	148	31	538	-	-	0.3	1.4	3.0
Corn-and -cob meal, South Africa	G	88	13.5	89	94	-	-	-	-	0.4	-	2.3
Grain	CW	87	13.8	91	104	39	117	18	700	0.1	1.3	3.0
Grain, Israel	G	87	14.5	96	110	-	-	-	-	0.1	-	3.2
Maize, Dent, White *[Zea mays indentata]*												
Grain	IFI	90	13.1	87	116	40	-	-	-	0.4	-	3.1
Maize, Dent, Yellow *[Zea mays indentata]*												
Bran	IFI	88	13.1	86	102	58	610	-	-	0.4	2.9	3.3
Grain	IFI	88	13.2	87	104	44	112	-	-	0.5	1.2	3.2
Oat *[Avena sativa]*												
Grain	CW	85	12.1	80	105	41	310	-	471	0.9	3.0	3.4
Grain	IFI	90	12.3	81	123	56	273	-	-	-	-	-
Rape *[Brassica napus]*												
Seeds, whole	IFI	92	19.1	126	279	361	-	-	-	4.1	-	6.3
Rye *[Secale cereale]*												
Grain, Israel	G	90	13.7	90	137	-	-	-	-	0.4	-	4.1
Sunflower *[Helianthus annus]*												
Heads with seeds, mature, South Africa	G	90	12.3	81	127	-	-	-	-	6.3	-	0.8
Triticale *[Triticum aestivum x Secale cereale]*												
Grain	MAFF	86	13.2	87	138	16	118	84	516	0.5	1.2	4.3
Wheat *[Triticum aestivum]*												
Grain	CW	87	13.6	90	123	19	166	58	660	0.6	1.1	3.4
Grain, Israel	G	89	13.9	92	135	-	-	-	-	0.3	-	4.8
Grain	IFI	89	13.3	88	142	24	104	-	-	0.7	1.6	3.9
Screenings, Iraq	G	93	-	-	161	-	-	-	-	-	-	-
Screenings	IFI	89	10.8	71	151	34	105	-	-	-	-	-
ENERGY FEEDS - Fresh Roots												
Beet, Fodder *[Beta vulgaris]*												
Roots, fresh	CW	18	11.9	79	63	3	136	660	1	2.8	1.6	1.8
Beet, Sugar *[Beta vulgaris altissima]*												
Fresh tubers, Chile	G	17	13.4	89	74	-	-	-	-	2.6	-	2.1
Carrot *[Daucus spp]*												
Fresh tubers	G	13	13.2	87	127							
Roots, fresh	CW	13	12.8	85	92	15	200	-	-	5.9	1.8	3.4
Roots, fresh	IFI	12	12.9	85	98	15	-	-	-	-	-	-
Mangold (Mangel) *[Beta vulgaris macrorrhiza]*												
Fresh bulbs, India	G	8	11.2	74	130	-	-	-	-	2.4	-	4.2
Roots, fresh	IFI	11	12.9	85	116	7	-	-	-	1.8	2.0	2.2
Potato *[Solanum tuberosum]*												
Fresh tubers, Israel	G	20	12.3	82	103	-	-	-	-	1.0	-	2.5
Tubers	CW	20	13.4	89	108	2	73	73	565	0.4	1.0	2.0
Swede *[Brassica napus var napobrassica]*												
Roots, fresh	MAFF	10	13.6	90	90	4	140	587	-	3.5	1.1	2.6
Turnip *[Brassica rapa var. rapa]*												
Roots, fresh	IFI	9	13.8	91	202	20	-	-	-	5.9	2.0	4.0
Turnip, Stubble *[Brissica rapa var. rapa]*												
Whole (tops plus bulbs)	CW	8	11.6	77	112	-	-	-	-	-	-	-

Feed, Species and Type	Source	DM %	ME MJ	TDN % DM	CP g	Fat g	NDF g	Sugars g	Starch g	Ca g	Mg g	P g
PROTEIN FEEDS												
Bean, Faba (Broad) *[Vicia faba]*												
Seeds	IFI	91	12.6	83	293	17	360	-	-	1.8	0.9	4.2
Bean, Faba (Broad), Spring *[Vicia faba]*												
Seeds	CW	87	13.4	89	333	13	186	-	365	1.1	1.8	5.2
Bean, Faba (Broad), Winter *[Vicia faba]*												
Seeds	CW	85	13.1	87	267	13	167	-	395	1.3	1.9	8.6
Bean, French (Dwarf) *[Phaseolus vulgaris]*												
Seeds, Chile	G	87	-	-	242	-	-	-	-	2.6	-	4.3
Seeds, Congo	G	92	14.1	93	255	-	-	-	-	-	-	-
Cotton *[Gossypium spp]*												
Whole seed	CW	90	13.8	91	250	200	390	-	-	1.3	3.5	5.7
Whole seed, India	G	94	10.3	68	206	-	-	-	-	-	-	-
Seed Cake (Meal)	CW	94	11.1	73	375	64	385	68	17	2.1	5.8	8.9
Oilcake plus hulls, mechanical extraction, Israel	G	91	10.8	72	269	-	-	-	-	2.2	-	6.3
Oilcake minus hulls, mechanical extraction, Israel	G	92	12.8	85	477	-	-	-	-	2.2	-	13.4
Seed meal, mechanical extraction, 36% protein	IFI	92	11.9	79	405	56	230	-	-	1.9	7.1	10.6
Seed meal, mechanical extraction, 41% protein	IFI	93	11.0	73	443	51	267	-	-	2.0	5.8	11.7
Seed meal, mechanical extraction, 43% protein	IFI	93	13.3	88	463	80	-	-	-	2.1	5.9	10.5
Lupin, White *[Lupinus albus]*												
Seeds	IFI	94	13.0	86	337	75	-	-	-	-	-	-
Pea *[Pisum sativum]*												
Seeds, Uganda	G	89	13.4	89	253	-	-	-	-	-	-	-
Seeds	CW	87	13.5	89	261	14	116	25	440	1.0	1.6	5.8
Seeds	IFI	89	14.3	94	260	12	195	-	-	1.4	1.4	4.6
Pea, Forage (Field) *[Pisum sativum arvense]*												
Seeds	IFI	92	13.0	86	256	16	244	-	-	1.5	1.3	4.3
Peanut (Groundnut) *[Arachis hypogaea]*												
Pods plus seeds, meal mechanical extraction	IFI	92	12.2	81	466	78	-	-	-	2.2	3.6	6.4
Pods plus seeds, meal solvent extraction)	IFI	92	10.7	71	492	12	-	-	-	2.3	0.4	6.9
Seeds minus coats, meal mechanical extraction	IFI	92	12.3	81	522	65	142	-	-	2.2	2.8	6.3
Seeds minus coats, meal solvent extraction	IFI	92	12.5	82	530	16	-	-	-	2.3	11.1	6.9
Rape *[Brassica napus]*												
Seeds, whole	IFI	92	19.1	126	279	361	-	-	-	4.1	-	6.3
Seeds, meal mechanical extraction	IFI	92	12.8	84	382	78	-	-	-	7.2	5.4	11.4
Seeds, meal solvent extraction	IFI	91	12.7	84	405	19	-	-	-	6.6	4.8	10.6
Rapeseed *[Brassica napus / Brassica rapa]*												
Meal, solvent extraction	CW	89	12.0	79	418	23	279	103	40	7.8	4.5	12.0
Oilcake, mechanical extraction, India	G	88	11.6	77	360	-	-	-	-	8.3	-	11.7
Rye *[Secale cereale]*												
Bran, Israel	G	88	11.3	74	170	-	-	-	-	-	-	-
Soya bean (Soybean) *[Glycine max]*												
Grain, whole	CW	90	15.5	102	408	222	122	84	15	2.7	2.4	5.9
Meal, mechanical extraction	CW	90	13.5	89	504	66	290	-	-	2.3	3.0	9.7
Meal, solvent extraction	CW	88	13.4	89	507	16	154	107	11	4.5	2.9	7.6
Oilmeal plus hulls, solvent extraction, Israel	G	89	14.5	96	499	-	-	-	-	2.0	-	7.4
Sunflower *[Helianthus annus]*												
Seeds with hulls, Chile	G	94	17.9	118	123	-	-	-	-	2.1	-	5.9
Meal, solvent extraction	CW	90	9.6	63	335	23	473	66	3	4.8	5.8	10.8
Seeds with hulls, meal, solvent extraction	IFI	89	6.0	40	339	20	-	-	-	4.8	6.7	11.9
Seeds without hulls, meal, mechanical extraction	IFI	88	11.2	74	456	90	-	-	-	4.4	7.2	11.5
Seeds without hulls, meal, solvent extracted	IFI	93	10.2	67	467	29	-	-	-	4.5	7.4	10.1
Urea												
Chemical	CW	99	0.0	0	2875	0	0	0	0	0.0	0.0	0.0
Wheat *[Triticum aestivum]*												
Bran	CW	89	10.8	71	178	39	475	-	196	1.1	6.2	12.6
Bran, Tanzania	G	88	-	0	169	-	-	-	-	-	-	-
Bran	IFI	89	10.5	69	174	44	471			1.6	5.9	11.4
Distillers' grains	CW	90	12.4	82	322	55	335	86	45	1.8	2.8	8.8

Feed, Species and Type	Source	DM %	ME MJ	TDN % DM	CP g	Fat g	NDF g	Sugars g	Starch g	Ca g	Mg g	P g
OTHER BYPRODUCTS												
Brewer's grains *[mainly Hordeum vulgare]*												
Wet	IFI	22	12.2	81	265	72	420	-	-	2.5	1.8	5.6
Wet, Malaysia	G	22	11.1	73	278	-	-	-	-	1.6	-	6.5
Ensiled	CW	28	11.7	77	245	77	572	10	57	3.3	1.5	4.1
Silage, Trinidad	G	25	10.9	72	239	-	-	-	-	-	-	-
Dried, Kenya	G	91	10.8	72	214	-	-	-	-	-	-	-
Grape *[Vitis spp]*												
Winery pomace (stalk, skin and seed), Italy	G	41	6.0	40	117	-	-	-	-	-	-	-
Winery pomace (skin and seed), Italy	G	46	5.1	34	137	-	-	-	-	8.2	-	2.0
Winery pomace (skin), Italy	G	45	5.0	33	183	-	-	-	-	16.3	-	3.3
Winery pomace (stalk & skin), Germany	G	89	4.6	31	149	-	-	-	-	-	-	-
Wheat *[Triticum aestivum]*												
Chaff	IFI	92	8.0	53	71	23	-	-	-	0.9	-	0.9
MINERALS												
Limestone, Calcitic												
Finely ground	G	100	0.0	0	0	-	-	-	-	370.0	-	0.0
Limestone, Dolomitic												
Finely ground	G	100	0.0	0	0	-	-	-	-	370.0	25.0	-
Rock phosphate												
Defluorinated	G	100	0.0	0	0	-	-	-	-	340.0	-	170.0
Tri-calcium phosphate												
Manufactured	G	100	0.0	0	0	-	-	-	-	130.0	-	100.0
Di-calcium phosphate												
Manufactured	G	100	0.0	0	0	-	-	-	-	240.0	-	200.0
Mono-calcium phosphate												
Manufactured	G	100	0.0	0	0	-	-	-	-	160.0	-	120.0
BUFFERS												
Sodium bicarbonate												
Manufactured		100	0.0	0	0	-	-	-	-	-	-	-

Annex 10.4. Maximum inclusion rates of some feeds available in central Tibet for high yielding cows

Feed	Maximum inclusion rate %		Comments and possible problems
	Total ration	Concentrates	
Beans – Faba (Broad)	10	20	Tannins can reduce protein digestibility. High in phosphorous (8.6g/kg) and starch (400g/kg)
Brewer's grains	-	-	Highly palatable wet feed, may be ensiled.
Cotton seed meal or cake	-	-	Contains gossypol which reduces appetite in animals other than mature ruminants. Check for aflatoxin.
Fodder beet and other root crops	24 kg fresh for 600 kg cow		Soil contamination and possible taint in milk. Must be washed to control soil intake. Maximum 8kg and 12kg fresh for cows of 200 and 400 kg liveweight.
Peanut meal (Groundnut meal)	10	20	Can contain aflatoxin; check for aflatoxin before permitting use in Tibet
Peas	10	20	Tannins can reduce protein digestibility. High inclusion rates can cause problems in milling
Rapeseed meal	15	30	Low palatability can depress intake of concentrates with rapeseed meal. Must not contain any mustard seed which is toxic.
Soya bean meal	-	-	A high quality protein supplement
Sugar beet pulp, molassed	15	30	Unmolassed form is dense pellet and is unpalatable. Soak in water before feeding. Molassed form is highly palatable.
Sunflower meal	10	20	Can have high fibre content, NDF should be below 400 g/kg DM. High oil content samples can go rancid in storage.
Wheat bran	-	-	Low in starch, high in digestible fibre. Used as protein feed. Highly palatable, but used in human diets so price may be high. High phosphorous content which may be phytate.
Wheat grain	20	40	Danger of acidosis. High in gluten; large inclusion rates can result in 'dough balls' forming in the rumen.

1. Adapted from Chamberlain and Wilkinson (1996).

Section 4 ECONOMICS

Chapter 11 ECONOMICS OF DOUBLE CROPPING FODDER CROPS

Ian Lane

Chapter 11 ECONOMICS OF DOUBLE CROPPING FODDER CROPS

11.1. Introduction

Partial budgets are presented for the introduction of zero-till cultivation of cereal crops, and extended to evaluate the introduction and development of double cropping systems. These budgets follow the format for Gross Margin analysis in the presentation of crop yields, outputs, variable input costs and margins. However input costs for field operations including machinery and hired labour are included since these are central to changes in cropping systems, although other fixed costs are excluded. Economic analysis of the models for crop-dominated farming systems in central Tibet as presented in the Introduction of this manual has to await further data on costs and returns for each component. The economic value of fodders and feeds are determined, and economic responses to fodder quality and feeding systems by Local, Crossbred and Exotic milk cows are presented through a series of models.

11.2. Economics of zero-till drilling for crop production

Zero-till drilling was introduced to central Tibet by the project in order to facilitate double cropping through improved timeliness of cultivation of both main and second crops. Its use was subsequently taken up by farmers in higher elevation sites for sole cropping of spring sown crops. Initial use without associated weed control led to reported reductions in crop yields, but as farmers became used to efficient control of weeds normal yields were obtained. Zero-till drilling when associated with good weed control and conservation of stubbles to maintain soil cover can lead to increased crop yields. In the following series of partial budgets for the introduction of zero-till drilling, these different scenarios are presented with appropriate levels of inputs. The economic data in these tables are based on costs and prices for Lhasa in December 2006 where available (Jin Tao, TARI, personal communication), but should be updated with further locally recorded data when available.

Machinery and labour costs for use of tractors and machinery were not available. Hourly rates for tractor use in relation to initial machinery cost are given in Table 11.1 based on depreciation, insurance and administration, repairs and maintenance, and fuel and oil, adapted from Nix (2003). This breakdown is extended to ploughs, seed drills and zero-till drills. Tractors are usually operated by driver plus assistant, so labour costs for 2 persons are included in tractor operating costs. In partial budgets, the cost of field operations includes tractor and staff plus costs for each item of equipment.

Table 11.1. Machinery and labour costs for use of tractors and drills

	20-25 HP Tractor		Plough 1-furrow	Seed drill	Zero-till drill
Initial cost (Y)	**16000**		**1000**	**2000**	**16000**
	Y / hour	**Y / day**	**Y / day**	**Y / day**	**Y / day**
Machinery costs					
Depreciation	1.92	15.36	0.96	1.92	15.36
Insurance and administration	0.42	3.36	0.21	0.42	3.36
Repairs and maintenance	1.60	12.80	0.80	1.60	12.80
Fuel and oil	1.69	13.52	-	-	-
Total machinery costs	**5.63**	**45.04**	**1.97**	**3.94**	**31.52**
Staff costs for use of machinery					
Driver		15.00	-	-	-
Driver's assistant		15.00	-	-	-
Total labour costs for use of machinery		**30.00**	**-**	**-**	**-**
Total machinery cost including staff		**75.04**	**1.97**	**3.94**	**31.52**

1. Breakdown of machinery costs are adapted from Nix (2003) for a 50 HP tractor, using Tibet capital costs.
2. A day is taken as 8 hours. Drivers and labourers are paid 15 Y/person/day.

Costs for field operations in Table 11.1 are realistic for central Tibet, and provide a basis for inserting machinery and labour costs into partial budgets. They should be checked with local contractors. In particular depreciation and costs for repairs and maintenance may need to be charged at higher rates for ploughs and seed drills compared to tractors, given their high rates of wear and tear.

11.2.1. Spring barley

Partial budgets for spring barley compare use of zero-till drilling and traditional cultivation (Table 11.2). Three performance levels are given for zero-tillage as noted above.

Table 11.2. Partial budget for the introduction of zero-till drilling – spring barley

Tillage method	Traditional	Zero-till			Comments
Performance factor	**1.0**	**0.8**	**1.0**	**1.2**	
Yield – grain (kg/ha)	*4000*	*3200*	*4000*	*4800*	
Yield – straw (kg/ha)	*4000*	*3200*	*4000*	*4800*	*At 1.0 of grain yield*
Yield – chaff (kg/ha)	*400*	*320*	*400*	*480*	*At 0.1 of grain yield*
Outputs					
Grain at 1.6 Y/kg (Y/ha)	6400	5120	6400	7680	0.8 Y/jin for barley
Straw at 0.2 Y/kg (Y/ha)	800	640	800	960	0.1 Y/jin
Chaff at 1.2 Y/kg (Y/ha)	480	384	480	576	0.6 Y/jin
TOTAL OUTPUTS (Y/HA)	**7680**	**6144**	**7680**	**9216**	
Inputs – field operations[1]					
Winter ploughing (Y/ha)	58	58	58	-	Ploughing by tractor: 20 mu / day / 2 persons.
Spring ploughing (Y/ha)	58	-	-	-	
Levelling–animal drawn (Y/ha)	30	-	-	-	15 mu/day, 30 Y/day
Drilling, farmer drill (Y/ha)	79	-	-	-	15 mu/day, tractor + drill
Zero-till drilling (Y/ha)	-	40	40	40	40 mu/day, tractor + 0-till drill
Spraying by hand (Y/ha)	15	15	30	45	15 mu/day, 1 person
Total field operations	**240**	**113**	**128**	**85**	
Inputs – variable costs					
Seed at 2.0 Y/kg (Y/ha)	360	360	330	300	1.0 Y/jin. Seed rates see (3)
Fertilizer (see (4) (Y/ha	462	462	462	462	Minimum rates for all systems
Sprays (see (5) Y/ha	24	24	60	96	
Total variable costs	**846**	**846**	**852**	**858**	
TOTAL INPUT COSTS (see (6))	**1086**	**959**	**980**	**943**	
MARGIN OVER INPUT COSTS	**6594**	**5185**	**6700**	**8273**	

1. Machinery and labour costs for use of tractors and drills are taken from Table 11.1.
2. Costs are not available for labour for cereal harvest, transport and threshing; differences in cereal yield will affect these costs.
3. Seed rates for spring barley: Traditional and poor zero-till: 180kg/ha, medium zero-till 165 kg/ha; good zero-till 150 kg/ha
4. Fertilizer: 100 kg/ha DAP at 3.30Y/kg + 100 kg/ha urea at 1.32Y/kg
5. Sprays – herbicides: 2,4-D on all crops: 4 litres/ha at 6Y/litre. Roundup before zero-tilled crops : 1.5 litres/ha at 24Y/litre (12Y/0.5 litre container) – poor system: no Roundup, medium system 1 spray, good system 2 sprays.
6. Other fixed costs such as annual rent for land (3000Y/ha) are not included. Water is not charged directly.

Due to the relatively low cost of field operations, introduction of zero-till without proper weed control that leads to a 20% reduction in yields leads to a similar reduction in margin over variable and field operation costs. Given that other fixed costs such as rent at 3000 Yuan/ha remain constant, profit is considerably reduced. However given the high work rate and reduced cultivation time of the zero-till drill, farmers who control weeds effectively do improve margins despite extra cost of Roundup and its application. It is uncertain that a 20% improvement can be obtained at present from full conservation agriculture as shown in Table 11.2, or even that it is possible to eliminate winter ploughing since this may be important for soil water management. However spring barley yield may be raised by other means, such as use of crop growth regulators combined with higher fertilizer rates, and the economic consequences can be modelled using similar partial budgets that take account of the quantity and quality of straw in addition to changes in grain yields.

11.2.2. Winter wheat

Zero-till for winter wheat has been introduced as part of double cropping programmes to reduce times required for tillage of both wheat and the following fodder crop. Feimai is the traditional variety but matures in early August. Short duration (S.D.) varieties mature in early-mid July. Some S.D. varieties have better grain quality, but lower grain yields and shorter straw. Partial budgets for variety and cultivation methods are in Table 11.3 for winter wheat. Grain yields are most important, while costs of field operations make little difference to margins. These changes need to be evaluated economically when combined in double cropping systems as for barley and turnips in Section 11.3. Similar partial budgets can be used to evaluate the economics of growing different varieties, and the development of crop agronomy such as use of fertilizers (potassium) and crop growth regulators.

Table 11.3. Partial budget for the introduction of zero-till drilling – winter wheat

Tillage method	**Traditional**		**Zero-till**		**Comments**
Variety	**Feimai**	**S.D.**	**Feimai**	**S.D**	S.D. = Short Duration
Yield – grain (kg/ha)	*4000*	*3000*	*4000*	*3000*	
Yield – straw (kg/ha)	*4800*	*3000*	*4800*	*3000*	*Fm 1.2; SD 1.0 of grain yield*
Yield – chaff (kg/ha)	*480*	*300*	*480*	*300*	*At 0.1 of grain yield*
Outputs					
Grain (Y/ha)	5280	4200	5280	4200	Fm 1.32Y/kg; S.D. 1.4Y/kg
Straw (Y/ha)	960	600	960	600	0.2 Y/kg
Chaff (Y/ha)	576	360	576	360	1.2 Y/kg
TOTAL OUTPUTS (Y/HA)	**6816**	**5160**	**6816**	**5160**	
Inputs – field operations[1]					
Winter ploughing (Y/ha)	58	58	-	-	Tractor: 20 mu/day.
Levelling–animal drawn (Y/ha)	30	30	-	-	15 mu/day, 30 Y/day
Drilling, farmer drill (Y/ha)	79	79	-	-	15 mu/day, tractor + drill
Zero-till drilling (Y/ha)	-	-	40	40	40 mu/day, tractor + 0-till drill
Spraying by hand (Y/ha)	15	15	30	30	15 mu/day, 1 person
Total field operations	**182**	**182**	**70**	**70**	
Inputs – variable costs					
Seed (Y/ha)	277	277	211	211	1.32 Y/jin. Seed rates see (4)
Fertilizer (see (5) (Y/ha)	924	792	924	792	Low rates for all systems
Sprays (see (6) Y/ha)	24	24	60	60	
Total variable costs	**1225**	**1093**	**1195**	**1063**	
TOTAL INPUT COSTS (see (7))	**1407**	**1275**	**1265**	**1133**	
MARGIN OVER INPUT COSTS	**5409**	**3885**	**5551**	**4027**	

1. Machinery and labour costs for use of tractors and drills are taken from Table 11.1.
2. Zero-till cultivation of winter wheat has to be confirmed on farm to ensure effective water management is not jeopardised.
3. Costs are not available for labour for cereal harvest, transport and threshing; differences in cereal yield will affect these costs.
4. Seed rates for winter wheat: Traditional: 210kg/ha; zero-till 160 kg/ha. Seed of Feimai and S.D. varieties at 1.32 Y/kg.
5. Fertilizer: All varieties - 200 kg/ha DAP at 3.30Y/kg ; Feimai + 200 kg/ha urea at 1.32Y/kg, S.D. 100 kg/ha urea at 1.32 Y/kg.
6. Sprays – herbicides: 2,4-D on all crops: 4 litres/ha at 6Y/litre. Roundup before zero-tilled crops : 1.5 litres/ha at 24Y/litre (12Y/0.5 litre container) – poor system: no Roundup, medium system 1 spray, good system 2 sprays.
7. Other fixed costs such as annual rent for land (3000Y/ha) are not included. Water is not charged directly.

11.3. Economics of double cropping winter barley and turnips

Double cropping winter barley Dongqing #1 with densely broadcast turnips which are harvested whole (called "Stubble turnips" in this section) is the double cropping system that has been widely adopted by farmers in central Tibet. It is therefore selected here to assess the economics of the system in terms of outputs, inputs and margins. Comparisons are made in Table 11.4 between the present short duration winter barley / stubble turnip double crop system and traditional single crop spring barley, zero-till short duration winter barley / zero-till stubble turnip, and zero-till high yielding winter barley / zero-till spaced turnips or radishes grown for large roots. The first two systems are well established but better data are required from farmers. The latter two systems are feasible but need to be developed in practice with farmers. Given the time saved with zero tillage, it appears possible to double crop existing high yielding winter barley varieties that are harvested at mid to end of July with short duration turnip and radish varieties sown at the end of July as tested at Lhasa in 2006. Similar budgeting exercises can be carried out for double cropping winter barley with local hairy vetch – with yields of 4000 kg DM vetch / ha valued at 1.50 Y/kg DM, equal to the value of wheat bran. Sensitivity analysis is needed to assess break-even yields for both barley and fodder crops.

Table 11.4. Partial budget for replacement of spring barley with double crop winter barley and turnips. I. Yields and Outputs

Cropping system	**A**	**B**	**C**	**D**	**Comments**
	Spring barley + stubble grazing	**Winter barley DQ1 + stubble turnips**	**0-T Winter barley DQ1 + 0-T stubble turnips**	**0-T Winter barley H.Y. + root turnips/ radish**	0-T is zero-till drilled crops Winter barley H.Y. is high yielding winter barley varieties Stubble turnips are traditional high density vs spaced root turnips/radish for yield of roots
MAIN CROP YIELDS					
Winter Barley					
Yield – grain (kg/ha)	*4000*	*2500*	*2500*	*4000*	
Yield – straw (kg/ha)	*4000*	*2500*	*2500*	*3000*	*DQ1:1.0; H.Y.:0.75 of grain*
Yield – chaff (kg/ha)	*400*	*250*	*250*	*400*	*At 0.1 of grain yield*
Second crop yields					
Stubble grazing (kg LWG/ha)	*90*	-	-	-	*6 local cows/ha for 60 days at 0.25 kg LWG/day*
Stubble turnips (kg DM/ha)	-	*3000*	*3000*	-	
Root turnips/radish (kg DM/ha)	-	-	-	*4000*	
OUTPUTS					
Winter Barley					
Grain (Y/ha)	6400	4000	4000	6400	1.6 Y/kg (0.8 Y/jin)
Straw (Y/ha)	800	500	500	600	0.2 Y/kg (0.1 Y/jin)
Chaff (Y/ha)	480	300	300	480	1.2 Y/kg (0.5 Y/jin)
Total Barley Outputs (Y/ha)	**7680**	**4800**	**4800**	**7480**	
Second crop					
Stubble grazing (Y/ha)	1440	-	-	-	16.0 Y/kg LW (8.0 Y/jin)
Stubble turnips (Y/ha)	-	4560	4560	-	1.52 Y\kg DM = value of wheat
Root turnips/radish (Y/ha)	-	-	-	6080	1.52 Y\kg DM = value of wheat
Total 2nd crop Outputs (Y/ha)	**1440**	**4560**	**4560**	**6080**	
TOTAL OUTPUTS (Y/HA)	**9120**	**9360**	**9360**	**13560**	

Table 11.4. Partial budget for replacement of spring barley with double crop winter barley and turnips. II. Inputs and Margins

Cropping system	A	B	C	D	Comments
	Spring barley + stubble grazing	**Winter barley DQ1 + stubble turnips**	**0-T Winter barley DQ1 + 0-T stubble turnips**	**0-T Winter barley H.Y. + root turnips/ radish**	0-T is zero-till drilled crops Winter barley H.Y. is high yielding winter barley varieties Stubble turnips are traditional high density vs spaced root turnips/radish for yield of roots
INPUTS					
INPUTS – FIELD OPERATIONS[1]					
Winter Barley					
Winter ploughing (Y/ha)	58	58	-	-	Tractor + plough: 20 mu/day.
Spring ploughing (Y/ha)	58	-	-	-	Tractor + plough: 20 mu/day
Levelling – animal drawn (Y/ha)	30	30	-	-	15 mu/day, 30 Y/day
Drilling, farmer drill (Y/ha)	79	79	-	-	15 mu/day, tractor + drill
Zero-till drilling (Y/ha)	-	-	40	40	40 mu/day, tractor+0-till drill
Spraying by hand (Y/ha)	15	15	30	30	15 mu/day, 1 person at 15Y/d
Total field operations – Barley	**240**	**182**	**70**	**70**	
Second crop					
Herding on stubbles (Y/ha)	90	-	-	-	60 days x 15Y/day x 0.1 share
Summer ploughing (Y/ha)	-	58	-	-	Tractor + plough: 20 mu/day.
Broadcasting turnip seed (Y/ha)	-	15	-	-	15 mu/day, 1 person at 15Y/d
Zero-till drilling (Y/ha)	-	-	40	40	40 mu/day, tractor+0-till drill
Spraying by hand (Y/ha)	-	-	15	15	15 mu/day, 1 person at 15Y/d
Thinning/weeding crop (Y/ha)	-	-	-	225	1 mu/day, 1 person at 15Y/d
Harvest of turnips	-	225	225	225	1 mu/day, 1 person at 15Y/d
Total field operations 2nd crop	**90**	**298**	**280**	**505**	
TOTAL FIELD OPERATIONS (Y/HA)	**330**	**480**	**350**	**575**	
INPUTS – VARIABLE COSTS					
Winter Barley					
Seed at 2.0 Y/kg (Y/ha)	420	420	300	300	1.0 Y/jin. Seed rates see (3)
Fertilizer (see (4) (Y/ha)	462	462	462	462	Minimum rates for all systems
Sprays (see (5) (Y/ha)	24	24	60	60	
Total variable costs - Barley	**906**	**906**	**822**	**822**	
Second crop					
Seed – Stubble turnips (Y/ha)	-	1350	450	-	See (6)
Seed – Root turnip/radish (Y/ha)	-	-	-	225	See (7)
Fertilizer (Y/ha)	-	-	-	132	See (8)
Sprays (Y/ha)	-	-	36	36	See (9)
Total variable costs 2nd crop	**-**	**1350**	**486**	**393**	
TOTAL VARIABLE COSTS (Y/HA)	**906**	**2256**	**1308**	**1215**	
TOTAL INPUT COSTS (11)	**1236**	**2736**	**1658**	**1790**	
MARGIN OVER INPUT COSTS	**7884**	**6624**	**7702**	**11770**	

1. Machinery and labour costs for use of tractors and drills are taken from Table 11.1.
2. Costs are not available for labour for cereal harvest, transport and threshing; differences in cereal yield will affect these costs.

3. Seed rates for winter barley: Traditional: 210 kg/ha, zero-till 150 kg/ha
4. Fertilizer for barley: 100 kg/ha DAP at 3.30Y/kg + 100 kg/ha urea at 1.32Y/kg
5. Sprays for barley – herbicides: 2,4-D on all crops: 4 litres/ha at 6Y/litre. Roundup before zero-tilled crops : 1.5 litres/ha at 24Y/litre (12Y/0.5 litre container).
6. Seed rates for Stubble turnips: Traditional broadcast – 22.5 kg/ha at 60Y/kg (3 jin/mu at 30 Y/jin). Direct drilled for dense stand – 7.5 kg/ha at 60 Y/kg (1 jin/mu at 30 Y/jin).
7. Seed rate for spaced Root turnip and radish: 3.75 kg/ha at 60 Y/kg (0.5 jin/mu at 30 Y/jin).
8. Fertilizer for root crops: Stubble turnips are not given fertilizer traditionally. For spaced root crops: 100 kg/ha urea at 1.32Y/kg.
9. Sprays for root crops: before zero-till drilling roots, spray Roundup: 1.5 litres/ha at 24 Y/litre.
10. Other fixed costs such as annual rent for land (3000Y/ha) are not included. Water is not charged directly.

The key factor that determines margins is output from the land. The yield of spring barley used, at 4000 kg/ha, may be higher than many farmers achieve, but they certainly regularly obtain 3500 kg/ha. The severe reduction in barley yield that farmers have to accept at present by using the short duration variety Dongqing #1 is a major constraint to farmers adopting double cropping. If allowance is made for the value of stubble grazing (this needs to be better defined by field measurements), even though stubble turnips have a high economic output, total output of single and double cropping systems is similar. When the higher costs of the second crop are taken into account, the margin over variable costs and field operations is 16% less than traditional production of spring barley. Farmers who grow stubble turnips must value them highly as a human food, exchange for other products such as barley, or as a feed for commercially kept cows or pigs, in order to grow them in this system.

The basic double cropping system must be developed to make it more profitable. It is suggested that properly managed, zero-till winter barley and stubble turnips can have the same output as traditionally cultivated crops, but have reduced input costs through cheaper (and more timely) cultivation: especially by reducing the excessively high seed rate currently used for stubble turnips. This reduction in seed rate could be achieved through use of full cultivation and drilling of seed by conventional equipment, and this should be evaluated; however it would take 2-3 days longer at cereal harvest time, when weather is unpredictable. Stubble turnips have been cultivated by the rotary seeder, and use of the zero-till seeder for this purposes needs further development on farm. If farmers remain with Dongqing #1 as the winter barley variety, drilling turnip seed at one third current rates will allow the double cropping system to match single cropping in profitability. It will also make the system more sustainable, as currently supply of turnip seed restricts areas of stubble turnips grown.

Pending higher yielding varieties of short duration winter barley, existing varieties of standard duration winter barley with yields equal or better than current spring barley varieties should be extended to farmers for double cropping. Even if allowance is made for slightly shorter straw, this would return the economic output of winter barley to that of spring barley. This measure is linked to growing shorter duration turnip or radish varieties as spaced plants for high root yields. Several varieties gave yields of 4000 kg DM/ha in Lhasa in 2006, when sown at the end of July. Even with additional costs of labour for thinning and weeding, an extra spray of Roundup and some fertilizer as urea, input costs are low due to the low seed rates of turnip and radish used for spaced plants. The combined use of standard duration winter barley and spaced short duration turnip or radish increases predicted total economic output by 45% from 9360 to 13560 yuan, and margin over variable and field operation costs by 78% from 6624 to 11770 yuan. This could be obtained using current varieties, and through using existing farm machinery, before use of zero-tillage is widespread.

Even when villages have adopted double cropping of winter barley / stubble turnips, only 1 in 10 farmers actually grow the stubble turnips. Other farmers suffer the loss of barley yield due to planting Dongqing #1, and lose the benefit of feeding up their livestock by grazing stubbles. Introduction of standard duration winter barleys will restore profitable barley production to these farmers, and maintain or increase areas planted to second crops. Partial budgets have been calculated for stubble turnips as the main double crop system currently adopted by farmers. With restructuring of crop lands and a move to more individual farming activities, opportunities exist for farmers who have grown winter barley to plant any of the second crops discussed in this manual. If short duration winter barley is grown a wide range of second crops is possible; however turnips, radishes, hairy vetch and some leafy brassicas can still be grown in combination with longer duration winter barley varieties.

11.4. Determining the economic value of fodders and feeds

The economic value of the feeds used in the RUMNUT models (Chapter 10) was estimated from their contents of Metabolisable energy and crude protein according to the equations in Table 11.5:

i. The value of ME in a feed was estimated by regression from the contents of ME in winter wheat straw and winter wheat grain (Feimai) on farm gate prices to farmers.

ii. The value of CP in a feed was estimated by regression from the contents of CP in winter wheat straw and wheat bran. Since wheat grain and wheat bran are traded weight for weight, the same price was taken for wheat bran as for wheat grain.

iii. The total value of any feed was then taken as the average of the value of the ME and the CP.

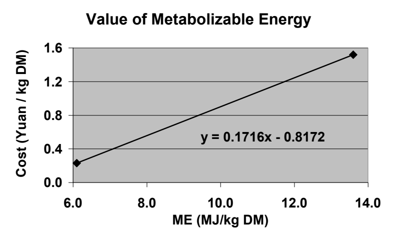
iv. Since the ME of wheat bran is similar to wheat grain but the CP is higher, it appears that wheat bran is undervalued. This reduces the value of protein, and undervalues all feeds. While this is acceptable for home-grown feeds such as fodders and roots, which are largely used for the farmer's own animals, it is not acceptable for feeds available for purchase on the market.

v. A factor of 1.256 was therefore use to correct the value estimated for wheat grain back to the market value. This correction factor was used for all purchased feeds, including both energy and protein concentrates.

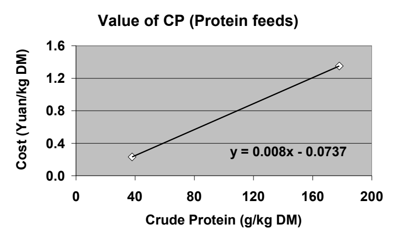
The values of feeds available for use with RUMNUT relevant to central Tibet are given in Table 11.6, expressed in terms of Yuan/kg DM, Yuan/ton feed, and Yuan/jin feed. Not all of these feeds were actually used in the models presented in this Manual. It was especially important to estimate the values of various types of fodders that can be grown by farmers, but for which no market values are available.

Table 11.5 . Estimation of economic values for feeds used in ration formulation using the energy in wheat straw and wheat grain and the protein in wheat straw and wheat bran as standards

Estimation of the value of Metabolisable Energy in a feed			
	ME MJ/kg DM	Cost of feed Yuan/Jin	Cost of feed Yuan/kg DM
Straw, Winter Wheat	6.1	0.10	0.23
Grain, Winter Wheat	13.6	0.66	1.52
Value of ME in a feed (¥/kg DM) = (0.1716 * ME [MJ/kg DM]) – 0.8172			



Estimation of the value of Crude Protein in a feed			
	CP g/kg DM	Cost of feed Yuan/Jin	Cost of feed Yuan/kg DM
Straw, Winter Wheat	38	0.10	0.23
Bran, Wheat	178	0.66	1.35
Value of CP in a feed (¥/kg DM) = (0.008 * CP [g/kg DM]) – 0.0737			



Estimation of economic value of feeds
1) Value of home-grown feeds (Yuan/kg DM) = ((Value of ME + Value of CP) / 2) * 1.000
2) Value of purchased feeds (Yuan/kg DM) = ((Value of ME + Value of CP) / 2) * 1.256

1. See notes in the text on estimation of economic values for fodders and feeds.

Table 11.6 . Estimated economic values for feeds used in RUMNUT ration formulation

	Value of feeds		
	Yuan / kg DM	Yuan / ton feed	Yuan / jin feed
Straws			
Straw, Barley, Spring	0.31	271	0.14
Straw, Barley, Winter	0.25	217	0.11
Straw, Wheat, Spring	0.20	177	0.09
Straw, Wheat, Winter	0.23	200	0.10
Straw, Pea	0.38	328	0.16
Hays			
Hay, Grass, DOMD <450	0.44	381	0.19
Hay, Grass, DOMD 450-500	0.52	439	0.22
Hay, Grass, DOMD500-550	0.69	583	0.29
Hay, Grass, DOMD550-600	0.78	669	0.33
Hay, Grass, DOMD600-650	0.90	773	0.39
Hay, Grass, DOMD650-700	0.92	803	0.40
Hay, Grass, DOMD>700	1.10	950	0.48
Hay, Vetch, Common, vegetative	1.41	1225	0.61
Fodders-fresh			
Fresh Beet-Sugar, Tops	0.90	145	0.07
Fresh Cabbage	1.56	165	0.08
Fresh Lucerne	1.06	212	0.11
Fresh Pasture, mixed, vegetative	1.21	236	0.12
Fresh Pea-Forage, empty pod stage	1.14	296	0.15
Silages			
Silage, Grass, poor	0.95	366	0.18
Silage, Grass, average	1.05	278	0.14
Silage, Whole-crop wheat, milky stage	1.05	278	0.14
Silage, Lucerne	1.13	365	0.18
Silage, Maize, cobs at dough stage	0.87	264	0.13
Root crops			
Carrots, roots, fresh	1.02	133	0.07
Beet-Fodder, roots, fresh	0.83	151	0.08
Turnips-Stubble, whole crop, fresh	1.00	80	0.04
Energy feeds (purchased)			
Maize, grain	1.44	1260	0.63
Wheat, bran	1.49	1313	0.66
Wheat, grain	1.52	1317	0.66
Protein feeds (purchased)			
Beans-faba, Spring	2.61	2262	1.13
Rapeseed meal	2.82	2535	1.27
Sunflower cake	2.66	2397	1.20
Buffers			
Sodium bicarbonate	3.00	3000	1.50

1. Values were estimated using equations determined in Table 11.5.
2. DOMD: Digestible Organic Matter in the Dry Matter (g/kg DM)

In the development of the feeding and economic models, the estimated values from Table 11.6 have been used. However, with the development of a market in feedstuffs, it will be essential for market prices to be used when formulating rations. There appear to be particular discrepancies with respect to protein concentrates, which are usually an expensive part of the ration. These discrepancies are noted in Table 11.7. The list of protein concentrates used for the models is deliberately limited, but with improvements in transport in Tibet a wide range of feedstuffs will be introduced.

Table 11.7. Discrepancies in pricing of protein concentrates

Protein concentrate	Market price[1] Yuan / kg feed	Estimated value[2] Yuan / kg feed	Comments
Wheat bran	1.32	1.32	Although generally considered an energy concentrate, wheat bran is the common protein feed used in Tibet. Its price is well established as equivalent to wheat grain, and it is widely available.
Rapeseed meal / cake	1.08	2.54	The price of Y0.54/jin was given by a family oilseed miller in Lhasa. This is low for its feed value. What price RSM is sold for by the industrial scale oil mill is not known. It is likely farmers and advisers confuse the oilcake from rapeseed with oilcake from traditional mustard varieties which should not be fed to milking cows
Broad beans	6.00	2.26	Broad beans have a high value as human feed, which at present prices them out of the market for animal feeding. Given that broad beans grow well as a sole crop, with restructuring of crop lands a greater area may be grown which should reduce market price to 2x that of wheat grain. This would then make them economic as an animal feed.
Sunflower cake	?	2.40	A number of oilseed cakes should come on to the market in Tibet, including sunflower cake, cotton seed cake, soya bean meal and groundnut cake. Inclusion rates in rations will depend on their market prices, and the particular nutritional characteristics of each feed.

1. Market prices from Jin Tao, December 2006
2. Estimated values calculated from Table 11.5.

11.5. Economic responses for models on fodder quality and feeding systems

The main fodders available to farmers in central Tibet are spring and winter barley straws and winter wheat straw. These are high in fibre, and low in metabolisable energy and crude protein. It is suggested that there are three main ways to develop the feeding of cows to support improved milk production, with many possibilities to combine these methods:

i. improvement of fodder quality, by harvest of fresh or conserved forages at increasingly immature stages of growth, or by replacement of straws by high quality fodders

ii. supplementation of cereal straws, to improve their digestibility and intake – but keeping straw as the basal ration

iii. estimation of the nutrient requirements of high yielding cows for metabolisable energy and protein, and formulating rations using the available fodders and feedstuffs that meet these requirements within the predicted dry matter intake.

Models using the UK Metabolisable Energy and Protein system were developed with RUMNUT ruminant nutrition software and the actual composition of UK feeds in Chapter 10 to demonstrate the effects of improved fodder quality and systems of feeding on nutrient intakes and milk production. Here the effects on milk incomes, feed costs and margins over home grown and purchased feeds will be presented for models that concern methods i) and iii) above. The models include:

- the influence of fodder quality on the intake of dry matter and nutrients, and on resulting milk yields - for local, crossbred and exotic milk cows;
- replacement of barley straw in straw based rations with whole-crop wheat silage;
- progressive supplementation of straw based rations with various fodders that might be grown as second crops; and
- the relationship between conserved fodder quality and "fodder-to-concentrate ratio" in the diet of milking cows for local, crossbred and exotic milk cows.

11.5.1. Improvement of fodder quality

a. Economic responses to progressive improvement in the quality of a single fodder with cows of different type and liveweight

Models were developed for Local, Crossbred and Purebred exotic cows fed hay made from ryegrass at successive stages of maturity from early vegetative (high quality = 11.5 MJ ME/kg DM) to post-ripe (poor quality = 6.1 MJ ME/kg DM). Improving hay quality increased intakes of hay, dry matter, and ME, and improved milk yields from zero to 7, 16 and 26 litres/cow/day for small, medium and large cows respectively. The models demonstrate the relationship between ME intake and milk yield, but the hays were not balanced for protein and minerals so that the milk yields and derived economic data may not be achieved in practice.

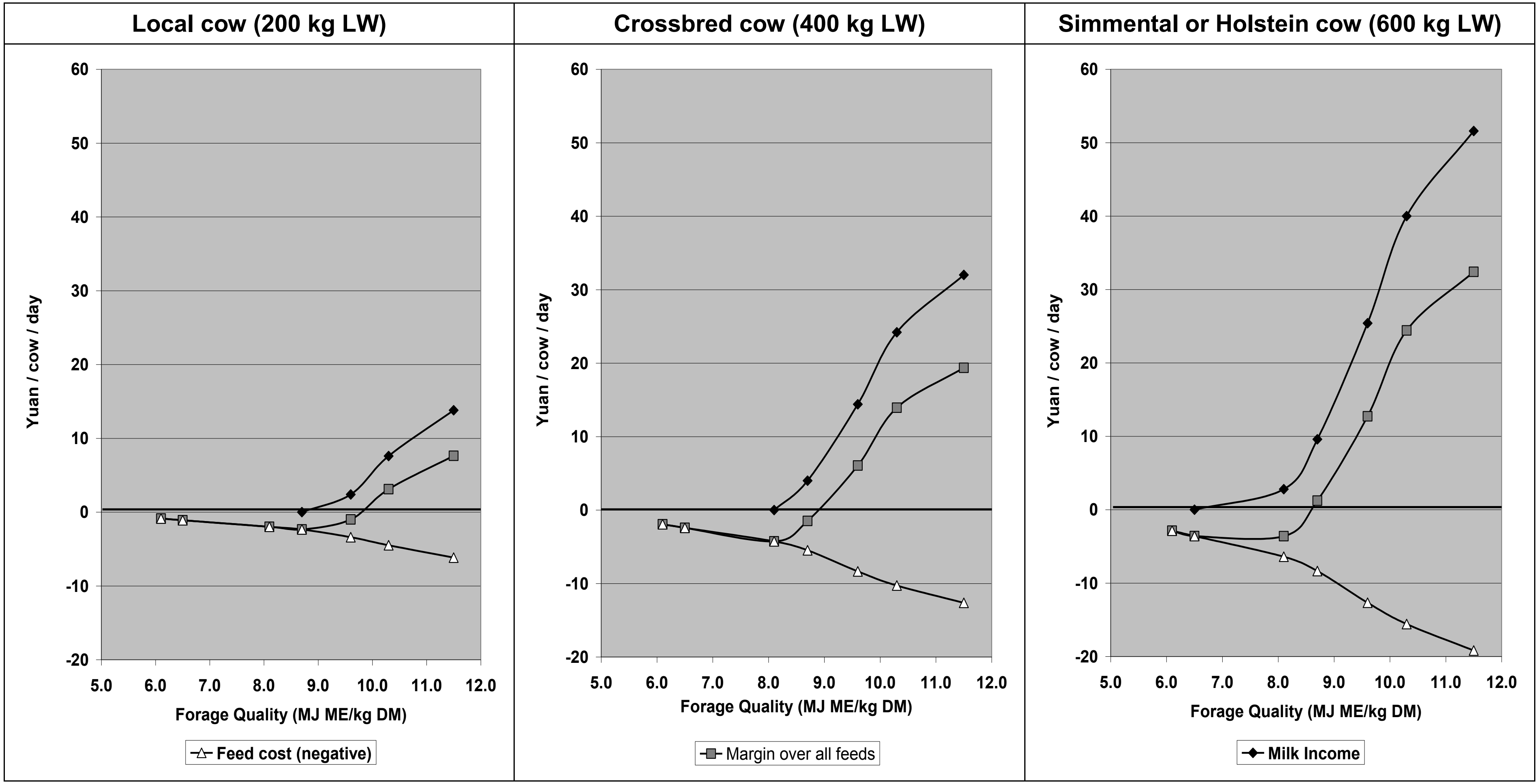
The effects of forage quality of the grass hays and cow type on milk incomes, feed costs and margins over feeds are shown in Figure 11.1. Points to note include:

- Milk Income is taken as Milk Yield x Milk Value, at Yuan 2 / litre.
- Costs of the hays are taken from Table 11.6 based on the value of ME and CP. Since the hays would be home grown, it is possible that the actual costs for the hays are less than those used here.
- As fodder quality improves:
  - Milk income increases progressively
  - The amount of hay consumed increases, and the better quality feed is valued more highly, so costs of hay increase (shown as negative values in the charts)
  - Margin over all feed costs increase following milk income
- Values for the highest fodder quality (11.5 MJ ME/kg DM) are summarised in Table 11.8.

Table 11.8. Income, feed costs and margins by cow size with grass hay at ME 11.5 MJ/kg DM

Cow type (Liveweight)	Feed intake (kg hay/day)	Dry matter intake (kg/day)	Milk yield (litres/day)	Milk income (Yuan/day)	Feed cost (Yuan/day)	Margin over feed costs (Yuan/day)
Local (200 kg)	7	6	7	14	- 6	8
Cross (400 kg)	13	12	16	32	-10	19
Exotic (600 kg)	20	17	26	52	-19	32

- These are useful margins, but additional feeds will be required to supplement the hay for protein and minerals - leading to reduced margins.



1. Legends apply to all charts.
2. Milk yields were estimated using RUMNUT ruminant nutrition rationing software based on the UK Metabolisable Energy system (Chamberlain, 2004). These charts illustrate the effect of forage quality with respect to ME content. The hays were not balanced for protein or other nutrients, so that milk yields and the derived Milk Incomes and Margins shown here may not be achieved in practice.
3. Milk Income is taken as Milk Yield x Milk Value at Yuan 2 / litre (Yuan 1 / jin) for cow's milk.
4. Margin over all feeds is Milk Income minus Feed Costs.
5. Costs of hays are taken from Table 11.6, and are based on the value of ME relative to the ME content and costs of wheat straw and wheat grain; and the value of CP relative to the CP content and costs of wheat straw and wheat bran. Since hays are home grown feeds, it is possible that the actual costs for the hays are less than those shown here.

Figure 11.1. Effect of Forage Quality of grass hays and Cow Type on Milk Incomes, Feed Costs and Margins over feeds

- If a comparison is made between the performance of three small cows (200 kg) and one large cow (600 kg), intake of hay will be the same, but milk yield is 5 litres more for the one large cow, resulting in greater milk income (Yuan 10/day) and margin over feed costs (Yuan 8/day).
- Cows at or below maintenance obviously still need to eat to stay alive, and the cost of the hay consumed, even if of lower value, results in a loss. The break-even point for fodder quality, when milk income covers the cost of hay consumed, is of great interest.
- Although feed intake is proportional to cow liveweight, large cows can fulfill their maintenance requirements from lower quality fodder than small cows. This means that they can support milk production on lower quality fodder – and reach the economic break-even point on poorer quality fodder. From Figure 11.1 the break-even point occurs with fodder quality of 9.8, 9.0 and 8.7 MJ ME/kg DM for small, medium and large cows respectively.

b. Replacement of straws by high quality fodder

Two examples are explored in which spring barley straw is progressively replaced by high quality fodders. Both models have been developed for purebred exotic cows of 600 kg liveweight. The models take spring barley straw as the starting feed, and record the additional fodders and concentrate feeds required to move the cow from maintenance to a high level of production. These models are balanced for energy and protein. The horizontal X axis is milk yield in litres/cow/day.

i. Replacement of spring barley straw by Whole-Crop Wheat Silage (WCWS) harvested at the early milk stage, and concentrate feeds

In order to meet the increasing energy and protein requirements as milk yields increase from 0 – 30 litres, spring barley straw is progressively replaced by whole-crop wheat silage. Root crops are introduced to meet energy needs of milk yields above 8 litres. Home grown fodders and feeds meet virtually all nutrient requirements up to a milk yield of 20 litres per day. However, given the concentration of ME at this point, dry matter intake effectively reaches a plateau, and further increases in energy and protein concentrations in the ration must come from purchased energy and protein concentrates that replace fodder weight for weight in the ration. At 30 litres milk yield, concentrates make up two thirds of the ration dry matter.

Costs of individual feeds; and milk income, feed costs and margins over total and purchased feed costs are presented in Figure 11.2. The following points should be noted:

- Due to the method used to value feeds, the total feed cost rises linearly with milk yield with a break at 20 litres when further increase in yield comes from purchased feeds. In UK the cost on a dry matter basis of home grown conserved fodders tends to be 50 – 66% the cost of mixed concentrate feeds. It is possible that home grown fodders will be cheaper than used here.
- It is possible that cheaper energy and protein concentrate feeds can be found than those used here, and that actual costs of feeds will be less, for example for rapeseed meal.
- Purchased feeds comprise 10 % of the total feed cost with a milk yield of 20 litres, and this rises to 75% with a milk yield of 30 litres.
- Milk income at Yuan 2/litre rises linearly to Yuan 60/day with a milk yield of 30 litres.
- Total cost of fodder and feeds increases from Yuan 5 at maintenance to Yuan 30/day with a milk yield of 30 litres.
- Total margins, margins per litre, and incremental margins per litre over total feeds and purchased feeds are summarised in Table 11.9 for milk yields of 10, 20 and 30 litres.
- The break-even point is at a yield of 4 litres.
- The margin over total feed costs continue to increase up to a yield of 30 litres, with an overall margin of Yuan 1.00/litre.
- The incremental margin/litre over total feed costs is less for 0-10 litres as the cost of feed for maintenance is spread over milk income from fewer litres; it is reduced for 20-30 litres as concentrates replace home-grown feeds.

Table 11.9. Summary of margins for milk income over total and purchased feeds

Margin	**Milk yield (litres/cow/day)**		
	10	**20**	**30**
Total milk income at Yuan 2.00/litre (Yuan/cow/day)	20	40	60
Margin over total feed costs (Yuan/cow/day)	10	22	30
Margin/litre over total feed costs (Yuan/litre)	1.00	1.10	1.00
Incremental margin/litre over total feed costs[1] (Yuan/litre)	1.00	1.20	0.80
Margin over purchased feeds (Yuan/cow/day)	20	39	37
Margin/litre over purchased feed costs (Yuan/litre)	2.00	1.95	1.23
Incremental margin/litre over purchased feed costs(Yuan/litre)	2.00	1.90	-0.20

1. The "Incremental margin/litre" is the margin/litre based on the previous 10 litres of milk yield, that is 0-10, 10-20 and 20-30 litres/cow/day.

- The margin over purchased feeds equals milk income until purchased concentrates are fed at 16 litres of milk, and peaks with a milk yield of 22 litres followed by a slight decline to 30 litres of milk. This reflects the average cost of concentrates of about Yuan 2.00/kg, and with high quality fodder almost 100% replacement rate of fodder by concentrate feeds above 20 litres milk yield.
- Margin/litre over purchased feed costs equals milk value up to 16 litres of milk, and declines rapidly from a yield of 22 litres up to 30 litres.
- Incremental margin/litre over purchased feeds summaries the chart well, showing high margins over 0-10 and 10-20 litres, followed by a small loss per litre of milk between 20-30 litres.
- While a reasonable margin appears possible from feeding high quality fodders with homegrown supplementary feeds, the profitability of heavy feeding of purchased concentrates is not certain.
- Cereal grains and peas and beans are included as purchased feeds even though they may be home grown. This is to reflect their ready market, so that they should be priced according to market values.

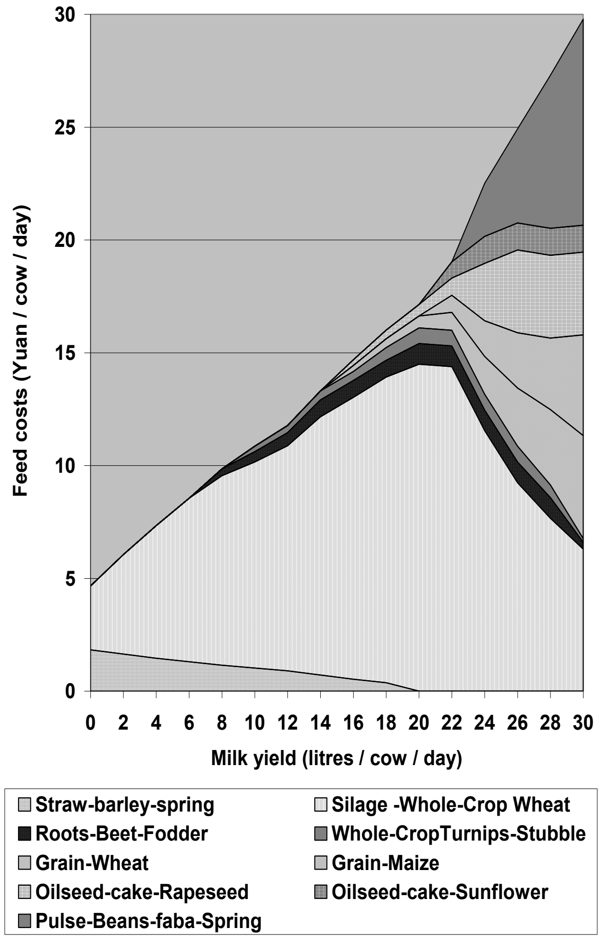
This particular model refers to cows near peak lactation, and any extra milk yield at this time will be carried forward throughout the remainder of the lactation, when home grown feeds can make up the bulk of the ration. It is therefore necessary to model the whole lactation and various lengths of dry period in order to obtain a complete view of the profitability of different feeding strategies. This model provides a good demonstration of how useful model development can be.

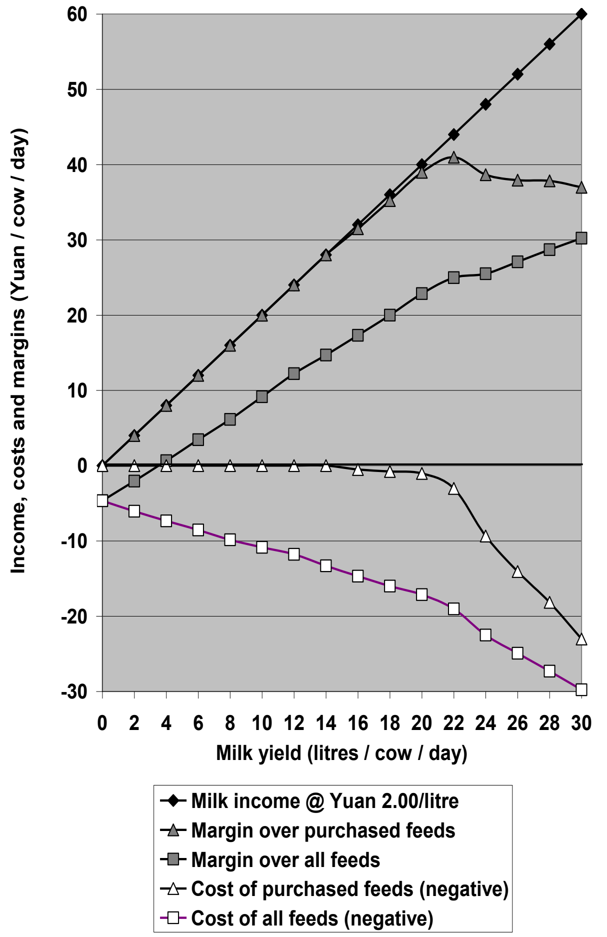
ii. Supplementation of spring barley straw with fodder crops

This model is only extended to a milk yield of 26 litres, since above this yield concentrate feeding again dominates. A range of fodder crops are used in this model to supplement / replace spring barley straw, with emphasis on those that can be grown as second crops under double cropping systems. Fodders include, in order of inclusion, the basal spring barley straw; high quality hay from vetch cut at the vegetative stage; whole-crop stubble turnips; fodder beet roots; maize silage; and lucerne silage. Values for these fodders are given in Table 11.6. Feed costs, and milk income, costs and margins are presented in Figure 11.3. Points to note include:

- Fodders are valued according to their ME and CP contents. Since feed rationing is carried out to meet the ME and CP requirements of increasing milk yields with the same 600 kg cow, total feed costs and margins over total feeds are similar to the previous model.
- By using a variety of fodders including top quality vetch hay with a high protein content it is possible to obtain a milk yield of 20 litres solely from home grown fodders and root crops.
- This maintains margins and incremental margins over total feed costs, and parity of margins and incremental margins over purchased feeds with milk income, up to a milk yield of 20 litres.

Feed Costs	***Income, Costs and Margins***

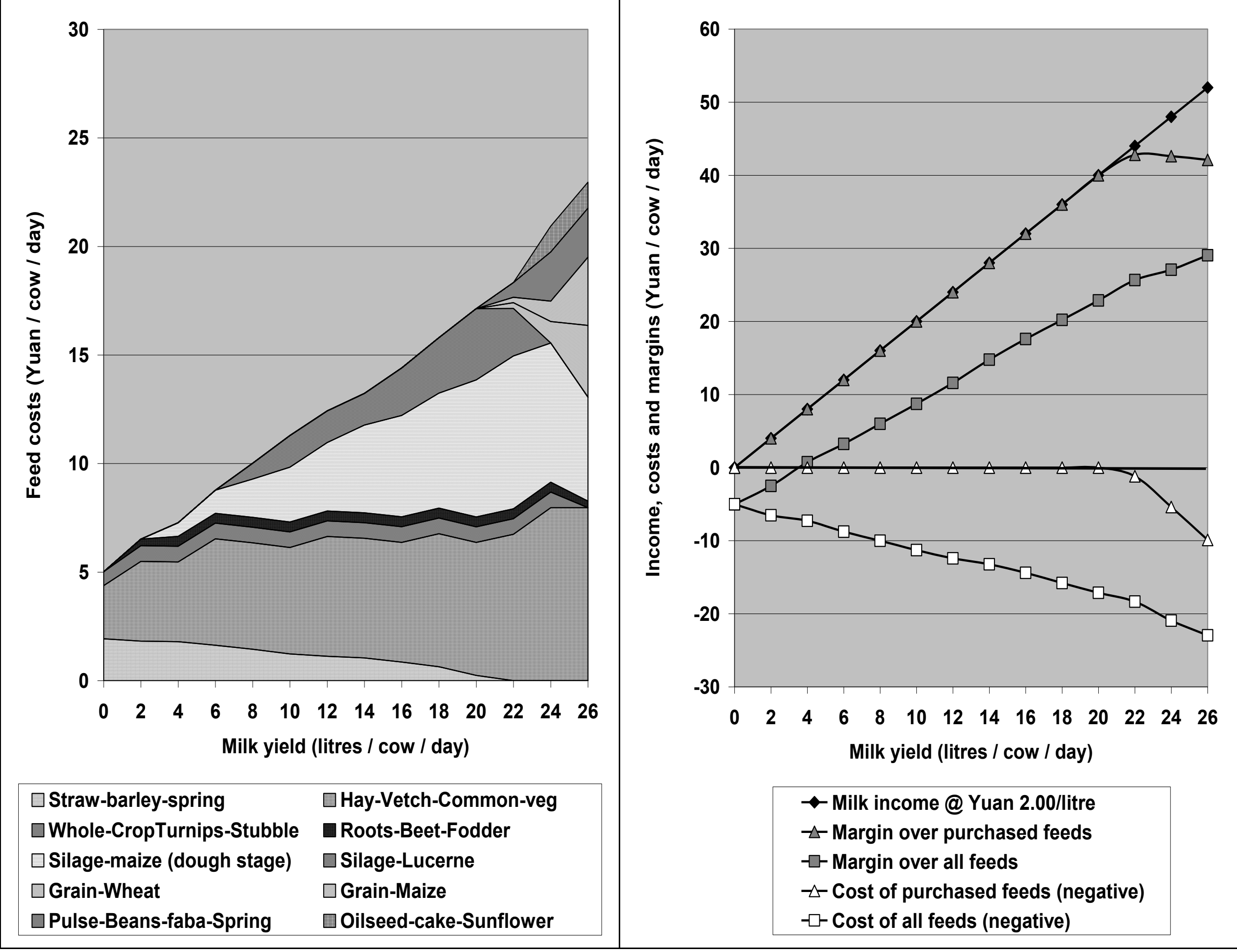




1. Rations were formulated using RUMNUT ruminant nutrition rationing software based on the UK Metabolizable Energy and Protein systems (Chamberlain, 2004).
2. Costs of feeds relates to the value of ME in the feed based on the differences in ME content and value of wheat straw and wheat grain; and the value of CP in the feed based on the difference in CP content and value of wheat straw and wheat bran (see Table 11.6.)
3. Milk Income is taken as Milk Yield x Milk Value at Yuan 2 / litre (Yuan 1 / jin) for cow's milk.
4. Margin over purchased feeds is Milk Income minus Cost of purchased feeds ; and Margin over all feeds is Milk Income minus Costs of all feeds. Costs of feeds are taken from Table 11.6.

Figure 11.2 . Replacement of Spring Barley Straw by Whole-Crop Wheat Silage (Early milk stage) and concentrate feeds for Milk production with Purebred cows (600 kg LW) – Feed costs; and Milk Income, Costs and Margins

Feed Costs	Income, Costs and Margins



1. Rations were formulated using RUMNUT ruminant nutrition rationing software based on the UK Metabolizable Energy and Protein systems (Chamberlain, 2004).
2. Costs of feeds relates to the value of ME in the feed based on the differences in ME content and value of wheat straw and wheat grain; and the value of CP in the feed based on the difference in CP content and value of wheat straw and wheat bran (see Table 11.6.)
3. Milk Income is taken as Milk Yield x Milk Value at Yuan 2 / litre (Yuan 1 / jin) for cow's milk.
4. Margin over purchased feeds is Milk Income minus Cost of purchased feeds ; and Margin over all feeds is Milk Income minus Costs of all feeds. Costs of feeds are taken from Table 11.6.

Figure 11.3. Supplementation of Spring Barley Straw with Fodder Crops for Milk production with Purebred cows (600 kg LW) – Feed costs; and Milk Income, Costs and Margins

- Concentrates have to be fed for milk yields above 20 litres, with replacement of fodders as previously observed. This has similar effects on margins over total feeds and purchased feeds.

11.5.2. Supplementation of cereal straws

The second approach to be investigated is how to improve the nutrition of cows, which may be local cows kept by the majority of small scale farmers in central Tibet, so that they give more milk while still fed the basal diet of barley straw[1]. A number of possibilities exist (Table 11.10), but at this stage economic responses have not been modelled for reasons given below:

Table 11.10. Development of available feed resources: economics for central Tibet

Questions	Answers for central Tibet	Economic consequences
What are the basic fodder resources?	Barley and wheat straws	Freely available at Yuan 0.28 – 0.20 / kg fresh respectively
How can these dry fodders be treated to improve their feeding values?	Fractionation of straws into stem and leaf, or by feeding surplus straws for animal selection Treatment with urea or bacterial fermentation	Can move from sub-maintenance feed to low production. Depending on proportion of leaf will increase cost of straw fed 2 – 3 x Urea treatment should be costed
How can fermentation of the basal fodders in the rumen be improved by fermentable supplements to provide fibre digesting bacteria with their minimum requirements for growth?	Supplementation with: ▪ nitrogen ▪ minerals ▪ a green fodder supplement	Simple to cost and model from on-farm trials
What Bypass supplements can be fed to stimulate the animal's metabolism and improve feed intake?	Bypass supplements for: ▪ protein ▪ starch ▪ oils	Combine with improvement of fermentation. Simple to cost and model.

- these methods are most relevant to farmers who keep local cows, and their potential productivity is not currently known (see results from the ACIAR project on dairy nutrition);
- many of the interventions are to overcome nutritional deficiencies that limit present production, but the reduction in production due to the deficiencies are not well quantified;
- other interventions are to provide bypass nutrients which may stimulate animal metabolism but again are not well predicted by standard models;
- many interventions will be introduced together, and it is the way that they complement each other that provides greatest returns;
- improvements in animal production may be small, and observed as improved performance over several lactations;
- frequently, simple partial budgets based on gross margin analysis will be sufficient to evaluate the results of simple on-farm feeding trials;
- increased yields of milk are likely to be consumed within the family; benefits will result from improved growth, health and fitness of children, and their better ability in school, but are hard to quantify.

11.5.3. Estimation of nutrient requirements and ration formulation to meet those requirements

The standard ways in which feeding systems for milk production are used are:

[1] See Preston and Leng (1987), who outline many methods for development of straw based diets, and provide some examples of economic responses.

a. to estimate the cow's requirements for energy and protein given her liveweight, stage of lactation, body condition, stage of pregnancy, target yield of milk of desired composition and target live weight change; and

b. to design a ration using available feeds that will meet those requirements.

Feed requirements can then be expressed as required ME and CP concentrations in the ration DM.

This approach is used here, in the form of the UK ME/MP system, to demonstrate the relationship between the quality of conserved fodder, and the 'fodder to concentrate ratio' necessary to meet the feed requirements of small, medium and large cows with the animal factors in Table 11.11.

Table 11.11. Animal factors for demonstration of the economic relationship between the quality of conserved fodder and the fodder to concentrate ratio in the diet of milking cows

Animal factor \ Cow type	Local	Crossbred	Pure exotic
Liveweight (kg)	200	400	600
Milk yield (litres/day)	4	12	20
Feed requirement (kg DM/day)	4.9	11.1	16.9
with ME (MJ/kg DM)	10.4	10.3	10.3
and CP (g/kg DM)	>120	>135	>150

Models have been produced using RUMNUT for each cow type. The milk yields used for each cow type are taken from milk yields estimated when these cows are fed good quality grass hay of 10.3 MJ ME/kg DM, the upper point for physical control of dry matter intake. Feed requirements are kept constant, but the quality of the fodder is progressively reduced from high quality at 10.8 MJ ME/kg DM and 183 g CP/kg DM comprised of high quality grass hay and vetch hay cut in the vegetative stage; to low quality at 6.3 MJ ME/kg DM and 38 g/kg DM comprised of wheat straw fed alone.

Feed costs for individual feeds and for feed classes are shown in Figures 11.4.1 and 11.4.2 respectively. Points to note include:

- With high quality fodders, the target milk yields can be met by home produced fodders alone. In fact some straw is fed to meet appetite requirements. This represents the lowest total costs for feed for large cows with high milk yields.
- As fodder quality declines, increasing amounts of home grown and purchased concentrates are fed, replacing fodder dry matter.
- With high yielding large cows, the cost of protein concentrates equals that of energy concentrates, and the total cost of feeds slowly increases. With the lowest fodder quality the cost of concentrates is 91% of the total feed cost, and purchased concentrates make up 95% of this cost.
- With small cows, due to their low milk yield, the requirement of protein is less. Total feed cost declines slightly from highest to lowest fodder quality. With the lowest fodder quality energy concentrates (including wheat bran) make up the largest cost of the diet, although the proportional cost of total concentrates is similar to that of large cows.
- With medium sized cows protein requirements are intermediate, and there is a small increase in feed costs from high to low quality fodder.

Income from milk, costs of total and purchased feeds, and margins are presented for the three models in Figure 11.4.3, and summarised in Table 11.12:

- Milk income at Yuan 2.00/litre is constant over the range of fodder qualities for each cow size.
- Given the small changes in total costs of feeds, there are only small declines in margins over total feeds for large and medium sized cows as fodder quality declines, and no effect for small cows. Margins are low for small cows, related to their low milk production. Margins are dependent on the valuations used for fodders and for purchased feeds.

- Margins over purchased feeds decline progressively as fodder quality is reduced, until it is similar to the margin over total feeds. There is great benefit to making use of home produced feeds, provided these can be produced economically with surplus family labour.

Table 11.12. Summary of the effect of forage quality on fodder to concentrate ration in the diet of milking cows - Milk income, feed costs and margins

Cow size	**Small**			**Medium**			**Large**		
Feed quality (MJ ME/kg DM)	6.3	8.3	10.3	6.3	8.3	10.3	6.3	8.3	10.3
Milk yield (litres/cow/day)	4	4	4	12	12	12	20	20	20
Milk income at Yuan 2.00/litre (Yuan)	8	8	8	24	24	24	40	40	40
Cost of all feed (negative) (Yuan)	-6	-6	-6	-14	-13	-12	-22	-21	-19
Margin over total feed costs (Yuan)	2	2	2	10	11	12	18	19	21
Cost of purchased feeds (negative) (Yuan)	-5	-3	-0	-12	-8	-1	-19	-14	-1
Margin over purchased feeds (Yuan)	3	5	8	12	16	23	21	26	39

The programme to develop double cropping for fodder cropping is linked to government programmes to develop commercial milk production on crop lands in central Tibet. This links use of exotic and crossbred cows with fodder crop production and conservation. In this manual the feeding requirements of local, crossbred and purebred exotic cattle have been considered. It is therefore appropriate to close with an economic comparison of milk production from rations with a range of fodder to concentrate ratios, as examined above. In order to make a realistic comparison between cow types adjustment must be made for cow liveweight, and the fodders and feeds consumed. The data in Table 11.12 has therefore been reworked to compare three groups of cows: six Local cows, three crossbred cows and two exotic cows. Each group has a total liveweight of 1200 kg. The range of fodder quality from good to poor is retained.

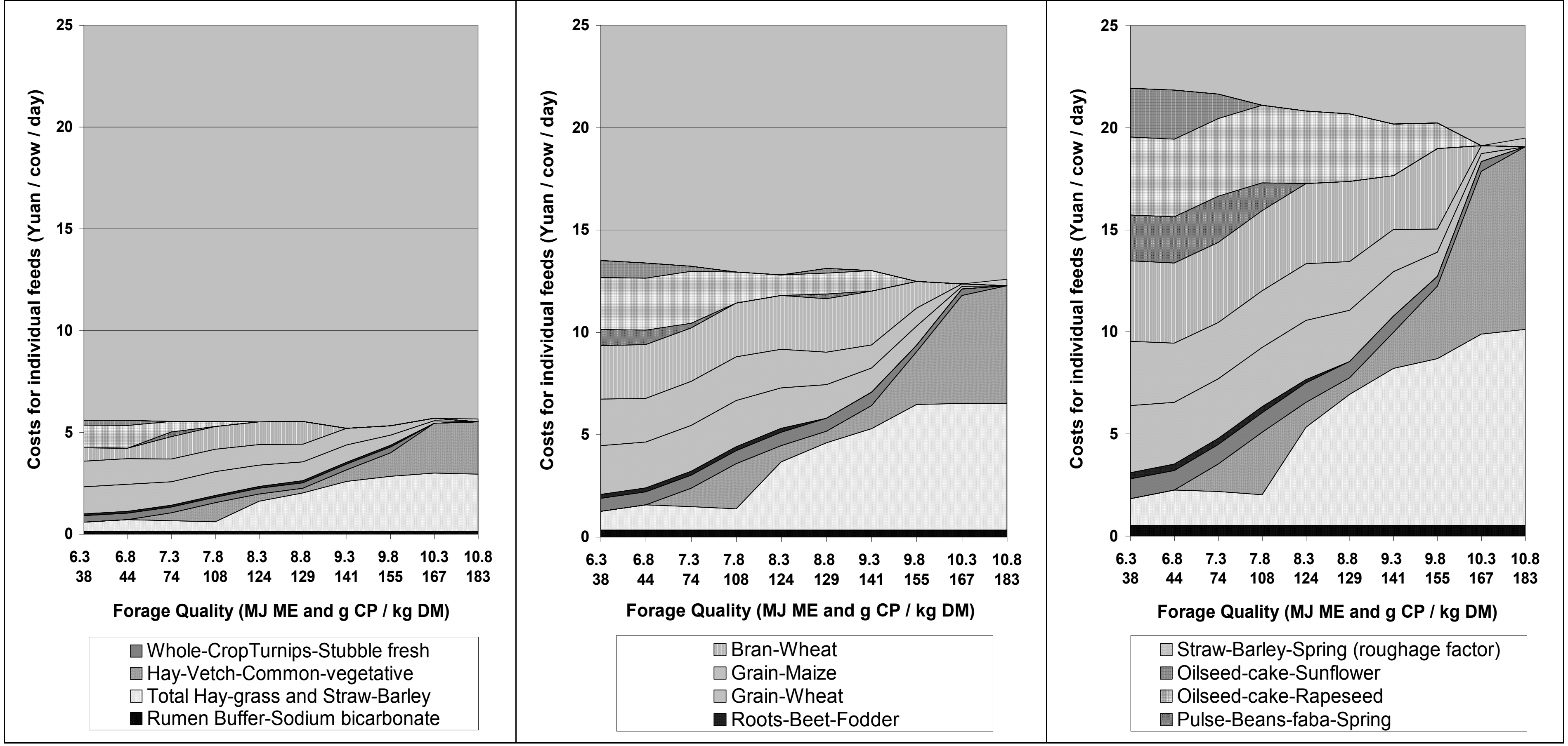
Table 11.13. Effect of forage quality on fodder to concentrate ration in the diet of milking cows - Milk income, feed costs and margins compensated for cow liveweights

Cow size	**Small**			**Medium**			**Large**		
Cow liveweight (kg)	200			400			600		
Number of cows in size group	6			3			2		
Fodder quality (MJ ME/kg DM)	6.3	8.3	10.3	6.3	8.3	10.3	6.3	8.3	10.3
Total milk yield (litres/size group/day)	24	24	24	36	36	36	40	40	40
Milk income at Yuan 2.00/litre (Y)	48	48	48	72	72	72	80	80	80
Total Cost of all feed (negative) (Y)	-34	-33	-34	-41	-38	-37	-44	-42	-38
Margin over total feed costs (Y)	14	15	14	31	34	35	36	38	42
Proportion of margin for large cows	*0.39*	*0.39*	*0.33*	*0.86*	*0.89*	*0.83*	*1.00*	*1.00*	*1.00*
Total Cost of all purchased feeds (negative) (Y)	-28	-20	-2	-35	-23	-2	-39	-27	-3
Margin over total purchased feeds (Y)	20	28	46	37	49	70	41	53	77
Proportion of margin of large cows	*0.49*	*0.53*	*0.60*	*0.90*	*0.92*	*0.91*	*1.00*	*1.00*	*1.00*

The following points are evident:

- Due to their lower milk production, the six small cows only produce 0.60 of the milk of two large cows; three medium sized cows produce 0.90 of the milk of two large cows. Given hybrid vigour, first cross Local x Simmental and Local x Holstein cows should perform almost as well as purebred exotics under local conditions.

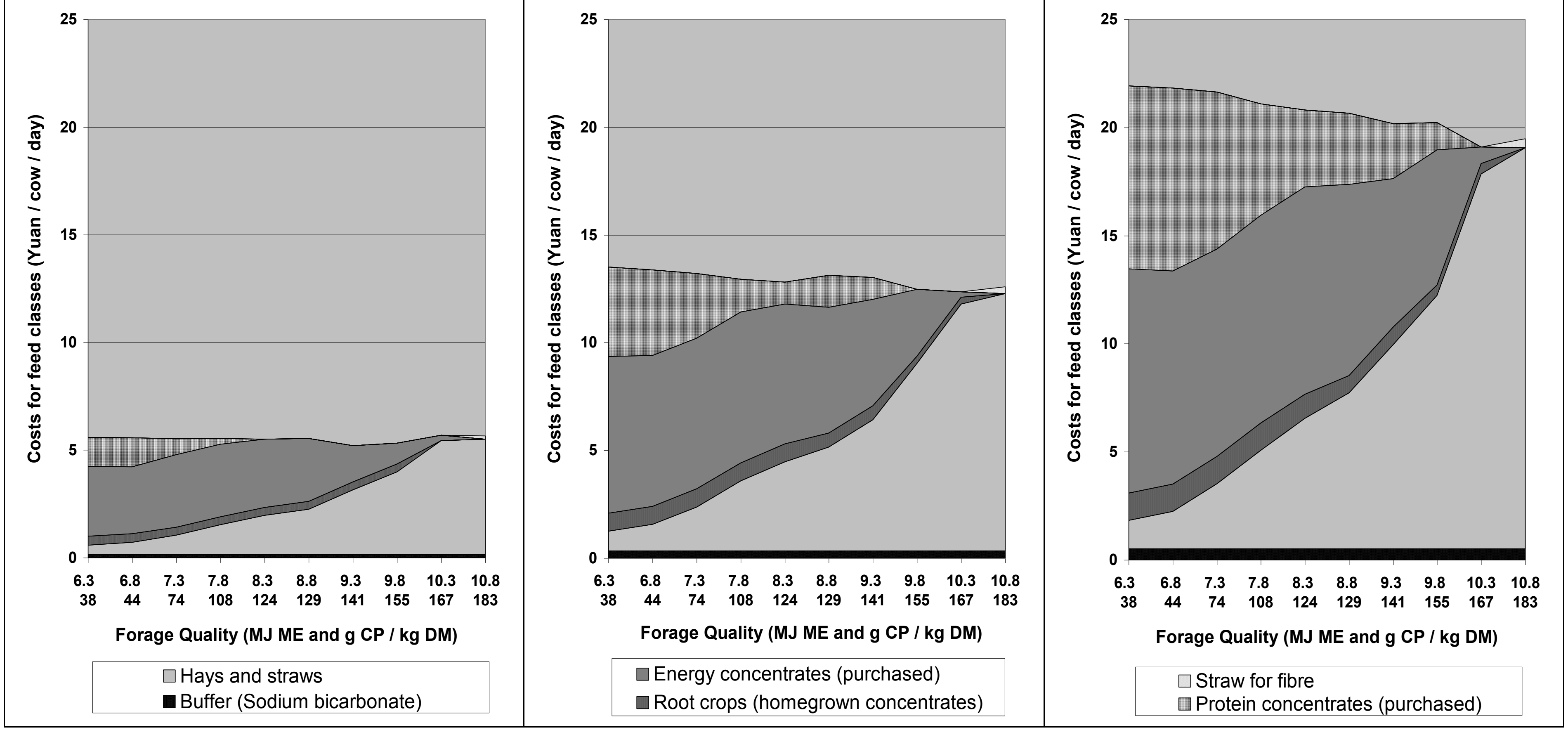
Local cow (200 kg LW)	**Crossbred cow (400 kg LW)**	**Simmental or Holstein cow (600 kg LW)**
Milk yield of 4 litres / day	Milk yield of 12 litres / day	Milk yield 20 litres / day
Feed Requirement: 4.9 kg DM / day with 10.4 MJ ME and at least 120 g CP / kg DM	Feed Requirement: 11.1 kg DM / day with 10.3 MJ ME and at least 135 g CP / kg DM	Feed Requirement: 16.9 kg DM / day with 10.3 MJ ME and at least 150 g CP / Kg DM



1. Legends apply to all charts.
2. Rations were formulated using RUMNUT ruminant nutrition rationing software based on the UK Metabolisable Energy and Protein systems (Chamberlain, 2004).
3. Costs of feeds relates to the value of ME in the feed based on the differences in ME content and value of wheat straw and wheat grain; and the value of CP in the feed based on the difference in CP content and value of wheat straw and wheat bran (see Table 11.6.)

Figure 11.4.1. Relationship between Conserved Forage Quality and Forage to Concentrate Ratio in the diet of milking cows. Costs of individual feeds

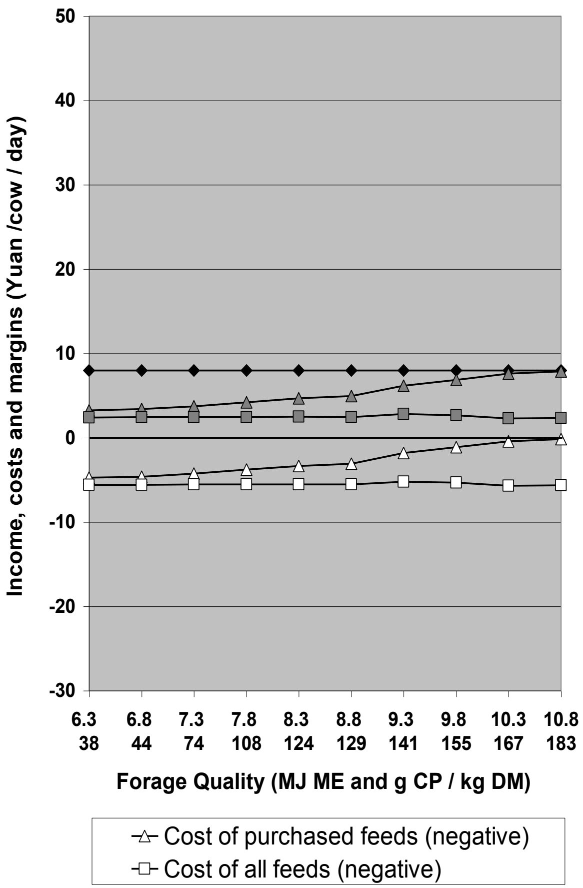
Local cow (200 kg LW)	Crossbred cow (400 kg LW)	Simmental or Holstein cow (600 kg LW)
Milk yield of 4 litres / day Feed Requirement: 4.9 kg DM / day with 10.4 MJ ME and at least 120 g CP / kg DM	Milk yield of 12 litres / day Feed Requirement: 11.1 kg DM / day with 10.3 MJ ME and at least 135 g CP / kg DM	Milk yield 20 litres / day Feed Requirement: 16.9 kg DM / day with 10.3 MJ ME and at least 150 g CP / Kg DM

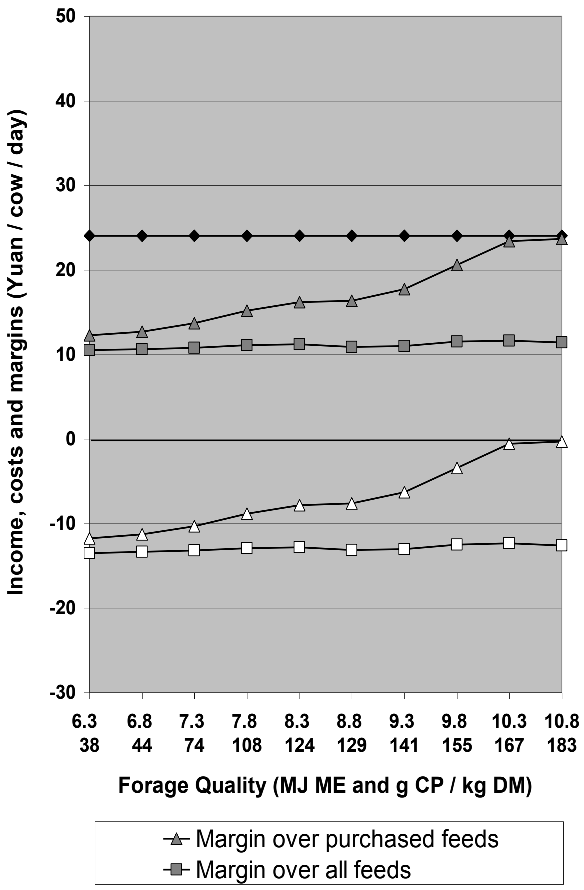


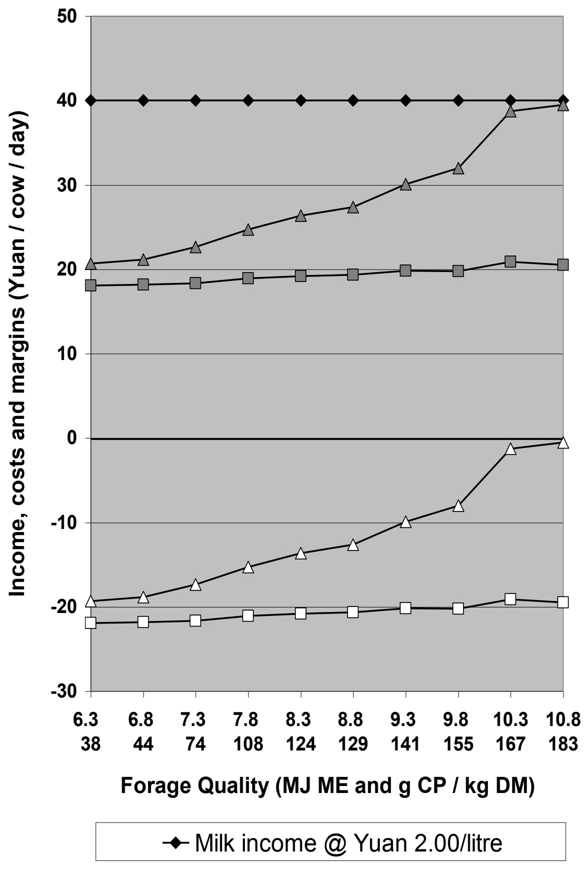
1. Legends apply to all charts.
2. Rations were formulated using RUMNUT ruminant nutrition rationing software based on the UK Metabolisable Energy and Protein systems (Chamberlain, 2004).
3. Costs of feeds relates to the value of ME in the feed based on the differences in ME content and value of wheat straw and wheat grain; and the value of CP in the feed based on the difference in CP content and value of wheat straw and wheat bran (see Table 11.6.)

Figure 11.4.2. Relationship between Conserved Forage Quality and Forage to Concentrate Ratio in the diet of milking cows. Costs by feed class

Local cow (200 kg LW) Milk yield of 4 litres / day Feed Requirement: 4.9 kg DM / day with 10.4 MJ ME and at least 120 g CP / kg DM	**Crossbred cow (400 kg LW)** Milk yield of 12 litres / day Feed Requirement: 11.1 kg DM / day with 10.3 MJ ME and at least 135 g CP / kg DM	**Simmental or Holstein cow (600 kg LW)** Milk yield 20 litres / day Feed Requirement: 16.9 kg DM / day with 10.3 MJ ME and at least 150 g CP / Kg DM







1. Legends apply to all charts.
2. Milk Income is taken as Milk Yield x Milk Value at Yuan 2 / litre (Yuan 1 / jin) for cow's milk.
3. Margin over purchased feeds is Milk Income minus Cost of purchased feeds ; and Margin over all feeds is Milk Income minus Costs of all feeds. Costs of feeds are taken from Table 11.6.

Figure 11.4.3. Relationship between Conserved Forage Quality and Forage to Concentrate Ratio in the diet of milking cows. Incomes, Costs & Margins

- However total feed costs for six small cows is 0.83 that of two large cows, so that margin over total feed costs averages only 0.37 for six small cows compared to two large cows. Three medium sized cows have total feed costs 0.94 that of two large cows, so that their margin over total feed costs averages 0.86 that of two large cows. Margins over total feed costs are better on good quality fodder for medium and large cows, but fodder quality has little effect for small cows.
- The cost of purchased feeds for six small cows is only 0.74 that of two large cows, so that the margins over purchased feeds averages 0.54 for six small cows compared to two large cows. Three medium sized cows have a cost of purchased feeds 0.87 that of two large cows, so their margin over purchased feeds is 0.91 that of two large cows. All margins over purchased feeds are higher with good quality fodder, and for six small cows this improves their margin to 0.60 that of two large cows.
- This exercise allows a comparison of the number of small and medium cows needed to produce the same margins as one large cow – part animals are allowed (Table 11.14)

Table 11.14. Numbers of small and medium sized cows required to provide equivalent margins to milk production as one large cow

	Numbers of cows ≡ one large cow					
Cow size	**Small**			**Medium**		
Cow liveweight (kg)	200			400		
Fodder quality (MJ ME/kg DM)	6.3	8.3	10.3	6.3	8.3	10.3
Number of cows according to margin over total feed costs	7.7	7.6	9.0	1.7	1.7	1.8
Number of cows according to margin over purchased feeds	6.2	5.7	5.0	1.7	1.6	1.6

- From Table 11.14 it therefore appears that from an economic perspective and with the production parameters specified, 7.0 small cows of 200 kg or 1.7 medium sized cows of 400 kg are equivalent to one large cow of 600 kg liveweight.
- Feeding models need to be worked out for Jersey cows and their crosses with Local cows, but given their smaller size and their higher butterfat and hence energy requirements for milk, they are likely to require higher quality rations than the crossbreds above. Jersey cows of 350 kg liveweight are likely to yield 10.0 litres of 4% fat corrected milk on a ration of 10.3 MJ ME/kg DM, and to allow for liveweight, 3.4 animals (total 1200 kg) would produce 34 litres of milk. On the basis of milk yield alone, it is estimated that 2.0 Jersey cows would be equivalent to one large cow.
- Similarly Local x Jersey crossbred cows of 275 kg liveweight are likely to yield 7.5 litres of 4% fat corrected milk on a ration of 10.3 MJ ME/kg DM, and allowing for liveweight, 4.4 animals (total liveweight 1200 kg) would produce 33 litres of milk. On the basis of milk yield alone, it is estimated that 2.7 Local x Jersey cows would be equivalent to one large cow. This is a major improvement over local small cows of 200 kg liveweight. In practice crossbreds may achieve higher yields due to hybrid vigour, while Local cows may not be able to produce the 4 litres quoted in these models.

These physical models need to be tested with practical feeding data from farms in central Tibet, and developed with laboratory analysis of local fodder and feed samples. Economic data gathered under the ACIAR dairy project then needs to be applied to the refined physical models.

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Fodder Production and Double Cropping in Tibet

TCP/CPR/2907-3101

Training Manual vs 2.0

Pdf version

This training manual was initially prepared as a project document for use by staff in the field, with a restricted edition of 20 hard copies. It was designed for education of local staff, and as resource material for preparation of farmers' extension materials by local scientists and extension staff. A translation into Chinese has been made.

A second edition (Vs 2.0) of 100 hard copies with minor edits and corrections was prepared for the Pasture Section of AGPC, FAO Rome for wider circulation, and it has been placed on the FAO website (see inside cover). This remains a project document, and has not passed through the standard publishing procedures of the FAO publications service. Material may be freely quoted from this document subject to the standard disclaimer, and quotation of the citation on the reverse of the title page – or the original document where information has been sourced from outside the project.

The manual was prepared so that each chapter can be used independently. Each chapter has its own front page, and carries its own references. In the printed version chapters are denoted by front pages with paper of different colours, with stiff paper used for section breaks.

This pdf version has been prepared for circulation on CD-ROM. Each chapter has its own folder. Each folder has separate files for the front page / contents; the chapter itself; and plates. Use of pdf files reduces the chance of corruption / accidents with file content, and broadens the range of computers that can access the material. Apologies for not making fancy linkages within the document.

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Kind regards

Ian R. Lane, 19th June 2011
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