HANDBOOK
FOR STRAW FEEDING SYSTEMS

Principles and applications

with emphasis on Indian livestock production

Edited by

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FOREWORD

The Indo-Dutch Project on "Bioconversion of Crop Residues for Animal Feed" started in 1985 on the development of biological methods to improve straw quality for animal feed. As the title reads, the work in the first phase was restricted to microbial treatments of straws, which proved to have only marginal benefits. Gradually, the project increased the understanding about the difficulties of these treatments, and other approaches were followed such as chemical treatment, supplementation, as well as breeding and/or management of grain crops for more or better straw. The project also yielded the insight that the application of a technology not only depends on its technical characteristics. Quite often, if not always, the success of a technical innovation is determined by the resource pattern, socio-cultural and economical conditions, combined with the demand for agricultural produce.

Farming Systems Research in its various forms was brought into the project in order to understand the needs, limitations and opportunities of farm families to apply technology and management in field practice. It has proven to be a key to the success of this project, not in the least because it brought researchers in contact with extensionists and farmers during Rapid Rural Appraisals and On Farm trials.

This book reflects the work and interactions during research in the laboratories, experimental station and discussions/meetings in the field. It is an important step for this country, and probably for Asia and elsewhere, to provide extension staff, consultants, scientists and students with such an extensive coverage on aspects regarding crop residue feeding. The uniqueness of the book lies in the variety of topics covered, but also in the collaborative efforts of researchers and extensionists working in a vast range of disciplines, institutes and farming systems in India and abroad.

I congratulate the authors and the editors with this unique publication, and I hope that the readers will supply the authors with their comments so that a following edition can be even more valuable.

R.S. Paroda
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MESSAGE

The economies of agricultural countries like India depend to a large extent on the production of crops and livestock. In spite of increasing industrialisation, the government will therefore have to give continuing attention to programs that enhance output and efficiency of crops and livestock. However, any technical program that aims to contribute to this process has to remember that, in the end, it is the farmers that have to put the improvements into practice. Unless they see and feel the benefit of the socalled transferable technologies, no rapid and large scale adoption can be expected.

The transfer of technology from our national research centres to the farmer has not always met the expectations of policy makers, researchers and agricultural planners. One of the reasons was that the technologies brought no perceptible improvement to the farm family. Another reason lies in the large variation in Indian agriculture. Apart from differences between agroecological regions, there is an even larger socio economic variation between farmers. In that sense, farming is done by men, women, their families, commercial oriented city dwellers, or by people in subsistence agriculture in the hills or rainfed agriculture of the semi arid regions of the country. A final reason for slow adoption of technology is perhaps the difficult communication between the scientists, the extensionists, and the farmers community.

I am pleased therefore to see that this Handbook is published by the Indo Dutch project on Bioconversion of Crop Residues. now called the BIOCON project. It precisely addresses the three problems that were mentioned above. In the first place, it aims to indicate the profitability of a number of transferable technologies, by stating when and where the proposes methods are useful.

Secondly, it provides insight into the diversity of Indian Farming Systems, and methodology to analyse farmers problems according to their own needs. In the third place, this publication makes much information available, that was thusfar hidden in books and scientific publications, where it was only accessable to the scientific community. The book is based on the information published in earlier BIOCON proceedings and Technical Bulletins, as well as on work of researchers outside BIOCON.

The purpose of this book, and of the BIOCON project will have been served fully if all those who read and use this book, will share the information with others. If, in addition to that, the readers and the users will provide feedback to the authors in terms of suggestions for improvements as well as new research needs, the unique group effort represented in this publication will be done full justice.

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EDITORS' COMMENTS

In the Indo-Dutch project on Bioconversion of Crop Residues (BIOCON), a considerable effort has been made to improve the application of appropriate technologies for the farming community. In this context the need for this handbook was felt during meetings between extension workers, researchers and policy makers, within as well as outside the BIOCON project. During such meetings, quite commonly the same questions were asked, and one purpose of this book is, therefore, to avail a general audience with information now available on this topic. Even though much of what is written in this book may need refinement, it was felt that the material is useful enough to be circulated.

A second objective of the book is to indicate what is known and what is still unknown. This has been accomplished by inviting authors from a variety of disciplines and backgrounds to contribute to the book, and while writing what is known, also the missing information was identified. The results of that exercise that are reported in the new research extension agenda that will be published separately.

The third objective is to avail the workers in agricultural development with a reference book that attempts to include an evaluation of technology in terms of farmers' perceptions. As experienced during Rapid Rural Appraisals (RRAs) and other BIOCON activities, it is not the scientists perception that determines the usefulness of a technology. Farmers are the ultimate judge of suitability of new methods and approaches, and their criteria can be different from those used at research stations.

The final objective is to initiate a discussion on the suitability and need for technology per farming system. We do not pretend that each statement in this book is universally true, but the information on screening and fit exercise should be useful to serve as a start of discussion.

The topic of straw feeding is a typical systems issue, where several disciplines meet, e.g., animal nutrition, crop science, sociology, economics, plant breeding, gender and FSR specialists. Not only between these disciplines, but also between institutions, regions and countries, within and outside BIOCON, the book depended on persons who went out of their way to make this publication possible. The book focuses on the use of straw as animal feed, because the mandate of the project was such. Relation is laid to associated areas of work and similar publications on other technologies.

Wherever the term technology is used, it should be remembered that we also refer to the use of management. The introduction of technology is commonly associated with the use of subsidies and incentives, overlooking the importance of management based on knowledge and understanding of the farming system.

The lay-out of the book reflects the BIOCON approach as evolved during series of sessions with project participants and outsiders. It starts with a systems approach, it then explains what needs and can be done under which conditions, and finally, it discusses the use of various fibrous materials from a systems point of view, i.e. not only as feed but also for other purposes. References and relevant addresses are given at the end of most chapters, and under tables and graphs. BIOCON does not claim to have generated all this work on its own, and work from other sources is referred to wherever possible. Depending on the topic, the editors have attempted to create uniformity between chapters, but room has been given and taken by individual authors to modify their outlines.

To avoid duplication, there is crossreferencing to other chapters, by using the "#" sign combined in the relevant chapter number. Due to the systems approach some overlap between chapters occurs, but we feel that it improves readability since essentially each chapter should be selfcontained. Basic knowledge about agronomy, economics and animal science is assumed to be available with the reader, and if not, the reader might best be referred to two other handbooks available from ICAR: one on Agriculture and one on Animal Production.

The various proceedings from BIOCON workshops, combined with the technical bulletins, may serve as a source of more in-depth technical information. In line with the attempts to avoid gender bias, there has been special attention for the role of women in livestock farming and crop residue feeding. Such attention is also explicit in the occasional use of terminology like "he/she" or the "farm family", rather than implicitly referring to the farmer as a man. The term Ms. is used to avoid the unnecessary distinction between Miss and Mrs.

The contribution of all authors, their flexibility with each other, and their patience with the editors' comments is unparalleled. The acknowledgement of all individuals is impossible since it would inevitably lead to omissions of others. Special thanks are due to H.P.P. Kessels and M.N.M. Ibrahim who assisted us to get the book out before the final deadline. Thanks are also due to the authorities in the Indian and Dutch Governments, to the wives and husbands of the authors and to many unnamed consultants, office staff, farmers and development workers for making this effort possible. A list with addresses of the authors is provided at the end of the book. It is hoped that the book serves its purpose, in India and abroad.

Photocopying and other use of the material is encouraged, mention of the source will be appreciated. The readers of the book are encouraged to share their comments with the editors or with the individual authors.

Januari 1995

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GEOGRAPHY, AGRO-CLIMATIC AND AGRO-ECOLOGICAL ZONES OF INDIA

For those readers who are not familiar with Indian geography, we have included the map of India (see Fig. 1). This book is however less concerned with geography than with the application of technology and management per agro-ecozone (#1.3.1.). Therefore, we have also included a few classifications of Indian farming systems that may be new even for those who know India very well. The maps concern the classification of India into fifteen agro-climatic regions of the Planning Commission (see Fig. 2), a statewise agro-climatic map (Fig. 3), and the division of 21 agro-ecological regions as per NBSS and LUP (see Fig. 4). All these maps were taken from Ghosh (1991). The geographical map comes from Oxford (1987). Even though such geographical and agro-ecological maps provide indispensable orientation, it should be remembered that they provide no information regarding - what BIOCON calls - the "non-geographical criteria": i.e., gender division, socio-cultural differences, or distinction in terms of access to the market, inputs and knowledge. Information regarding those aspects can only be collected on site and mapping in that sense cannot easily be done on a national scale.

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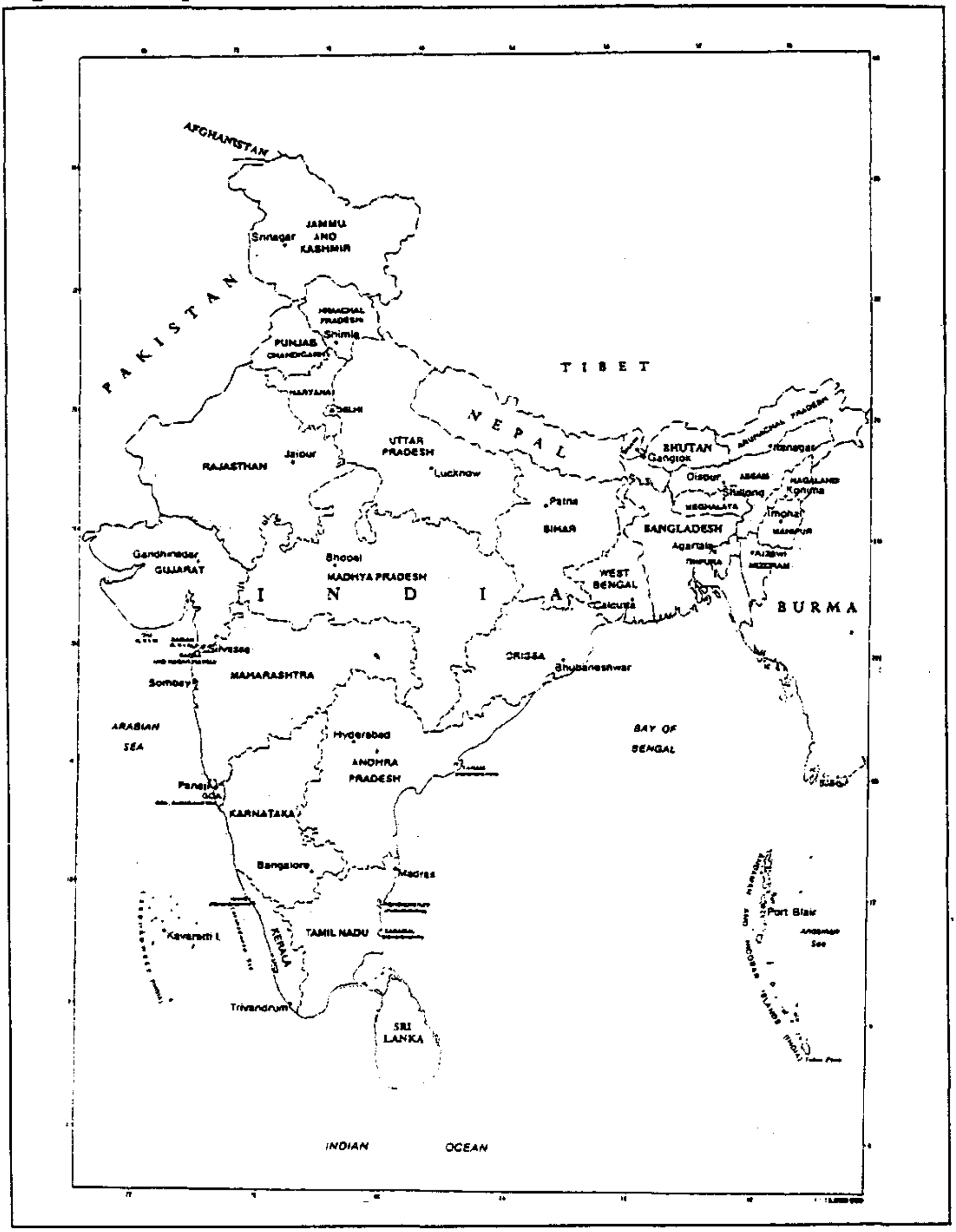
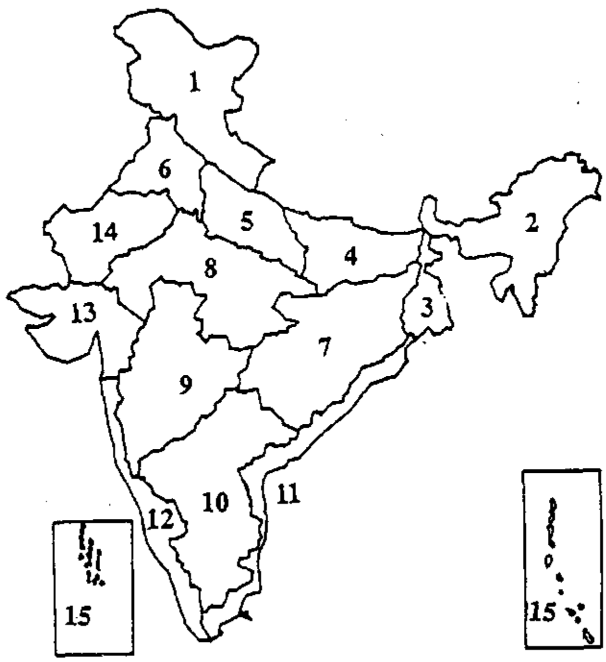
Figure 1. Map of India



(Source: Oxford 1987)

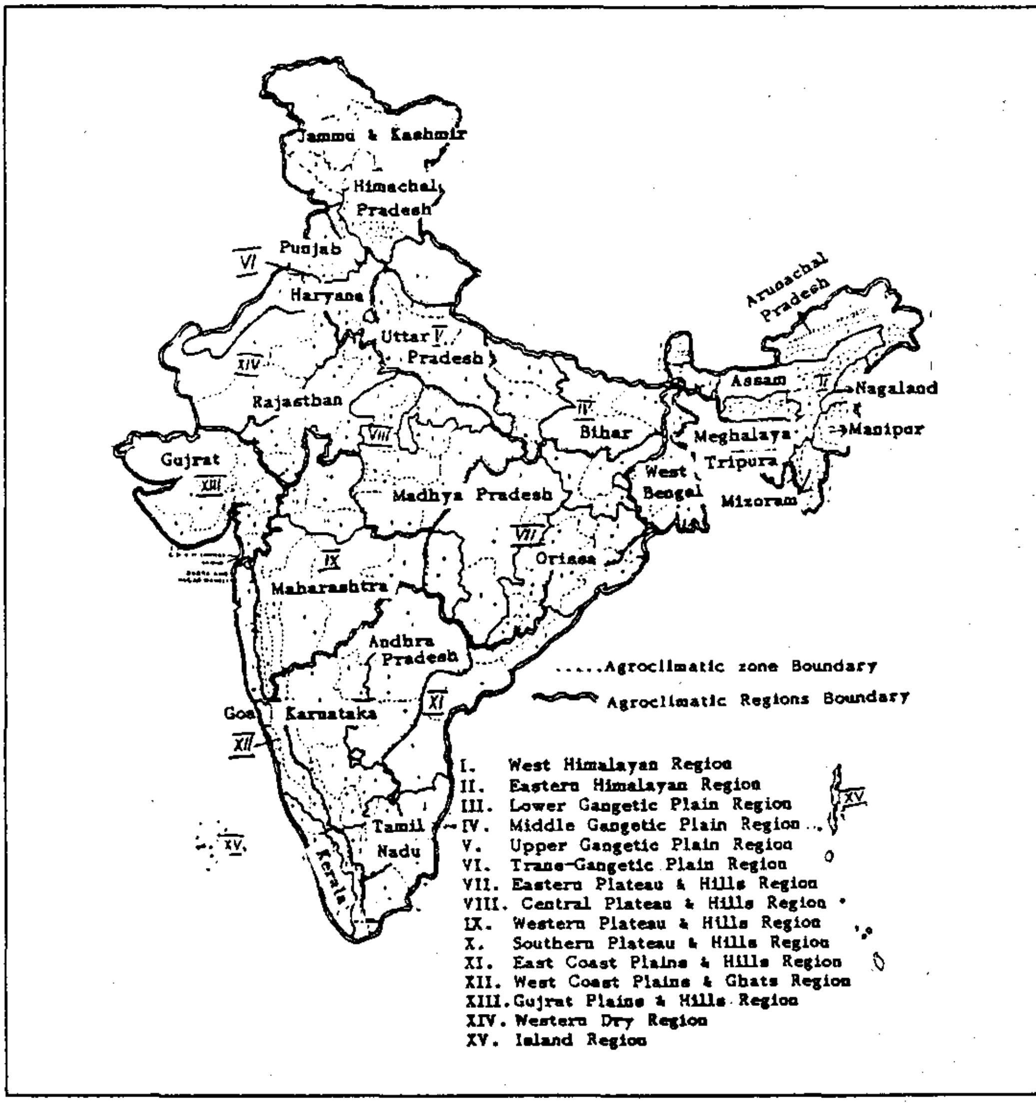
Figure 2. Fifteen agro-climatic regions of the Planning Commission in India



1. Western Himalayan Region
2. Eastern Himalayan Region
3. Lower Gangetic Plain Region
4. Middle Gangetic Plain Region
5. Upper Gangetic Plain Region
6. Trans-Gangetic Plain Region
7. Eastern Plateau & Hills Region
8. Central Plateau & Hills Region
9. Western Plateau & Hills Region
10. Southern Plateau & Hills Region
11. East Coast Plains & Hills Region
12. West Coast Plains & Ghats Region
13. Gujrat Plains & Hills Region
14. Western Dry Region
15. Island Region

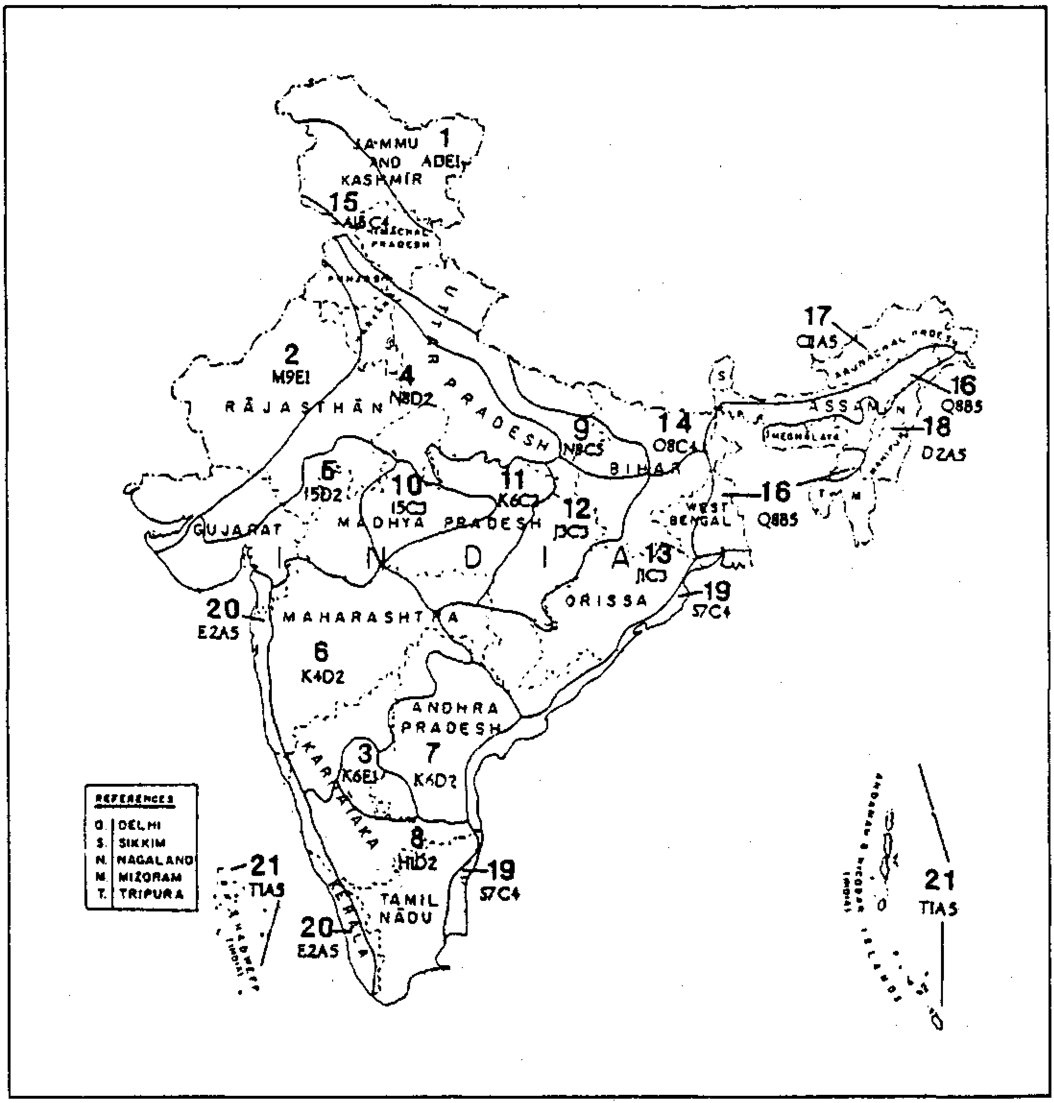
(Source: Ghosh, 1991)

Figure 3. Statewise agro-climatic zones shown under various agro-climatic regions in India



(Source: Gosh, 1991)

Figure 4. Twenty-one agro-ecological regions of India as per NBSS & LUP, Nagpur



(Source: Ghosh, 1991)

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SECTION 1

CROP-LIVESTOCK SYSTEMS

GENERAL ASPECTS

1.1. LIVESTOCK AND CROP RESIDUES, MANAGEMENT AND TECHNOLOGICAL CHANGE

J.B. Schiere, Kiran Singh, A.J. De Boer and D.V. Rangnekar

INTRODUCTION

Both in society and farming, some strange tensions exist between the need to change and the wish to keep doing what has been practised and learned over ages. Indeed while at the same time one can look back at the good old days, it is tempting to look forward to a better future. While there are so-called non-progressive farmers who do not apply management and techniques as suggested by scientists and extension workers, there are other developments in society that go faster than even policy makers and scientists can grasp with. In fact, some farmers are often ahead of the academic community. Technological change is often expected to result in positive changes, but it also causes less desirable side effects like urbanization, deforestation, labour displacement and salinization. What is then the need for change, which are the trade-offs between technical progress and social equality, why do farmers not follow the advice of specialists and how do these issues apply in livestock development based on use of crop residues? This first section of this handbook intends to throw some light on these questions, and this chapter discusses technical change in general terms.

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LIVESTOCK AND CROP RESIDUES

Though much of today's livestock in India survives on crop residues, this has not always been so. In his *History of Agriculture*, Randhawa (1980) writes that the early Aryans would cultivate crops in the forested Gangetic plains and herd their animals on grassy areas or in the forest. Nowadays little forest is left in those Gangetic plains. Herdsmen from Rajasthan come increasingly to Haryana, letting their animals graze on crop residues, whereas in the long past there would be enough fodder in Rajasthan itself.

Changing resource/demand patterns force society to look for other ways to produce. These shifts in resource use (e.g. between grazing-based and straw-based feeding systems) reflect shifts in the relative scarcity of resources used in production, particularly the relation between land, labour and capital. The changes are also reflected in the generation and use of technologies and in private and public sector investments in research and development in response to these change in relative scarcity. This is called the "theory of induced innovations" (Hayami and Ruttan, 1985) where innovations in the production process are "induced" by changes in scarcities that are reflected in market prices. The returns to be had by increasing the efficiency of a scarce factor (e.g. irrigated land in India) are greater than for a change in the life efficiency of an input which is in abundant supply (such as unskilled agricultural labour in the densely populated areas of India). This is clearly seen now where rapid increases in agricultural productivity and output in Punjab and Haryana has led to labour shortages and increased wage rates, leading to innovations in labour-saving mechanical technologies (such as tractor ploughing and combine harvesting) and chemical technologies (use of herbicides to reduce weeding labour). The same parallels can be applied to the livestock sector where increasing scarcities of common grazing lands led to increased reliance on feeding of crop residues and by-products and increased investment in research and development efforts to improve utilization and productivity of these feedstuffs. The research for induced innovations is apparent in the recent emphasis on work with unconventional feeds, the effort to use tree leaves for feed or the need to import inputs from elsewhere, e.g concentrates feeds, fertilizer or tractors rather than bullocks that used to feed free on plenty cropland. In present days it has become difficult to let the animals graze on common grounds, village land and forests. There is even a feeling that a cow that used to provide wealth and power, now costs money and feed to maintain. From being a "kamdhenu", i.e, the cow that provides all the needs, livestock are slowly but surely becoming a burden. Feed needs now to be purchased and straw has to be stored and kept for feeding, whereas in the past the straw was often left in the field or burned.

From these examples it becomes clear that ways and purposes of keeping animals are changing, due to the changing resource/demand patterns, whether one likes it or not. Fibrous crop residues (straws) are becoming the basal feedstock for the survival of many village animals. Also in cities the straws become expensive as source of fibre for high producing animals. The more valuable crop residues like brans and oilcakes are increasingly being taken to urban centres where they serve as feed for high milk producers or for pigs and poultry. Also, they are exported to other countries, depriving the place of origin from valuable minerals and a possibility to add value.

THE POTENTIAL OF STRAWS

Large quantities of straw are available from cropping, and one hectare yield of rice straw can essentially support the energy needs of one small 350 kg animal (Box 1) for something like a year, though yields and qualities of straw vary. Whereas the nutritive value of wheat and rice straw is not good enough to provide maintenance requirements, the use of coarse straws e.g. from maize, millets and sorghum may allow animals to survive and maintain body weight. In absence of better feeds, the proper use of crop residues can therefore help to maintain more animals, and to retain more nutrients and income in the village. Fortunately, the yield of straw from fertilized and irrigated area may be higher than the yield of fodder from the natural vegetation (#4.5.). Also, and contrary to common belief, the straw yield of new varieties may be relatively less but it can be more in absolute terms . There is no evidence that straw from newer varieties is always inferior to straw of old varieties : shorter stiffer straws can have a higher leaf to stem ratio, resulting in generally better straw! (#4.5.).

Unfortunately however, the nutritional value of straws is likely to be less than that green leaves from forest or grazing. As a result, the quality of the feed resources tends to decline. Many ways to overcome these problems are sought and presented in this book, but before that it is relevant to discuss technical change in general terms.

Box 1. Some facts and figures about straw

- Burning of a hectare of straw from a average rice crop of let us say 3000 kg paddy results in the loss of 4000 kg x 0.6 % N = 24 kg of Nitrogen in the smoke: the equivalent of almost 50 kg of urea!
- Export of the bran results in the loss of 300 kg bran of 10% protein, i.e. 5 kg of Nitrogen, leave alone the other nutrients like P and K.
- If a cow of 300 Kg body weight can eat approx. 5 kg dry matter of straw per day, the same quantity of 4000 kg straw provides for 800(!) days animal feed.
- The quality of particularly slender straws like from rice and wheat is not good enough to keep the animal alive over a long period, but the quantity is large and the value of the straw yield can represent between 10-15% or higher of the total crop value (#4.5.).

CLASSIFICATIONS OF TECHNICAL CHANGE

Different types of technology can be distinguished, but we will discuss it in terms of:

- adjustment of the output to resources (the low input system approach)
- adjusting the resources to the output (the high input system approach)

A combination of these two is possible, and technological change can be categorized differently also, e.g. in terms of either the use of inputs, knowledge, or their combination. Input based technologies are applied for example when fertilizer is used to increase fodder or grain yield. Information based technologies focus on the proper timing of fertilization, e.g. to maximise the output per unit input.

The low input approach is well known from societies or communities that have learned to survive by adjusting to the circumstances. In conditions of low access to inputs, it may even be useful for farmers to deny inputs to animals and to use them on a priority base for the crops. In that sense the animal subsystem has to adjust more to the lack of inputs than the crop subsystem. The high input approach it its extreme form, solves a local lack of resources by obtaining them from elsewhere, e.g. through technologies such as described in #4.3. Urban dairy farmers have purchasing power to extract straws and grain or oilseed milling byproducts from rural areas, turning the surrounding systems effectively into low input systems as far as feed is concerned. Typical high input solutions to feed shortage are the use of fertilizer and irrigation for cultivated fodder.

A strict distinction of technology on the basis of use of input or knowledge can not be made, but the principle can be illustrated by saying that a farmer can prevent the need for inputs by proper management:

- proper milking avoids the need for medicine inputs to cure mastitis;
- the choice of a suitable grain with useful straw reduces the need to grow fodder;
- timely harvest of a fodder reduces the need for purchase of concentrates.

The use of knowledge as a management tool can thus reduce the need for inputs and also the side effects of high input use in terms of waste disposal.

ADOPTION OF TECHNOLOGY

Much of the extension work in India focuses on the provision of services (e.g. inputs like seed, fertilizer, A.I) and provision of knowledge appears to receive insufficient attention. The choice between a proper combination of inputs and knowledge depends on the local conditions. Unlike vaccination campaigns that use the same vaccine and the same syringe on animals for large and small, poor or rich, northern or southern farmers, the application of feeding technology is highly system dependent. The fact that farmers do not adopt a technology from a scientist or an extension worker does not mean that they do not adopt new methods. In fact, the study of traditional or indigenous knowledge systems reveals that much knowledge travels between farmers themselves, completely outside the extension officers sphere of influence. It may also be that farmers perception of needs differs from those of the researcher, or that the need of one farmer is not like that of his neighbour or wife (#2.1.). Last but not least, it may be that a farming community lack the skill or understanding to comprehend the full effect of old practices in new conditions. The emphasis on input supply in may extension programmes is therefore regrettable. Research has shown that investments in exchange of knowledge, rather than one way transfer, is much more effective than programmes aimed at input supply alone.

RECENT DEVELOPMENTS ON INTRODUCTION OF TECHNOLOGY

Much work is recently done to improve the understanding between the researchers, extension workers and the farmers communities. Methodologies are developed to distinguish between farming systems (#1.3.1.), to understand farmer's real needs (#1.3.2.), or to select technologies or management approaches that might be useful for particular conditions (#1.3.3.).

The use of farming systems research methodology for the application of straw feeding techniques implies a stress on the fact that:

- cows and other animals are part of a system;
- large differences exist between systems.

A focus on the production of an individual animal, plant or farmers community, without understanding the overall system, can results in non-acceptance of technology or in undesirable side effects on other sub-systems.

For example: *Crossbreeding and stall feeding may mean extra work by women in collection of the grass. The labour or leisure that they used to spend on other subsystems can now no longer be applied to other activities.*

Neglect of differences between systems results in blanket recommendations that can be effective in one place, but ineffective and wasteful of resources in other conditions.

CONCLUSION

Technological change is sometimes seen as a guarantee for progress, and sometimes it is resented for its undesirable side effects, a remarkable tension indeed. Innovations can be based on use of inputs, on knowledge or on their combination. Transferable technologies in general, and feeding methods more specifically need to take into account that animals are part of a system and that large differences between systems preclude the use of simple blanket recommendations. Change of systems due to shifting resource basis forces farmers and scientists to look for innovations, but not after understanding the overall system, in order to avoid ineffective or undesirable results.

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1.2. LIVESTOCK AND CROP RESIDUES, A SYSTEMS APPROACH

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INTRODUCTION

The objective of this handbook is to provide practical information about methodology to study ruminant feeding and management, with emphasis on systems aspects of the utilization of fibrous crop residues. The need for a systems approach arises from the fact that:

- straw has more uses than for animal feed alone, e.g. it can also be used for fuel, thatching, soil conservation or other purposes. Innovations in the feeding and keeping of animals are therefore likely to affect the cropping system, and changes of cropping pattern affect the way and purpose of keeping animals;
- relevant activities or recommendations in one particular farming system of India, e.g. in rainfed farming conditions of the Deccan Plateau, are not necessarily relevant in another farming system e.g. in the humid condition of West Bengal or Assam.

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Blanket recommendations as followed in the time of the green revolution are clearly not possible in the development of livestock production and feeding systems.

The chapters in this section, therefore, provide methodologies and concepts that focus on:

- the understanding of why and how all those different systems function in the way they do;
- the identification of bottlenecks for system development and the possibility to apply new or indigenous technologies/ management approaches;

By explaining these issues we provide a framework, based on the concepts of FSR (#1.3.). It puts the technologies and background information of section 3, 4 and 5 in this handbook in their practical context: i.e. they are meant to meet the needs of (Indian) farm families that depend on mixed farming for their livelihood. The concepts and methodologies from the Farming Systems Research and Extension approach (FSR/E) help to better understand the resources, accessability, aptitudes, objectives, problems and constraints faced by smallholders as they try to cope with their environments. The chapters in this section, therefore, explain the principles and methodologies required for doing a better job of providing technologies and services to rural communities. But before elaborating further, we briefly review the importance of livestock in the national economy.

IMPORTANCE OF LIVESTOCK IN THE ECONOMY

The contribution of agriculture to the national economy declines, as economic development occurs and industrialization advances. Within agriculture, the relative importance of products with high income elasticities of demand (fruits, animal products) increases. The current contribution of agriculture to Gross Domestic Product (GDP) (1991-92) is 28.4 percent compared to 34.7 percent in 1980-81. Domestic product from livestock output as a percent of value of all agricultural output increased from 8.6 percent in 1980-81 to 21.3 percent in 1990-91 (at 1980-81 prices).

Typically, however, the perception of policy makers with respect to the national importance of livestock may differ from that of individual farmers (#2.2.). Government is often interested in cheap food for urban masses and high output of export commodities. Farmers are, however, interested in their own survival and high prices, even when caused by low yields. Moreover, products that remain within a farm do not enter the Gross National Product, e.g. the value of dung, draught or security provided by the animal is often underestimated by applying GNP as a measure of national wealth. Even though corrections and estimates can be made, the value of straw fed to cows, goats or bullocks is not represented in most estimates of contribution of grain to the national economy. Hence, for the farmer, the totality of crop has value (#4.5.), but for government statistics mostly the grain is the only output that counts. Meat output may be important on a national scale, but for many individual farm families it has hardly any value. Within those limitations we will briefly elaborate the importance of milk, meat and dung on a national scale, e.g. probably underestimating the value of livestock for the individual farmer.

Table 1. Contribution of various groups to the total value of output of livestock sector during 1990-91 (in Rs. crores)

Groups	At Current Prices		At 1980-81 Prices	
Milk group	29,269	(67.0)	11,711	(68.1)
Meat group	6,982	(16.0)	2,638	(15.3)
Eggs	1,343	(3.1)	715	(4.2)
Wool and hair	145	(0.3)	66	(0.4)
Dung	4,347	(10.0)	1,523	(8.9)
Silkworm cocoons and honey	860	(2.0)	271	(1.6)
Increment in livestock	713	(1.6)	269	(1.5)
Total Livestock Output	43,659	(100.0)	17,193	(100.0)

Source: National Accounts Statistics 1993. Central Statistical Organization, Department of Statistics, Government of India, New Delhi

Note: 1) the figures in parentheses represent percent contribution of various groups to the total value of livestock output.
2) the inclusion of silkworms and honey is disputable but hardly affects the total picture

Milk is an important and gradually increasing contributor to the value of output from the livestock sector. Its contribution during 1990-91 was Rs.29,269 crores, which accounts for 67% of the total value of output of the livestock sector. The meat group is next to milk as a contributor to livestock sector output. Its contribution is about 16 percent of the total value of the livestock sector at current prices whereas it is about 15 percent at 1980-81 prices. The contribution of dung to the total value of output of the livestock sector is about 10 % at current prices and 8.9 % at 1980-81 prices (Table 1).

THE NEED FOR THE FARMING SYSTEMS RESEARCH AND EXTENSION APPROACH IN INDIA

The basic objective of agricultural research and development is to improve farming systems productivity by increasing productivity of resources used. Productivity is a term that indicates a ratio of output over input. In general, however, high output of a single commodity is considered synonymous with a high productivity, overlooking the expense (denominator) at which such an output is achieved. Livestock is an integral and often essential part of many mixed farming systems in most parts of the country, but great variation in livestock keeping occurs in farming systems across agro-climatic zones (#1.3.1.). In different ways, livestock production is dependent upon crop production or vice versa. When cattle can survive on crop residues, even though their output in terms of meat and milk is low, their productivity is high when they use otherwise wasted resources.

A typical aspect of farming systems research is that it considers farming systems to be composed of households, crops, animals, birds, insects, weeds, soil, water etc. In contrast with commodity research, FSR recognizes that the household, crop and animal subsystems are closely integrated and interdependent. The household provides land, labour, capital and management; crops provide food, feed and fuel, animals provide milk, meat, manure, draft power and capital to other sub-systems. Moreover, the farming system is a part of a larger agro-ecosystem, which is composed of non-agricultural systems like market and credit system and other farming systems. Livestock production subsystems, in particular, need to be viewed from a farming systems perspective due to their interdependencies with other (crop) sub-systems. Therefore it is imperative to adopt a farming system approach to analyze farming situations keeping in view the broader dimensions so as to improve socio-economic conditions of resource poor smallholders.

Farming systems research (FSR) covers a range of objectives, concepts and methodologies. It has, therefore, been given different names by different researchers and FSR workers. The most relevant approach for this book is called the FSR/E (#1.3) which uses techniques like zoning, transects (#1.3.1.), RRA's (#1.3.2.), and on-farm trials (#1.3.4.).

FSR/E is a multidisciplinary approach to make research and development relevant to small holders. FSR/E aims at a holistic approach, focusing on interdependencies of the components such as crop and livestock enterprises and interactions of these with biophysical and socio-economic environment of the farming systems. Earlier research and extension efforts focused on increased output of one component like milk or rice. As such, it could not solve the multifarious problems of the resource poor farmers that survived on various outputs, often produced in close interaction. The researchers, especially biological scientists, did not have the proper perspective of the whole environment of the farmers and farming systems. As a result, they developed technologies which were not appropriate to solve the farmers problems.

THE UTILITY OF MODELLING IN SYSTEM ANALYSIS

Farming system research involves the study of the existing system of farm activities, particularly but not exclusively of resource poor farmers. The aim is to improve the well-being of individual farming families by increasing the productivity of their farming system under the constraints imposed by the local resources and environment. For this purpose the farm as a whole is to be viewed as a system, with subsystems like crops, livestock and family members being interdependent among themselves. In addition to this interaction within the farm system, an understanding of the relations with systems at a higher level like markets, are the topic of the studies in FSR *sensu stricto*, or of the first stage in FSR/E, e.g. surveys and RRAs.

Modelling can help to identify the essential components and linkages in systems, by depicting them as simple conceptual models, flow charts, block diagrams and mathematical models. The computer helps to predict the effect of changes in one subsystem on the other subsystems. It cannot be stressed enough that models are simplifications and that they cannot be expected to give complete answers. Moreover, they need to be continuously verified with actual practice. (Box 1)

Models provide an effective means of analyzing the existing system, and of developing new systems. Essentially they are a form of New Farm Systems Development (#1.3.). They enable the study of systems where real life experimentation is either impossible or too costly or disruptive.

Conceptualization of a system in model form permits the exploration of systems that do not exist.

Box 1. Some comments on the degree of desired perfection of a model

The choice is always the same. You can make your model more complex and more faithful to reality, or you can make it simpler and easier to handle. Only the most naive scientist believes that the perfect model is the one that perfectly represents reality. Such a model would have the same drawbacks as a map as large and detailed as the city it represents, a map depicting every park, every street, every building, every tree, every pothole, every inhabitant, and every map. Were such a map possible, its specificity would defeat its purpose: to generalize and abstract. Mapmakers highlight such features as their clients choose. Whatever their purpose, maps and models must simplify as much they mimic the world.

(Source: Gleick, 1989)

It also permits explorative study of long-term effects. The use of models in FSR is often disputed but the critics tend to forget that the main purpose is to assist us to understand systems, rather than to give precise answers. Models, properly conceived and validated, can represent the systems and processes with a specific purpose in view. It can therefore be a useful tool in farming systems research and development.

Models also play an important role in various farm management functions like planning, organization, operation and control with the help of suitably designed management information systems. Economic models and tools like partial budgeting, gross margin analysis, break-even analysis, etc. may be profitably used in the evaluation of various new technologies pertaining to livestock and crop production systems. *Ex-ante* and *ex-post* analysis is done too little rather than too often. When combined with the proper assessment of farmers perceptions these approaches can prevent waste of costly development funds.

PROBLEM DEFINITION, CONSTRAINT ANALYSIS AND SCREENING OF TECHNOLOGY

An important aspect of problem solving as part of the systems approach consists of defining problems facing the farm family in its own terms and conditions. The techniques described in the following chapters include agro-ecological zoning, transects, rapid rural appraisals, economic analysis, and technology screening techniques. They can work together to allow the broadest possible view of how improvements of the problem situation may occur.

Problem trees and screening of technology

"Problem trees" have proven to be a useful tool for research/extension teams and farmers, to chart out the basic factors leading to a problem and possible solutions. Cause and effect relationships are clarified, again with farmers perspectives playing a key role (#1.3.3.).

Screening of technologies is to be combined with problem identification based on agro-economic zoning and transect exercises followed by RRA and focused RRA. Possible solutions can then be set out, criteria established for which the technology is to be screened, comparison of all possible innovations against these criteria, followed by field testing. Both the "lab-to-land" and "land-to -lab" models are explained using these procedures (#1.3.3.).

Socio-economic constraints

While defining problems and constraints as well as solutions, it is not sufficient to only look at physical factors like topography, climate and soil type. Socio-economic factors are decisive on local and farm level in determining the success or failure of technologies. One of the important factors besides access to resources, caste and religion is the role of gender, i.e. the division of work, responsibility and benefits between men and women (#2.1.).

The decision to adopt a technology or new form of management depends on farmers perceptions. These in turn, depend on their socio-economic status, knowledge, past experience, and physical as well as socio-economic surroundings. It is well established that the rate of adoption is influenced by the farmers perception of the characteristics of the technology and changes in the farmers management and roles of the farm family. The researchers' lack of knowledge of the farming situation, and their low perception of farmers needs is identified as one of the major constraints for effective exchange of agricultural research results to farms. (#2.2.). Appreciation of perceptions and priorities of farmers is, therefore, required not only when recommending technologies, but even before initiating any research to address the farmers problems. A good example of a crop farmers perception of the value of a concentrate feed is found in the comment of a Bengali farmer during an RRA in a village near Kalyani. He asked:

> *"Why should I waste the valuable mustard oil cake as animal feed?*
> *I rather use it as a fertilizer for my crops".*

Farmers may measure the response of new technologies in terms of higher fat content in the milk, economics of production, increased milk yield or body weight, whereas researchers often talk in terms of fat corrected milk, crude protein or bypass nutrients. Many of these terms are overlapping, but their differences complicate communication between farmer and scientist. Researchers have only recently started to understand farmers perceptions, while studying farmers problems, possible solutions, and response criteria for the evaluation of new technologies. Only a few years back, it was difficult to think of farmers' involvement in planning and/or designing research, e.g., in conducting on-farm research. But on-farm experiments are now increasingly common to evaluate technologies, and it is now more and more recognized that it is the farmers perceptions which matter in the adoption and diffusion of technologies.

CONCLUSIONS

Livestock development is important for the national economy, but its inter-relation with the cropping systems demands a particular attention to systems aspects. FSR in its various prices provides tools to analyze systems, e.g., by way of RRA's, zoning, transects and models. Another aspect of FSR work is that it requires interaction between farmers and development agents. Without such interaction it will be impossible for research and extension to develop a better understanding of the farmers needs and conditions. Research agendas should be determined by explicitly identifying farmers needs following from our understanding of farming systems. This approach contrasts strongly with the traditional "top-down" approach, or the "technology driven transfer of technology". The approach of on-farm research with a farming systems perspective (OFR/FSP), is in this handbook captured with the term FSR/E.

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1.3. FARMING SYSTEM RESEARCH IN AGRICULTURAL RESEARCH AND DEVELOPMENT

C.B. Singh, A.J. De Boer and D.V. Rangnekar

INTRODUCTION

Farming System Research (FSR) covers a wide range of activities. It originated from the need of researchers to better understand the needs and constraints in the development of resource poor small holders. A large majority of these farmers did not adopt new technologies and management because the technical innovations and management packages were evolved without keeping in mind the environments and problems of those farmers. In that way, several research and development projects initiated and implemented with best intentions failed and were not accepted by farmers because the planners did not have adequate perspective of the area, the farmers and their problems and felt needs. Thus, it became clear that traditional approaches of research and extension systems did not meet the needs of a majority of farm families. A new approach to applied research, technology development and dissemination had to be evolved so as to generate technology appropriate to resource poor farmers. Farming System Research (FSR) has been viewed as such a new approach as it views the whole farm as a system. It focuses on the interdependencies of the components under the control of the household, it takes into account

Handbook for Straw Feeding Systems
Kiran Singh and J.B. Schiere (eds.), 1995
ICAR, New Delhi, India

the interactions of on-farm components with physical, biological and socio-economic factors; and it aims to increase the efficiency of research and extension by improving the focus of agricultural research in order to better generate and test technology.

FSR, in its diverse appearances, is now also promoted by ICAR, as a means of addressing (a) the problems of increasing productivity in marginal areas under less favourable environments, (b) addressing special problems faced by limited resource farmers and landless labourers and (c) issues leading to loss of sustainability of the resources supporting agricultural production. After explaining the different types of FSR, this chapter will concentrate on the applications of FSR/E methodologies as a basis for field work and also for subsequent chapters in this handbook.

FSR: APPROACHES AND DEFINITIONS

FSR covers a large range of activities, approaches, objectives and practitioners. In a useful review, Simmonds (1986) describes a series of these activities as FSR *sensu latu*, i.e. FSR in a broad sense. In an attempt to classify the many approaches of FSR sensu latu, the following categories of FSR can be identified:

- FSR sensu stricto;
- on-farm research with a farming systems perspective (OFR/FSP);
- new farming systems development (NFSD).

Even more forms of FSR can be identified, e.g.

- farming systems research and extension (FSR/E);
- farming systems approach to infra-structural support and policy (FSIP),

- farming systems research and development (FSR&D) which includes (FSIP + FSR/E).

FSR *sensu stricto* is the in-depth study of existing farming systems as they exist but typically without a commitment to follow-on action programs. In fact, it is more of an academic activity.

On-Farm Research with a Farming Systems Perspective (OFR/FSP) seeks to test socio-economic suitability of research ideas on-farm before recommending the technology to extension. The sub-systems of the whole farm are isolated and studied just enough to allow research to gain the necessary perspective of what farmers really need. On-farm research is then carried out in collaboration with the farmers after screening appropriate technological interventions. In this approach, emphasis is laid on active participation of researchers, farmers and extensionists in designing, testing and evaluating new technologies leading to improvements in crop and animal productivity. This is also essentially the approach used in the FSR/E work reported in this handbook.

New Farming Systems Development (NFSD) is based on the assumption that many existing farming systems are becoming unsustainable and radical change may be necessary to correct the underlying problems. The objective here is to evolve, test and introduce new farming systems. Introduction of new crops, cropping systems, or new species of animals in the area would be considered a form of NFSD, whether or not supported by government institutions. NFSD may occur in the form of established prototype farms, usually on university or experimental station compounds. It can also occur in a more abstract form of modelling new farm designs, which are eventually translated into practice.

Farming Systems Research and Development (FSR&D) is a part of FSR, *sensu latu*. There are two basic and complementary components of FSR&D under different terminology: Farming Systems Approach to Infrastructural Support and Policy (FSIP) and Farming Systems Research and Extension (FSR/E) approach to technology generation and delivery. The two components together comprise the farming systems approach to research and development (See Hildebrand and Waugh, 1986; Norman, 1982). The table below describes differences between the two approaches.

FSIP	FSR&E
1. It is more macro than FSR/E. Since it deals with policy, the variables treated by it are mainly outside the farm-gate and involves more socio-economic scientists than agro-biological scientists.	1. It is more micro in scope and deals mostly with conditions inside the farm concerned with technology generation, evaluation and delivery where more biological scientists than socio-economic scientists are involved.
2. Methodologies include surveys to provide the perspective on farming systems as a means of predicting farmer responses to different policy stimuli.	2. Methodology includes on-farm agro-biological research with less time devoted to surveys.
3. It is applied, farmer oriented socio-economic research supported by agro-biological sciences.	3. It is applied, farmer oriented agro-biological research supported by the socio-economic sciences.
4. The principal product is information.	4. The principal product is technology.
5. The primary clients are policy makers and managers of services and infra-structure.	5. The primary clients are the farmers.

Although these two approaches use different methods and have different clientele, still they are highly complementary and compatible. On the one hand, FSR/E may have impact on policy makers by providing more detailed information on farms and farmers, their problems and felt needs than FSIP. On the other hand, FSIP can have impact on agricultural technology because it provides more information on infrastructure and policy than FSR/E. Thus, FSR/E and FSIP together comprise a complete development concept termed as FSR&D.

Farming Systems Research and Extension (FSR/E) is a multidisciplinary methodology for technology development which merges research and extension efforts. It is often called by other names such as on-farm adaptive research (OFAR) with a farming systems perspective. FSR/E is thus a means of integrating farmers with researchers and extensionists in a systematic way for identifying problems and constraints for target farmers by defining Research or Recommendation Domains through rapid survey techniques, i.e., Rapid Rural Appraisal (RRA) or Sondeo and then create, adapt and test alternative solutions. Solutions are matched to specified bio-physical environments and socio-economic conditions of farm families. Factors that particularly characterize FSR/D include:

- a farmer-based approach, where the practitioners pay close attention to farmers conditions, and where they integrate farmers ideas into the research and development process.
- a problem solving process that seeks opportunities to develop and guide research and identify ways to make local services and national policies more attuned to the needs of small-scale farmers.
- a comprehensive research and development approach where all farm

activities are included in the search for improvements in the farm family's output and welfare; as it is to identify flexibility of change and to evaluate the results of studies in terms of the interests of both farm and society.

- multidisciplinarity, where researchers and extension staff "who work with the farm families come from a variety of disciplinary "backgrounds".
- an iterative approach, where research results are used to understand the system better and to design improved research and implementation approaches for the future.
- a dynamic approach, where "modest changes are first introduced in the farm families routine" and if these are successful and acceptable to the family, "more significant changes are encouraged".
- Responsible to society, where the "long-term interests of the general public are kept in mind, in addition to the concerns of farmers immediately affected".

OBJECTIVES AND PROCEDURES OF FSR/E

In order to remove various misconceptions about the concept and approach, various inter-related objectives of FSR/E are given below with slight modifications and additions.

A FSR/E essentially attempts:

- to understand physical, biological and socio-economic environments within which agricultural production and household decisions are taken by the farmers (#1.3.1.);
- to describe different farming systems, as they are revealed due to

different resources, environments, goals and objectives (#1.3.1.);

- to gain an understanding about the farmers' skills, problems, constraints, goals and preferences (#2.2., #2.3.);
- to analyze inter-relations among problems and causes, identify and evaluate possible solutions for interventions in the existing farming systems and thus improving the focus of agricultural research;
- to provide direction to the agricultural research organizations for conducting and evaluating relevant on-station and on-farm research on priority areas (#1.3.4.);
- to access technical feasibility and economic viability of new technologies and farming systems along with their components;
- to monitor the adoption and farmers' perceptions of new technology and assess the benefits of improved farming systems, and
- to provide feed-back to the scientist, extensionists, planners and policy makers.

The above objectives can be achieved with the help of baseline data analysis, on-station and on-farm studies which will eventually provide a basis to focus additional research. Considerable differences in FSR/E approach may be due to the nature of the development institution involved. For example: *a rice breeding station or a milk federation may undertake FSR/E to see how grain production or fodder cultivation technologies can be introduced. Gender or youth groups may use FSR/E to improve the condition of particular target groups. A true FSR/E approach allows all sorts of proposals to come up for consideration in a development plan: the liquidation of a local liquor shop, the construction of a speed brakes, the use of plant protection measures or the training of local inseminators may assume a higher priority than the* *introduction of straw treatment of fodder.*

It is clear that FSR/E can be both "technology driven", as well as "problem driven". Concepts that are called "lab to land" and "land to lab" in #1.3.3. In a true systems sense, dairy development or straw treatment should not be separated from other activities in the systems. A narrow focus, originating from a technology driven approach may turn out to be contra-productive.

FSR/E STEPS

The number of stages or steps of FSR/E presented by different authors can range from four to six. Generally, the following stages in the FSR/E process have been used:

- diagnostic stage,
- design stage,
- testing stage,
- dissemination stage.

A fifth stage, that divides the dissemination stage into a pilot development phase and the dissemination phase is also common. In fact, most stages of FSR/E occur simultaneously. For instance, when urea treatment in paddy straw has been tested in the Operational Research Project of the National Dairy Research Institute at Karnal some constraints and some alternative solutions are developed and designed for on-farm testing, e.g. adjusted crop rotations, supplementation. The important concept of each of the five phases are discussed below.

The **diagnostic stage** has a major objective to identify, characterize and analyze the existing farming systems through close consultation with farmers. It is supposed to diagnose problems and constraints of different components of the farming systems and to understand the felt needs, goals and preferences of relatively homogeneous groups of farmers engaged in a particular farming systems (the "recommendation domain").

An earlier concept that sought homogenous groups of farms, has been modified to allow its incorporation in the technology screening process. Environments can be associated with farms or fields or portions of fields. Use of socio-economic considerations in the choice of environments within the research domain increases the efficiency in technology development and evaluation. The nature of on-farm research in a research domain is exploratory; to answer the questions, what and where? In defining a research domain, a multidisciplinary team conducts, analyzes and characterizes the environments of each location, to design plans for farmers' evaluation of technology, and then to define recommendation domains.

Previous thinking about the recommendation domain was that it pertained to homogenous group of farms or farming systems. Now the recommendation domains can refer as well to individual fields on a farm or different locations in the same field. The most important concept is to consider recommendation domains as environments whose bio-physical and socio-economic characteristics are almost identical. The purpose of on-farm research within recommendation domains is to confirm answers about how each alternative technology or management approach responds and where each alternative performs the best (#1.3.4.).

In order to achieve the objectives of the diagnostic stage, informal survey methods such as Rapid Rural Appraisal (RRA) or Sondeo can be used (#1.3.2.). These are done by multidisciplinary teams that interview the farmers in groups or individually. These informal survey methods have an advantage of being quicker and less data intensive with more feedback. In order to focus the choice of area, and the relation with surrounding systems, it can be useful to proceed these exercises with zoning and transect studies (#1.3.1.).

Design stage: The RRA's or Sondeos are carried out once the process of identification and ranking of problems has been completed. The FSR team has to identify possible solutions, it should review previous research findings, and consult scientists, extensionists and farmers before planning on-farm research (#1.3.3.). There might be readily available on-the shelf technologies that can be selected for on-farm testing after assessing their economic feasibility. *Ex-ante* evaluation of the technologies should be done in this stage. There may also be problems for which technologies are yet to be developed on-station, leading to the identification of new research priorities. Thus, in design and planning stage, four distinct steps can be distinguished:

- identification of causes of the problems;
- analysis of inter-relations among problems and causes;
- identification of possible solutions;
- evaluation of solutions.

More information on identification of problem and screening of technologies is found in #1.3.3. and #1.3.4.

Testing stage: In order to test new technologies, three types of on-farm trials may be conducted by the team:

- researcher-managed trials;
- farmer managed trials, and
- superimposed trials.

The researcher-managed trials are conducted to develop new technologies under the management and control of the researchers. However, farmer managed trials are conducted to learn how farmers respond to the suggested improvements to be made under their management control. Superimposed trials conduct experiment across a range of farmer managed conditions (#1.3.4.).

Technical feasibility of a new technology needs to be tested by on-station and on-farm research. Socio-cultural acceptability may be tested by personal discussion with farmers to know their reactions. Sustainability of new technology may be assessed through the evaluation of its impact on human, livestock and natural resources. Economic viability can be assessed through partial budgeting, gross margin analysis, cost-benefit analysis, break-even analysis. The use of these tools depends upon the type of technology, design and objectives of the experiments, type and availability of data on relevant parameters, etc. Various economic models can be used both for *ex-ante* and *ex-post* evaluation of any technology. It is extremely important to assess farmers' evaluation and perceptions of the technologies.

Lack of adoption of technologies by farmers occurs even though technologies were found to be technically feasible, economically viable and socio-culturally acceptable. It's, therefore, often necessary to study, examine or redefine the extension process and institutional or input supply constraints. This was a reason why new approaches such as Pilot Outreach Projects or Operational Research Projects (ORP's) were started. The ORP or NDRI is such an example where close linkages with various institutions and organisations at village, district, state and national level have been established and various proven technologies for dairy and crop production are transferred. In addition, veterinary services, artificial insemination, credit and milk marketing facilities were made available to the farmers. Thus, new technologies are fine-tuned during this stage for their effective extension on a large scale. In ORP, a system of continuous monitoring, evaluation, constraint identification and feedback has been developed which help the researchers and administrators to bring about desirable changes in the technology transfer programme.

Dissemination stage: Once "lab to land" and "land to lab" mechanisms have been developed in the Pilot Outreach Programme, the major task of transfer of benefits of new technologies to the rest of the region or the country remains to be fulfilled. It can be achieved by collaboration with extension organization of both public and private sector, and research alone cannot clear that taste.

CONCLUSION AND A LOOK AT THE FUTURE

FSR/E should be included as part of a range of activities for crop and livestock and development in India. It redirects the emphasis from the traditional "top down" or "lab to land" approach towards dealing with the emerging issues of agricultural development at farm-system level, i.e., "land to lab". Its proper application is critical for the success of programmes which focus on problems faced by small producers in rural areas, where innovation in crops or livestock affect and depend on the activities in the rest of the farming system. Several steps can be indicated along which the FSR/E process needs to take place. Adherence to the protocol in any study, however, may be less relevant than use of the proper attitude and the realisation of system-specific solutions. The fact that this requires greater input in terms of man power should be balanced against the failure of development programs based on top down recommendations and the possibility of mobilizing farmers knowledge for development by applying the principle ideas of FSR/E.

Looking to the future, Simmonds (1986) makes several pertinent comments. First, the OFR/FSP approach is becoming well established in National Agricultural Research Systems, and training and dissemination of information about approaches and results needs to be institutionalized. Second, careful though needs to be given to the structure, objectives and working in extension services which generally are used to the top down approach. Collaboration between farmers, FSR researchers and extensionists in multidisciplinary teams is estimated to achieve progress in this regard.

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1.3.1. AGRO-ECOLOGICAL ZONING AND TRANSECTS

D.K. Jain, S.V.N. Rao, B.R. Patil and P.K. Dixit

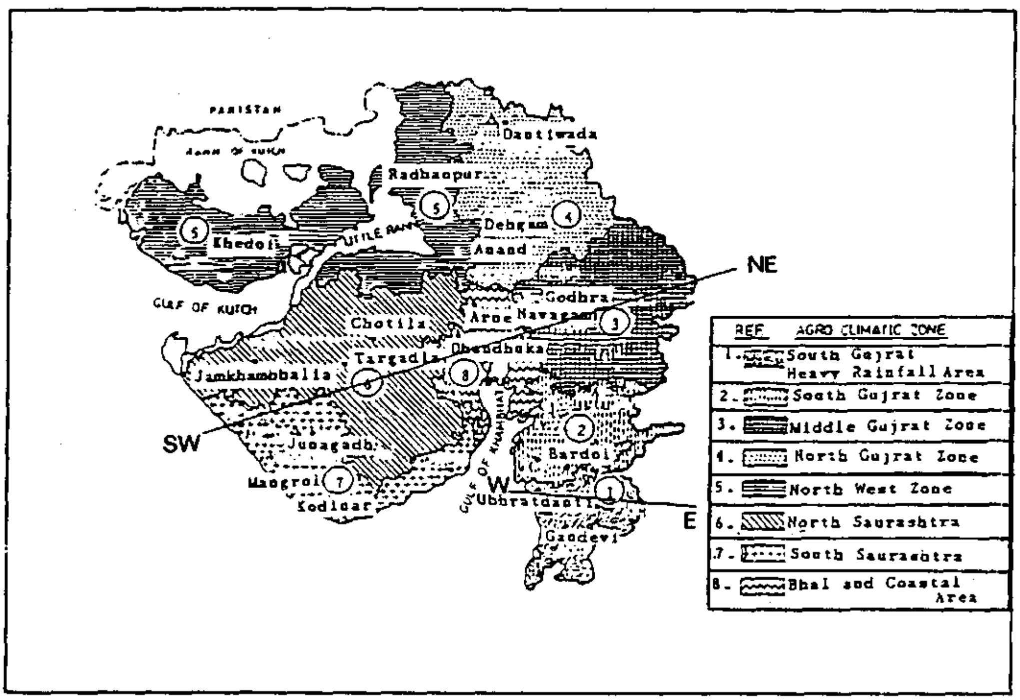
INTRODUCTION

Many extension messages in crop-livestock development are suitable only under certain conditions, and problems of one system are not found in another system. This implies that extension and research have to know for which area and problems they work, before embarking on development programs. An important step in FSR/E is the definition of research or recommendation domains. These are farming systems chosen in such a way that they are broad enough to be operationally sensible, but narrow enough that recommendations could be expected to be applicable throughout. The use of agro-ecological and agro-climatologic zoning with or without transects is set out in this chapter while focusing specifically on the Indian situation. The main function of zoning and transects is to focus discussion and research/extension programs on the needs of a given farming system. Some examples and drawbacks of this work are described in this chapter.

DEFINITIONS AND RELEVANCE OF AGRO-ECOLOGICAL ZONING

An agro-ecological or agro-climatological zone is a geographical or socio-economic area on macro- or micro-scale, for example at village-, regional- or national level, which is relatively homogeneous in terms of natural conditions and agricultural activities. A transect is a crosscut through a village, region or larger area that graphically depicts the (agricultural) differences in the main zone.

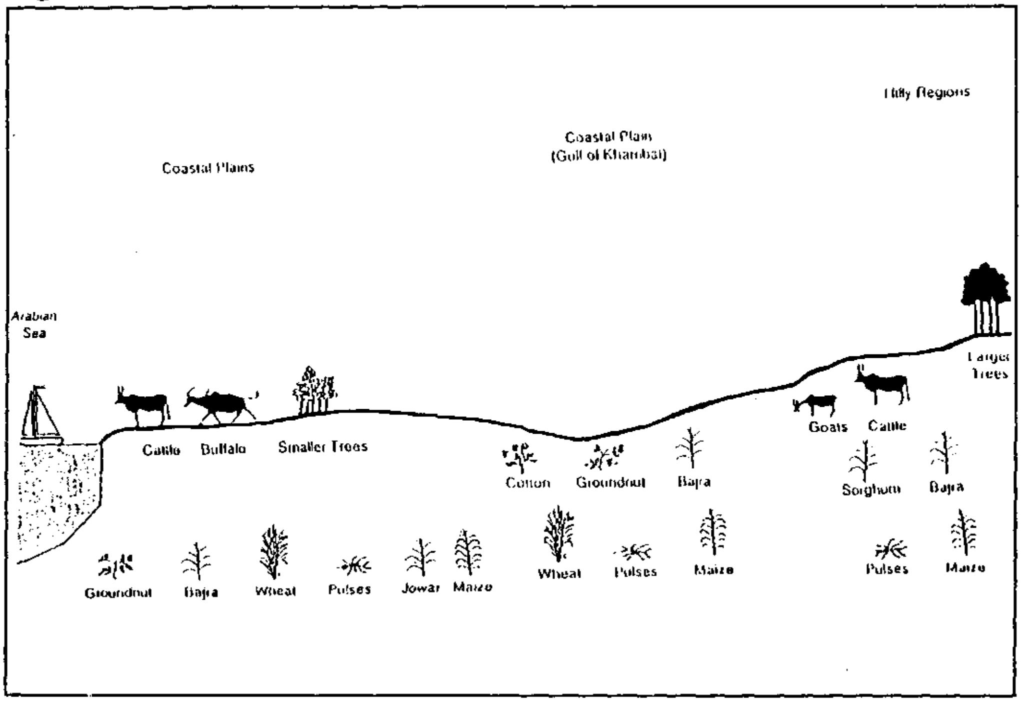
Figure 1a. Agro-climatic zones of Gujarat, with the direction and location of a transect



(Source: Ghosh, 1991, quoted in De Boer *et al.* (1994)

The illustrations in Fig. 1a and 1b show how a map and a transect can be used on state level, in this case for Gujarat. Figures 2a and 2b show the same principle at village level.

Figure 1b. Features of the Gujarat SW-NE Transect

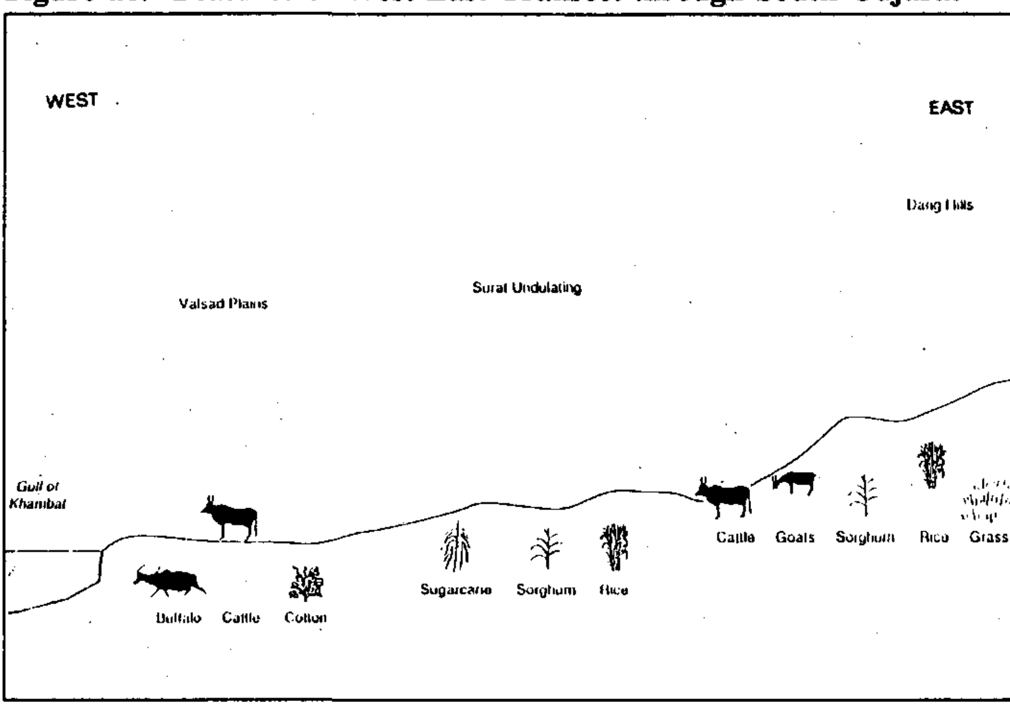


(Source: De Boer *et al.* (1994))

The relevance of zones and transects lies in the possibility to extrapolate research results and extension approaches, since conditions within zones are more similar than between zones. It is assumed that farmers living in the same zone would have similar problems whereas their technical requirement would also be similar.

Socio-economic factors, however, e.g. social status or access to the market, are difficult to put on maps of regional or higher level. For example, the criteria for application of urea treatment of straw are the supply of plenty of straw and a relative scarcity of other feeds, combined with a medium producing animal and access to the market (#4.6.1.). Since these criteria may differ between neighbouring farmers, the suitability of these messages is difficult to indicate on a map, though an attempt was done by the BAIF team in Gujarat, as shown in Figure 3. Transects and mapping on regional level or higher level can assist in the identification of broad recommendations, but they need follow up with RRA's for local verification and refinement (#1.3.2.).

Figure 1c. Features of West-East Transect through South Gujarat



(Source: De Boer *et al.* (1994))

REVIEW OF AGRO-CLIMATIC ZONING IN INDIA

With the ever increasing demand for food, clothing, and shelter to support the growing population of India, there is a strong need to have a systematic appraisal of the soil, climatic and livestock resources to develop an effective land and livestock use plan and to guide research and extension programs.

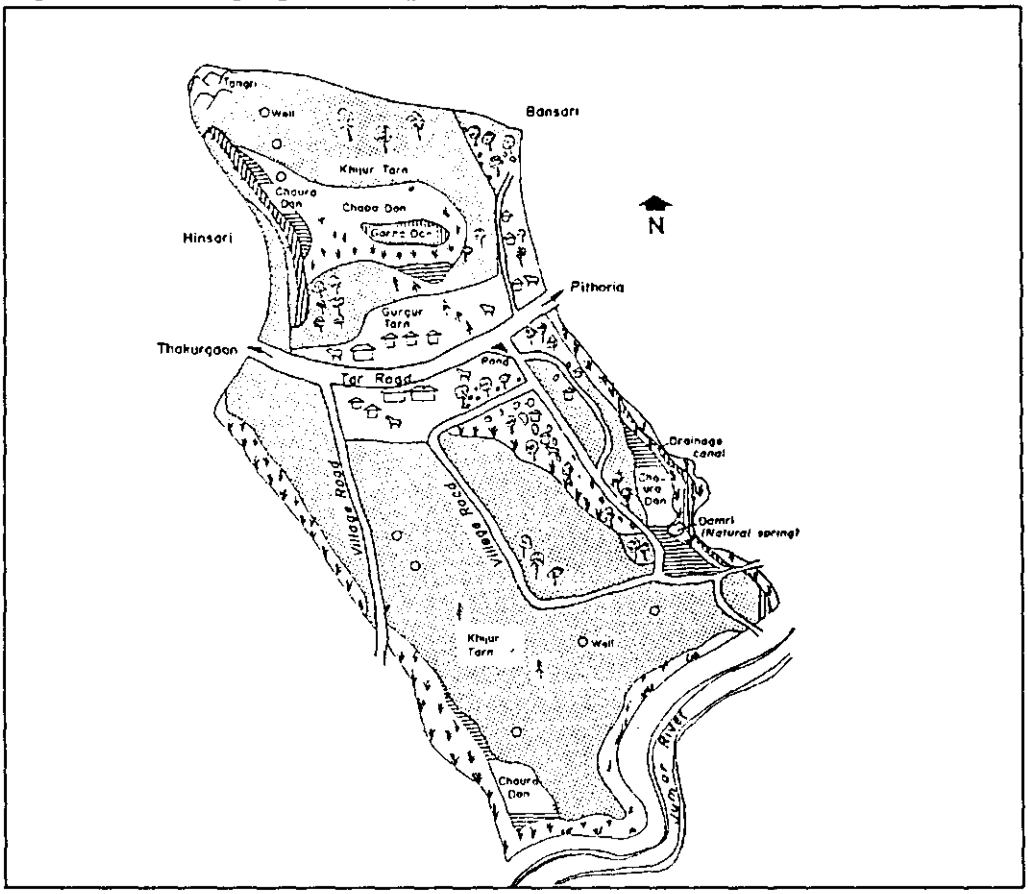
Box 1. A review of different approaches in the agro-ecological zoning of India

India was divided into different climatic regions on the basis of:
- Thornthwaite criteria for climatic classification (Carter, 1954);
- livestock units per 100 ha of cropped land (Singh, 1974);
- soil types and moisture index (Krishnan, 1988);
- livestock density and per capita milk production (Muthaiah, 1988).

The Planning Commission divided India into 15 broad agro-climatic zones based on physiography and climate (Alagh *et al.* 1989). These zones were further sub-divided into 120 micro-climatic sub-zones by taking into consideration the rainfall patterns, temperature, soil types and existing cropping patterns (Saxena, 1989; Ghosh, 1991). All these approaches suffered, however, from the limitations of non-uniform application of criteria and the use of states, (i.e. political divisions), as unit of classification. These limitations were taken into consideration by the National Bureau of Soil Survey and Land Use Planning (NBSS and LUP, 1992) of Indian Council of Agricultural Research. Two Agro-ecological maps with 54 and 21 delineations were prepared and the agro-ecological map with 21 delineations was finally approved (Sehgal *et al.*, 1990). Ultimately of course, the classification criteria depend on the place and purpose of classification : religion may not much affect the choice of crops, but it can be an important criterion for the choice of animal production system. Soil type and rainfall are important to decide the choice of crop in low input conditions, but it is hardly relevant in farming systems with high input conditions, e.g. where irrigation and fertilization are easily available. The use of different criteria is briefly discussed by Jain and Dhaka (1993)

Since the soil and climatic conditions of a region largely determine the suitability of different crops and livestock and their yield potential, intensive efforts have been made by various researchers to map agro-ecological regions having uniform soil-site characteristics. (See the maps of India, p. viii-xi in this book).

Figure 2a. Geographical depiction of the Baraudi agro-ecosystem



(Source: Lightfoot *et al.* (1990))

The studies reviewed in Box 1 show that India is very diverse with regard to land use patterns, cropping systems and livestock rearing. As such, the country has been classified into different agro-climatic or agro-ecological regions by different workers depending upon the purpose with which the classification was needed.

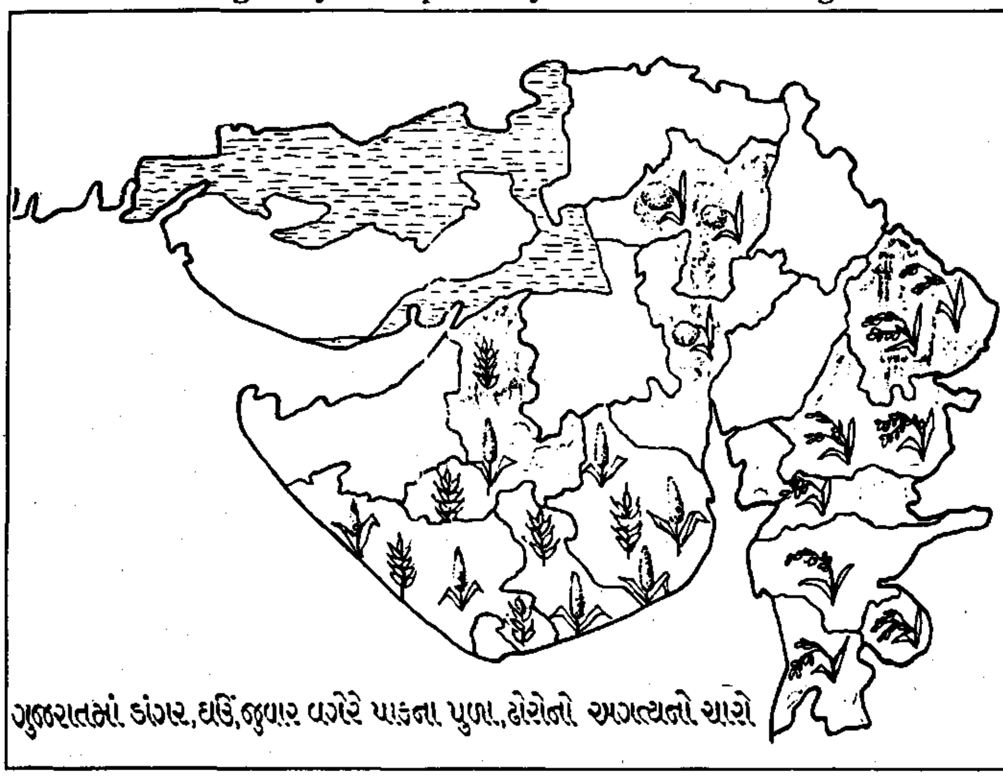
Figure 2b. Transect of the Baraudi agro-ecosystem ,

LAND TYPE	UPLAND (*GURGUR TARM*)	UPLAND (KHIJUR TARN)	MIDLAND (CHAURA)	LOWLAND (*CHAPA DON*)	LOWLAND (GARHA DON)	RIVER
SOIL	Gravely coarse sandly loam (Gurgur)	Coarse sandy loam (Bala)	Sandy loam (Bala-Krirel)	Loam (Khiral)	Silty clay loam (Nagra)	
WATER RESOURCES	Wells, Hand pump Ponds	Wells		Danri		
CROPS VEGETABLES	Vegetables Maize	Rice arher,maize, ragi, black gram cowpea, gundil, vegetables(potato, radish, tomato, okra) Wheat, vegetables in rabi season	Rice, wheat vegetables	Rice, vegetables	Rice	
TREES	Mango, jackfruit emili, papaya bamboo, karanj udukul, ghamar pipal, neem mohua, galachi jamun, bair putukal, sal kadam, katai eucalyptus Bargad					
ANIMALS FISH	Cow, goats, sheep, poultry, ducks, pigs, fish, honeybee buffalo	Cut and carry grasses Grazing - Grasses	Cut and carry Grazing in rabi season	Cut and carry grass Grazing in rabi season	Fish	Fish
PROBLEMS	Shortage of fodder insufficient irrigation Disease & pest *in horticture* & vegetable crops Disease in animals esp. in cattles, poultry Lack of input delivery system, fertilizer and seeds	Drought and lack of irrigation Low soil fertility Gandhi bug in rice Stemborer and other insects in maize Soil erosion Insufficient supply of seeds Soil acidity	Lack of irrigation *Rice hispa* Low soil fertility Soil erosion Stem borer in rice Lack of good seeds Assured fertilizer supply	Lack of irrigation for rabi crop Weeds Lack of input delivery Rice pests	Lack of assured supply of good seeds & fertilizers Flooding	

(Source: Lightfoot *et al.* (1990))

The suitability of macro-regions or political classifications for development of crop-livestock farming needs to be reconsidered. Physical parameters like livestock density, availability of feeds and fodders, milk availability, resource infrastructure, roads, mode of transport, distance and access to the market need to be supplemented with socio-economic parameters.

Figure 3. A map of Gujarat with prevailing crops indicated in a number of districts, developed as an audiovisual aid by BAIF to show the region/system specificity of extension messages



• (Source: Courtesy BAIF-Gujarat)

Traditional classification criteria distinguishing between marginal (< 1 ha), small (1-2 ha), semi-medium (2-4 ha), medium (4-10 ha) and large holdings (> 10 ha) are not valid throughout the country and may be

counterproductive when applied in other situations than what they were developed for.
Factors like family size, social status, income, literacy rates, role of women in crop and dairy activities along with their role in decision-making and access to financial resources also need to be taken into account while classifying the farming systems of the country.

Classification of the country, region or village into macro and micro regions will help in recommending technologies suitable to crop and livestock enterprises, resulting in better utilization of available natural and human resources. It will help in focusing research, development and extension strategies for each region, or agro-ecozone.

It should be noted however, that most socio-cultural variables (eg. power relationships, social status, position of women, cultural differentiation) cannot be readily included in a zoning/transect study. Not only the lack of reliable secondary data, but also the high local variations among many of these factors imply that these factors cannot easily be mapped. These variables are equally relevant for extension and development programs, but can best be understood through RRA/PRA approaches.

ZONING, TRANSECTS, RRAs/PRAs

Agro-ecological transects are relatively easy to define depending on the ruggedness of terrain and visibility as affected by topography and vegetation. The transect is particularly appropriate when relatively rapid changes in topography and natural conditions are found on village or state level. A transect exercise can be very useful to identify areas with homogenous conditions, as well as to focus discussions, for example in a RRA-team. This helps to plan, manage, channel and target the resources for technology generation, on-farm testing and other extension efforts. In order to appropriately plan research and development it is necessary to follow a sequence of steps.

As a first step, an agro-zoning exercise should be done on state-, region- or local level to identify the homogenous agro-ecological zones suited to the purpose of the classification. (Fig. 1a). Then transects can be made to further specify the areas with nearly identical conditions (Fig. 1b). Later, target groups can be identified through RRA/PRA's by multi-disciplinary team. This needs to be followed by focused RRAs that further assess the needs of the target groups in order to identify farmers' constraints and thrust areas for future research (#1.3.2.).

The construction of a Problem Tree can further help to identify the major problems which call for research and extension (# 1.3.3.). The ultimate aim of all these exercises is to identify the felt needs and constraints of the farmers in the area.

The solutions to the problems, if any, available in the research institutions can be combined with the farmers' indigenous knowledge system to plan and conduct on-farm crop and animal trials (#1.3.4.; #2.3.). Otherwise, the problems can be referred to scientists, other research and development personnel to find solutions through research in specialised centres, preferably in combination with, the farm community themselves. The problems relating to policy matters need to be referred to the administrators and policy makers. Lastly it can be said that the problems differ between areas. Therefore, development options should be addressed according to the problems and potential of the particular agro-climatic zone, target group and stages of development. Zoning and transects can be the first "tools" to focus in on the local situation. A practical example of this approach will be given in the next paragraph.

RESULTS OF A TRANSECT/AGRO-CLIMATIC ZONING STUDY

The farming system groups working under BIOCON carried out zoning, transecting and Rapid Rural Appraisals in Haryana, West Bengal, Karnataka and Gujarat to be followed up by on-farm trials (De Boer *et al.* 1994a/b; Yazman *et al.* 1994). They were meant as exploratory exercises, using information on natural, physical, human and animal resources of the states as available from secondary sources. A few salient findings of the transect exercise of Gujarat are discussed below to serve as an example of the approach.

Gujarat is one of the states with large variations in livestock density, rainfed/irrigated agriculture, the ratio of tribal population and well defined cattle (Kankrej and Gir) and buffalo breeds (Mehsana, Surti and Jafrabad). Two transects were drawn covering areas of primary interest to BAIF (Bharatiya Agro Industries Foundations, a partner in BIOCON). One transect covered the South-West to North-East while the other cut West-East through the peninsular, higher rainfall area (Fig. 1b/c). Extension material prepared by BAIF now indicates the relevance of technologies and crops on state level (see Fig. 3).

The West-East transect passes through the Western plains along the Arabian sea through the hill area of Surat district to the wetter hilly areas of Dang. A strong caste structure prevails in the West while there are large tribal populations in the hilly areas of the East. Average size of land holding increased to the East. Crop harvesting is manually done throughout the transect and waste of straw is minimal. Alternative uses of straw include thatching in the East and packaging and paper industries in the Central and Western areas along the transects. Production of crops as well as livestock declines from West to East despite higher rainfall. Labour availability also increases from West to East, and marketing facilities are better in the West. Adoption of input-based technology is better in the West and poorer in the East, probably because of differences in proximity to the market. The availability of communal grazing land is better in the East. The straw availability in the West is that of paddy straw in kharif; paddy straw, sugarcane tops, sorghum in rabi and summer, while in the East the straws available are paddy straw, dry grass, nagli (red millet) in rabi and sorghum, nagli and dry grass in kharif and summer periods.

The Southwest-Northeast transect passes through the central parts of Gujarat. Along the transect, the rainfall increases from SW to NE. The West has a large pastoralist population while the Eastern districts have large tribal populations. Losses of straw from harvest and storage are negligible in all districts. Some paddy straw is used for packaging around the city of Baroda in the Central region. Yield of both crops and livestock are higher in the Western and Central districts. Labour availability is relatively low in the West and better in the East where a strong milk marketing co-operative system prevails. A strong animal marketing system exists in the West based on the sale of milk and draft breeds. Availability of sorghum/pearlmillet straw is good all along the transect. The availability of groundnut straw declines towards the East while paddy straw is available from Baroda on to the East. There is more forest and grazing land in the West while central Gujarat is predominantly agricultural with less communal grazing area. The East has more grazing land in the hills and valleys.

At the time of writing this chapter the on-farm trails are underway and results will be published in Yazman *et al.* 1994. Particularly the chapters on RRA's and problem identification (#1.3.2.; #1.3.3.), along with those on feeding systems (#4.1. - #4.7.), provide an overall picture of how these procedures can be used to increase the efficiency of FSR/E as related to research and extension on livestock production and use of fibrous crop residues.

CONCLUSION

Agro-climatic, agro-ecological or agro-social zoning is a tool that can be used to focus agricultural research and extension programs. This tool, supplemented by the use of transects, RRA/PRA, and screening of technologies, are key elements of stages 1 and 2 of the FSR/E approach. As the socio-economic factors are difficult to include in zoning and transects beyond village level, local verification with RRA/PRA methods is essential. The zoning and transects can be applied to and can be expected to improve efficiency of research and development efforts.

ACKNOWLEDGEMENT

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The perceptions of women, member of a dairy cooperative, in a few villages of West Bengal, about the priority of problems in dairy production (see also #2.2.) The data were obtained in an RRA organized during the BIOCON gender miniworkshop ERS-NDRI, Kalyani, West Bengal (Muylwijk and coworkers, 1994).

group ranking		ranking according to individuals						
1	low milk price	1	1	1	2	5	1	3
2	expensive feed	2	2	2	3	2	3	4
3	inadequate veterinary facilities	4	3	5	5	3	2	2
4	repeat breeding	3	7	4	7	1	7	1
5	small herd size	5	5	3	1	6	6	5
6	fodder shortage and small holding	6	4	7	4	4	4	7
7	low price for male calf	7	6	6	6	7	5	6

1.3.2. RAPID RURAL APPRAISAL IN CROP AND LIVESTOCK RESEARCH AND DEVELOPMENT

C.B. Singh, D.K.Jain, S.V.N. Rao, Lotan Singh and A.J. De Boer

INTRODUCTION

Most FSR/E is action oriented and requires rapid data collection. Therefore, a series of procedures was developed that became known as Rapid Rural Appraisal (RRA) techniques. Together with zoning and transect techniques (#1.3.1) the RRA is one of the tools in the first stage of FSR/E (#1.3.). Participatory Rural Appraisal (PRA) techniques were developed later, to get the potential beneficiaries more closely involved in the design of action programs. This chapter briefly reviews the definitions, background and methodologies of RRAs.

DEFINITION

Even though many forms of RRA are possible as per the needs of the researcher or development agency, an RRA can be defined as:
a systematic but semi-structured study, carried out in the field by a multi-disciplinary team over a short period ranging from three days to three weeks, based on information collected in advance from published and/or

Handbook for Straw Feeding Systems
Kiran Singh and J.B. Schiere (eds.), 1995
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unpublished sources, direct observations and interviews as to generate working hypotheses for subsequent action (Chambers, 1983; Ison and Ampt, 1992).

The RRA methodology has been referred to with many other terms, e.g. Rapid Reconnaissance, Exploratory Survey, Sondeo and Reconnaissance Survey. Each one of these methods has its own specific features, but the key features of all these forms of RRAs are that they are innovative, interactive and informal, and that they are conducted within and with the community. Basically, the RRA is a methodology to plan and link on-farm and on-station research, and to support rural development projects. It is a process of learning about rural conditions, problems and constraints in an intensive, iterative and expeditious manner. Since farming systems are complex due to their interaction with physical, biological and socio-economic factors, the agricultural research and development administrators should rely upon multidisciplinary teams of scientists/technicians to understand the economic activities of the farmers and their environment.

THE GENESIS AND APPLICATION OF RRA

Conventional surveys on problems and issues dealing with agricultural and rural development are time consuming and expensive. Information is often obtained after a long process, the data become quickly outdated and ultimately, many data are irrelevant to the needs of researchers. Therefore, such information does not serve the purpose for which it was collected. Besides, this research and development projects are often initiated without requisite information and understanding of the farms and farmers, their environments, problems and felt needs. Consequently, projects that started with the best intentions either do not achieve success or are not accepted by the people. All these considerations have led to the emergence of RRA techniques.

Apart from their use in crop and livestock production systems, an RRA can be used in other sectors of rural development as well, e.g. agro-forestry, fishery, water and pest management, health care, family planning, education or natural calamities. RRA's may thus be used to :

- quickly identify, explore and diagnose rural systems and problems;
- design, implement, monitor and evaluate programs/projects;
- to develop and disseminate new technologies;
- record farmers' perceptions about new technologies, and projects, i.e. to assist in policy formulation and decision making;
- identify priority areas for on-station and on-farm research;
- improve, supplement or complement other types of research;
- locally verify the details of zoning and transects made at state or regional level (#1.3.1).

RRA's thus provide useful, preliminary information for the design of on-farm trials and testing, or for the identification of future research needs. RRA's serve to assess differences in livestock and crop yields, input and output levels, technical feasibility, economic viability, socio-cultural acceptability and sustainability of new technologies. Monitoring and evaluation of specific development projects can be done through focused RRAs. With a view to designing appropriate technology, the RRA methodology may be used to acquire information from farmers that is needed to develop an understanding of their knowledge and problems along with their perceptions on important issues. This helps scientists and farmers to jointly identify appropriate solutions/ interventions for testing through on-farm trials.

TYPES OF RRA

Based on their objectives, it is possible to identify different categories of RRA, some of which are now briefly discussed.

Exploratory RRAs

These are used in the early stages of planning research and development projects. Their purpose is to formulate preliminary hypotheses for testing by the researchers and/or extension workers.

Topical RRAs

Topical RRAs may also be called focused RRA's and they are used to investigate a specific topic, to learn answers specific questions and to develop hypotheses that can serve as basis for research and design. The output can be a key input for research and development. However, a topical RRA has a narrower scope of investigation than the exploratory RRA.

Participatory Rural Appraisals or (PRAs)

PRAs were developed in response to the top-down nature of RRAs where researchers went to the field to ask questions with a relatively one - way flow of knowledge as outcome. For example, a dairy cooperative may be interested to find out why its fodder program is a failure or a success (Prasad et al. 1994). Also, a crop development program may use an RRA to push new grain varieties rather than to really be concerned about the problems in the community.

PRAs stimulate rural people to describe their situation on the basis of local terms, concepts and indigenous knowledge systems. They also provide a venue in which participants can actively participate in the design of programme to improve their welfare, again based on their local needs. A PRA tends to focus less on interests of a research team, as villagers often fail to see the relationship between research and their welfare, preferring to focus on immediate social and infrastructural needs. Ensuring the maximum participation of men and women in the PRA is necessary, as it is in all types of RRAs.

Monitoring RRAs

These are used to assess the success and impact of an intervention via development projects already initiated.

RRA METHODOLOGY

The review and collection of data relevant to the issues of development in the target area are important to understand the background of the existing rural systems. This work should be done before initiating the RRA exercise. As a general practice, an RRA involves a multidisciplinary team of scientists/technicians that interacts with farmers in groups and individuals as well as with "key informants" such as Sarpanch/Pradhan of the village, Panchayat members, school teachers, merchants, shopkeepers and officials of any society/association operating in the village.

A number of specific research tools and techniques are used in RRAs to meet the research objectives. The use of a semi-structured interviewing technique is considered important, besides the use of direct observation, maps and photographs. Other useful tools and techniques include organizational techniques, such as interview protocols, selection of respondents, focus groups, interview introductions and schematic tools such as crop calenders. Sketch maps, labour schedule, decision trees, family structure diagram, measurement and recording tools such as (video) cameras, measuring tape, and observational techniques, such as field walks and transects are of great help.

Interviews with the farmers, held by teams that are divided into small groups are generally done in the forenoon in an informal manner. The processing of information and exchange of views with team members should be done in the same afternoon so that a consensus is arrived at after thorough discussion. Missing links in the information are identified for collection during the next day visit to the same site, or during evening interactions with the village. Small groups are allotted specific topics to write the reports which are read and discussed among the team members, and preferably with the villagers. These reports are amalgated into one final report after due modifications. It should be remembered however that, depending on the purpose of the RRA, the discussions with the villagers are more important than the preparation of the formal report.

METHODOLOGICAL ISSUES FACING THE RRA PRACTITIONERS

A number of common issues are generally faced by the RRA practitioners. They determine the outcome of future decisions and actions and based on the experiences of different FSR/E teams, some RRA practitioners may have divergent views on these issues. But, given the flexibility of RRA methodology, each group can take its decisions as per the general guidelines given below.

Duration of RRA

The duration of an RRA may range from three days to three months depending on factors such as type and objectives of RRA, area and villages to be covered, number of members in the team, time and resources available etc.

Who participates in an RRA team ?

Smaller teams, comprising biological and social scientists, are preferred to larger teams. Large teams take longer time to produce a report and recommendations. Relatively small multidisciplinary team composed of five to eight members from biological and social sciences are split into sub-teams for field work, to reconvene for discussions. Team composition is not critical as long as there is a mix of technical backgrounds and insiders and outsiders. Inclusion of people who have already participated in other RRA's is desirable, and it is essential that none of the participants comes with preconceived ideas.

Research orientation

Implicit assumptions often determine to a large extent what happens during RRA and how the results are interpreted. There are certain issues which need consideration by the team members. These are:

(i) whether guidelines to the questions should be used, and if they are to be used how long they should be;

(ii) whether the team should seek averages or emphasize variability;

(iii) whether to focus on problems or opportunities, (iv) whether to focus only on individuals or also look at groups, gender and the community.

Structuring the research team

Everyone agrees on the need to divide time between collection of data, team interaction and report writing. Tentative schedules can help to optimize the use of time, but adherence to any given schedule is not critical. The essential purpose of an RRA is to be as open as possible to new ideas and problems, therefore, time schedules should be an aid and not a goal to the RRA process.

Information to be collected in advance

Secóndary data are needed to provide obvious information about the natural, institutional and economic circumstances. They can be arranged by agro-ecozoning or transecting the region (# 1.3.1). Secondary data can be obtained from published and unpublished reports and records of government departments, research studies, or key persons, or farmers themselves.

Use of interviews

Local participants, district and village level officials, key informants and farmers may be interviewed to gather relevant information. Individual knowledge, however, varies greatly. Seven related issues which concern interviews as part of RRA are:

(i) selection of respondents;
(ii) the use of individual vs. group interviews;
(iii) timing of interviews;
(iv) strategies to get the most out of interviews;
(v) use of interpreters;
(vi) note taking, and
(vii) appropriate locations for interviews.

These issues should be decided in advance while planning a visit to the villages.

Indirect observations

Indirect observation is an important RRA tool that serves to validate data collected in advance, to provide checks on data collected from interviews, and to suggest additional topics for interviews. Indirect observation of key indicators such as birth weight, type of housing and social status often provides more valid and less costly information than other research methods.

Preparation of the report

An RRA is not complete until the report has been written. The Sondeo guidelines for report preparation indicate that all team members should be assigned a portion of the report. All members work at the same location where individual sections of the report are drafted. Each team member reads his/her part to the group for discussion, editing and approval. On the final day, each section is read again, conclusions are drawn and specific recommendations are made and recorded. The team should not worry too much about organization of the report, its grammar and style. The goal is to prepare a report that reflects the interdisciplinary nature of RRA for further action, rather than a formal report that ends up on the pile of unread documents.

Getting results factored into decisions

The results of an RRA should be factored into decisions for subsequent intervention. RRAs should guide future actions in terms of new research priorities as well as in terms of development, most directly the identification of on-farm trials. The information should constantly be upgraded as the activity progresses.

CONCLUSION

An RRA is a method to organize people and time for the quick collection and analysis of information. Several form of RRA are possible, some focus more on the introduction of a technology, others focus on the identification of village needs in a more participatory manner. In spite of being flexible, there are minimal requirements for a successful RRA, i.e. one should utilize standard tools of communication so as to collect more accurate and useful information for planning of agricultural research and development. RRAs is gaining importance amongst government and non-government organizations to identify the prevalent problems in Indian Farming Systems.

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1.3.3. PROBLEM IDENTIFICATION AND ANALYSIS LEADING TO POTENTIAL SOLUTIONS

D.K. Jäin, S.V.N. Rao and A.J. De Boer

INTRODUCTION

Much time and effort is often spent collecting field data, secondary data and experimental statistics. Seldom is this information merged, however, within a framework that addresses the ultimate objective of agricultural research: the identification of priority problems of rural communities, the analysis of these problems in terms of our current knowledge base, the inclusion of indigenous technical knowledge, and the identification of possible solutions. The FSR work in BIOCON has relied heavily on agro-ecological zoning and RRA, supplemented by focused RRAs (#1.3.1.; #1.3.2.). As expected, farmers' primary problems and priorities were often not concerned with animal production, but with issues like a declining water table, plant disease, salinity or lack of affordable credit. For purposes of animal husbandry, RRA teams have to focus on one or a very small number of primary problems to work on per agro-ecological zone. Cause-effect relationships should be specified, followed by means - ends statement leading to a hierarchy of objectives and possible solutions. Some procedures to accomplish this are set out in this section, while stressing that gender - differentiation, farmers'

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perceptions of technologies and indigenous technical knowledge all play a key role in this process.

PROBLEMS AND SOLUTIONS

Acceptance or rejection of a technology by farmers depends on the nature of the technology, quality and distribution of extension personnel, farmers knowledge and attitude towards the technologies, performance under their conditions, accessibility to inputs and services and knowledge essential to inputs, services and knowledge essential for the maximum performance of the technology. The rate of adoption has been found to be influenced by relative profitability, observability of results, simplicity or complexity of the technology, cultural and technical compatibility and initial cost (#2.2.). Gender bias is also an issue, particularly in provision of extension services as farm women have major roles in many agricultural activities (#2.1.).

Farmers usually compare any innovation with the traditional or existing practice and if they perceive that the innovation is superior to the existing one, then only they may think of adopting the innovation. However, the farmers' perception depends to a large extent on, for example, their knowledge, source of information, past experience and socio-economic status studies for specific dairying technologies. Low adoption rates showed that no technology is suitable to all farming systems. Though A.I. is being promoted in villages since 1964 with the implementation of Intensive Cattle Development Project, it was only found suitable for small proportion of all the areas covered. Similarly, urea treatment of straw and urea molasses block licks were better accepted in some areas than others, their application is highly system specific. One should also realize that there is a gestation period from the introduction of technology to its adoption by the majority of farmers in a social system; animal technologies are no exception. Hence, it is essential to know beforehand to which farming system a particular technology is most suitable or likely to be accepted by the farmers. It is in this context that screening of technologies can be helpful to find out which technologies might fit where a "lab to land approach". It is however equally important to start at the farmers homestead and then see whether there are any problems to be solved: "a land to lab approach", rather than to try to disseminate a technology that has no use in a local condition.

"LAND TO LAB" AND "LAB TO LAND"

Indeed, it is possible to discern essentially two directions in technology transfer, besides the exchange of information between farmers themselves. The direction from the lab to land is the rather traditional approach in India, whereas the land to lab approach is closer to the FSR philosophies. In practice, a mix of the two will be required, but here, we will discuss the two approaches separately.

The "lab to land" approach helps researchers from the "lab" to evaluate the usefulness of the research output for specific farming systems (the "land"). The process can be likened to "*ex-ante* evaluation of technologies". Thus, there is a need to systematically examine the factors that influence technology adoption or rejection. These factors can be categorized as positive and negative and they may result in description of an ideal situation, where the technology would seem to achieve a "perfect fit" to the farmers' conditions. The process can be started by examining in detail the requirements and characteristics of a particular technology, followed by a listing of ideal conditions for the technology to be most successful (technically, socially and economically). Then the conditions existing within various farming systems described in Stage I of the FSR methodology are examined. They can be assigned a simple ranking of existing conditions relative to the ideal state in order to determine which farming systems or recommendation domains appear to be most favourable for the use of this technology. Subsequently, one should proceed with on farm testing and validation of the priorities.

The "land to lab" approach is more consistent with the FSR/E approach. Its focus is on the description of important features of farming systems (land), including problems, objectives and constraints. It then proceeds to evaluate a range of available technologies (lab) that suit the farming system. It may even be able to select one outstanding technology from the available set, and then proceed with on-farm testing.

TOOLS AND METHODOLOGIES

The variety of tools and methodologies that are available to identify and to analyze the problems, and to find possible or appropriate solutions, include methods such as:

- decision analysis;
- problem analysis;
- risk analysis;
- fit analysis;

- screening;
- ranking.

Each of these will be discussed briefly in the following sections.

Decision Analysis

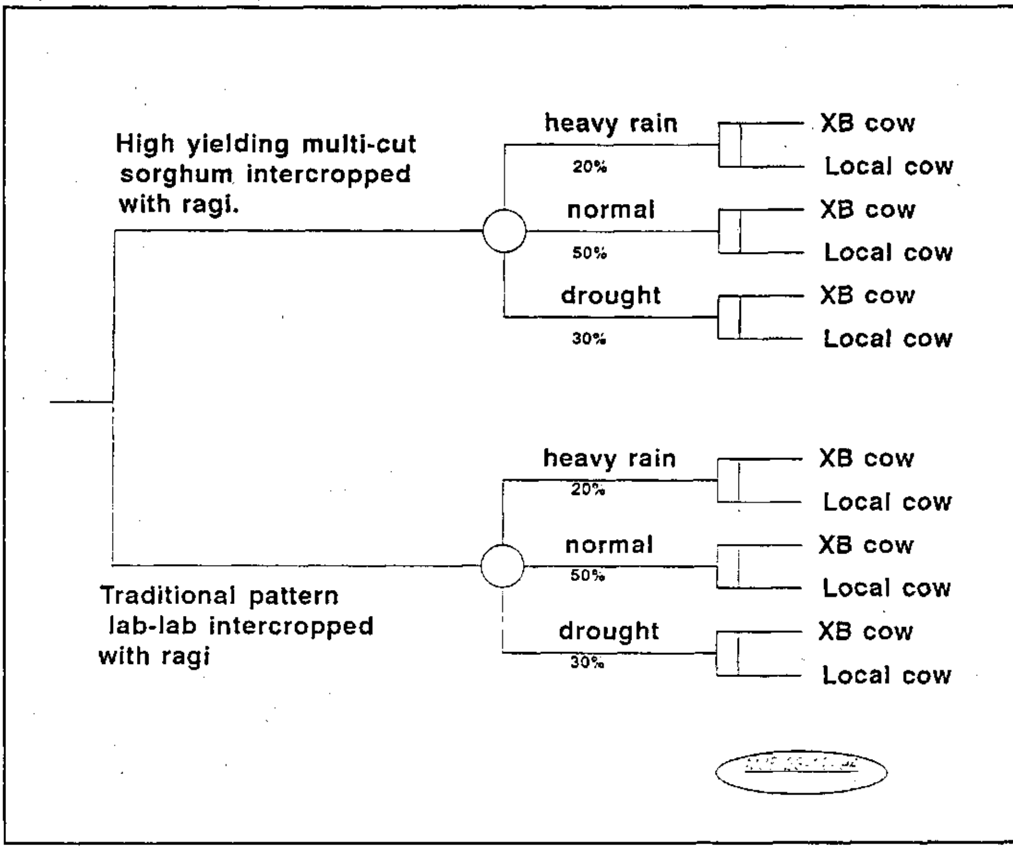
Decision analysis is one of the tools that can be used to screen an individual technology. Livestock farmers have to routinely make decisions about breeding, feeding, culling and animal health treatments. Decision analysis can enhance our judgements about the possible acceptability of new technologies. The four steps in carrying out a decision analysis are:

1. adequately define the problem at hand, including identification of all possible alternative courses of action;
2. construct a "decision tree", involving the structuring of the problem over time starting with the initial decision to be made. Each course of action represents a branch of the tree, branches are referred to as nodes which may be under the control of the manager (square box) or a chance node (determined by fate) represented by a circle (See Fig. 1);
3. identify probabilities associated with each branch arising from a chance node. The sum of the probabilities assigned to the branches must equal 1.00;
4. assign monetary values to the ends of each branch (the final outcome). (Source : Dohoo, 1984)

The solution to the problem is the outcome with the highest expected value. Costs assigned to a node are subtracted from revenues generated by the node. One intervention (technology) examined during a BIOCON mini-workshop was the use of high yielding multi-cut forage sorghum intercropped with fingermillet (ragi) in the Eastern Dry Zone in Karnataka

State (Fig. 1). That option was compared with the traditional pattern of lab-lab/fingermillet intercrop. The chance node is rainfall; decision nodes are use of this technology plus choice of crossbred or local cows. Thc example could be completed by adding probabilities and net returns for each combination. Costs are subtracted along each branch from the revenue figure for each cow type - weather-cropping system technology combination. The highest estimated outcome would give the preliminary indication of the potential usefulness of this technology, but risk attitudes play an important role in technology adoption and this should eventually be factored in through risk aversion studies.

Figure 1. A simple structure for a decision analysis.



Problem Analysis

It was found that a simple "problem tree" can also help in linking major problems to possible causes and to a list of possible solutions. Note that a problem tree is not a "decision tree", as discussed in the previous paragraph. An example of a problem tree to examine possible solutions to the objective of increasing low farm incomes is presented in Figure 2. The root problem here is low farm income and its possible causes are identified, followed by possible research and extension issues.

Figure 2. An example of a problem tree

PROBLEM	POSSIBLE CAUSES		POSSIBLE RESEARCH OR EXTENSION ISSUES
Low income	Low animal output	Low milk yield	Management of animals
		Low meat yield	Plane of nutrition
			Farmer's priorities
			Genetic potential
			Milk prices
	Low crop yield		No money for inputs
	Low output prices		
	High production costs		Use of more expensive feeds than necessary

Potential topics that may require improved technologies are then set out as a set of separate branches, leading finally to potential solutions to be subjected to a screening process, as described later in this chapter. As a special note to the outcome of this problem tree it can be mentioned that a monodisciplinary approach, whether from veterinary officers, animal breeders or nutritionists, is likely to miss the mark. Of all problems mentioned at the end of the tree branches only few really pertain to a simple discipline. Moreover, simple disciplines only play a minor role, e.g. only one out of the six constraints are on animal nutrition in the example of Figure 2.

Risk Analysis

A procedure which is also fairly easy to use as a simple model to look at a range of possible outcomes of a for changed farming practice is called a Risk Analysis. This requires estimates of the worst possible outcome, the most likely possible outcome, and the best possible outcome of a particular technology, each with their associated probabilities. One common method of dealing with the latter is to put the worst and best outcomes plus or minus one standard deviation from the mean. The mean parameter serves in that case as the most likely outcome, finally represented at the corners of two triangles (see Fig. 3).

For most agricultural technologies, weather conditions will often provide much of the variability leading to these different outcomes. Prices can also be considered as a source of risk that must be considered by farmers. By combining combinations of outcomes, a simple distribution of possible profits and losses can be constructed using a stochastic activity budgeting approach. To look at possible combinations that farmers may face, the question of correlation between the budget parameters must be considered, i.e., does the "high or best" fodder production outcomes influence milk price?

Figure 3. An example of a risk analysis with the triangle approach.

An example would be short duration green fodder production and possible milk prices. The possible outcome (kgs of green fodder produced/ha) can be represented as a "triangular" distribution.

Fodder production

Most likely outcome: 32 t/ha

Lowest outcome 23 t/ha

Highest outcome: 40 t/ha

Milk prices

most likely outcome: 6.50 Rs/litre

Lowest outcome: 5.50 Rs/litre

Highest outcome: 7.20 Rs/litre

(Source; based on Cassidy *et al.*, 1970)

Table 1. Possible Outcomes in Fodder Technology.

Fodder outcome	Milk outcomes	Outcome No.
Lowest	Lowest	1
Lowest	Most likely	2
Lowest	Highest	3
Most likely	Lowest	4
Most likely	Most likely	5
Most likely	Highest	6
Highest	Lowest	7
Highest	Most likely	8
Highest	Highest	9

Based on Figure 3.

If there is a good season in terms of climate and many farmers are growing green fodder, production of green fodder will expand, milk production will rise and prices will fall. A more likely situation is where the green fodder technology is to be tried on a limited number of farms and high production on these new farms will not influence local milk prices. Possible outcome for this uncorrelated case is given in Table 1, based on the results of Figure 3.

These values, when put into a production or budgeting model, produce nine different outcomes of output or profit/loss figures. Each combined outcome also has a probability attached to it, the product of the separate, uncorrelated probabilities. Again, farmers' risk aversion will eventually have to be factored into this type of analysis and a minimum acceptable level of risk may have to be determined for different classes of farms.

Fit analysis

An example of a fit approach, here applied to the case of urea treated straw, is presented in Table 2. The characteristics about how the technology performs and the cause-effect relationship between the technology and the characteristic of the farming system are listed.

Screening of Technclogies and Management Practices

Screening is really a summary of what technology or management practices can achieve in one, or a set of farming systems. It can consider not only nutritional parameters, but also farmers perceptions and socio economic aspects, not to forget gender issues. Screening is meant to help in:

- *ex ante* evaluation of the likely productivity and acceptability of the

innovation in a given farming system;
- saving of resources for technology generation and on-farm testing;
- identification of areas conducive for the introduction of an innovation;
- comparison of technologies that can solve a given problem.

Table 2. An example of a "Fit" exercise for urea treated straw, i.e. a listing of factors that determine the usefulness of this technology

Characteristic	Best Fit Case
type of straw	works best with slender straws (rice, wheat, barley)
availability of straw	good supplies are required relative to other feed
type of animal	medium production
water availability	should be readily available
green fodder availability	limited available relative to straw
cost and availability of urea	should be low cost and plentiful in supply
cost and availability of (plastic) covering	low cost and good availability
market price of milk	should be good enough to allow purchase of inputs like urea and polythene
support service	should be good in initial stages of adoption

Notes:
- high availability is often the same as low cost, unless subsidy schemes interfere;
- based on information from Stage I of FSR/E, one would use information from agro-ecological zoning and RRAs to determine specific farming systems that had most or all of the favourable characteristics listed on the right hand column, then proceed with on-farm trials. Other fit-analyses are given, among others in chapter #4.3. and #4.6.1.).

Available animal technologies and management methods in livestock production can be screened by criteria such as:
- adaptability of the technology in the socio-economic situation where the target farmers are operating;

- availability of technical inputs and services such as medicines, feeds and markets;
- economic viability of the technology within acceptable risk levels;
- acceptability of technology according to cultural norms and values.

A simple example of a screening exercise is given in table 3, concerning the application of different animal breeding options. Throughout this handbook a number of tentative screenings are given, e.g. for supplementation and fodder conservation (#4.3.; #4.7.).

Table 3. Screening of Breeding Technologies based on farmers perceptions.

Characteristic	Selective breeding of indigenous cows	Crossbreeding of local cows	Grading up of local buffaloes
Profitability	Low	Very high*	High
Observability of results	Very slow	Slow	Very slow
Simplicity	Simple	Not so simple**	Simple
Cultural compatibility	High	Low	High
Extent of risk	None	High	None

* provided there is a good infrastructure of support systems and marketing of milk or crossbred animals;

** even when artificial insemination (AI) is available, it may be not accessible; communication, dedicated AI service and good heat detection skills are essential.

Scoring/Ranking

Problems can be ranked using different criteria, according to which they could be ranked according to their relative importance. The important issue here is to remember that the ranking can differ between interest groups, for example between farmers and extension workers or policy makers (#2.2.), or even between gender groups (#2.1.). an example of a ranking exercise are shown in Table 4 clearly showing differences of ranking according to interest group, and the second is a ranking of animal production problems as perceived by women during a RRA in West Bengal.

Table 4. Ranking of research topics by gender-differentiated groups.

Research topics	Female group interviewed by females	Male group interviewed by males	Female group interviewed by males	Mixed group interviewed by males
A	III	II	IV	V
B	II	III	I	II
C	I	I	III	III
D	V	V	IV	I
E	IV	IV	II	IV

Source: Lightfoot et al., 1990.

CONCLUSION

In order to match field problems and technical/management solutions from the field, there can be a mix of two directions of thinking: from the "*lab to the land*" and from the "*land to lab*". Different methods are available that can help to determine the problem of the farmers, or the place of particular solution. Also, the more specific issues behind a general problem statement can be decided while using decision trees.

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1.3.4. ON-FARM RESEARCH AND STATISTICAL INFERENCE

D.K Jain, S.V.N. Rao, J.A. Yazman and H.M.J. Udo

INTRODUCTION

The basic objective of Farming Systems Research (FSR) is to enhance the effectiveness of agricultural research in order to improve the welfare of farm families. On-farm research (OFR) is an important component of FSR and its main function in crop and animal improvement is the testing of component technologies (e.g. varietal and fertilizer trials on crops, feed additives for dairy cattle). In the FSR activities under the BIOCON Project, OFR is done only after an identification of farmers' problems, production constraints and screening of potentially useful technologies. This helps to ensure that OFR will have the best chances of being useful to the largest possible number of farm families. OFR supports the FSR approach by determining whether a new technology is appropriate to the needs of rural households and whether it is compatible with existing systems. OFR thus offers the opportunity to study technical, economic and social effects, and their interactions. The planning of OFR requires consideration of the characteristics of rural households including economic status, decision-making, social relationships and gender division of labour. While traditional researchers might hope to detect statistically significant differences on biological criteria between

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treatments through OFTs, it is equally important to determine farmers' reactions and perceptions about new technology.

OBJECTIVES OF OFR

Some objectives of OFR include:

- to verify performance of a new technology under farmers' conditions;
- to determine the range of farming systems under which the new technology offers promising results;
- to provide feedback to station researchers on the performance of a new technology in the farmers' fields and herds;
- to observe interactions between the technology and socio-economic parameters within agricultural communities, including gender-specific differences in the management and impact of new technologies
- to achieve participation of farm men, women and children in the development, testing, and evaluation of new technologies and management practices.

CONSIDERATIONS IN THE DESIGN OF OFR

OFR, of course, does often have a demonstration effect, but its main aim is to test technology and management practices before demonstration and extension takes place. OFR is therefore not the same as a demonstration trial! Various classifications of OFR are cited in the literature and the general term "on-farm experimentation" can also be applied. Literature distinguishes three types of on-farm experimentation:

- **exploratory trials** used in cropping systems research to test the technical feasibility of a new technology; farmers' participation is limited;

- **"adaptation trials"** or **"determinative trials"** with emphasis on technical aspects but farmers' reactions are also measured;
- **"verification"** or **"validation trials"** where farmers management is included as a variable, with emphasis on socio-economic aspects.

OFR can also be distinguished as **"researcher-managed"** and **"farmer-managed"**, the explanation of which should not be necessary. A further distinction can be made between **"trials"** and **"tests"**. "Trials" evaluate the technical merits of improved technology in farmers' fields and herds, while "tests" evaluate the economic viability and social acceptability of improved technology. On-farm experimental trials intend to show statistically significant effects of experimental treatments, often in relation to different categories of farming households. On-farm experimental tests are used to find out how the farm household and/or community handles the technology.

Selection of Technology

Treatments in OFTs are generally new, or modified technologies and management practices. Selection of either one of those for OFR depends on the screening of their suitability to local agro-ecological conditions, input availability and farmers' resources and objectives. (#1.3.3.). The needs and problems of farmers can be assessed through zoning and RRA's (#1.3.1. and #1.3.2.). Importantly, the social and cultural differences between farmers and within the family should be taken into account. It is not uncommon that when a new technology is tested, the men of the family will take part in all activities. However, once the activity becomes a routine, the women or children become responsible, even when the activity does not well fit into their labour films or priorities (#2.1.).

Design of On-Farm Trials

Experimental design follows the basic objectives of all research projects, but complicated experimental designs are difficult to manage on-farm. A minimal amount of hypothesis testing should be carried out. Data analysis should be expressed in simple biological and economic terms. Still, farmers' perceptions and suggestions are equally or more important than measurement of bodyweight gains. An experiment, whether on-station or on-farm, should never include too many treatments. In OFTs, single factor experiments are easiest to manage and interpret. On-farm livestock experimentation generally includes experimental controls, organized as follows :

- control and treatment animals on the same farm under similar management conditions; treatment effects not confounded with farm effects. This "**within approach**" is generally not suitable for farms with a small number of animals.
- non-participating farms can serve as controls, the "**with and without**" approach, but this may introduce a bias due to different management between farmers, it may also cause friction in the society, for example between neighbours.
- the period before and after the introduction of the technology can serve as control; the disturbing factors may be the seasonal effects, decrease in milk yield over the lactation in dairy-type animals and carry over effect. This "**before and after**" approach is only suitable for short-term experiments where no serious carry over effects are likely.

Due to the small numbers of animals on most Indian farms, the first method is seldom possible but it may be feasible at the village level where animals can be effectively segregated on different farms. For short-term trials, the third method is useful. For OFT where biological responses are expected the second method may be more appropriate.

Interactions and selection of experimental units

A major consideration in experimental design is the presence or absence of "a treatment x environment, or treatment x farm interactions", where the performance of a treatment is influenced by the characteristics of, or actions taking place on the farm(s) on which it is assigned. In case no interactions are expected, replication can be done at one site (farm) if the number of experimental units (plots, animals) are large enough. If interaction is expected (the more common case), replication should be done across farms. Treatment X farm interactions generally are less for varietal trials and more stable within land types. If the same land type across farms are selected, bias should be minimized. If treatment * farm interactions are expected, minimize replications per farm and maximize replications across farms. This equates farms with blocks and treatments are thus replicated across farms. This is particularly relevant in upland and rainfed areas where land types, farm resources and environments vary much more than lowland rice or plantation crop environments. Analysis of Variance (ANOVA), with farms equal to treatment blocks, cannot be used if there is a treatment X farm interaction. In such cases, it is better to use t-tests of mean differences with paired observations for each site and the post-stratification of sites.

Component Technology vs. Farmer-Managed Trials

The above trials, dealing with effects such as varietal performance, fertilizer response or strategic feeding of concentrates, are "component technology trials". Verification trials or farmer managed trials are simpler in nature and they allow wider evaluation of alternative technologies giving due consideration to farmers' perspective and economic and social acceptability. These trials usually involve only two treatments, with the farmer practice as control. Replication across a large number of farms is usually called for, generally 25-30 farms as a minimum, but the number may be different, depending on the type of treatment and expected response. Selection of sites and farms should be based on principles of recommendation domains which are generated by agro-ecological zoning and RRA's (#1.3.1. and #1.3.2.). Farmers' interest to cooperate is an essential part of the design of OFT's.

Treatments are assigned to experimental units. Selection of experimental units depends on the type of technology to be tested, categories of farm types for which a technology is designed, input availability, types of animals and herd structure, and status of each individual animal needed for the purpose of forming treatment groups. Experimental units can be animals when the treatment is expected to influence only animal performance or they can be farm households when the treatment is expected to influence labour use or allocation of capital within the farm. The more similar are the experimental units, the more precise the results of the experiment. However, the more homogeneous the experimental units, the smaller will be the range for which the experimental results are valid.

Farmers may well have their own objectives which differ from those followed in the experimental design, e.g., preferential feeding of sick animals. Moreover selection of treatments must consider researchers' or farmers' ability to measure the variables at the farm level. Weighing scales are usually not available to weigh large ruminants in the village and milk yield must often be adjusted for calf suckling. Frequency of data collection depends upon the nature of the trial, available resources, constraints and opportunities faced by the farm family (including women) in participating in data collection and measurement of biological parameters of the experiment.

Type of data to be collected

The major objective of OFR, and particularly of on Farm tests is to measure the farmer's reaction. That being so, it is important to focus the data collection as much as possible to the measurement of farmer's perception, men and women, experimental farmers and neighbours and so on. The use of open questions may complicate statistical elaboration of the data, but it is crucial to maximize the output of the tests. The measurement of biological responses like live weight gain, butterfat content or kilos dry matter and crude protein should therefore not draw attention away from issues such as: labour calendars, shifting workloads between men, women and children, or economic versus biological response. The BIOCON experience has shown that biological responses can be significant in on-station trials, but not statistically significant in variable field conditions. This should not only tell us to include more animals or fodder plots etc. in the OFT, it also represents a lesson that technologies that look so nice in on-station trials, may give different responses in the field. Also, whereas a biological response is not significant, it might be a reduction in expense or workload that is the real criterium why a farmer, his wife or their parents decide to adopt an innovation or not.

STATISTICAL PRINCIPLES AND CONCEPTS

Statistical analysis of livestock and crop residue OFR is necessary if one wants to draw valid inferences and conclusions about differences between treatments or between the treatment and control. It involves the collection, compilation, tabulation, analysis and interpretation of data sets. Knowledge is thus required about selection of experimental units (regions, farms, animals) and about statistical concepts. Therefore, it is important to choose appropriate statistical methods for the treatment of data. This section describes these basic concepts.

Sampling

Sampling is the process of choosing a representative group from the population. A sample is a number of individual units (e.g., farmers, cows, buffaloes, goats or sheep) selected from all those units that compose a population. The members of the sample must reflect the variations within the population so that the inferences drawn about the population on the basis of sample are valid and reliable. Sampling must be carried out systematically and the following considerations should be kept in mind:

- purpose of the investigation;
- size of the population;
- cost of collecting statistical data;
- time availability;
- nature of data to be collected.

Various sampling techniques are used to draw a sample, including methods such as non-random, or purposive sampling, probability sampling, random sampling, systematic sampling, stratified random sampling or multistage stratified random sampling. The selection of a sampling technique depends on the homogeneity of the population, the degree of precision required to separate treatment responses, and the researchers' need to control non-treatment variation. For further review of sampling procedures, the reader is encouraged to consult standard references on sampling techniques, such as given under suggested reading.

Selection of Sample Size

Sample sizes of OFR can be expected to vary widely, depending upon objectives of the trial and variability in the parameters to be measured. For most purposes, a sample size of 25-30 farms in each stratum for which an independent estimate is probably adequate to collect reliable quantitative information. When OFR emphasizes qualitative information (e.g., case studies), the number of farms per stratum may be less. The number of animals required in OFTs is a function of the variability of the biological parameter under investigation and the difference between treatments that the researcher regards as relevant. For example, milk yield is a highly variable parameter and there will thus be a large number of animals required to find significant differences between treatments. In drawing samples for the collection of field data, it is the sample size, and not the fraction of the population or group, that is important. For example, if the co-efficient of variation (CV) is 30 percent and the experiment is desired to have an 80 percent chance of detecting a 15 percent difference between treatments the sample size per treatment should be about 60. The sample size will be only

16 when the difference between treatments is expected to be 30 percent. Provided that the variation is known from previous trials, the minimum number of replications required is calculated as:

$$n = 2\,x\,t \quad \frac{CV^2}{d}$$

where:

- '*d*' is the least significant difference desired to be specified, i.e. the smallest difference between treatment means which is statistically significant.
- '*CV*' is the coefficient of variation and is determined as the mean divided by the standard deviation.
- '*t*' is determined from tables available in statistics textbooks and is usually selected to represent a 5 percent level of significance. The value of '*t*' is generally assumed to be 2 for sample sizes exceeding 20 at 5 percent significance level.

The smallest true difference, "*d*", to be detected should be specified by the researcher. The higher the predicted variation within the experimental units and the smaller the difference specified by the researcher, the more replications required. Usually, it is most convenient to express CV and d in percentages of the mean. If several population characteristics are of importance, the number of replications required should be calculated for the most variable characteristics.

Frequency of Sampling

Some examples of data collection schedules for different types of trials are given in Table 1. Sampling should be done as frequently as necessary to detect changes in the parameter of interest, but not so frequently as to cause disturbance to the animal or its owner and to significantly increase costs. Researchers often try to collect too much data, only to find later that half or less of the data collected is not useful. Weekly variation in bodyweight, for instance, is less important than monthly changes. Increasing sampling frequency does not necessarily increase the usefulness of the data to the separation of treatment effects.

Table 1 Examples of data collection schedules by types of trial

Type of trial effects on	Frequency
Testing new feeds	
Milk production	weekly / fortnightly
Bodyweight	fortnightly / monthly
Economic analysis	monthly
Labour calender	monthly
Task division	monthly
Testing of mineral mixture	
Calving interval	annually
Lactation length	annually
Dung consistency	in beginning weekly
Feed intake	in beginning weekly / fortnightly
Farmer's perceptions	monthly
Testing management practices like deworming	
Farmers perception	in beginning weekly
Body weight	fortnightly
Milk production	fortnightly

Statistical analysis

The statistical analysis of data from OFTs may be as simple as calculation of averages and standard deviations followed by preparation of graphs. Student's 't-test' can be used to test the significant difference between control and treatment means. Paired 't-test' should be used whenever it is possible to pair the animals or farms according to weight, age, feeding practices, etc. Non-parametric tests such as sign test and Wilcoxon signed-rank tests can also be used whenever the underlying population distribution is not known. Analysis of variance (ANOVA) is used whenever comparisons among several treatment means is to be made and the volume of data is large. Least squares analysis for non-orthogonal data can also be used when the number of observations in each treatment class are unequal provided there is sufficient data.

Correlation and regression analysis is useful to determine if, and how a certain variable is influenced by other variables. The first step is development of a suitable statistical model which relates the variables one to the other. The suitability of a model depends upon the types of data and the objectives of on-farm trial. For more details on design of experimental trials and specific models to process and interpret data from OFT, the reader is again referred to suggested reading.

CONCLUSION

On farm research is part and parcel of the FSR/E procedures. Though OFT's will result in some demonstration effect, their primary purpose is to precede extension and demonstration. Different degrees of farmers' and scientists' involvement in the trial management can be found, depending on the objective of the studies. Though statistical analysis is important, it may often be difficult due to large variation in the field : a lesson for those who want to translate on-station research into extension messages without testing the actual responses in the field. Questions may have to be open ended in order to encourage farmers perception to become clear, and the "loss of statistical reality" is a small price to pay. The statistical procedures can involve a set of techniques, mainly applying simple methods due to the lower number of treatments that can be accommodated in on-farm research. Though the measurement of biological response is important, it should be remembered that the primary aim of on-farm experiments is to study the introduction of the new technology in farmers condition. Economical, sociological, gender related aspects and farmers modifications are important to be elicited in the first place, and they should not be neglected in favour of measuring biological effect.

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SECTION 2

CROP-LIVESTOCK SYSTEMS

SOCIO-ECONOMIC ASPECTS

2.1. GENDER ANALYSIS

R. Chakravarty and J.P. Dhaka

INTRODUCTION

Gender analysis is recognised worldwide as an important aspect in the design, implementation and evaluation of development projects. The large amount of recent literature, conferences and workshops on gender issues in development clearly indicates that the distinction between the roles of women and men is critical to agricultural production. It also indicates that quite often the access of women to resources and technologies is constrained due to gender barriers. People and institutions may be genuine to include the aspect of gender analysis in their development programs and research projects, but they often have misconceptions about 'gender', 'gender analysis' and 'gender issues'. This chapter attempts to explain the concepts and definitions involved, and to give examples of gender issues in practice.

DEFINITIONS AND CONCEPTS

The term 'gender' describes the socially determined attributes of men and women, including male and female roles. Sex refers only to the physical and biological difference between men and women. Too often the word 'gender'

Handbook for Straw Feeding Systems
Kiran Singh and J.B. Schiere (eds.), 1995
ICAR, New Delhi, India

is associated with 'women' and 'feminism' only, whereas it actually includes attention both to 'men' and 'women'. Due to previous neglect of women's role in agriculture, however, there is a tendency in gender work to particularly highlight the position of women. Moreover, and at another level of analysis, it is not only the distinction between socio-economic roles of men and women, but also between parents, children and other social categories that affect the result of development programs or choice of technologies.

Gender cannot be treated as a separate issue. It is involved in all aspects of research and development in which socio-economic and power relations play a role. During planning and implementation of agricultural development projects, the household is generally taken as the unit of analysis and the male heads of households as the principal decision makers. Thus, the role of other household members is often ignored. This hampers the success of the project as women, men and children have specific skills, resources, priorities and responsibilities in farm production. For instance:

men prepare the land, women do the weeding. Senior women (e.g. the mother-in-law) may work on their own field, while junior women (e.g. the daughters-in-law) work in their husband's field.

The differences between the role of men and women and the patterns of intra- and inter-household relations depend on the farming systems and the socio-economic context in which they take part. These differences are determined by social organization, cultural beliefs and values. The typical aspect of gender issues is that they concern role-patterns that are not biologically, but socio-culturally determined, and therefore, they can change. Particularly in livestock production, however, as it takes place around the home, the role of women is paramount. As shown in figure 1, the animals provide not only milk, but also dung and calves, much of which is handled by the women.

Figure 1. The cow produces dung, milk and offspring, much of which is managed in a way or another by the women of the family

The gender analysis studies the way male and female roles interact with the research goals or project targets, and how they influence the result. The objective of gender analysis is to focus on the effectiveness of development activities rather than on the equivalence of men and women, though the latter aspect is not less important. Through gender analysis, project planners can better understand changes taking place in the farming system, looking at the role of family members in performing the household and farm tasks, earning money, spending money and making decisions about other resources. Given such information, both women's and men's concerns are considered, and resources are directed towards individual and common development needs and opportunities. The tools of gender analysis not only include checklists or schedules for data collection. They are also analytical frameworks designed specifically to deal with gender issues. Their use enables the design of strategies to ensure that both men and women, and all other family members are better integrated into development efforts.

In addition to the influence of caste and economic status, a number of regional factors also act as powerful determinants of rural household strategies for the deployment of female labour. The level of development, as well as socio-cultural variables, play a role. *Purdah* is applied more strictly in the Northern parts of India than in the Southern parts. Data collected back in 1974 by the 'Committee on the Status of Women' revealed a pronounced contrast between North and South in the proportion of women who veil before males and elders. Higher dowries and strong evidence of daughter neglect have been documented for the North. Literacy rates of women are lowest in the North, except in Punjab. Religious beliefs do have a major impact on gender roles. While some of these rules may not be observed in individual families, the social 'norm' of behaviour can result in the fact that women - during surveys and RRA's - deny that they participate in certain farm activities, even when circumstances force them to do such work. Also, it is often found that women do not consider the care of animals as work, since they believe that it is "part of their normal duties at home".

Households can be analyzed through their labour hierarchy, and this approach is consistent with the gender ideology: the more a women's activity permits her to remain inside, i.e. in the domestic sphere, the higher is its status, and that of the household. A schematic representation of hypothesized female occupational status in farm production by land holding categories is given in Box 1.

Box 1. Schematic representation of hypothesized female occupational status in farm production by land holding categories.

Inside (high status)

Poor / Small — Economical status / Land holding size — Rich / Large

Occupational status		Landless	Marginal	Small	Medium	Large
	Domestic work	*	*	*	*	***
	Expanded domestic work	*	*	*	***	-
	Agr. work (family labour)	-	***	***	-	-
	Agr. work for others (wage labour)	***	***	-	-	-

Outside (low status)

Legend: *** = Primary activity, * = Secondary activity, - = No (significant) activity

(Source : World Bank, 1991)

PRACTICAL ASPECTS OF GENDER ANALYSIS

The specific roles and responsibilities for men and women vary between cultures, countries and social classes. This is explicit in the definition of gender, i.e. that the ascribed roles can change. Table 1 shows some difference in roles of men and women in different farming systems. Income is clearly a decisive factor, as women from rich farmer families undertake much less work directly: they generally hire labourers for most jobs.

Unfortunately, some think that 'gender analysis' represents a kind of 'gender warfare' that challenges the dominance of males in the household and the society at large. This general attitude hinders the success of many development programs, because even the choice of the researcher for gender analysis is not gender-neutral. Both male and female researchers can be equally proficient at gender analysis, and both can be equally 'gender blind'. Gender blindness is the inability to perceive different gender roles and responsibilities. Gender blindness implies, for example, the perception that all farmers are males and that research and extension activities have the same effect on men and women. For a deeper understanding of the gender issues in rural development it is important to consider the following factors:

- the division of labour,
- access to and control over productive resources,
- stakes and incentives in project activities,
- contribution to household income,
- degree of income pooling within the household,
- responsibilities for different types of expenditure.

Gender analysis as an activity should continue throughout the duration of a development project, from design via implementation to evaluation. At the design stage, gender analysis should be done by the persons responsible for the project's economic and social analysis. During the course of its implementation, gender analysis can be handled by the project management.

Table 1. Women in dairy production: initial observations on sharing of work and decision making (community and region-wise).

	Udaipur tribals	Baroda tribals	Baroda pastoralist
MANAGEMENT			
Cleaning	W 100	W 100	W 100
Watering	W 100	W 100	W 50
Milking	W 100	W 100	W 50
Grazing	W 100	W 50	W 70
BREEDING			
Calling the veterinarian	M 90	W 50	M 70
Administer medicine	W 80	W 100	W 80
A.I. or natural service	M 90	W 50	W 50
FODDER			
Harvesting/Bringing	M 90	W 90	W 80
SALE OF ANIMAL	M 100	M 100	W 50
DECISION MAKING			
Milk disposal	W 100	W 100	W 100
Type of feed	M 100	M 80	M 80
Use of income	M 100	W 70	W/M

Notes: W= Women, M= Men
(Source: adapted from Rangnekar *et al.*, 1993)

At all evaluation stages, it is desirable to tap the expertise of a social scientist. Thus, the integration of women in the design and implementation of any development project is important to help identify what women should do and why. After this, it is essential to investigate the relationship between socio-cultural and economic factors and women's decision- and participation levels.

The BIOCON project for instance, was set up against the background of the mixed farming system in India, wherein men and women are engaged in crop and livestock activities. The project initially focused on biological treatment of straw and later on other straw feeding methods. It was realised, however, that technology cannot be seen separate from the living conditions of its users. Therefore farming systems, in their totality, along with extension component became important elements of the BIOCON project. In a later phase of the project, gender was also considered as a relevant topic, with the realization that in many parts of India it is the women who care for animals. They feed and water the animals, they bathe and milk them, they clean the sheds and process the milk. Often, but not always, it is the men that receive the money. The inclusion of gender aspects in the project, even though at a later stage, has increased the gender awareness of researchers and extensionists. Relevant information has been collected, including gender segregated data on the division of labour in many aspects of various farming systems. For example:

> *high yielding varieties often produce less straw of a different quality than the traditional varieties. Generally speaking, for the male farmer, the amount of grain is more important than the amount of straw. He sells the yield and controls the amount of money which he receives. The women on the other hand, may have to do with less straw and need more supplementary feed, such as greens which they have to collect. This leads to a substantial increase in the work load of women. Also, since straw treatment influences the quality of the 'dung' for use as fuel cakes in the household (#4.6.1.), the women may have a different perception of feeding treated straw. The extra milk produced is sold by the man, but if treatment increases the*

workload, the extra income is achieved at the expense of more drudgery for the women. Equally so, a case has been reported from Orissa where male farmers refused to treat the straw if their wives could collect the extra income without sharing it with them.

CONCLUSION

'Gender' is an analytical concept which shows concern for both men and women by highlighting men's and women's roles and responsibilities in relation to each other. Since gender refers to the study of socio-economically determined differences between men and women, and not to biologically determined differences, its conclusions and approaches will differ between socio-economic categories and farming systems. As the household members, e.g. men, women and children do not have equal access to resources, nor to the benefits from production, the neglect of gender issues may lead to failures in project success. Gender analysis has become the commonly accepted term for analysis of gender roles and inter- and intra-household dynamics in farming systems. It can help to make projects more efficient and to reduce unwanted negative side-effects, for example when a new technology is beneficial for the total household income, it should not unduly increase the workload and drudgery for women.

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2.2. FARMERS' PERCEPTIONS OF INNOVATIONS

S.V.N. Rao, D.V. Rangnekar, R. Dey and A.W. Van Den Ban

INTRODUCTION

A large part of the transferable technologies in agriculture is not adopted by the farmers. The reasons for this poor adoption are commonly believed to lie in ineffective extension services, inadequate input supplies, credit support and market infrastructure, and last but not least: farmers' lack of knowledge as well as imperfections in the technology. Lately, however it has been realised that there is also a lack of awareness on the part of the researchers and extension agencies regarding the farmers' priorities. This has led the development community to address the wrong problems resulting in technologies which are not suitable or relevant to the farm families for whom they were evolved. The ultimate decision to adopt a particular technology depends to a great extent on the farmers' perceptions about the technology, their socio-economic situation and their need for the technology. Hence, there is now a growing concern among the researchers, extension staff and policy makers to better understand the farmers' perceptions with reference to technology generation and adoption. The perceptual differences among the farmers themselves and between the actors in development like farmers, extension workers, researchers and policy makers are discussed below, along with the implications for development and extension.

THE CONCEPT OF PERCEPTION

The interpretation of information is called perception. These perceptions play an important role in decision making of people in general and farmers are no exception. For example, farmers have to take decisions about cropping patterns, type of seeds, time of sowing and harvesting, type of animal to be reared, time of selling of animals, and to whom to sell the produce. Based on their perceptions of cost, benefit and risk, they will decide to adopt a technology or management practice. The perceptions are relative rather than absolute and they are influenced by the surroundings to a great extent. Due to past experiences, different people can interpret the same object differently, and this in turn affects their behaviour.

DIFFERENCES IN PERCEPTIONS BETWEEN ACTORS IN DEVELOPMENT

Much of the traditional transfer of technology (TOT) was based on the perception that "researchers know better than the farmers" and that the "farmers need to be educated". Researchers were placed at the top of the knowledge hierarchy with farmers at the bottom. Farmers were considered as receivers or "clients", but never as a source of information. However, with the growing realization that farmers also know about their own conditions, they are now becoming to be seen as partners to researchers in the development of technology. From clients they have become actors and it is for this reason that the emphasis of Farming Systems Research lies on the use of farmers' knowledge, e.g. through RRAs, mapping, transect analysis and on-farm trials (#1.3.1.; #1.3.2.; #1.3.3.). That farmers and developers live in different worlds is not only true for India (Fig. 1), and there are also perceptual differences among farmers of different social groups within the same region or even village (Box 1).

Figure 1. Farmers live in a different world than the development agencies, not only in India but also elsewhere, automatically leading to different perception of reality

A poster from the Australian CSIRO-DPI project "Improving Research through Extension".

The difference in perception of problems and solutions can be large indeed between the actors in development as tentatively indicated in Table 1. They ultimately reflect the actions of the actors in the development process. For example, local cows are perceived by researchers as a source of milk rather than for the production of bull calves. This implies that these animals are a prime target to be utilised in crossbreeding programmes for increased milk production. Lack of adoption of such programs is than caused by the fact that farmers consider the local cow not for milk but for production of bull calves to cater to their draught needs. For this very reason some farmers wish that the local cow gives birth to a male calf of a local breed, not by crossbreeding. They may then also prefer to leave the milk entirely to the calf for its better growth. It is surprising indeed that in India the development effort is almost solely directed towards increased milk production and hardly to improved draught capacity of animals.

Box 1. Differences in the use of straw quality between actors in development

Not only between extension and farmers, but also between farmers themselves there may be difference of perception. The farmers of Haryana and Punjab for example perceive the quality of wheat as superior to paddy straw. In fact paddy straw is often burnt in the field to save labour and to prepare the field for the next crop. Though, the rice straw may be valuable as a feed, the farmer has to compromise between alternative uses of labour for agricultural operations at that period of time. Farmers of West Bengal and Gujarat prefer to feed paddy straw over wheat straw. Researchers, using laboratory estimates of nutritive quality, consider that there is hardly any difference in the nutritive quality of these straws. They, with their perceptions, find it hard to understand why any straw should be burned at all. Some of them see straw as a feed to be treated with urea in order to achieve better liveweight gain or milk production. Agronomists, industrialists and farm women may again have different perceptions of differences between wheat and rice straw. Whereas, some agronomists focus on grain yields only, farmers may also be keen to have sufficient straw for their animals (#4.5.).

Even within the same region there can be wide variations in the use of various resources. Whereas some farmers in West Bengal use mustard oil cake as concentrate feed for animals, other farmers in the same state consider mustard oil cake as a fertilizer for use in horticulture or on vegetable crops!

Table 1. Examples of perceptual differences between researchers and farmers.

Object	Researcher	Farmer	Extension Worker	Policy Maker
Local cow a source of	milk	bull calves, dung	milk	milk
Utility of X-bred bullock as draught animal	good	not good, and it may be better to dispose of male X-bred calves	not convinced, but has to recommend it to the farmer	?
Castration of bull calves at 1-2 years	recommended for better growth of the animal	consider it as a bad practice as it weakens the animal	?	?
Gram husk	poor feed	good feed supplement	?	?
Early weaning of calves	recommended	viewed as a bad practice since it weakens the calf	?	?
Nutritive value of paddy & wheat straw	no difference in the quality	some like wheat straw better, others prefer paddy straw	?	?
Criteria for feed evaluation	TDN & CP	cost of feed and its effect on growth, fat yield	feed responses on milk production	possibility to earn foreign exchange
Reason for non-adoption of technologies	farmers ignorance & or ineffective extension	technology is not relevant	technology is not relevant and farmers are "uneducated"	technology is not reaching the farmers
New grain varieties	grain yield	grain and straw yield	more grain and may be more straw	more grain
Objective of research	to increase biological efficiency of milk production	to increase farm income	to increase milk as well as draught capacity	to increase milk supply to feed the growing urban population

Note: The readers may fill the gaps with question marks depending on their perceptions. It should be remembered that perceptions are perceptions, i.e. they may differ between observers.

Perceived differences in goal setting

The diverging goals of policy makers, researchers, extension personnel and farmers often originate from different perceptions about development. Policy makers are usually interested in popular measures which may or may not contribute to agricultural production. Researchers tend to address national problems by trying to develop standard packages with little or no concern for the differences which exist between zones and among the regions. Hence the researchers' goals may not be in consonance with that of the farmers and policy makers. The extension aims at achieving their targets by concentrating their efforts on a few resource rich farmers with little or no concern for the concept of equity. When different partners of development pursue diverse goals it is difficult to achieve unanimity and to secure farmers participation resulting in delay or failures in goal accomplishment.

Perceived differences in response criteria

Farmers measure the responses of new technologies in livestock in terms of butter fat content in the milk, draught performance, dung consistency, economics of production, increased milk yield or body weight. Farmers will only prefer to rear Holstein crosses over Jersey or Brown Swiss because of their high milk production potential provided there is demand and ready market for cow milk. When milk fat is the criterium for either consumption or sale of milk, farmers prefer buffaloes to cows. The researchers' concept of fat corrected milk (FCM) has no relevance to farmers or private vendors who estimate the fat content by dipping the index finger in the milk and checking its viscosity.

Similarly farmers have their own criteria to evaluate animal feed, e.g., palatability, intake, refusals, effect on milk, body condition, diarrhoea or constipation. Feeds which result in high milk fat production are usually ranked high. Generally farmers are interested primarily on the cost incurred and benefits received from the feed stuffs rather than feed conversion ratios, live weight gains etc. which are often mentioned in scientific articles. Concepts like TDN and CP, however valuable, have little meaning to most farmers or even development workers or extensionists. The same is the case with feeding standards, though in principle it should be remembered that the standards of farmers and scientists are complementary. Unfortunately, in practice their formal expression and purpose of application differ considerably as to create an impression of differences (#3.1.). Not only nutritionists may have a wrong perception of how farmers operate, many methodologies of economists also fail to properly grasp the economics of farming (Box 2).

Box 2. How is it that farmers are still in business ?

Many studies have indicated that the cost of milk production is very high. In that way it is not remunerative for the farmers to rear animals for milk production. But still, there are farmers that produce milk ! Usually cost of milk production is calculated by considering all costs, including family labour and costs of fodder growing or collection. Though this may be a valid approach for commercial farmers, it does not apply to all farmers in the same manner. Obviously, not all farmers consider dairy farming as a losing proposition. Some may have different perceptions about costs and benefits, and they accept low returns on family labour, and to some extent on costs for feeds and fodders.

Perceptions of technology

The rate of adoption is influenced by the farmers's perception of the characteristics of the technology and the required changes in farm management and distribution of family labour. Some important characteristics that farmers, men and women each in their own way tend to consider are such as:

- relative advantage,
- observability of results,
- divisibility,
- simplicity,
- complexity
- initial cost,
- compatibility with the social system.

Research has confirmed that farmers compare new technologies and management approaches with the traditional or the existing ones on the above characteristics before deciding on whether to adopt a new method or not. However, a particular technology need not to be superior to the traditional technology on all these counts and trade-offs are common. For example, many dairy farmers in India do not like to dispose of their unproductive cows to the butchers. Even though it is profitable to do so, it is not compatible with the existing social system. Similarly it is also common that farmers adopt a particular technology, not because it is profitable, but because it is adopted by opinion leaders in the social system. For some farmers, it may be more preferable to spend money in order to save labour.

Perceptions can even differ among the family members on various aspects of farming. For example, men and women may differ on issues like an increased herd size which adds to the workload of women, while it may increase the cash flow for the man. Gender issues like these are socially determined, and the reverse is possible (#2.1.), even though most of the farm technologies aim primarily to reduce the burden of the men, rather than work and drudgery of womens' labour. Farm men are mostly associated with activities such as ploughing, spraying, harvesting, threshing etc., for which machines are available. Strenuous activities like transplanting of rice, or weeding of a crop are often done mostly by women, activities that are yet to get the attention of the researchers.

All these differences help to explain the reasons for the differential adoption of technology among farmers. For example landless dairy farmers prefer to rear more low producing animals than one or two high producing animals (crossbreeds). Their perception is that high producing animals require better management, quality of feed and other inputs which are not accessible to them. Further, the risk of losing the high producing animal is high compared to low producing local cattle. Similarly, resource poor farmers have to accept getting less milk on roughage, rather than more milk by feeding concentrates which need ready cash to be purchased.

ASPECTS OF PERCEPTIONS IN MESSAGE DEVELOPMENT AND COMMUNICATION

The skill of the extensionist lies in communication, e.g. the identification and transfer of appropriate messages of the farmers, as well as the extraction of proper feedback. To be effective the message must not only be received by the farmers. Some of the principles of perception can be utilised while developing messages, and while planning to disseminate them. The aim of the extension worker is to capture and maintain attention of the audience or the farmers for the duration of the message. At the same time, the extensionist has to be keen to pick up signals and information from the farmers. Some techniques that might be used while communicating with the farmers' community are given in Table 2.

Table 2. The use of "perceptions" for the development of appropriate messages

Contrast	a moving object among other stationary objects, bright light in darkness, loud noise in silence, objects on white or black background will attract attention.
Novelty	video is a novelty in many developing countries attracts the attention of the farmers at least in the initial stages.
Pictures or models	or live examples are more effective than numbers or words.
Involve as many senses	as possible e.g. eyes and ears, to enhance the concept development among the farmers.
Avoid conflicting messages	to reduce distortion among the receivers.

CONCLUSION

It is essential to appreciate and recognize the perceptions and priorities of the farmers before contemplating development programmes. Only a shared vision among the researchers, extension personnel, farmers and the policy makers can help to evolve suitable strategies for increased production and prosperity. Research and extension staff must bear in mind the cardinal principles of perception i.e., relativity, selectivity, organisation and psychology if it wants to understand and develop suitable messages to increase their communication farmers.

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2.3. INDIGENOUS TECHNICAL KNOWLEDGE AND LIVESTOCK

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INTRODUCTION

A common question raised by extension and research workers is "Why don't farmers follow the advice that we give them?" In fact, research and extension staff tend to blame farmers for rejection or non adoption of technologies without realising that the farmer may have valid reasons for doing so. However, lately the scientific and extension community has started to appreciate that the rejection of technology may be due to unsuitability of the technology to the farmers' situations rather than farmers' ignorance. Fortunately, there is a growing realisation on the part of researchers and extensionists for the need to study and understand the farmers' situation before suggesting changes. As a result, the emphasis in development shifts to the use of RRAs, zoning and farmers participation in choice and design of technology, bottom up communication and respect for farmers' wisdom. This itself has led the scientific world to appreciate the role of indigenous technical knowledge (ITK), also referred to as traditional knowledge/wisdom. It is evolved by members of the farm community and passed on from generation to generation, or developed on the basis of recent

Handbook for Straw Feeding Systems
Kiran Singh and J.B. Schiere (eds.), 1995
ICAR, New Delhi, India

experimentation by farmers. ITK is unique to a given culture and society, but it has value also for the scientists and planners that are involved in development projects. This paper provides a comparison of ITK with modern practices, it discusses possibilities to use ITK and problems associated with ITK.

THE NEED TO STUDY ITK

Attempts to impress researchers with the need to study traditional animal husbandry practices were already made in the late sixties (Verma and Singh, 1969). The study and appreciation of ITK is important because:

- ITK may have scientific basis and its technologies could be transferred to other similar farming situations;
- documentation and screening of ITK is necessary before the valuable information is lost for ever;
- ITK may be an alternative, a substitute or a complement to modern technology;
- ITK may generate ideas for future research;
- it is often easier to secure adoption of ITK than modern technology.

PROBLEMS OF ITK

Each technology or concept has limitations, and ITK is no exception, e.g.:

- the scope for improvements based on ITK is limited to what can be done with local techniques, materials and genetic resources;
- many new developments (genes, techniques, materials) may be unknown, and can therefore not be explored with the informal system;

- the informal system has neither the necessary forward perspective, nor the information to anticipate opportunities and constraints arising from changing environments;
- the indigenous materials and methods used vary from area to area, because ITK is unique to a particular culture.

COMPARISON OF ITK WITH MODERN PRACTICES

ITK may be old, but it need not be outdated. In fact it can very well be compared with modern practices in a number of situations. ITK is farmer oriented and evolved by the farmers. Modern technologies are developed by researchers and often not suited to the local environment. ITK is passed on and modified from generation to generation and from farmer to farmer, whereas modern technologies are communicated from researchers via extension personnel and/or farmers.

ITK is compatible with the local situation and easy to adopt, being often less dependent on the use of external inputs. The modern technologies may or may not be compatible with the existing situation of the farmers and they may need external inputs for adoption. For example:

> *The traditional practice of applying turmeric and mustard/coconut oil to wounds is very easy to adopt, whereas modern veterinary practice involves the use of external inputs like antibiotic preparations and sometimes the services of a stockman or the veterinarian to treat the wounds.*

ITK is not well documented and there is only a start of an organised effort to promote it. On the other hand modern technologies are very well documented and there is a sustained effort mostly by the government institutions to promote them. Some organizations, e.g., the Indian Institute of Management in Ahmedabad (HONEY BEE) and SEWA in Tamil Nadu, have only recently started to document and circulate available information on ITK. For example:

> *The administration of syrup containing Ajwain, Black pepper, Soanf, dried ginger, jaggery etc. to the freshly calved animals is a tested practice to facilitate expulsion of the placenta. Though it is being practised by the farmers as well as in dairy farms maintained by institutions like NDRI, it has never been documented.*

ITK is often considered to be unscientific and primitive, whereas modern technologies are seen as advanced. For example:

> *Most dairy farmers house the animals in sheds made of locally available materials such as wood, coconut or palm leaves, paddy straw etc. These sheds appear primitive but, they are economical and sustainable. The so-called scientific recommendations about modern cattle sheds are often too expensive for small farmers conditions.*

Traditional technologies are specific to local situation, because they are based on locally available inputs, whereas modern technologies are often incorrectly considered as having blanket application to all the situations. For example:

> *In districts of the Eastern Coast of India (Andhra Pradesh,*

Tamilnadu, West Bengal) almost all farmers maintain an earthen or stone or cement pot in a corner of the house to fill it with rice washings, gruel, gram husk, rice bran, vegetable scraps, excess rice etc. This kitchen waste serves as a feed supplement to the animals. Although this practice is followed only where rice is the staple food, the modern technology of offering compound cattle feed is considered as applicable to all dairy farming situations.

It is high time to consider ITK as complementary to scientific knowledge especially in its capacity to provide non-commercial solutions to location specific problems. It is necessary to understand that the information from so-called scientific research alone is not enough to solve most problems in livestock farming.

POSSIBILITIES TO USE ITK

The use of ITK offers possibilities depending upon the farm system in which one is operating, and ITK can be complementary to modern science. For example:

The practice of chaffing of fodder was complemented by the researchers by designing and making available the chaff cutter to the farmers. The chaff cutters were very well accepted even by the resource poor dairy farmers in Haryana, Punjab, Uttar Pradesh etc. However, these were not popular in the states of South India where chaffing of fodder is not a practice (#4.6.2.).

Equally so, the use of herbal medicines in combination with allopathic drugs in the treatment of livestock diseases is common in all parts of the country. Ethno-veterinary medicine depends on the indigenous knowledge, skills, methods and practices pertaining to the health care of animals. (See Mathias-Mundy and McCorkle, 1989 for a Bibliography). Some of the age old methods are still being practised in the organised herds because of their merits. For example:

> *Feeding of concentrates to the animals at the time of milking is one such example which is very common throughout the world. Similarly many dairy farmers in Indian villages milk the first few strippings on the floor, even though they do not know the scientific logic that the fore milk has maximum bacterial load which can reduce the keeping quality of milk if mixed with the clean milk. However, in organised herds this milk is used for mastitis testing by stripping the fore milk from all the quarters on to strip cup.*

At times the use of a traditional practice may **generate research ideas** to the researcher. For example:

> *Feeding of cotton seed, cotton seed cake and oil to milk producing animals was traditionally practised by the farmers in Gujarat. However, this practice was considered by the researchers as of less value and they tried to dissuade farmers not to use it as a feed till they discovered its value as bypass protein (Pradhan et al., 1993; Rangnekar, 1993; #3.4.).*

DOCUMENTATION OF AVAILABLE ITK

It is well recognised that farmers are a rich source of information. Already, there are a number of native animal doctors (who are mostly farmers) and a traditional system of low-cost veterinary medicines and drugs which are not only ignored but, often dismissed as being primitive and unscientific. Women are also involved in performing various animal husbandry activities, and generally they are not approached by the extension worker. Women are known to use many plants for treatment of animals in West Bengal. Similarly the tribal women of Gujarat had the skill of identifying the weeds, tree leaves, creepers which can be used for feeding livestock. There is a danger of losing such valuable information which needs to be documented. This could be achieved through group discussion, Rapid Rural Appraisals, personal discussions etc. with the farmers.

The number of all these technologies will run into thousands and it will be a herculean task to validate or scientifically verify each one of them. Nevertheless, there is a need to screen the technologies, to cull the nonsens and to utilize the relevant ones, for example:

> *What is the truth that feeding excreta of birds can to induce heat, that mud on wounds can help the healing, and that mulling of testicles or removing them through open methods is a better methods of castration.*

Some of the traditional practices already attracted the attention of the researchers to test and validate their efficacy, e.g.:

> *The traditional practice of using milk while outplanting tobacco seedlings to reduce the spread of tobacco mosaic virus (TMV) in some parts of Andhra Pradesh was verified and its efficacy confirmed by the researchers through laboratory and field trials (Chari and Nagarajan, 1992). Similarly the use of cow dung to control bacterial leaf-blight, a traditional practice in many parts of lowland and water logged areas of India was found effective*

(Gangopadhyay and Das, 1992). Another example of ITK is that many farmers allow part of the feed to be refused, a practice that makes much sense under certain conditions as described under #4.4.

CONCLUSION

Farmers have good reasons not to accept new technologies. In fact, they possess a large amount of information that can solve their own problems without resorting to advice from technical advisers who have little understanding of local conditions. Indigenous knowledge plays a major role in finding location specific solutions for problems based on the land of the farm family, its micro-climate, the access to land, inputs and labour in different times of the year. Much of this knowledge is not based on formal research, but on careful observations and experience from the farm family, the parents, friends and colleagues. Since every technology has positive and negative effects, it is necessary to analyze the available ITK technologies carefully before recommending adoption by the farmers. This is true for both scientific and traditional knowledge. It may be necessary to refine or modify the modern technologies.

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SECTION 3

CROP RESIDUES

NUTRITIONAL ASPECTS

3.1. RATION FORMULATION

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INTRODUCTION

Formulating animal rations involves selecting and combining a number of feedstuffs to meet the animal requirements at the lowest possible cost, for the most economical level of production. In its most basic form, it has developed along with the domestication and keeping of livestock, and ration formulation as a daily farm practice requires knowledge on availability, price and composition of feeds. It also requires insight into the nutrient requirements of the animals. Ration formulation or a given level of production may not always result in an economically optimum level of production, as will be explained in this chapter. Different approaches are often used by extensionists and farmers to formulate rations, though their conclusions may be similar.

The following is a description of the historic development, background, principles of ration formulation, and of its relevance in different farming systems. A number of approaches to ration formulation are discussed, and illustrated with examples.

Handbook for Straw Feeding Systems
Kiran Singh and J.B. Schiere (eds.), 1995
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HISTORIC DEVELOPMENTS AND BACKGROUND

Livestock husbandry in early civilization involved feeding strategies based on whatever was provided by the natural environment. Animals were left to graze on vegetation abundantly available in those days, while they were hardly fed anything at home. Milk was produced without purchased inputs, and milk production levels per cow were generally low as compared to present levels. However, they were sufficient to meet the demand of small local populations, and low individual milk yields could be compensated by having a large herd.

Today, this ecological balance between supply and demand of animal products is gradually disappearing. Global expansion of population and consumption levels has resulted in an increased demand for milk and in a drastic reduction of the natural rangelands vegetation available for ruminants. Two necessities have evolved in livestock production from these processes of change:

- the need for increased milk production per animal to meet the present high demand for milk or cash needs, and
- the need to utilize more feeds from sources other than natural rangelands.

A man-made environment has evolved, using new methods replacing the old natural management techniques. The genetic ability for higher milk production levels has gradually increased, and animals are kept more and more in confinement and under controlled conditions with access to veterinary services. As far as the feed inputs in most farm systems today are concerned, insufficient feeds are produced on many farms to obtain the minimal income level required. This has prompted some farmers to purchase feeds from outside, creating a high market demand for feed and resulting in an overall price rise of feed ingredients as compared to the milk price. Other farmers face this problem and they are also forced to improve the utilization of crop residues that are available on-farm.

In such a situation, a farm/family, depending on its enterprise and production objectives, feels the need to control and regulate the supply of feeds to animals in order to sustain farm output and maintain the economic viability of the farm. Thus, a rational allocation of feeds is needed at low- and high-input farms, in such a way as to maintain the economic viability of the farm without affecting the desired production level of the farm. This is also known as ration formulation, and is being applied to an increasing extent in livestock farming systems today.

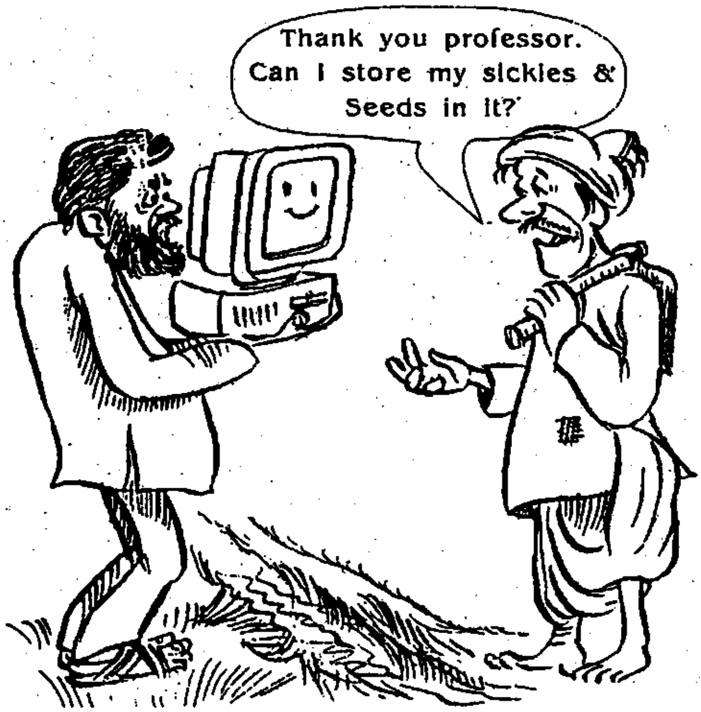
PRINCIPLES OF RATION FORMULATION

Ration formulation involves the selection and allocation of feed ingredients in such a way that the cost of the ration is kept low while sufficient nutrients are supplied to the animal for its maintenance and for its desired production level. Traditionally, farmers have used some sort of least cost ration formulation (LCRF) method to achieve this, which was based on farmers' experiences. Income maximisation is not always attained by LCRF, since the cheapest ration for an individual animal may lead to a suboptimal allocation of all available feeds to the herd as a whole. The optimal ration may be found through 'trial and error', but a farmer or extensionist may want to calculate it. One graph, or a few equations solved for a number of combinations, may get them close to the optimum, but if a computer is available, a simple linear program is most appropriate to find the answer. When the number of possible ingredients is large, linear programming (LP) on a computer can be useful to perform the required calculations. There is, however, quite some work to be done before computer information can be matched with farmers' expectations (Fig. 1). Ration formulation then becomes a purely mathematical process of minimizing the feed cost of a ration without affecting its feed value. Increasing feed prices and commercialization of dairy farms prompts farmers or feed companies to use LCRF in that way. The required information to apply LCRF consists of:

- the type and quantity of feed resources available in an area: agricultural and industrial (by)products;
- the concentration of energy (TDN), protein (CP) and other nutrients in each feed resource;
- the price of each feed resource;
- the nutrient requirements for maintenance, production, reproduction and growth functions of the animal;
- the maximum intake level of the animal;
- the desirable production level.

The usefulness and desired accuracy of feeding standards depend on the context and purpose of their application. Farmers develop standards by their experience of feed allocation as related to factors such as palatability, dry matter intake, fat content, production of milk and animal health, while scientists conduct experimental trials under controlled conditions. It is desirable that the use of standards developed by farmers and scientists are complimentary rather than mutually exclusive. Scientists often fail to understand farmers' values and priorities in low input farming systems.

Figure 1. Quite some work needs still to be done to match results from computer calculations with expectations and reality (Source: Honey Bee, Vol 4 (2&3), 1993)



RELEVANCE OF LCRF IN DIFFERENT FARMING SYSTEMS

A large variety of farming systems exists in India, due to differences in climate, geography and soil, as well as in family size, off-farm income and market prices. One of the important factors known to determine the relevance of LCRF in a particular system is the degree of external input use.

Low external input farming systems

The base of most Indian farming activity is a smallholder enterprise with one or a few animals, which are raised on roadside or bush grazing, or on feeding of crop residues and crop byproducts, done by family labour, often women. Although financial returns from the animals are low, they are still cost-effective (#2.2.). Over 60% of the milk output in the Operation Flood areas comes from these households.

Feed is a large constraint in this farming system. The feed availability is low and the situation further becomes critical due to regional and seasonal imbalances. Thus, in a low external input farming system, production is achieved mainly through grazing and grass cutting, straw feeding, and supplying an almost insignificant quantity of concentrate feed. For example:

> *A focused Rapid Rural Appraisal revealed that most poor farmers allocate concentrate only for two to four months, and only to lactating cows during the first phase of lactation. As soon as the supply of home-grown concentrate feed is exhausted, concentrate feeding is stopped.*

In a low-input farming system, periodic feed scarcities are coped with by allowing the animals to reduce their daily gain or even to loose body weight. Purchased feeds in such systems is not financially attractive, and LCRF needs to be applied in a different way, i.e. for medium of low, rather than necessarily high production levels.

High external input farming systems

Farmers in high external input farming systems purchase relatively large quantities of feed from the markets. Mostly, feed inputs are adjusted to the desired production level. In a high input farming system, sufficient feeds are purchased to increase the production level of high yielding crossbred animals. These farming systems have a good access to the market and remun erative produce prices.

A class of farmers, traditionally known as "GOWALAS", have been established for ages as specialised dairy farming communities in India. They follow a high input system, and in these production systems, farmers purchase various feeds at different prices. For them, LCRF is useful to maximise profit while minimising feed cost. Another class of farmers, i.e. those of the urban dairies are specialised in dairy production near large towns or cities, with excellent market facilities. Milk production on these farms is based entirely on purchased feed inputs, but many do not apply LCRF as a tool to economise on concentrate use for their targeted high level of production. Given the high milk price, the cost of concentrate is not so relevant for those systems.

AVAILABLE RATION FORMULATION METHODS

A few methods to obtain relevant information on optimal rations are now described. Each of them can be adapted for use under local conditions, such as the available resources, weather conditions, individual farming practices, cropping patterns, feeding practices and personal preferences.

Farmers' perceptions about feed value and ration formulation

Farmers have their own perceptions of the nutritive value of feeds, and they allot feeds to the animals strictly according to that (#2.2.). In that way, they can be said to use their own way of LCRF. Their practices are often based on traditional experiences and they may be quite appropriate (#2.3.). Some farmers believe that mustard oil cake (MO cake) is a "hot feed" and must not be fed to lactating cows. Others think that it can be fed during winter months only, and still others think that it can be fed in all seasons. A Bengali farmer even mentioned once on different grounds:

> *"Why should I waste MO cake by feeding it to my animals when I can also use it to fertilize my horticultural crops?"*

Traditional farmers' notions vary from place to place (Box 1). In the Districts Purulia and Bankura in West-Bengal, most farmers feed mustard oil cake round the year if it is available. In many areas, oil cake is fed along with mustard cake to 'neutralize' the so-called "hot" effect of mustard cake. Oil cake as such is considered to be a "cold" feed. Some farmers in villages think that boiled rice-grid should not be fed to cows during the first week of lactation, in order not to disturb the initiation of lactation. Many farmers think that feeding of bamboo leaves may help in bringing anoestrus cows into heat. Many such concepts exist in villages and they are worth further study (#2.3.).

In general, the livestock enterprise in rural India is managed by women. They receive occasional help from the male counterparts who are mostly engaged in other agricultural activities and who dedicate less time to the livestock enterprise. It is mostly the women that feed the livestock and know in their own way what to feed, when to feed, how to feed and how much to feed. They try to get the best possible output within the framework of resource constraints at their farm (Box 2).

Box 1. Some traditional feeding practices and results claimed by dairy farmers from semi-arid and tribal areas in Gujarat and Rajasthan (source: Pradhan *et al.*, 1993)

Material used	Feeding method	Animal type	Farmers' claims regarding effect
Cotton seed and Cotton seed cake	Cooked/soaked and with other material	Cows Buffaloes	Improvement in milk yield and fat%
Pods and seeds of *Acacia* and *Prosopsis*	Soaked/cooked and with other material	Cows Buffaloes Goats	Improvement in milk yield, fat%, inducing heat
Bibba seed	As such or with concentrates	Cows Buffaloes	Induces heat and oestrus signs
Tinosperma Cordifolia (creeper)	Green-both leaves and stems	Cows	Increases milk production
Tree leaves of *Alanguim salvifolium*, *Bassia latifolia* and *Butea monosperma*	Green Buffaloes	Cows milk Goats	Increases production
Flowers of *Bassia latifolia*	Fresh or after drying	Cows Buffaloes Bullocks	Improves milk production, maintains body condition
Prosopsis cinereria leaves and pods	Fresh, also as leaf meal	Cows Buffaloes Goats	Helps to maintain production
Maize cobs and cotton bolls	Cooked with other material	Cows Buffaloes	Liked by animals, maintains production

Box 2. Perceptions of women regarding livestock keeping (adapted from Rangnekar *et al.*, 1993)

Women's perception regarding livestock keeping provides an interesting field of study. Women in rich families generally have servants to look after the animals, and they themselves do not have a lot of interesting information regarding perceptions, except some communities like Rajput or Darbar, who considered livestock a status symbol. In many other cases, women were not even aware that their work constituted an important economic activity. They consider the care of cows and buffaloes as part of the usual household chore which is traditionally their responsibility. Just like house cleaning and cooking, animal care is not even counted as work. However, in villages where marketing of milk is organised and where development programs were initiated, the women did feel that they can earn substantial amounts by selling milk. These women would like to keep 3 to 4 milch animals, a number which they can manage in terms of labour input. Even these women still do not perceive dairy as a commercial operation, but as a source of supplementary income and as asset which can be encashed in times of need. Cow dung is an important produce - as fuel and source of manure. For women from pastoralist communities, the male progeny from the cows is more important than milk because they can be sold as draught animals. Grazing of animals is considered essential to maintain the health of the animals. Milk rich in fat is considered to be a better quality product than milk with a low fat concentration. Tribal women found it difficult to imagine that milk production could be an important economic activity and that a cow is capable of giving large quantities of milk. After a few visits, most women showed keen desire to know about high producing cows, artificial insemination, quality fodder, etc. Particularly from traditional cattle breeder communities, many women strongly believe that animals should be washed and kept clean to keep them healthy.

Least cost ration formulation for livestock in Indian farming systems exists in its own way. Farmers have their own perceptions, partly inherited from local traditions, about the quality of feeds. They try to balance animal rations in such a way as to keep the total costs at minimum, or better, to achieve maximum income. With local cattle, farmers usually are able to approach the minimum cost with the available resources, since the animal requirements in terms of quantity and quality are relatively low. With crossbred cows, in most situations higher quality feeds have to be purchased.

Although in those cases the total costs of the ration will increase, most farmers are able to realize low costs, and they are likely to be interested in technical support regarding LCRF from external agencies such as State Departments, State Agricultural Universities, Non-Governmental Organisations or even feed manufacturers.

Use of locally available extension material

In many states, extension materials are available in the form of leaflets regarding feed values of local feeds, ration formulation methods, and quantities to be fed to different species and classes of animals. They are often written in regional languages and in an easily understandable form, and are supplied to farmers by the State Extension Departments, the Agricultural Universities or Non-Governmental Organisations. This extension method may not be very exact, but mostly distinguishes sufficiently, for example between growing, lactating and dry animals, in order to be satisfactorily used by the farmer. Even so, the recommended ration often needs to be modified according to personal insights and particular seasonal feed availability. The advantage of such extension material is that it is written in local language and understandable terminologies, avoiding complicated technical terms.

The recommendation in percentages or parts is a risky method. For example, if an animal consumes a high quality feed, and the required amount of calcium (or any nutrient) is expressed as a percentage, e.g. 0.5%, then this percentage is to be doubled if a low quality feed such as straw is consumed. This is due to the limited intake of the straw. For example, a farmer may be advised a concentrate mixture as part of a straw-based ration for his or her dairy animal(s). This type of recommendation will only be reliable if the available feeds are classified in terms of their composition and dry matter percentage, and if the advise is given for a complete feed rather than for individual ingredients. The farmer does not have to know technical terms, nor perform a number of calculations to define the ration. An example of such recommendation per leaflet is shown in Table 1.

Table 1. Recommended diets and daily amounts (kg) for two groups of dairy animals

Ingredient	**Animal type**	
	Zebu cows	**Purebred Indian cows Crossbred cows Buffaloes**
Straw	4 kg	4-6 kg
Concentrate mixture for maintenance	1-1.5 kg	2 kg
Concentrate mixture for milk production	1 kg/2 litres of milk	1 kg/ 2 litres of milk
Concentrate mixture for gestation	1.25-1.75 kg additional	1.25-1.75 kg additional

When green fodder is available, the amount of concentrate mixture may be reduced at the rate of 1 kg concentrate for every 8-10 kg fresh green fodder. This type of information extended through leaflets to farmers by State Animal Husbandry Extension Departments, NGO's or State Agricultural Universities may be useful for use under village conditions, but requires clear language, careful interpretation and frequent updates under changing feed resource conditions.

Experimental rations may be tried out on-farm before making recommendations. An example of the joint investigation by farmers and researchers of economically viable options for improved feeding practices is described in Box 3.

Box 3. Ration formulation with locally available feeds: a village experience in Nadia District of West-Bengal, India (source: Saha and Singh, unpublished 1994)

Thirteen early lactating cows at thirteen different farms in Charsarati (Nadia District, West-Bengal) were fed, in addition to a basal ration of straw and roadside grass, a feed mixture containing:

40% mustard oil cake
40% rice kura
18% crushed maize

One kg salt and one kg of lime were added to every 100 kg of the above feed mixture. The calculated CP% and TDN% of this mixture were 18% and 73%, respectively. During 4 months, farmers fed their own concentrate and the experimental feed mixture in alternative months, while daily milk yields were recorded for each cow. All daily concentrate doses were based on the following rule of thumb: 1 kg per cow for maintenance, plus 0.5 kg concentrate per litre of milk. Each of the thirteen farmers fed his/ her own home-made concentrate in the first and third month, and the experimental diet in the second and fourth month. On average, the farmers realised an increased milk production of 600-900 g/cow/day with the experimental diet, whereas the feed cost per kg of milk remained equal on the two diets.

Nutrient requirement tables

The aim of using feeding standards is to optimize nutrition, and generally it does not consider social and economic factors. Economic optimization will have to be executed by selecting cheaper feeds, and by their judicious incorporation in the ration, either calculating by hand, calculator or computer. Box 4 describes feeding standards for low-input animal production systems.

Box 4. Feeding standards and feed requirements

Feeding standards for low-input animal production systems in temperate systems have been developed by the Agricultural Research Council in the U.K. and by the National Research Council in the U.S.A. They have been discussed for survival feeding by Cronjé (1990). Various attempts have been made to develop feeding standards for India. Ray and Ranjhan (1978) based their recommendations on studies of basal metabolic rates, mostly conducted on IVRI, Izatnagar and feeding trials conducted at other research stations of the country. ICAR also published the nutrient requirements for cattle, buffaloes, sheep, goats, camels, poultry and swine, the most recent set of nutrient requirements is Ranjhan (1990). The publication by Kearl (1982) on nutrient requirements for the developing countries was partially based on such Indian work. The application of feeding standards developed for high input systems for use in low input systems is doubtful and needs to be done with care (Ketelaars and Tolkamp, 1991; Schiere and de Wit, 1993).

Linear programming

The use of computers for extension and/or personal use is facilitated in recent years by the increased availability of computer software and hardware in most parts of India. Linear programming (LP) can be used for development and/or evaluation of a ration under low input conditions. However, its application and use is in most cases restricted by the lack of information on the quality and quantity of locally available (affordable) feeds, as well as by the knowledge about optimum levels of production. However, the use of computers can be effective when such data are available and when there is a realistic expectation of cost reduction by applying LP. Box 5 describes the basic LCRF approach when it is to be tackled by linear programming.

Box 5. The basic linear programming problem for LCRF

The following example describes the formulation of a ration consisting of forage and concentrate. One kg of forage costs 4 Rs and contains 10 MJ, 8% CP. One kg of concentrate contains 20 MJ, 24% CP and costs 10 Rs. Thousand kg of ration is to contain a mixture of forage and concentrate, such that its cost is minimized while energy and protein concentrations exceed 12 MJ/kg and equal 16%, respectively.

Characteristic	Unit	Forage	Concentrate		Constraint
Cost	INR *)	$4 * X_A$	$10 * X_B$		Minimize
Weight	kg	$1 * X_A$	$1 * X_B$	=	1000 kg
Energy	kJ ME/kg	$10 * X_A$	$20 * X_B$	>=	12 * 1000 kg
Protein	% CP	$8 * X_A$	$24 * X_B$	=	16 * 1000 kg

The least expensive combination of green fodder and concentrate can be found by transforming the above information into a set of equations. The solution can be found either graphically, by hand, calculator or computer. When this is done, it will be found that the least expensive solution to this problem is to mix 750 kg forage with 250 kg concentrate. The mixture will contain 16% CP and 12.5 kJ ME per kg. Even though the outcome in the case of two feeds with only TDN and CP will be rather obvious, the problem becomes much more complicated when three or more feeds, and more constraints are included. One constraint should be the maximum dry matter intake by the animal, which is limited by the quality of the feed. The solution dictated by a linear model is sensitive to the input parameters and conditions assumed in the model. A sensitivity analysis may indicate the parameters that most influence the answer. These parameters can be refined to yield more accurate answers with the model.

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*) INR = Indian Rupees
X_A = weight of feed A (kg)
X_B = weight of feed B (kg)

CONCLUSION

Ration formulation can be undertaken in several ways. For most farmers and at present, LCRF with linear programming is not recommended for defining local rations. For extension workers without access to, or sufficient acquaintance with the required hardware and software, it may be difficult to yield any fruitful message with this method. At this stage, suitable technical bulletins in an easily understandable language may be the most appropriate tool to help farming communities in formulating optimal rations for their animals. Nevertheless, LCRF with or without linear programming has a role to play in the future of Indian livestock development, provided that it takes into account the farmers objectives of keeping animals, not only high biological yields.

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3.2. FEED INTAKE REQUIREMENTS

S.K. Ranjhan, J.B.Schiere and M.N.M. Ibrahim

INTRODUCTION

Animals have to be given feed, and generally, as the animal eats more, the production in terms of milk, draught and meat will be higher. There are exceptions however, and a few things are to be kept in mind before suggesting that dry matter intake is a guarantee for higher production. In fact, the nutrient concentration of the feed, and the capacity of an animal to eat what it is offered is more important than the focus on dry matter intake. Last but not the least it is the farmer who may decide to feed lower levels of feed than what the animal could eat, purely for practical or economic reasons. Some of these issues are discussed with special reference to straw based rations.

FEED QUALITY AND INTAKE

Not all the feed is the same, and accordingly the intake of their feeds will vary. No hard and fast rules can be suggested, but a few points should be taken into account when discussing "intake" for the formulation of rations

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and feeding strategies: dry matter content, nutrient concentration and physiological state of the animal.

Dry matter content

While computing rations, the intake of a wet succulent feed like water hyacinth, alfalfa or young grass must be corrected for its dry matter content. Since ten kilos of such feeds contain only 1 - 2 kilo of dry matter, one has to be cautious in comparing the nutritive value of ten kilos of straw with ten kilos of green feed. As a general rule, it is always best to express everything on a dry matter basis. Only when this is to be translated to farmers conditions, does it make sense to express the total feed on a fresh matter basis.

The other problem with the dry matter content is that when feeds are very succulent, the intake may be reduced because of the large amount of water that is ingested. This effect is difficult to quantify. Wilting of the grass may help, but the argument that highly succulent feed need to be given straw in order to increase their dry matter intake is questionable. In fact, the intake of dry matter i.e. of nutrients, from for example alfalfa or berseem is higher than from straw as shown in Table 1. Straw may be added to these feeds for other reasons, for example, because it can help to improve dung consistency, to avoid bloat, or to actually reduce the nutrient intake:

farmers in the berseem growing area are known to mix chopped straw with the chopped berseem, but high producers are given a higher ratio of green to straw than low producers. This implies that the farmer dilutes the concentration of nutrients more for low than for high producers. If the milk production of the animals is still *higher, less straw will be added, unless again, the secondary effects of straw become important, such as on dung consistency or rumen function.*

Nutrient concentration

Some international literature about nutrient requirements uses the term "dry matter requirements" (NRC, 1987). However, they do so while stating at the same time the nutrient contents of the feeds that are considered in these estimates. The principle is that of a feed like straw, with 0.40 kg TDN/kg feed dry matter the animal would have to eat twice as much dry matter as when the feed contained 0.80 kg TDN per kg dry matter, as is the case in a good concentrate supplement. The problem is however, that whereas an animal should eat more straw to cover its nutrient requirements, in reality it can eat less. Whether this lower intake is regulated by the animal metabolism, or by rumen fill will be a matter of scientific dispute for some time to come, but the fact is that the poorer the feed, the lower is its intake (Table 1). What it really means is that the intake of straws is low, and since that is combined with a lower nutrient concentration, the total intake of nutrients is generally too low to even let the animal maintain its weight. What really counts therefore is not the dry matter intake, but the absolute intake of nutrients, better expressed as digestible organic matter, or as TDN, ME or whatever measures one uses. The use of tables with dry matter intake requirements is particularly misleading in case of poor quality feeds, and mainly based on conditions where feed is homogenous and of good quality.

Table 1. Some approximate intake values of feeds, estimated for animals at maintenance.

straw	1.5 kg/100 kg BW
treated straw	1.9 kg/100 kg BW
medium quality grass	2.2 kg/100 kg BW
good quality grass	2.6 kg/100 kg BW

Physiological state of the animal

Depending on its physiological state, the animal has the capacity to eat more, or less. High producers can eat up to twice as much of the same feed as low producers, starved animals may eat more than what one might expect on the basis of their bodyweight. Disease, parasite infections or mineral deficiencies will all cause the animal to eat less than what would be expected on the basis of its bodyweight (#4.1.).

THE FARMER AND THE DRY MATTER INTAKE

It may be clear from the above that dry matter intake depends on feed quality and physiological status of the animal. However, ultimately the farmer takes decisions on the basis of economics. Clearly, if a feed is very expensive (= scarce), the farmer may even temporarily decide to forego some production rather than to let the animal produce milk at prohibitive cost. The farmers' idea is then not how to feed as much as possible, but how to feed as little as possible. But the issue is more complicated, let us go back again to the case of straw mixing in berseem rations.

If a good feed like berseem is relatively scarce, and if straw is relatively cheap, the farmer prefers to feed as little berseem as possible, particularly when the animal is producing only small quantities of milk. In that case, the farmer stretches the farm feed resources by mixing poor quality feeds. If necessary, the straw is chopped and soaked to increase the intake of on-farm feed, not so much to increase the daily nutrient intake of a cow, but to maintain the animals in a situation of limited supply of good feed.

The other case occurs where a farmer with high producing animals, and good access to the market, will reduce the roughage component in the feed as much as possible. To ensure a higher production of milk, the feed should be of the best quality, and it pays to replace the roughage with concentrate, e.g. the strategy of substitutional supplementation is applied (#4.3.). In these cases the roughage is only useful to maintain a certain level of fibre in the ration for optimum rumen function. Again, it should be clear that what counts is not just the dry matter requirement, but the intake of digestible nutrients. Though the increased dry matter intake is associated with the increased nutrient intake, the two are not synonymous.

CONCLUSION

The feed consumed by the animal determines to a large extent what the animal will produce, but it is incorrect to assume that a high dry matter intake guarantees a high output. Depending on the type of feed, the availability of feed and the type of produce), the farmer may decide to reduce rather than to increase the dry matter intake, or to decrease the nutrient intake by replacing berseem dry matter with straw dry matter.

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3.3. CELL WALLS AND CELL SOLUBLES

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INTRODUCTION

Animal nutritionists have attempted to describe feed quality by laboratory analyses at least since the 'Proximate Analysis ' was developed in Germany in the previous century. Quite obviously, these older methods are replaced or supplemented by newer approaches. Since the last few decades the measurement of crude fibre and so called Nitrogen Free Extract ("Soluble carbohydrates") is replaced with the use of cell walls and cell solubles as an indicator of digestibility (quality). Because these terms are frequently used in this book, we will briefly explain the principles and concepts behind this analysis.

THE PROXIMATE ANALYSIS

Laboratory values are not the same as those used by the farmers, but fortunately they appear to overlap at least to some extent (Table 1). Since long, nutritional characteristics of feeds have been expressed in chemical terms. One of the oldest systems of analysis is the Proximate Analysis, also called Weende system. It describes the feeds in terms of crude protein (CP),

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crude fibre (CF), crude fat or ether extract (EE), ash, and nitrogen free extractive (NFE). The components of these different fractions are shown in Table 2. It was soon recognised that the digestibility of feeds, and hence their nutritive value, was adversely affected by CF content, while high protein feeds were more digestible. Based on these observations, the CF contents have long been useful as an indicator of feed quality.

Table 1. Likely similarities between farmer perception of straw quality and laboratory evaluation

Straw characteristic desired by farmers	Correlation found in laboratory evaluation
Leafiness	Leaf digestibility > stem digestibility (for most crops)
Sweetness	More cell solubles (NDS) in sweet varieties
Stay green	More cell solubles in varieties that stay green longer
Texture	High silica in varieties with coarse texture
Colour	Spoilage/pigmented varieties

Note: This list is prepared on the basis of discussions in the National Seminar on variability in quality and quantity of straws (Joshi *et al.*, 1994)

The proximate analysis is still used in description of animal feeds, but its limitations in predicting the digestibility of fibrous feedstuffs are becoming increasingly obvious. The laboratory procedure for CF determination involves successive use of mild acid and alkali, which tends to dissolve part of the (hemi)cellulose and lignin. The problem is that in reality, these latter components are part of the plant cell wall, i.e. the fraction that is resistant to the digestion in the rumen. Thus due to analytical problems, part of the fibre that is variably available to the animal is estimated as completely digested, thus overestimating the nutritive value of the feed. This is because the NFE fraction which is meant to represent the soluble nutrients minus the proteins, is calculated by difference.

Table 2. Components of different fractions in the Proximate Analysis of foods.

Fraction	Components
Moisture	Water (and volatile acids and bases if present)
Ash *)	Essential and non-essential
Crude protein	Proteins, amino acids, amines, nitrates, nitrogenous glycosides, glycolipids, B-vitamins, nucleic acids
Ether-extract **)	Fats, oils, waxes, organic acids, pigments, sterols, vitamins A, D, E, K
Crude fibre	Cellulose, hemicelluloses, lignin
Nitrogen-free extractives	Cellulose, hemicellulose, lignin, sugars, fructans, starch, pectins, organic acids, resins, tannins, pigments, water-soluble vitamins

Source: Adapted from Mc. Donald *et al.*, 1981

Notes: *) Particularly in rice straw and sugarcane tops, the silica content is very high.

**) In fibrous feeds, the ether extract (EE) is generally very low around 0.5-1.5% of the dry matter. It contains a high proportion of the non-fats; it is therefore not very useful to determine EE or digestible EE in fibrous crop residues.

Analytical errors or assumptions in fibre determination can cause marked errors in its estimations. As the nutritive value of grasses, straws and stovers for ruminants depends on the digestibility of the fibre, a more precise determination of this fraction is important particularly in farming systems utilizing fibrous feeds as a major feed resource.

THE "VAN SOEST" FORAGE FIBRE ANALYSIS

A newer, and more fundamental approach to feed analysis was developed during the late 60's and early 70's in the U.S.A. by a group of workers headed by P. Van Soest. Their approach partitions the feed organic matter into cell wall and cell solubles, the latter is also called cell contents. This division was considered more logical in view of the chemical uniformity of the fibre fraction which was overlooked in the older system. Furthermore, these two fractions can also be classified as having low and high digestibility in the rumen. The cell walls are variably, but generally not easily and rapidly digestible, whereas the cell contents can be assumed to be completely digestible.

The significance of this distinction for those involved in feeding of fibrous feeds (i.e. straws), lies in the fact that the cell wall is the part that ultimately remains in the straw. When harvest approaches, i.e. when grainfill starts, the soluble cell contents are transported (translocated) to the grain, whereas the remaining cell walls mature and thicken into an even less digestible fraction (Table 3). One can note here that:

A failed harvest implies that the ratio of cell solubles/cell walls increases. This is to the benefit of straw quality: more solubles remain and the cell wall may be less mature.

There are more factors, however, like duration of the crop, light, temperature, rainfall, use of fertilizers which influence the formation and /or utilization of the cell solubles and therefore the digestibility of the straws/stovers (#4.5.).

In chemical terms, the cell wall fraction consists of the structural components of the cell, i.e. cellulose, hemicellulose and lignin. In theory, the first two of these are potentially (100%) available through ruminal digestion, because rumen microorganisms provide the enzymes cellulase and hemicellulase.

Table 3. Effect of stage of maturity of crop on composition and digestibility of finger millet stovers *)

	Characteristic *)			
Stage of maturity	**NDF(%) cell wall**	**NDS(%) cell solubles**	**OMD(%)**	**NDFD(%)**
Flowering	59.0	30.2	74.0	60.7
Dough	59.1	30.6	69.4	53.6
Physiological maturity (PM)	66.5	22.5	60.9	47.8
Ten days after PM	68.5	21.7	56.6	42.8
After 150 of storage	70.5	17.5	48.7	36.0

Source: Subba Rao *et al.*, 1993
*) NDF = Neutral Detergent Fibre
NDS = Neutral Detergent Solubles
OMD = Organic Matter Digestibility
NDFD = NDF Digestibility

The actual degradation of these two energy yielding fractions is however limited on account of the lignin associated with the cellulose and hemicellulose, and also because of the relatively short time that the feed remains in the rumen. Whereas lignin is often blamed for the low digestibility of the straws and stovers, its role is rather limited. The first cause for the inferior nutritive value of crop residues is the low content of cell solubles, i.e. the feed component that makes young grass so valuable is lacking in straw.

The detergent analysis is so named because it uses detergent solvents of different pH, represented schematically in Figure 1.

Figure 1. The process of fibre fractionation according to the Van Soest detergent analysis.

Step			Abbreviation
	Feed dry matter		
1	→	extracted with neutral detergent (pH 7) Cell contents dissolve (neutral detergent solubles)	NDS
	Cell walls remain	neutral detergent residue also called neutral detergent fibre	NDR NDF
2	→	extract with acid detergent (pH 0) Hemi cellulose dissolves (= acid detergent soluble)	ADS
	Acid detergent fibre remains		ADF
3	→	digest with permanganate solution Cellulose dissolves	
	Lignin and ash remains		
4	→	ashing Lignin disappears	ADL
	Ash remains		

(Source: Ranjhan, S.K., 1993)

The cell wall content is determined in the laboratory by boiling the dry ground feed with a solution of neutral detergents with a pH of 7.0. This solution dissolves all the soluble nutrients from the plant material leaving behind residue of plant cell walls. Due to the use of the neutral detergent solution in the analysis the residue (cell walls) is often referred to as Neutral Detergent Fibre (NDF) and the cell solubles as Neutral Detergent Solubles (NDS). The cell wall fraction (NDF) can further be treated with acid detergent solution to dissolve hemicellulose leaving a residue called Acid Detergent Fibre (ADF) which is made up of the cellulose, lignin and ash. The ADF is separated into its components by using sulphuric acid or potassium permanganate. Thus a complete description of the plant cell wall is obtained through the detergent analysis system. In most cases, an analysis for NDF is sufficient for characterization of the feed as it basically represents the fibre fraction.

The NDS fraction consists of the soluble nutrients in the cell i.e. amino acids, peptides, sugars and minerals. This is estimated indirectly by subtracting %ash and %NDF from 100. i.e.

$$NDS = 100 - (\%ASH) - (\%NDF)$$

The NDS fraction is almost completely (>90%) available to the animal.

The NDF content is generally expressed as %DM (dry matter) but when expressed on the organic matter (OM) basis it facilitates the calculation of organic matter digestibility (OMD). Expression of these values on OM basis also increases the precision of comparing feeds with different ash contents. Analysis of the feed organic matter for NDF content and digestibility of NDF by a suitable technique can be used to estimate the OMD by the following equation:

$$\%OMD = (\%NDF) * (NDF\ digestibility) + (\%NDS) * (NDS\ digestibility)$$

For example, a straw sample containing 70% NDF (OM basis) with 45% digestibility of NDF will have an OMD of

$$\%OMD = (70)*(0.45) + (30)*(0.9)$$
$$= 31.5 + 27 = 58.5$$

The laboratory technique for determination of NDF is simple, quick, reproducible and can be used to describe the nutritional quality of the feed along with other nutrients like CP. Comparison between the detergent analysis system (Figure 1) and the Proximate analysis (Table 2) shows the inaccuracy of the previously used CF analysis as a measure for fibre content of the plant.

CONCLUSION

The use of crude fibre has long served as an indicator of digestibility and hence of nutritive value of animal feeds. However, the inaccuracy of the chemical approach has led to the development of a more reliable, simpler and biologically more acceptable method to distinguish between cell walls (NDF) and cell solubles (NDS). The understanding of these principles helps for example, to see why - within species - straws of mature and longer duration crops tend to have a lower nutritive value than a failed grain crop or crops of shorter duration. Together with other laboratory measurements like ash, protein content and (rate of) degradation, the new approach will function as a useful parameter of nutritive value for both agronomists and animal nutritionists.

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3.4. FEEDING OF BYPASS NUTRIENTS TO RUMINANTS

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INTRODUCTION

The term "Bypass Nutrient" refers to that fraction of the nutrients which gets fermented in the rumen to a comparatively low degree. It then becomes available at the lower part of the gastro-intestinal tract in the intact form for subsequent digestion and absorption. These slowly degradable proteins also have a function to provide the rumen microbes with a steady supply of nutrients, rather than with sudden bursts from easily soluble nutrients. These concepts were introduced in the early eighties, primarily to replace the conventional digestible crude protein system which has many limitations. They describe the protein quality of a feedstuff for ruminants, and the protein requirements based on rumen degradable protein (RDP) and undegradable dietary protein (UDP). Subsequently, the term has been extended to other nutrients like carbohydrates and fats that could also escape rumen fermentation partially, to be digested in and absorbed from the small intestines. The new approach envisages minimisation of ruminal fermentation losses, and better utilisation of the nutrients after their digestion and absorption from the small intestines. This paper discusses the new approach

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for conditions in India and other countries, where quality feed resources are available in limited quantities, and where cereal straws form a major source of roughage.

THEORETICAL CONSIDERATIONS ABOUT SLOWLY DEGRADABLE NUTRIENTS

There are three type of nutrients that could bypass rumen fermentation to certain degree:

- protein/amino acids,
- starch/glucose,
- fats/fatty acids,

Minerals (Zn, Cn, Mn) can be chelated, but in that form they entirely bypass the rumen, as they are stable at ruminal and abomasal pH.

The slowly degradable or "bypass" nutrients may occur in feeds in their natural form, but feeds can also be manipulated to restrict their degradation in the rumen. Nutrients should be made resistant to microbial enzymes to such an extent so that rumen microorganisms get sufficient nutrients for efficient rumen functioning with respect to fibre digestion and microbial protein synthesis.

The purpose of feeding "bypass" protein is that a large proportion of the protein is available directly at the lower part of gastro-intestinal tract, where it is digested and then absorbed as amino acids for utilisation at tissue level. Feeding of "bypass" starch reduces excess production of lactic acid in the rumen which would otherwise result in low rumen pH (acidosis), thereby affecting fibre digestion. Feeding of "bypass" fat (protected fat) is done primarily to avoid ruminal hydrolysis of bio-hydrogenation of unsaturated fatty acids and increasing energy density of feeds. The fats are thus digested mostly in the small intestines and absorbed as unsaturated fatty acids without affecting the fermentation of fibrous feeds in the rumen.

METHODS OF MAKING BYPASS NUTRIENTS

Some nutrients have bypass characteristics in their natural forms. However, others are required to be manipulated to reduce their rumen degradability for optimisations of ratios between degradable and undegradable nutrients in the diet.

Protection of proteins

The main methods available to protect proteins are the use of chemical reagents or heat treatment. In the past, formaldehyde was used (applied @ 1.2 g/100 g CP) to reduce the degradability of highly degradable proteins in rumen. However, its corrosive nature and possible carcinogenic effect had prevented it to be used as an agent for protection of proteins. Recently a group of Australian workers, however, have demonstrated that formaldehyde is metabolised to CO_2 and water after its absorption from intestines, thus reducing the fear for carcinogenic effects.

Other technologies for inhibiting protein degradation in the rumen include the treatment with metal ions ($ZnCl_2$ and $ZnSO_4$), coating with insoluble protein (blood, zein), acid and alkali treatment (NaOH, HCl, propionic acid), alcohol (ethanol) treatment and acetylation of peptides (acetic anhydride). But, to-date none of these have been commercialised. With regard to heat treatment, the temperature and the period of treatment is critical. If this combination is not proper, the protein is either under protected or over protected. Heat treatment of groundnut cake and soybean meal at 150°C for two hours seems to give sufficient protection. However, such a processing may not be economically feasible due to the high cost of equipment and energy. During the solvent extraction of oil cakes, the temperature reaches only 90-95°C and the proteins are only partially protected at this temperature.

Protection of carbohydrates

Protection of starch can be achieved with formaldehyde treatment. Ammonia treatment could be another effective method to protect starch from ruminal hydrolysis. Treating starch with sodium carbonate plus sodium hexameta phosphate has been demonstrated to reduce starch degradation in the rumen.

Protection of fats

Lipids encapsulated by formaldehyde treated protein is an effective method of protection against ruminal hydrolysis and bio-hydrogenation of lipids, but due to the use of formaldehyde, the method has its limitation. During the refining of edible oils, free fatty acids are removed by treating with sodium hydroxide and then with acid. The free fatty acids thus removed by centrifugation are termed as acid oil which has roughly one-third the price of edible oils. These acid oils can be converted into calcium salts either by fusion or participation method. Thus, the fatty acids in the form of calcium salts are protected against the rumen enzymes, a method that can be commercially used for the protection of lipids.

NATURALLY OCCURRING BYPASS NUTRIENTS

In some feedstuffs, nutrients are naturally bound to other feed components, thus reducing their rumen degradability. The bonds with which the nutrients are linked remain intact in the neutral environment (pH = 6-7) of the rumen, but they are broken in the acidic environment of the abomasum (pH 2-3). These are referred to as naturally occurring bypass nutrients. Bypass protein values for some of the commonly used feedstuffs are given in Table 1. The feeds with higher bypass protein values are: cottonseed cake, maize gluten meal, coconut meal, fishmeal and leaf meals like *Leucaena leucocephala* (subabul). Similarly, the fermentation of starch from maize in the rumen is limited, thus, it is good source of bypass starch. With regard to fats, when fed through oilseeds, they are partially degradable in the rumen.

METHODS TO EVALUATE THE EXTENT OF PROTECTION

Whether the nutrients are naturally or artificially protected, there is a need to measure the extent of protection, i.e. the extent of degradation/hydrolysis in the rumen. For proteins, the rumen degradability by nylon bag technique is widely used. Values of effective degradability from different regions are available in India from published papers (Table 1). From these, the RDP and

UDP values can be calculated for feeds. ARC (1984) and NRC (1985) have given the requirements for these two protein fractions in dietary protection for ruminants with respect to growth and milk production. For starch, limited work has been carried out so far. Those who have worked to measure the degree of protection, have done so by way of using labelled glucose and measuring glucose uptake at the intestinal level. With regard to fats, the percent of unsaponified or free fat can be found out by extraction with petroleum ether. The unsaponified fat gives degree of protection. The major problem in the measurement of degradation rate is that it indicates degradation for a given time. Since, it is not always clear how fast the feed passes the rumen, it remains difficult to estimate the actual fraction that leaves the rumen undegraded.

PRACTICAL IMPLICATIONS OF FEEDING BYPASS NUTRIENTS

Theoretically speaking, there appears to be good reasons to feed bypass nutrients for increased efficiency of nutrient utilisation by ruminants, especially at higher production levels. In practice, however, the animals' response is quite variable. In the case of lactating ruminants, the response depends on several factors, such as:

- physiological status;
- stage of lactation;
- level of production;
- body condition score;
- availability of other nutrients.

Table 1. Undegradable dietary problem (UDP) in feedstuffs (g/100 g CP).

Feedstuffs of high UDP (60-100% of CP)		Feedstuffs of medium UDP (30-59% of CP)		Feedstuffs of low UDP (0-29% of CP)	
Bajra (pearl millet)	68	Brewers grain	53 (48-61)	Barley	18 (11-27)
Blood meal	79 (76-81)	Canola meal	31 (26-37)	Exp. Proc. Coconut cake	28
Sol. extr. coconut cake	76 (70-81)	Corn ground	41 (31-52)	Gingelly cake	24 (10-43)
Coffee seed cake	82	Cotton seed cake	49 (35-70)	Gram Chuni	18
Corn grain, cracked	81 (71-87)	Fish meal	59 (40-70)	Lupin meal	24
Feather meal	84 (83-86)	Groundnut cake	32 (6-38)	Niger cake	19 (16-23)
Fescue pasture	72	Horse gram	43	Oats, grain	18 (14-20)
Mahuva seed cake	75	Karanja cake	47	Rape seed cake	25 (10-46)
Meat meal	61 (53-76)	Linseed meal	35 (11-45)	Silk cotton seed cake	22
Rice bran	62	Meat and bone meal	53 (49-70)	Sunflower cake	15
Sorghum grain	75	Mesta seed cake	43	Wheat grain	25 (20-36)
Alfalfa, dehydrated	60 (57-69)	Rubber seed cake	31	Wheat bran	27 (23-33)
Subabul (Leucaena Leucocephaia)	68 (51-75)	Ricebran, deoiled	56	Alfalfa, fresh	24 (21-27)
		Safflower cake	39	Alfalfa, silage	23
		Soyabean meal	34 (10-50)	Barley silage	18
		Tobaco seed cake	57	Corn silage	24 (11-31)
		Toria seed cake	57		
		Alfalfa hay	33 (22-43)		
		Cornfodder, fresh	41		
		Cow pea fodder	32		
		Guineagrass	60		
		Oats fodder, fresh	49		
		Para grass, fresh	52		

Responses are likely to be more favourable in high yielding animals in the early part of lactation or fast growing animals. These are typical situations where the demand for nutrients is high and where the animal may be in negative protein and energy balance with lower body condition score.

Feeding bypass protein

Generally, straws are poor in protein and minerals, but rich in cellwalls which are degraded in the rumen only through microbial fermentation. Feeding of slowly degrading nutrients along with straw provides ammonia and to some extent minerals which might improve fibre digestion.?

The net result of feeding bypass protein could be the enhanced supply of amino acids from the intestines available for absorption and the overall improvement in the utilisation of dietary proteins. Some of the work done on bypass protein in India is given in Box 1.

The achieved positive responses in gain, reproduction and milk yield to feeding bypass nutrients should be interpreted with caution. In many instances, much of the responses achieved could be explained to the supply of other nutrients (such as energy or critical minerals like P and S) rather than to the supply of bypass nutrients. This is more so when the basal diet is deficient or has limited supply of energy. Also, due to the slower release of nutrients in bypass feeds, the rumen function can be more stable.

Feeding bypass starch

Feeding of bypass starch can reduce excess production of lactic acid in rumen, which otherwise inhibits fibre digestion due to acidic pH condition in the rumen. Thus, starch which escapes rumen fermentation, is digested in the small intestines producing glucose, which after absorption is more efficiently used as energy source by the animals, compared to lactic/propionic acid absorbed from rumen.

Box 1. Some animal production responses to feeding of bypass nutrients.

Growth responses to the feeding of bypass proteins have been positive in some trials. At Karnal, feeding of formaldehyde treated GN cake and soybean cake gave significant increases (up to 100-150 g/d) in liveweight gain, while the combination of ammoniated straw and bypass protein produced the highest growth rate in calves. The feed conversion (kg feed/kg live weight gain) for growth was highest with untreated straw supplemented with bypass protein. Another positive aspect attributed to feeding of bypass protein, appears to be the increased reproductive efficiency in both male and female ruminants. Whether this is a secondary effect due to improved health of the animal, or whether it is directly due to bypass nutrients remains to be determined.

In a recent study in Karnal, maize gluten meal and cottonseed meal supplementation to provide 60% bypass protein gave significantly higher (1.5 kg/d) milk yield over the supplementation providing 50% bypass protein in lactating crossbred cows, yielding between 10-15 l of milk/d. Similarly, when all the nitrogen from GN cake in the concentrate was replaced by leucaena leaf meal, lactating goats yielded more milk than control.

Feeding bypass fats

Feeding of protected fats, mostly as calcium salts of fatty acids can increase milk yields and also the efficiency of energy utilisation in high yielding animals that receive diets of too low energy content. Although in many parts of India, the supply of energy feeds for ruminants is limited, normally it may not pose an acute problem because many cows are low yielders. However, it is difficult to meet the energy requirement of high yielding cows, especially in early lactation as the dry matter intake increases few weeks after the cows have attained peak yield. During 2 to 3 months, high yielding cows can be fed bypass fat. The minimum dietary fat level should be 3 percent in high yielding cows. However, in countries where animals are fed primarily on crop residues, feeding of bypass fat could help increasing milk production and growth. Inclusion of fats in the diet (more than 4-5%) generally causes disturbance in rumen fermentation, mainly through inhibition of fibre digestion. However, the inclusion of protected fats in ruminant diet can cause increase in the energy density of the diet without causing any reduction in fibre digestion in rumen.

In developing countries, where cost of fatty acids (fat) is very high, acid oils can be converted into calcium salts and fed which are otherwise toxic to the rumen microflora. However, under those situations where feeding fat is not cost prohibitive and is to be fed more than 5 percent in the diet, fat can be again fed in the form of calcium salts without affecting ruminal fermentation.

CONCLUSION

In general, feeding of bypass nutrients may prove beneficial for past growing calves and high yielding dairy animals as they have greater demand of nutrients. The animal response may be, however, quite variable due to other limiting factors (nutrients, health, management) affecting the utilisation of nutrients. The positive response to bypass protein feeding at lower levels of production may be partly attributed to the supply of energy through these diets. This is particularly so when supplements containing bypass nutrients are fed together with low quality fibrous feeds such as straws.

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3.5. SOME COMMON RECOMMENDATIONS IN ANIMAL PRODUCTION SYSTEMS RECONSIDERED

D.V. Rangnekar, J.B. Schiere and S.V.N. Rao

INTRODUCTION

This chapter discusses common beliefs, recommendations and assumptions about animal production that are held by either the scientific community or by farmers. Some of these may need a second consideration in the face of new information and changing farming systems. Therefore, the purpose is to encourage rethinking of traditional recommendations, taking into account the whole farming system approach, farmers' perceptions, indigenous knowledge and applicability of extension messages and management practices under different conditions. While mentioning farmers' perceptions, it needs to be emphasised that small farmers account for a large proportion of the farming population in India. They are therefore, a major target group and focus of most discussions of this paper. It is the intention of this chapter to provide food for thought, not so much to take one position or the other, nor to provide answers.

Handbook for Straw Feeding Systems
Kiran Singh and J.B. Schiere (eds.), 1995
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COMMON BELIEFS - SOME CASES

Traditional farmers' knowledge and scientific reasoning are both based on time tested experience. However, something that is true in one place or time, may be untrue in another condition. Particularly in rapidly changing and regionally variable systems, it is, therefore, useful to test and retest existing ideas. Some of them may reflect wisdom for other farming systems than prevalent in India. The following topics will be briefly discussed:

- green fodder feeding
- efficiency of high producers
- the need for early weaning
- balanced feeding
- oxalate poisoning
- "scientific requirements"
- technology and progress
- straw is poor quality feed
- the interest of the farmer

Green fodder feeding

The need to provide green fodder on a year round basis for maintaining crossbred cattle is a common recommendation. Green fodder requirements are often worked out and deficits projected. However, only a small fraction of farmers with crossbreds are able to provide green fodder more than a few months in a year and still their animals produce milk. Also, large farms as well as many smallholder dairy systems in many parts of the world produce milk by feeding hay or straw for a considerable part of the year. Still in India, many meetings or discussions are held to orient farmers with respect to green fodder production and its benefits. Demonstrations are arranged as if a new technology is being introduced, and sometimes it is stated that except for farmers from Haryana, Punjab or Western U.P. or a few pockets in other States, hardly anyone cultivates fodder.

The reality might be different in a few ways. In the first place, fodder has traditionally been produced in many farming systems or states besides Haryana, Punjab or Western U.P. and many farmers are well aware of the usefulness of green fodder. Authentic records are available from the British Period (early 19^{th} century) where colonial officers described indigenous husbandry practices based on cultivation of sorghum, pearlmillet and lucerne for the feeding of livestock. In the second place, even though nutritionally the fodder can be called good feed, many farmers cannot afford to spare land for production of green fodder. Particularly, the systems approach tell us that the introduction of one technique will affect the output of other parts of the farm. Therefore, it may not always be profitable to grow grass, even more so for low producers. In the third place, the production of a cow may be so high in terms of milk, that even with extremely good fodder, the nutrient requirements can only partly be covered with good green fodder. At such high levels of output, fodder like grass or straw is fed to provide fibre to maintain rumen function rather than to provide energy, protein or vitamins. The feeding practices in urban dairies are a case in point (#4.3.).

Efficiency of high producers

High producing, fast growing and regularly breeding animals are often believed to be most profitable and efficient. However, in the case of many small farmers this may not always be true. There is a need to critically analyze and understand aspects like quality and cost of feed, returns from milk and other products, availability of feed/fodder, labour, housing, veterinary care, etc. A well-known Indian saying goes as follows:

"Kuch paane ke liye, kuch khona hai"

It implies that in order to gain something one has to lose something. The cost to achieve high output of a single commodity may simply be too high, particularly for small farmers who have no access to other supporting agencies like veterinarians, reliable artificial insemination services or fertilizer inputs, marketing or management information. Money or other resources spent on cows can be often be used with more benefit on other farm activities, e.g. cropping, and benefits like dung, draught and saving accounts from low producers are often underestimated.

In the same vein, many reports state that indigenous animals are uneconomic and non-descript animals are often referred to as unproductive. It is necessary to rethink some of these aspects since for many farmers the animals are productive even if they produce only little milk. Many times milk is not even the (only) product for which cattle, buffaloes and goats are maintained. The concept of productive cow varies from farmer to farmer depending upon the objective of rearing the cow. In some parts of India, it is not uncommon to find the farmers using heifers and dry cows for draught purposes. In such situations these animals appear productive to the farmers, in spite of the low milk production, and thanks to the indirect effect on crop output.

Fortunately, there is a change in the approach of economists and animal production officers in the last few years. By using a farming systems approach they are forced to take most of these aspects into account, as is done customarily by many farmers. The importance of social aspects like prestige and economic aspects like labour, avoidance of use of cash, convenience etc. is now increasingly recognised. It alters the way one looks at unproductive cows. Products like ghee, male animals for draught, security, and dung also make a significant contribution to the economy.

The need for early weaning

One common management recommendation is to wean calves at an early age. Early weaning is considered to be a scientific way of calf rearing. But one wonders why suckling is marked as unscientific? If science is defined as a process of repeated observation and testing of ideas, would not farmers practice/knowledge imply at least some scientific methodology? Practically speaking, on many small farms, and even on some institutional farms, early weaning creates problems. Early weaning is beneficial when the price of milk is high and where the alternative calf rearing feeds are well available, a condition that does not apply everywhere. In this respect however it is necessary to stress that farmers' practice is not beyond "strange" concepts either (#2.3.). Unbelievable as it may seem, many farmers believe that colostrum feeding to new born calves is harmful. The effects like diarrhoea and worm infestation are ascribed to colostrum feeding, but it may not be due to colostrum per se. However, the fact remains that in spite of years of effort to promote colostrum feeding soon after calving, it is still not a commonly accepted practice. In some areas colostrum is fed to new born calves only after the placenta is shed and some farmers offer colostrum to rivers as a form of sacrifice. It is also common in some places for farmers to sell colostrum at a high price as it is used for preparation of sweets.

Balanced Feeding

Similarly, use of balanced concentrate mixtures is emphasised as if it were the most critical aspect of proper feeding. The reality is that balancing of the entire ration (#3.1.) is essential rather than harping on the use of balanced concentrate mixtures only. Also the prices of balanced feeds may be prohibitive and moreover the required mix differs between animals and production objectives. Balanced feeding makes little sense to dairy farmers that have neither the knowledge to compute the ration, nor the facility to feed the animals separately on the basis of their body weight and production requirements. Since the very concept of requirements depends on economics it is impossible to provide a nationally valid standard for balanced feeding (#3.1.).

Oxalate Poisoning

Excess oxalates may cause gastro-intestinal irritation, but the major effect is that of precipitation of blood calcium resulting in muscular weakness and paralysis. However, the stress on oxalate problems appears to be a little excessive. Oxalates are normally metabolised in the rumen and even the continued ingestion of oxalates in small quantities increases the ability to decompose the oxalate. In addition not all the oxalate ingested is absorbed, and oxalate "poisoning" occurs only when large quantities are suddenly ingested by the animals.

Scientific Requirements

Scientific requirements, or similar terms, are expressions used in many technical publications or textbooks, often based on experiences in other countries, times or farming systems. The feeding tables of NRC, ARC or

ICAR are in a sense no more scientific than data sets collected in the so called *ignorant* or illiterate minds of farmers with vast experience. Both contain fact and fiction. Also, scientific recommendations can appear to be correct, but they can at the same time be irrelevant for the particular farming system. The major points of difference where scientists and farmers might misunderstand each one are such as:

- **the evaluation criteria of feeds**. Scientists use measures such as TDN, degradability, ME and CP whereas farmers use indirect criteria like effects of the feed on butter fat content, intake of feed, skin appearance, dung texture etc. The scientists rely more on indirect measurements that may not mean anything to the farmers. Better translation of "scientific" measurements to field criteria might solve a large part of the disagreement between science of farmers and researchers (Table 1, in #3.3.);
- the **production objectives**. Whereas many scientists aim for high production of a single commodity, farmers look at other criteria or their combination, e.g. milk, draught and dung. Many scientists and policy makers aim at high biological output of a single product, whereas, most if not all farmers aim for economic output which may imply low milk yield (#2.2.).

Good interaction between farmers and scientists can pave the way for better understanding. It will even show that many criteria are the same, though expressed differently. Ultimately, there may be differences in objectives and criteria between farmers (men and women) of different farming systems, ie. to talk about farmers' versus scientists' perceptions is a serious oversimplification.

Technological progress

Technology is often seen as the solution to problems or as a way to progress. The expression "necessity is the mother of *invention*" shows however that application of a technology can be a response to a need, rather than a step on the way to progress. In most cases, the researchers work on a problem which they perceive as a farmers' need though the farmers may not really want it. And what is progress for one farmer, may be a loss for another farmer. For example, it could be that farmers starting to feed treated straw now have insufficient straw left to give it to the labourers. Agrochemicals can save on labour, but they rid other people from their jobs and landless animal keepers from weeds for their cows or goats.

Straw is poor quality feed

Straw is commonly believed to be poor quality feed, but is this true? For many farmers in low input systems straw is an extremely valuable feed in times of feed shortage. Even for farmers in high input systems, straw may have high value, e.g. in peri-urban dairy systems where straw is a valuable source of fibre to buffer rumen acidity, to provide structure for better digestion, or to prevent low butter fat content in the milk. In low input areas with seasonal droughts, the straw is valuable because it can be the only way to let animals survive. The value that the farmers attach to the straw also differs. Farmers in Haryana and Punjab perceive wheat straw to be superior to paddy straw, whereas farmers in Gujarat consider the reverse to be true.

The farmers' interest

Sometimes, everything is believed to be alright if "the scientist" listens to "the farmer", as if both scientists and farmers come only in one kind.

Nothing is less true, because some farmers are lazy, others are hardworking, some are cattle keepers and others only cultivate crops. Even husband and wife may disagree on priorities just as well as father and son (#2.1.). A single solution and problem for each one of the actors in development is therefore unlikely to be found. In fact, clashes of interest may occur. Lately, the contribution of women to agriculture and the existence of woman headed families became rightly recognised. Males are generally considered superior to females in terms of their prevailing labour wages/hiring charges, and some economists consider one male as equivalent to two women or four children. It is time that those standards be reconsidered.

CONCLUSION

This chapter uses a number of cases/exceptions to illustrate that standard concepts may need to be reconsidered, in the light of new developments as well as due to differences between farming systems. A number of these concepts and issues in ruminant nutrition and development of livestock systems are discussed. They may have been true at one point time or in a particular farming system, but if they are extrapolated to other systems they may do more harm than good. No definite answers on each of these can be given but the points are made to provoke thinking and further research. Improved interaction between farmers and scientists paves the way for improved communication/ collaboration.

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SECTION 4

CROP RESIDUES

FEEDING SYSTEMS

4.1. METHODS TO INCREASE INTAKE OF STRAWS

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INTRODUCTION

Straws are bulky, long, and often abrasive in nature. They are low in nitrogen and minerals and high in fibre, i.e. low in soluble nutrients (#3.3.). All these factors limit the rate and extent of digestion by the rumen microorganisms, and together with the resulting mix of increased retention time of digestion products in the rumen, they limit the intake of feed. A major concern in systems where plenty of straw is available, is how and wether the intake of digestible nutrients from straws can be increased. Improving intake from straws may not always be relevant, e.g. for village farmers who have limited access to straw, or in urban dairies where straw intake is kept low to feed as much supplement as possible (#4.3.). Improved intake of straw is relevant mainly where farmers have easy access to straw, limited access to concentrates or other supplements, and when they have low or medium productive animals.

This chapter discusses options to improve the straw intake, and reference is made to other chapters where the technologies are discussed in more detail.

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SUPPLEMENTATION FOR HIGHER STRAW INTAKE

Supplementation for increased straw intake is done via improved rumen function. The amount of supplement is small in this case, since high levels of supplementation decrease straw intake through substitution (#4.3.). Generally, the addition of small catalytic amounts of supplements increases the intake of poor quality roughages more than of good quality roughages. As such, the use of supplements like urea, oil cakes or green leaves should improve the intake of crop residues by providing a more favourable rumen environment. For example, feeding of straw sprayed with 2% urea, improves straw intake by about 10%, just enough for an animal to achieve maintenance. Groundnut cake fed at the rate of upto 20% of straw dry matter intake has been found to improve total or straw intake and diet digestibility. Also, young grass or legumes that supply nitrogen and minerals help to increase intake. However, to achieve this additive effect the level of forage supplement should be low, e.g. upto 2.0 kg of the fresh legume per 10 kg DM straw.

Molasses is used to improve the taste of the basal feed, or as a source of readily fermentable energy which may stimulate microbial fermentation in the presence of other nutrients like nitrogen and phosphorous. Straws can be sprayed with either molasses alone, or in combination with urea to improve their intake. Straw sprayed with 10% molasses and 2% urea, i.e. 10 kg molasses + 2 kg urea/100 kg straw, is found to improve intake. However, the field application of urea/molasses spraying is limited owing to the difficulty in handling of the mixture and due to toxicity in case of uncontrolled intake/application of the mixture to the straw. The additional problem of flies may be relevant to be mentioned, and finally, the price of molasses can be prohibitive.

Recently, the National Dairy Development Board has come up with a urea molasses block lick (UMBL); a solid, hard, compact and water soluble block that is easy to handle and transport. It provides rumen degradable nitrogen and essential minerals for optimum rumen fermentation. Like all other supplementation approaches that aim at improved intake of straw, the method may be particularly useful in conditions with plenty straw, medium to low animal production and limited access to other supplements.

Since straws are low in minerals and also some of the minerals are present in insoluble form, the deficiency of minerals may negatively affect the digestion of cell wall material in the rumen. Particular reference could be made to sulphur and phosphorus supplementation that can increase fibre digestion. A common ratio of 15:3:1 is N:P:S is generally recommended (#4.3.2.). Though there is a belief that common salt enhances intake as it adds to the taste or water consumption, there is no evidence that this is always the case. Some studies have shown a positive effect of salt on the intake, whereas other work has shown marginal or no increases on intake and digestibility of straw. At this stage it is difficult to make any generalized statement, since also the quantity and quality of additional feeds will affect the results.

TREATMENTS

Chopping is a common practice in some parts of India (e.g. Haryana, West Bengal) and other parts of the world. The straws are chopped either by using knives (sickle), hand operated/motor driven or mechanical chaff cutters. Feeding of chopped straw avoids wastage and prevents animals from selecting particles of higher quality. Reduced wastage is useful where feed is scarce and where animals have to be kept through the lean season at limited amount of feed. Chopping may be useful in instances where straw is used as fibrous mixture for rations based on very succulent feeds, e.g. berseem to avoid bloat. it may also be done to avoid acidity in the rumen, a problem that is usually encountered after feeding large amounts of concentrates (#4.3.). Grinding, i.e. resulting in smaller size particles increases the surface area, i.e. the accessibility of straw to the rumen microorganisms. It can increase the rate of digestion and removal of material from the rumen, probably increasing intake, but sometimes at the expense of digestibility (#4.6.2.).

Soaking, like chopping is said to improve the voluntary intake of straw in some cases, but not always. The abrasive nature of straw often leads to injury of the muzzle region and tongue causing low intake, while soaking softens and makes straw more pliable. Soaking is also reported to reduce the oxalate content of straw. Negative effects of soaking on straw intake include loss of readily soluble materials in the feed. (#4.6.2.).

Chemical treatment of straws increases digestibility and intake through weakening of some cell walls. Several chemicals, or even treatment with steam have been used but, treatment with strong alkali has been found to give the best technical results (#4.6.). Field application of this method is limited however, due to the combination of high cost, complicated handling of chemicals and treatment procedures. However, urea-ammonia treatment has been accepted at the field level to some extent. It generally increases the intake and digestion depending on straw type, i.e. if an animal of 100 kg eats 1.5 kg of DM of untreated straw, it can eat approximately 1.7-2.00 kg of DM of treated straw. The degree of response to treatment of straws depends on the initial quality of the straw, as straws of low initial nutritive value generally respond better than straws with higher initial quality (#4.6.).

IMPROVING INTAKE THROUGH FEED AND ANIMAL MANAGEMENT

Apart from treatment procedures, there are other management practices which could improve intake of crop residues. Formal research on these aspects is scarce and definite conclusions cannot be drawn, even though farmers may use them in practice (#2.3.). Besides suggesting management methods that increase intake, we should also be alert on methods that negatively affect intake, like leaving mouldy or foulsmelling refusals in the manger, lack of drinking water or excessive exposure to heat (#4.2.).

A better understanding as to what controls the start and termination of feeding and the rate of eating can help suggest management practices that may increase the intake. Ruminants eat between five and twenty meals during a 24 hour period. Frequency and the size of the meals is less during the night. Dairy cows need access to feed for at least 12 hours to maximize forage intake. However, free access to concentrates and cakes leads to changes in the rumen environment, which can decrease fibre (straw) digestibility. Therefore, regular feeding in small amounts at frequent intervals should essentially help to provide a more stable rumen environment, i.e better roughage digestibility.

Animals offered straw in excess of their voluntary consumption will select the more nutritious parts of the plant. They thus can increase their intake of digestible nutrients, provided there is enough feed to allow selective consumption. Stemmy refusals in the manger do not imply that the animal has ingested sufficient nutrients! Nor will the animal ingest sufficient nutrients when it is forced to eat the low quality stems after chopping. The degree of selection depends both on animal and plant species and selection is less possible with chopped straw, and impossible with homogenous feeds. (#4.4.)

Shaking of feeds can be done to mix the feeds properly so that good leafy material lying below is available to the animal. Animals may also "think" that fresh feed is being offered every time the feed is shaken. Though shaking of feed may have a positive effect on straw intake, the extent of improvement is not very clear.

Animals fed in groups tend to eat more due to competition as compared to individual feeding. Individual feeding allows to adjust according to requirements, which is important for economic feeding of high-yielding cows. Young and weak animals may consume less when group fed as they will be less able to compete with larger animals. Generally group feeding tends to accentuate the difference between animals.

Provision of drinking water is essential for animal health, but it also affects intake. The extent to which animals can tolerate dehydration and efficiency with which they can regulate water imbalances varies between species. Depriving water to lactating cows causes reductions in milk yield within the first 24 hours. The reduction could be partly due to the associated reduction in feed intake, since cows with restricted access to water can show a decrease in dry matter intake of around 25%. Frequency of providing drinking water is also important as the animals receiving water once a day or once in two days in a hot dry climate showed depressed feed intake relative to animals receiving water at lease twice a day. During high environmental temperatures (greater than 35°C) the water provided should be preferably cools as cattle may not drink warm water. Obviously, the task of carrying water or leading animals to a drinking place can be a burden often for children and women in arid regions. Precautions need to be taken to keep the animals cool during hot, humid conditions, for example by keeping them under shade so as to minimize the heat stress,thus improving or maintaining their feed intake (#4.2.).

Proper storage of feed helps to avoid spoilage and occurrence of mycotoxins. Particularly feeds with high moisture content, or stored feeds in damp places can be affected by fungi which can decrease intake. Straws and hays are to be stored only after they are completely dried (less than 10-15% moisture). Allowing the feed to dry in the open field or under a roof can be required before storing. Rain or moisture during daytime or harvest of straws can also cause fungal growth or loss of nutrients due to leaching prior to storage. To minimize spoilage, straws should be stored in well ventilated sheds, or in well stacked open heaps. Farmers all over India and Asia have developed stacking methods that do not depend on use of polythene or roofs.

Straw wastage is often seen while feeding as the animals tend to draw the material out of the feed mangers onto the ground where it is spoiled by urine and dung. Sometimes even, no attempt is made to provide something that looks like a manger.

Crossbred animals are relatively more prone to parasitic infestation compared to the native breeds. Internal parasites (endoparasites) decreases the appetite of the animals affecting the overall performance. Animals infested with internal parasites look thrifty, have a rough coat and a loss of appetite. By improved hygiene and periodical deworming this problem can be controlled. It is advisable to deworm during the onset and after the end of monsoon as this is the most vulnerable period.

CONCLUSION

A number of options to increase intake are available, and they can be roughly based on supplementation, treatments and feeding management. The relevance of each of these approaches differs per farming system. The main effect of chopping and soaking seems to be that less feed is wasted rather than that more feed ingested or digested per animal per day (relevant in straw/feed scarce areas). Urea ammonia treatment improves straw intake by

10-15%, mainly relevant for medium producing cows in areas with plenty of straw and other feeds are relatively expensive. Overall it can be said that improved intake of straws is relevant mainly for farmers with animals of low to medium production, having ready access to straw and less access to concentrate supplements.

ACKNOWLEDGEMENT

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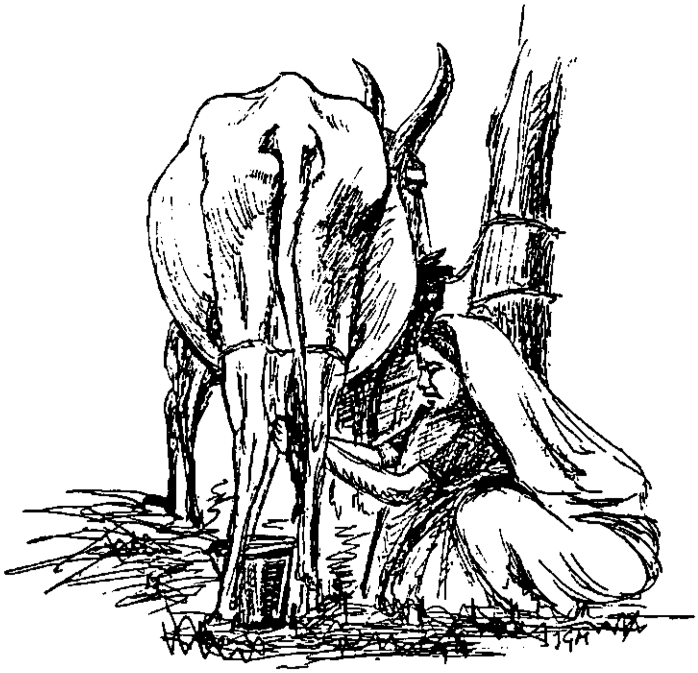

Milking. Gujarat Joke Muylwyk '93

4.2. WATER NEEDS OF CATTLE

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INTRODUCTION

Water is an essential component in animal feed, but it is seldom discussed when nutrient requirements are considered. Water also plays a role in the management of the animals. This chapter explains the occurrence of water in feeds, its functions in the animal body, and it briefly discusses aspects of other use of water on farm. It also elaborates problems associated with water shortage and water requirements in relation to farmers perceptions on need and difficulties encountered to provide adequate water.

WATER IN ANIMALS AND PLANTS

The principal nutrients of feedstuffs are water, organic and inorganic matter. As the animal uses water for all its vital needs, it may be appropriate to term water as an essential nutrient, just like protein, energy and minerals. In fact, animals can better tolerate lack of food than lack of water.

The animal body is composed of two-thirds water, the proportion of water being higher in younger animals (8-10 months, 70-75%) and gradually

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reduces as the animal grows older (18-20 months, 40-45%). As animals mature, the proportion of protein in the carcass remains almost constant but, the fat content varies. As the fat content of the body increases, the water content decreases. Fat animals may contain less than 50% water, whereas thin animals may contain 60-70% water. The water requirement of the animals could be met by:

- water consumed voluntarily,
- water present in feeds/fodders,
- water formed within the body due to metabolic oxidation (metabolic water)

The water is excreted or lost from the animal body through saliva, urine, faeces, milk and evaporation from the skin or respiration. The loss of water is influenced by the composition of diet, water intake and the physiological status of the animal. The latter depends on the environmental temperature and the stress on the animal.

Water in the animal serves:

- as a medium to transport nutrients and minerals;
- as a carrier for excreting the waste products;
- in maintaining body temperature;
- in maintaining the acid-base balance;
- as a medium for digestion and metabolism;
- as a major component of milk;
- as a lubricant to prevent friction in joints;
- in diluting the toxic associative factors of feed;

The water content in plants/feeds can differ considerably. It can be as high as 90% in feeds like water hyacinth or very succulent grasses, 70-80% in green fodders and between 5-15% in dry feeds like straws and concentrates. The water content of plants decreases with stage of maturity. Water in plants serves to transport nutrients to and from leaves to roots, to maintain the rigidity of the plant and as a medium for the various biochemical reactions.

WATER REQUIREMENTS

As is the case with other nutrients, the requirement for water depends on factors, like:

- animal species,
- environmental conditions,
- type of food eaten, i.e. amount of dry matter ingested
- physiological state of the animals (maintenance, growth, lactation, work).

Young calves receiving milk diets consume greater amounts of water in relation to the dry matter of their diet, than older cattle fed on dry feeds such as straws. Lactating animals require the greatest amount of water in proportion to their live weight as water constitutes 85 to 90% of the milk they yield. A cow yielding 12 litres per day secretes over 10.5 litres of water in the milk, and for every litre of milk produced about 3 litres of water is said to be required, apart from what the animal needs for its body function (Table 1). Working bullocks require more water as compared to the non working bullocks as they loose much water through respiration due to work.

Table 1. Optimum water intake depending on ambient temperatures for dairy cows in warm climates

Milk Yield (kg)	Ambient temperature 11-20°C		>20°C	
	Body weight (kg)			
	350	600	350	600
0	46	63	56	77
10	58	86	70	105
20	69	98	84	119
30	81	109	98	133
40	98	120	119	147

Water intake = liquid + food moisture kg/day
Source: Oliver,1987 (cited by Matthewman, 1994)

The extent to which animals can tolerate dehydration and their efficiency of regulating water needs, differ widely between species. For example, cattle have limited ability in this respect, compared to camels, but exotic breeds of cattle have greater difficulty to cope with water shortage than as most native breeds.

The type of feed also influences water intake. Grazing on low quality pastures results in reduced water intake. As the dry matter intake of large cattle is greater than that of smaller breeds under the same environmental and physiological conditions, also the volume of water consumed increases with increasing body size. Animals fed on straws treated with sodium hydroxide will increase their water intake as the sodium needs to be excreted in the urine. A similar situation arises if too much salt is offered or mixed in animal feeds. Cattle drink more water on a high-protein than on a low-protein diet, since the nitrogenous end products need a greater urine volume for excretion. Diets with high levels of indigestible fibre (straws, matured grass) result in increased loss of water in faeces and animals fed such diets have an increased water intake.

The water intake increases with the ambient temperature. An animal kept under cool conditions (below 20°C) usually need 4-5 litres of water for every kg of dry matter eaten. But once the temperature rises above 30°C, the amount of water needed increases to 10-12 litres per kg dry food. Cows consume less water under humid than under arid/dry conditions. Water loss varies with the temperature. At 20°C more water is lost through faeces and urine and at temperatures above 30°C the loss is more through body surface followed by urine and respiratory tract.

Frequency of providing water is also important. Animals having free access to water drink more and yield more milk than those offered water only once a day. Normally, lactating cows drink 2-5 times daily and providing water 3 times a day would be quite sufficient. Frequency of watering can also affect milk composition. Animals deprived of water overnight, when offered water in the morning drank copiously but, seldom drank again during the day. This increased intake of water in the morning caused increased water content in the evening milk. Cattle deprived of water showed marked decrease in their feed intake by fourth day and lost weight equivalent to 16 per cent of their live weight. Water deprivation in lactating cows causes severe reduction in milk yield after the first 24 hours, probably also due to an associated reduction in feed intake (#3.2.): (non-)lactating cattle and sheep show reduced feed intake when deprived of water. The faeces becomes dry and deprivation of water can lead to loss of weight in growing calves.

Animals receiving drinking water once a day or once in two days in a hot dry climate show depressed feed intake relative to animals receiving water at least twice in a day. Animals should be prevented from drinking water from lakes/ponds that contain high algal growth because they are sometimes poisoned when they drink such water.

Apart from meeting the water requirement through feeds, and voluntary consumption, the water formed within the body due to metabolic processes is another important source of water for animals. For example, one kilo of carbohydrate when metabolised in the body produces half of its quantity (500 ml) as water. Similarly 1 kilo of fat gives about 1000 ml of water and 1 kilo of protein about 400 ml as water.

Providing water

There is no doubt that animals should have a free access to clean drinking water, but in areas with scarcity of water, the water has to be used judiciously and priorities have to be set. For example, lactating and pregnant animals should be given priority over young animals and bullocks; crossbred animals should be given priority over local breeds, and sick animals should be given priority over healthy animals.

Water needs other than for drinking

Apart from drinking purposes, water is required for activities like bathing of animals and cleaning of sheds. Many animals are sprinkled with water and their udders washed before milking. This not only helps in cooling the animal body but, also to maintain hygiene. Water/swamp buffaloes often require water ponds/tanks for wallowing, and many farmers are reluctant to maintain buffaloes where they had no tanks or ponds in their villages. The water needs of animals may therefore be much more than normally estimated. Like with many other farm activities, it is often the women and children who have to heavy work like the carrying of water. Before suggesting changes in management, their ideas should be taken into account.

CONCLUSION

The water intake of animals are partly supplied through feed and partly through water consumed voluntarily. The physiological state of the animals influences the water intake. Variation exists between animals and factors such as nature of the feed and environmental temperature can affect water needs. There is no clear advantage in restricting water intake (other than in places where water is scarce. As the advantages of providing drinking water are many, animals should be provided with clean drinking water at least twice a day, according to the conditions and availability of water.

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4.3. SUPPLEMENTATION OF STRAWS

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INTRODUCTION

Feeding of only straws does not generally provide sufficient nutrients to maintain body weight of ruminant animals, though coarse straws (e.g. millets, maize and sorghum) give better results than slender straws (e.g. rice, wheat, barley). Feeding of straws for a short period of time may be alright for survival or for dung production, but to achieve any level of milk, meat or draft production over long periods, straw must be either supplemented with better feeds and/or they must be treated (#4.1.). Aspects of desired type, level and strategy of supplementation and their application in different farming systems are discussed in this chapter.

TYPES OF SUPPLEMENTS

In principle, supplementation can be done with either concentrates, roughages or both. Concentrates are those types of feeds in which a higher concentration of digestible nutrients or protein are available. They comprise feeds like brans, oil seed cakes or grains.

Compounded feeds are prepared by mixing concentrate ingredients in desired

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proportions to achieve a particular level of protein, energy or minerals and even vitamins in the mixture. The proper mix in compound feeds depends on type and level of animal production and on the quality, quantity and cost of basal feed related with the supplement. Roughages usually have high cell wall contents (in the past called crude fibre) as compared to concentrates (#3.3.). Some commonly used concentrates and roughages are given in Table 1, along with their crude protein (CP) and energy (TDN) content.

Table 1. Commonly used concentrates and roughages with their average composition on dry matter basis

Concentrates			**Roughages**		
Name	**CP**	**TDN**	**Name**	**CP**	**TDN**
Protein supplements			**Legumes**		
Groundnut cake	45	70	Lucerne	20	55
Cottonseed cake	28	70	Berseem	22	55
Mustard cake	35	70	Cowpea	18	55
Sunflower cake	30	65			
			Non-legume		
Energy supplements			Maize	6	60
Maize	8	80	Sorghum	6	53
Sorghum	8	70	Oats	5	50
Milling byproducts			**Mature grasses and straws**		
Wheat bran	14	65	straws	4	45
Rice bran	12	60	stovers	5	50
Gram husk	0	50			

TYPES OF SUPPLEMENTATION

Several types of supplementation can be distinguished, each one serves a particular purpose and fits the need of a particular farming system.

Catalytic Supplementation

Supplementation of straws with deficient nutrients like Nitrogen, Sulphur and Phosphorus is called catalytic supplementation if it is done to achieve improved rumen function, resulting in increased intake and digestibility of straws. The supplement is said to have a positive associative effect on digestion. Essentially this approach aims to improve straw utilization by using a minimum quantity of supplement. Obviously, this is attractive where straw is cheap and supplement expensive, and where only near maintenance growth/production is aimed at. The most common example is the use of lickblocks, but feeding of small amounts of kitchen waste or green leaves may achieve the same objective.

Strategic supplementation

Another approach to make efficient use of limited stock of supplements is to use the supplements only for the most important or physiologically sensitive animals. This is called strategic supplementation. It is applied where better feeds are given to reproductive and young valuable animals, while allowing adult or less valuable animals to lose weight. A typical, but somewhat disguised form of strategic supplementation is the application of selective consumption, where the better animals are allowed to select the better feed parts, and where the feed refusals are fed to less productive or idling animals (#4.4.).

Substitutional supplementation

When higher levels of milk, meat or draught output per individual animal are desired and economically attractive, more supplements are required than for catalytic supplementation only. High level of supplementation will, however, decrease the intake of straw, since straw is substituted with supplements, the so-called substitution effect. Substitution rates of more than half a kilo of straw per kilo of concentrate supplement are not uncommon. Generally, the substitution rate in good forages or treated straw is higher than in poor quality forages or untreated straw (see Fig. 1). However, good roughages require less supplement to reach the same level of production, so in practice these two effects will cancel each other. The substitution effect means that the expected and theoretical production potential of a supplement cannot be realized fully, as shown in the following example:

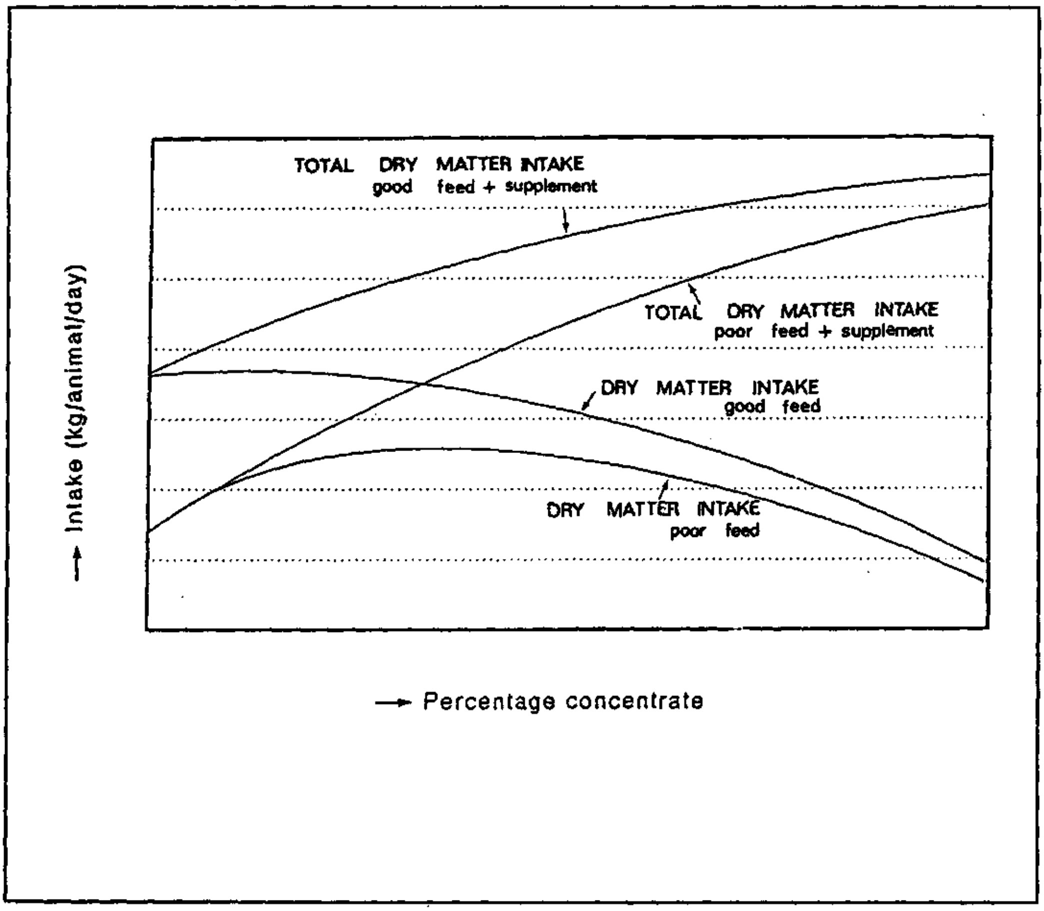
When one kilo of a concentrate mixture with 0.64 kg TDN is fed, a theoretical response of two litres of milk is expected since a litre of milk requires approximately 0.320 kg of TDN. However, if the concentrate mixture replaces half a kilo of basal roughage, the net effect of one kilo concentrate is only 0.44 kg TDN, i.e. 1.45 litres of milk (0.64 kg TDN of concentrate mixture minus 0.20kg TDN of replaced basal roughage).

Nevertheless, the substitution effect is acceptable if high levels of production are economically attractive. It is also acceptable if the cost ratio of concentrate/straw is low, i.e. when relatively expensive straw is replaced with not so expensive concentrate.

SUPPLEMENTATION STRATEGIES

Animals at low levels of production do not generally require much supplementation to meet their requirement. They obtain sufficient nutrients by grazing on roadsides or fallow lands and by consuming crop residues and kitchen offal at home.

Figure 1 Dry matter intake (total and straw) with increasing percentage of supplement in the ration



Note: The substitution rate tends to be higher for better feeds with higher initial intake levels

During scarcity/lean periods they lose some body weight which they can regain as compensatory growth during the more favourable season. If farmers want their animals to maintain body weight, it is appropriate to recommend catalytic supplementation with some nitrogen, phosphorus, sulphur and fermentable energy in order to improve rumen function. This can be achieved by feeding non-protein nitrogen like urea, small amounts of cake, brans or green fodder (#4.3.1.).

In order to achieve higher levels of milk production, growth, reproduction and work, supplementation with concentrates, green forages or compound feeds is required. Supplementing straws with concentrate feed ingredients (e.g. brans, cakes) is commonly done by farmers to increase production on straw based diets. Alternatives available are compounded feeds to be purchased from feed companies or the use of other locally available byproducts (e.g. brans and cakes). The level and type of supplementation depend on the availability of these supplements, their cost and the desired level of production.

Box 1. The economics of supplementation

If one kilo of concentrate yields two kilos of additional milk (an optimistic estimate), then it will be quite profitable to feed concentrate at Rs.3/kg when milk is sold at Rs.8/litre, e.g. in urban dairies. In situations however, where concentrate is sold at higher price, or where there is no market for the milk, the farmer sees no advantage in feeding concentrate. This issue is further complicated by the fact that farmers have to balance the use of scarce cash for milk production against its use for school books or medicine for the family, or for example, for the use of fertilizer or pesticides on crops.
It is often difficult, and sometimes unwise to convince a farmer that if s/he feeds well now, the future production will be increased sufficiently to cover the initial cost. Even if the farmer understands, s/he may decide to have other priorities.

For supplementation to be economically attractive, the value of the increased output has to be greater than the cost of the supplement (see Box 1). The choice for either strategy depends on the condition prevailing in the farming system under consideration as indicated in Table 2.

Table 2. A screening of supplementation strategies for three hypothetical and simplified farming systems

	Urban dairies	Village conditions	Survival feeding; plenty roughage of low quality	Survival feeding; no roughage available
System characteristics				
Cost ratio supplement/roughage	low	high	very high	N.A.
Price ratio milk/supplement	high	low	very low	very low
System objectives	milk	milk, dung, draught, etc.	survival	survival
Supplementation Strategies:				
Catalytic	not relevant	not so relevant	very relevant	not relevant
Strategic	not relevant	sometimes relevant	relevant	N.A.
Substitutional	very common	not so common	irrelevant	N.A.

Note: This screening is an approximation, to guide and stimulate discussion.

SPECIAL ASPECTS OF SUPPLEMENTATION

Apart from strategies and types of supplements, one can also consider other aspects associated with the discussion and need of supplementation. In a rather random sequence they will be mentioned here briefly.

Feeding of slowly degradable nutrients

Recent research suggests that inclusion of rumen undegradable (bypass) protein in the ration of animals fed straw as a basal diet can result in increased production. Feeding of slowly degradable proteins is likely to have a greater effect on cows with a higher production. Common feeds that are high in slowly degradable (bypass) protein include cottonseed cake, solvent extracted coconut cake, maize gluten and subabul leaf meal (*Leucaena leucocephola*). Not only proteins, but also other nutrients like fats or starch can be fed in a slowly degradable form (#3.4.).

Acidosis

Feeding large amounts of concentrates to high yielding cows, e.g. over 70% of the ration in urban dairies, can lead to acidosis and impaired rumen fermentation, depressed intake and butterfat content of the milk. In those cases, it is necessary to provide a minimum quantity of fibre, e.g. approximately 30% NDF in the total DM provided to the animal. For example:

If a ration consists of a concentrate mixture of about 14% NDF, the minimum amount of roughage DM that is to be provided is:

- *25% if the roughage contains 70% NDF, e.g. finger millet straw;*
- *30% if the roughage contains 60% NDF, e.g. maize and sorghum stover;*
- *39% if the roughage contains 50% NDF, e.g. lucerne, berseem and cow pea.*

Addition of sodium carbonate in the concentrate mixture helps in reducing the acidosis, but it needs to be considered as a somewhat extreme approach, i.e. it is a cure rather than prevention.

Bloat

Feeding of large amounts of succulent leguminous fodders like lucerne and berseem leads to foam formation in the rumen resulting in bloat, also called tympany. This can be prevented by mixing some 10% of fibrous feeds like straws with leguminous fodder. Otherwise, it can also be useful to wilt the succulent feed and to provide for regular feeding to avoid sudden ingestion of large quantities.

Depression in milk fat content

Feeding of large amounts of concentrates can lead to depressed fat content in milk. Addition of specific supplements like cottonseed will enhance the milk fat content, and in some commercial dairy farms oil is added in the ration to achieve higher fat content. However, a fat content of more than 6% in the ration is likely to depress fibre digestibility (#3.4.). Keeping sufficient fibre in the feed is often the most economical and practical method to maintain the fat level in the milk, apart from including other animals in the herd, e.g. buffaloes or Jersey crosses.

Mineral and Vitamin "A" Deficiency

Mineral deficiency on straw based diets can be prevented by mixing a mineral mixture or a specific mineral with the supplement (#4.3.2.)

If the animals are maintained on straw diet for a long period of time, they are likely to suffer from vitamin "A" deficiency. Feeding small amounts of green fodder or tree leaves can prevent such a condition. If green fodder or tree leaves are not available, then synthetic vitamin A (oral or injections) can be provided once in a month.

Other socio-economic issues

Many reasons can be quoted for not supplementing animals according to what scientist or extensionists perceive to be the "requirements". If the women has to buy the concentrate and if she does not share the return on the milk then she might be reluctant to use her scarce resources for animal feed. Why feed the animal if it is already producing so well? Some womens' perceptions on aspects of supplementation of roughage based diets are given in Box 2.

Box 2. Supplementation of roughage based diets, some perceptions of women

Cattle cannot live and produce by consuming just straw. Some supplement is needed if they are expected to produce milk, offspring or to pull the plough. Both treated and untreated straw can be supplemented, with different effects for the production and economics of animal keeping. Supplements or concentrates that can be used include wheat flour, oil cakes, compounded feed, cultivated green forages, collected green fodder, hay and roughage. In large parts of India, women daily spend much time to collect green grass from the roadside, or weeds from the cropland. The use of supplements, other than what women collect, will decrease the work load of women. The availability of cheap concentrates, agricultural or industrial residues is very important for the poorer women who have a shortage of straw. In Haryana, the periods from mid-October to mid-December, and also during May and June, are lean periods in the sense that no green fodder is available for cattle. Then supplementation is a must, unless farmers prefer the animals to lose weight and to diminish the production. When cows are an important source of income for a farming family, and when the products are sold at the market, the farmer will make a different choice than when the cows are kept for subsistence mainly. Women farmers prepare various dairy products, and they know how to influence the quality of the milk in relation to the products by mixing the feed. A change in feeding patterns often results in lower milk production during the first days. The influence of different supplements and the basal ration on the smell of the milk or for example on dung quality, is very important for women who make dairy products like cheese and ghee, or who prepare dung cakes for fuel.

(Source: Adapted from J.G. Muylwijk, BIOCON consultancy report, Sept. 1994)

CONCLUSION

The decision about strategies, need and method of supplementation in straw rations relates to the feed resources available and the farmer's objective. For supplementation to be economically beneficial, the increased value of the output has to be greater than the cost of the supplement. There are even cases where it makes sense to let the animal temporarily lose weight, like in seasonal drought where purchase of feeds is not economic. Animals can regain weight through compensatory growth when feed again becomes available locally. The economic value of the animal produce, (e.g. whether a market is available) relative to the cost of feed determines the choice of supplementation strategy.

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4.3.1. FEEDING OF NON-PROTEIN NITROGEN AND CROP RESIDUES

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INTRODUCTION

Animals and humans need protein and energy, besides vitamins, minerals, water and other nutrients. Particularly protein is relatively scarce and generally quite expensive. As a gift of nature, ruminants have the capacity to convert nitrogen from non-protein sources (NPN) into protein for the animal, and thus indirectly, for humans. This chapter explains the backgrounds, health aspects and feeding systems that are relevant when feeding of NPN is considered.

PRINCIPLES AND BACKGROUND

By possessing a rumen as part of the digestive tract, i.e. a large fermentation vessel full of microorganisms, the ruminants are capable of handling non-protein nitrogen (NPN) and fibrous crop residues. NPN compounds break down to ammonia, that together with the "sugars" from the fibrous material is converted into microbial protein. These ammonia compounds - even when not added to the feed - also occur naturally in the animal as a

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byproduct of the protein digestion and metabolism. They are excreted from the rumen into the blood, to be detoxified in the liver, recycled to the rumen or excreted via the urine. Since urea and ammonia are compounds that occur in the rumen as a natural byproduct of protein digestion, and provided no excessive amounts are given, they are quite safe for animal health.

TYPE OF NPN COMPOUNDS

The NPN sources that can be used in ruminant feeding include organic and inorganic ammonium salts, dicyanodiamide, biuret, urea and ammoniated feeds. The nitrogen content in these chemical compounds is presented in Table 1. The organic and inorganic ammonium compounds are well utilized by ruminants provided fermentable carbohydrates are available in the rumen combined with sufficient P and S, generally in a ratio of N:P:S = 15:3:1. Ammoniated fibrous crop residues and industrial byproducts not only become a source of nitrogen, but the chemical effect of ammonia also improves the digestibility of fibre complex in the plant cell wall. A fixed minimum value of ammonia concentration for optimal rumen function can not be given since it depends on the body condition of the animals and on the type of feed. However, on pure straw rations, the digestibility of feed is likely to improve at least slightly when some ammonia source is added.

Of all NPN sources, dicyanodiamide contains most nitrogen, but its nitrogen is not well utilized. Biuret is slowly hydrolysed to ammonia in the rumen, but it does not appear to be superior to urea when fed to animals on high energy supplements. Biuret is also more costly than urea, not easily available and it requires at least some time for adaptation of the rumen. Urea is the most commonly used NPN compound in ruminant rations, either as a supplement or after urea ammonia treatment of the feed. Farmers should have no hesitation to use fertilizer grade urea since feed grade quality is not available in the country. The only advantage of feed grade urea is that it contains an anti lumping agent. Efforts have been made to achieve a slow release of ammonia from urea, either by combining urea with molasses or starch or by adding a urease enzyme inhibitor. Other NPN sources like poultry manure in animal feed are used in practice, and straw treated with urine is a potential NPN source.

Table 1. Nitrogen content in some NPN compounds

	Nitrogen (%)	Protein equivalent (%)
Urea	45	281
Biuret	35	219
Ammonium acetate	18	112
Ammonium bicarbamate	18	112
Ammonium carbamate	36	225
Ammonium lactate	13	81
Dicyanodiamide	66	412
Oilseed meals	5.8 to 8.0	36 to 50
Protein	16	100

UREA FEEDING

Urea can be added directly to the concentrate mixture to replace part of the protein supplement. The urea level should not exceed 3% of the given mixture/concentrate, and ISI even recommends to add urea in the concentrate at a level of 1%. Urea may either be added after grinding in a powder form or dissolved for example in molasses or water. In all cases, it should be evenly mixed in the concentrate because sudden ingestion of a large amount can be toxic, the reason to add the anti-lumping agent in feed grade urea.

Urea can also be used on straw/crop residues because the low nitrogen content in crop residues restricts intake as well as (rate of) digestion. Addition of 2% urea dissolved in water, with or without 10% molasses, 2% mineral mixture and 1% common salt over a batch of 85 kg straw enhances the crude protein content of the feed by about 5% and its intake by 5 to 8 units (#4.3.). This product could be fed as such or dried in the sun and stored for future use. It is important here to state that this addition of urea as a supplement, with or without molasses usually does not improve digestibility and intake as well as in the case of urea treatment (#4.6.).
When fodder crops like maize/sorghum/oats are ensiled at 35% DM, it can be useful to add 0.5% urea, evenly sprinkled over the material at the time of filling the silo pit. The added urea is hydrolysed to ammonia which penetrates the plant biomass, primarily acting to improve the crude protein, i.e., nitrogen level of the ensiled material. Addition of urea along with 0.5% common salt also facilitate to preserve the high moisture forages (#4.7.).

Since urea needs to be fed slowly, several ways are explored to ensure an even intake of urea. One technical solution is the addition of urea in urea-molasses-mineral block. The block is a compact brick, placed before the animal to lick. This helps to meet the nitrogen requirement of rumen microflora, resulting in the enhanced rumen activity and increased degradability of crop residues. In that sense, it is a form of catalytic supplementation (#4.3.).

Urea can also be fed along with liquid supplements, provided the animal is prevented from drinking the liquid. For example, a mixture of urea and liquid molasses can be prepared and placed before the animal for licking, in specially designed licking drums. In this mixture 2.5 parts of urea is dissolved in 2.5 parts of water with 2 parts mineral mixture, 1 part common salt and 92 parts molasses. The whole material is thoroughly mixed. Animals started on this feed should be given at least 15 days as adaptation period. Though molasses can be used well as a carrier of urea, the present day prices have increased so much that it has become too expensive to be used as feed.

UREA TREATMENT

Urea treatment of straw is actually a process of ammoniation of the wet biomass, affecting and loosening the chemical bonds in the lignocellulose complex of the fibre (#4.6.; #4.6.1.). The treatment process increases availability of energy from the fibres in the straw, apart from providing nitrogen for better rumen function and microbial protein synthesis.

Urea treatment of high moisture industrial byproducts, e.g., pulp obtained from fruit processing industry has also successfully been done. Apple-pomace, a waste from apple fruit industry when treated with 3% urea achieved a feeding value similar to maize grain. Other high moisture industrial by-products like maize bran or brewery's waste, ensiled with straw and urea improved feeding value of both the products.

SLOW RELEASE UREA PRODUCTS

The nitrogen source, the rate and the extent of its degradation in the rumen plays a major role in determining the efficiency of microbial protein synthesis. Efficient utilization of degraded nitrogen from any NPN or even true protein source requires that the energy released from dietary organic matter must be supplied at the rate which matches synthetic abilities of the rumen microorganisms. Urea hydrolysis occurs so fast in the rumen that the corresponding energy availability does not match to nitrogen release from urea. The result is that most ammonia leaves the rumen and the body via the urine. It can therefore be useful to develop methods for a slow release of nitrogen from urea, or to supply the urea at a steady rate. The latter approach is followed by using lickblocks, or by spraying urea on the straw.

Slow release of urea is attempted by making products that combine starch from different types of grains and urea, exposed to heat/extrusion. A starch controlled urea product was produced by passing mixture of ground grain or other starch source and urea through a cooker extruder under conditions causing starch to gelatinize. In another product called "*Starea*", a mixture of finely ground grain such as corn, sorghum, barley, and urea is treated in a cooker extruder under moisture, temperature and pressure that causes starch to gelatinize. This product was reported equal to soybean meal as a protein supplement for lactating cows, and similarly, urea and cassava meal were pressure cooked, dried and ground. When urea was treated with molasses in the ratio of 1:9 (w/w) at 110°C, the resulting product was called "*Uromol*". Rice bran mixed with "*Uromol*" can safely be used in place of groundnut cake in ruminant diets. Other slow release urea products prepared by extrusion cooking are obtained from deoiled salseed meal and urea (*'Salurea'*), and tapioca flour and urea (*'Tapurea'*). *'Salurea'* complexes have replaced up to 67% of groundnut cake nitrogen in the diets of growing steers and even replaced it to 100% in concentrate mixture of adult cattle. *'Tapurea'* was included at 10% level as a protein supplement in complete rations for growing lambs.

UREA/AMMONIA AND TOXICITY

Urea, when fed in sudden and large amounts, is toxic to the animal, resulting in death within an hour or so. Even though urea and ammonia compounds occur naturally in the animal body, an excessive amount cannot be detoxified quickly enough by the liver and the animal succumbs. This is the case when an animal consumes lumps of urea or improperly mixed concentrates with high urea concentrations. The same happens when the animal is allowed to drink water or molasses containing urea. Feeding of urea in a slow manner, e.g. sprayed on straw or feeding of straw after treatment or providing it in the form of urea molasses blocks that cannot be chewed is perfectly safe. Symptoms of urea toxicity together with the precautions to be taken when feeding urea or urea treated straw are given in Box 1a/b.

Ironically, and in spite of its toxicity at high levels, urea/ammonia treatment can successfully be used for the detoxification of certain antimetabolites (tannins, aflatoxin, mowrin) present in some feedstuffs.

The mechanism is mainly the elimination of the toxin by ammonium hydroxide, which acts as a weak alkali.

Box 1a. A note on the toxicity of urea

Urea is toxic to cattle if ingested in large quantities over a short period. This usually occurs due to accidental access to solutions of urea or feeding on it after insufficient mixing with concentrates. Urea toxicity from straw is highly unlikely because even distribution is assured by spraying and straw intake is necessarily slow. The picture is different for concentrates containing urea, and the addition of urea to concentrate cannot be readily recommended. Toxicity occurs when too much urea breaks down to ammonia at one point of time. The ammonia then passes into the bloodstream beyond the safe threshold, the liver cannot detoxify ammonia rapidly enough into urea, and the ammonia concentration in the blood rises steeply. It then affects the brain and causes death. Signs will develop within 20 to 30 minutes after feeding and the toxicity symptoms are:

- severe abdominal pain, muscle tremor, incoordination, weakness, bloating, violent struggling and bellowing;
- the animal walks with a 'proppy' gait. It goes down on its sternum (breast) and then later rolls over onto its side. The legs are extended in tetanic spasms;
- breathing is slow, deep, laboured, asthmatic (dyspnoea);
- frothing (foaming) at the mouth and display of tracheal/rales, excessive salivation;
- paralysis;
- the carcass is dark in colour;
- internal haemorrhaging occurs in the epicardium, endo- cardium, abomasum and small intestine;
- congestion in the liver, spleen and lungs, and
- rumen contents are dry.

Due to the acute course of the condition and the high mortality rate, strong emphasis should be placed on prevention rather than cure. Animals should never be allowed access to stocks of urea or solutions prepared for treating straw. The quantity of urea to be fed during a day should be distributed over a long period. If so, there is no chance of causing toxicity.

Box 1b. Quote from a "Handbook for Veterinary Surgeons" (Blood *et al.*, 1979)

"The course on the symptoms and treatment of urea poisoning is short and death occurs about 1-4 hours after ingestion. Mortality rate is high. There are no characteristics lesions at necropsy, but most cases show generalized congestion and haemorrhages, and pulmonary oedema. Clinical signs of toxicity appear in cattle when blood ammonia nitrogen concentrations reach 0.7-0.8 mg per 100 ml. In sheep, death may occur at levels of ammonia nitrogen of 0.033 mg/ml of blood. The ruminal contents are alkaline when tested with litmus paper (pH elevated from 6.9 to 7.9) and ruminal ammonia levels rise from 6 to 50 mg per 100 ml. The antidote for urea poisoning is vinegar. If there are reasons to suspect urea poisoning, dose the animal immediately with 2-3 litres of vinegar (concentration: household vinegar or a 5% v/v) solution of acetic acid (Schmidt and Van Vleck, 1974). Even four litres may be needed by a large dairy cow; for a sheep 0.5-1 litre. Treatment is unlikely to have any effect, especially when given after the onset of the tetany; oral antidotes may have no or very little effect. Introduce the vinegar with a bottle or rubber hose into the mouth of the animal. Call the veterinary surgeon (time may be too short!). Repeated dosings may be necessary as clinical signs tend to recur about 30 minutes after treatment. The only really effective treatment is prompt and efficient emptying of the rumen, either via a large bore tube or by rumenotomy".

The effect of tannins present in sorghum seeds and tree leaves can be reduced to large extent by ammonia treatment. In mahua seed cake, treatment with 1% ammonium hydroxide reduced the 'mowrin' content by about 50 percent. Urea and ammonia treatment also deactivates aflatoxin.

CONCLUSION

Urea is a naturally occurring chemical in the body and digestive system of a ruminant. It provides a cheap form of nitrogen, and with the help of rumen organisms the ruminant can convert the urea or other forms of NPN to protein. Urea can be toxic when fed in excessive amounts or at excessive rates, but under proper care it is a perfectly safe compound that can help to economize on feed cost. Several feeding systems are available, and most have direct relevance for straw feeding methods.

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4.3.2. MINERAL REQUIREMENTS AND STRAW FEEDING SYSTEMS

C.S. Prasad, S.P. Arora, T. Prasad, A. Chabra and M.N.M. Ibrahim

INTRODUCTION

Minerals are required in small quantities compared to the nutrients like nitrogen and energy. However, mineral deficiency can have a marked effect on productivity, particularly on reproductive performance and health. Straws and stovers contain certain minerals well below the animals' needs, but they contain an excess of minerals like Silica and in some regions Lead, Selenium and Fluorine, leading to either deficiency or toxicity in animals. Mineral imbalances depend on the type of straw (varieties) and on the area where the straw is grown. Mineral requirements are related to animal output, and therefore, the use of mineral supplements is particularly important for high producing animals. First we will give a classification of minerals, then we will discuss functions, requirements and toxicities. The final part discusses deficiencies and ways of mineral supplementation.

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CLASSIFICATION, FUNCTIONS AND REQUIREMENTS OF MINERALS

It is well established that certain mineral elements perform essential functions in the body, and they must therefore be supplied in the feed. Calcium, Phosphorus, Magnesium and Fluorine are constituents of bones and teeth and give strength to skeletal structures of the body. They are also constituents of soft tissues. Elements such as Calcium, Phosphorus, Magnesium, Iron, Manganese, Copper, Zinc and Selenium play important roles in enzyme systems. Sodium, Potassium and Chlorine function as soluble salts to maintain osmotic pressure, acid base balance and pH in the body fluids in addition to water metabolism. Iron, Copper and Cobalt form vitamin B^{12} through rumen microbes which is later necessary in the formation of Haemoglobin. Iodine is an essential element in a hormone released from the thyroid gland and it functions in many ways in soft tissues. Sulphur occurs in organic compounds, notably in sulphur containing particular amino acids.

REQUIREMENTS

While calculating mineral requirements, it is essential to see the types of feed ingredients that are used in the ration, along with the kind of straws and stovers fed. Feeding of low quality roughage generally results in increased faecal endogenous losses, for example, Ca and P, leading to increased maintenance requirements for these minerals. If the feed ingredients contain anti-metabolites like tannins, phytates, oxalates or silica beyond a particular limit, some minerals like P and Ca have to be supplemented to ensure adequate absorption. Also, the need to supplement may be greater in animals with parasitic infections due to increased mineral requirement. The mineral elements are classified as macro, micro and trace elements, depending on their content in animal tissues and on their biological functions (Table 1).

Table 1. Classification of Minerals

Class	Elements
Macro-Elements	Calcium (Ca), Chlorine (Cl), Potassium (K), Magnesium (Mg), Sodium (Na), Phosphorus (P), Sulphur (S)
Micro-Elements	Copper (Cu), Fluorine (F), Iodine (I), Iron (Fe), Manganese (Mn), Zinc (Zn)
Trace-Elelements	Lead (Pb), Molybdenum (Mo), Cobalt (Co), Chromium (Cr), Nickel (Ni), Selenium (Se), Vanadium (V)

The requirements of Calcium and Phosphorus in high producing dairy animals are higher than in low yielders owing to the high concentration of Calcium (0.13%) and Phosphorus (0.11%) in milk. The Ca:P ratio is important and a ratio of 2:1 to 6:1 seems to be optimum for cattle. The Ca and P requirement for maintenance of an adult cow weighing 40 kg and yielding 10 kg milk with 4 percent fat will be 46 and 36 g, respectively. Mineral requirements for growth, milk production and work for cattle are given in Tables 2a and 2b.

The mineral requirements can be expressed in amounts per day or per unit of product, or as a percentage of the dietary dry matter intake. The former is more accurate but the latter is simple and practical as long as there is no variation in feed intake. Since dry matter intake varies considerably in straws and stovers, the expression in absolute amounts may be more appropriate.

Table 2a. Requirements of Ca and P for maintenance, growth, milk production and work

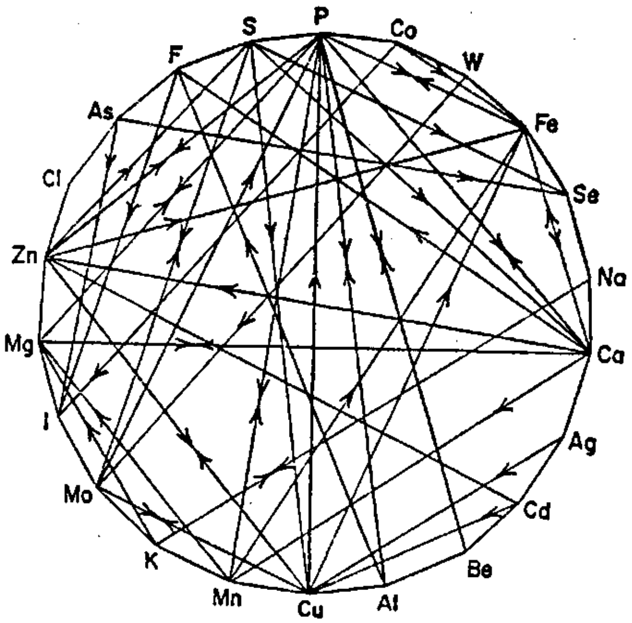
Description of animal	Calcium	Phosphorus
Pre-ruminant calves (% of diet)	0.8	0.5
Growing calves (% of diet)	0.8	0.5
Maintenance of adult animals (400 kg)	18	12
Adult cows (400 kg, 3000 kg milk)	18	14
Pregnant cows* (g/day)	19	19
Milk production (g/day/kg milk)	2.8	2.0
Working bullocks (g/day)	15	15

* In addition to what is provided for maintenance

Table 2b. Requirement of other minerals (mg per kg bodyweight)

Minerals	Young stock	Mature dairy animals
Cobalt	0.1	0.1
Copper	10	10
Iron	100	50
Magnesium	700	2000
Sulphur	2000	2000
Zinc	30	40
Sodium	2500	4600
Potassium	6000-8000	6000-8000

Figure 1. Interrelation of mineral matter in animal metabolism. The arrows indicate synergism and antagonism between elements. (Source: Hafer and Dyer, 1969 (quoted by Banerjee, 1982))



MINERAL INTERACTION

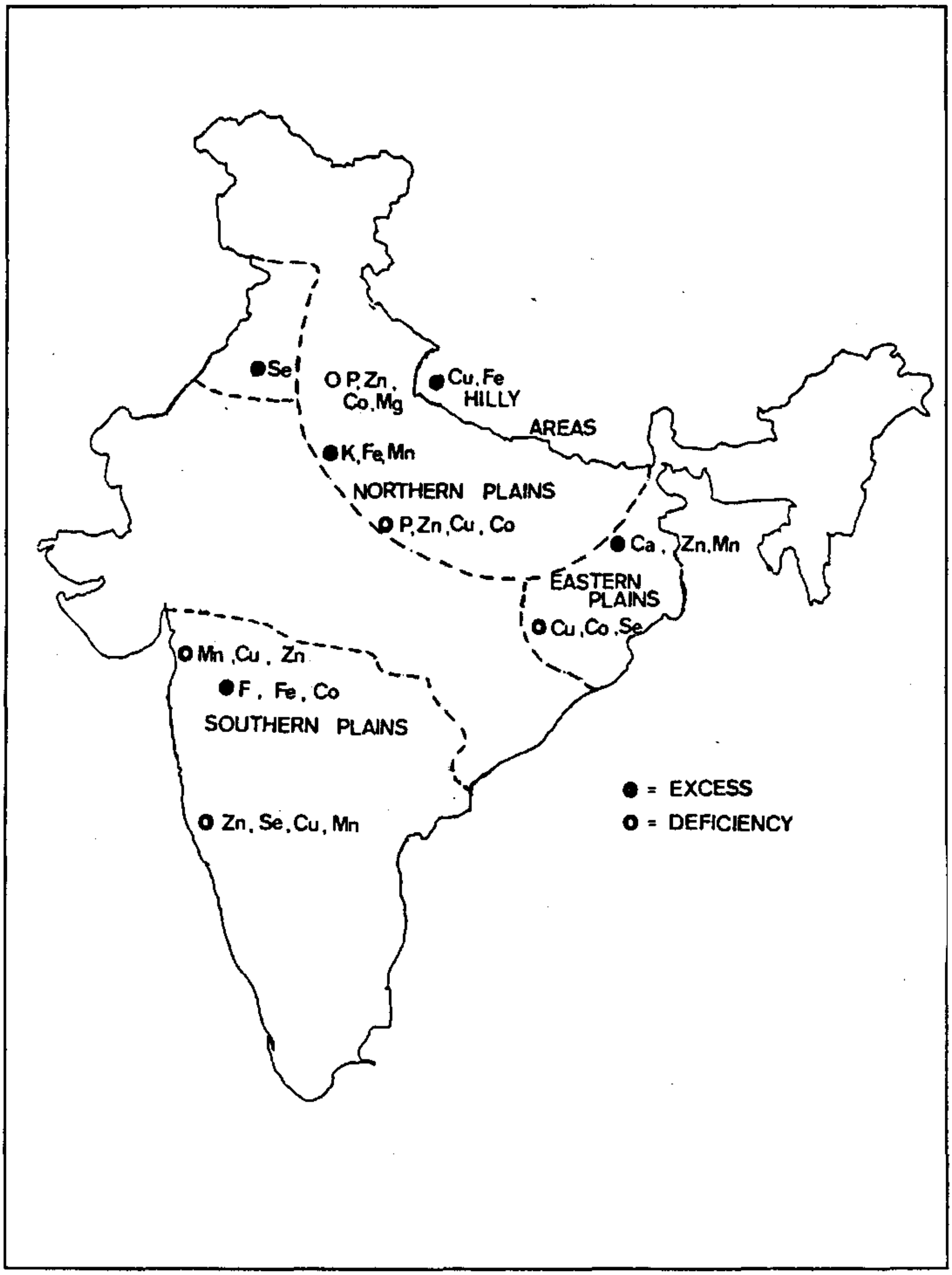
Minerals interact with each other and with other nutrients (Figure 1). Interactions which mutually enhance absorption in the digestive tract and jointly fulfil some metabolic function are termed synergistic. The interactions which inhibit the absorption of two or more minerals and produce opposite effects on a biochemical function are termed antagonistic. These interactions can take place in the feed itself, in the digestive tract and during tissue and cell metabolism. Because minerals tend to form bonds or complexes, they are more liable for interaction than other nutrient substances. Examples of synergistic effect are between Ca and P, Na and Cl, Zn and Mo. Examples of antagonistic effects are the formation of Magnesium Phosphates in the presence of excess Mg, formation of triple Ca-P-Zn salt in the presence of high Ca and between Cu, Mo and S. The balance between these minerals is therefore an important consideration when fixing up the requirements of animals.

TOXICITY AND DEFICIENCY SYMPTOMS

Based on soil analyses, the areas in India that are likely to be in excess or deficient in minerals are shown in Figure 2. Farm animals are not particularly sensitive to an excess of most of the elements and the mineral levels need to be high before any toxicity symptoms are seen. Peculiar differences are seen between goats and sheep on Cu excess. However, elements like Se, F, Pb and Cd may accumulate in straws and can cause toxicity leading to impaired metabolism and loss in production. In areas of Punjab, Haryana, and Western U. P. there are cases of Selenium excess. It affects the hooves and other extremities. It is popularly known as "Degnala disease", and attributed by some to mycotoxins in the straw.

Some minerals like Ca, P and Zn are stored in body tissues, and their deficiency symptoms will only appear after a period of time. In the case of Calcium and Sodium, deficiencies can be observed more quickly, particularly in high producing milch animals and fast growing young stock. When Ca is deficient, or when the Ca metabolism is upset after parturition, clinical signs of milk fever may develop in high yielding cows.

Figure 2. Map of India showing areas that are likely to be in excess or deficient in minerals, based on soil analysis.



Ca and P deficiency in young growing animals can cause rickets, unsteady walk, lameness and stunted growth. A moderate deficiency of P in the diet may lead to retardation of growth, impairment of bone mineralization and high mortality in young calves. In adult animals, P deficiency may lead to a decrease in live weight and milk yield due to reduced consumption of feed. The animals show reduced appetite and start chewing wood and other objects, a condition termed "Pica". Mg deficiency in adult ruminants causes what is known as 'grass staggers' or 'grass tetany', leading to high nervous excitability, shivering and unsteady walk. This condition results from consuming large quantities of grass on pasture land with imbalanced elements (excess K). In ammonia treated straw it might however show up since a high ammonia concentration in the rumen is reported to impair Mg absorption. It needs to be remembered that feeding of berseem (crude protein content about 20% of dry matter) is likely to produce more ammonia than the feeding of urea treated straws with a crude protein content of around 11% or lower.

In working animals the allowance of minerals like common salt has to be increased due to increased muscular activity. Salt, consisting of Na and Cl, is lost through increased sweating in hot conditions. Salt addition is often claimed to increase palatability, but that is not yet conclusively proven. The deficiency of most of the micro and trace elements indirectly affect animal performance by impaired metabolism. Typical symptoms of mineral deficiency are loss of appetite, rough hair coat, listless appearance and decreased body weight. Deficiencies may, however, not appear until the animals are deprived of the minerals for a long time as the body tries to maintain normal blood levels in spite of deficiency.

The economic losses due to mineral deficiencies could be high depending on the type of animal. It may range from losses caused by delayed maturity of female calves, losses in milk production, low performance of working bullocks and reproductive problems.

SOURCE OF MINERALS

Straws, stovers and other feed ingredients commonly fed to livestock are usually deficient in minerals. Therefore, supplementation of each mineral is necessary, depending on its availability in a particular area and level of desired production. In the absence of survey information, when dealing with high producing animals, it may be necessary to provide mineral mixtures that contain all elements. Animals can be supplemented directly with suitable minerals (Table 3) or with mixtures in boxes or with mineral licks. Calculated quantities can be incorporated in special feeds, e.g. concentrate or urea-molasses lick blocks. When making mineral premixes of licks, attempts must be made to reduce the cost so that the main advantage of feeding low quality roughage is not offset by expensive supplements.

A list of common straws with their mineral content is given in Table 4. Costly mineral supplements that are required in relatively large quantities are Calcium and Phosphorus. In order to reduce this cost, it is possible to supplement with ingredients that are relatively rich in these minerals, e.g., rice bran, wheat bran, rice polish or leguminous fodders. For example, when 8 kg DM treated rice straw was provided to a cow weighing 400 kg and producing 7 litres milk, the daily Ca and P balances were -6 and -21 g respectively, which was reduced to -5 and -4 g per day respectively, when

1 kg bran was supplemented. With 5 kg straw and 5 kg greens and 1 kg rice bran, both the minerals showed a positive balance.

Table 3. Mineral salts used for livestock feeding and their nutrient mineral content in g/kg (CMN, 1973).

	Ca	P	Mg	Na	Cl	Cu	Co	I	Zn	Mn
Dicalcium posphate ($CaHPO_4.2H_2O$)	220	170								
Decalcified bone meal *)	300	130	10							
Chalk ($CaCo_3$)	360									
Monosodium phosphate ($NaH_2PO_4.2H_2O$)		190		150						
Disodium phosphate ($Na_2HPO_4.12H_2O$) **)		80		120						
Dehydrated disodium phosphate		220		320						
Magnesium sulphate ($MgSO_4.7H_2O$)			90							
Magnesium oxide (MgO)			500							
Iodized salt (NaCl)				390	590			0.04		
Copper sulphate ($CuSO_4.5H_2O$)						240				
Cobalt sulphate ($CoSO_4.7H_2O$)							200			
Stabilized iodine preparation (CuI) (10 g/kg)						3		7		
Zinc sulphate ($ZnSO_4.7H_2O$)									210	
Zinc oxide (ZnO)									750	
Manganese sulphate ($MnSO_4.H_2O$)										220
Manganese oxide (MnO)										580

*) Bone meal which is not decalcified can be also considered as a practical Ca and P supplement.

**) Most sodium phosphates contain much water of crystallization and are hygroscopic. forms with little or no water are desirable and a guarantee on the content of phosphorus is useful. A guarantee is also needed that phosphates are sufficiently low in fluorine.

Table 4. Mineral content of different crop residues

Type of Straw	Mineral content (g/kg)				
	Ca	P	Mg	S	Co(ppm)
Rice	21-40	0.05-0.22	0.07-0.25	0.05-0.11	0.081
Wheat	22-42	0.2-1.5	0.08-0.16	0.04-0.10	0.065
Oat	17-36	0.02-0.07	0.11-0.30	0.11-0.30	0.245
Sorghum	8-54	0.10-0.34	*	*	0.205
F. millet	16-30	0.08-0.32	*	0.08-0.11	*

(Source: Ranjhan, 1981; Kearl, 1982)
* not known

Most cereals are rich in Zn, Fe and S, but poor in Ca. Oil cakes are rich in S, Co and are moderate sources of Zn and Cu. All roughage tend to contain less P. Mineral contents of some of the common feed ingredients are given in Table 5. This mineral composition could vary considerably depending upon the fertility status of the soil and/or processing conditions (oil cakes, brans, polish).

Feeding of formulated mineral mixtures, or pure ingredients, can be a simple way to provide deficient minerals if and when they are available. Selection should be on the basis of biological availability, or release and absorption coefficient. For example, dicalcium phosphate is the best Ca and P supplement, derived commercially from bone meal. On the other hand, rock phosphate though a good source of Ca and P, is rich in F, and can cause F toxicity. Biologically, most sulphates and chlorides are more readily available than oxides. The ferrous form of Fe (Fe^{++}) is utilized in tissues and thus better for supplementation than the ferric (Fe^{+++}) form, though the latter can be converted into its Fe^{++} form, in the gastrointestinal tract.

Amongst the chemically prepared salts, orthophosphates are readily available, but meta- and pyrophosphates have limited absorption rates. Calcium as Calcium Silicate is not absorbable.

Table 5. Mineral content of common feed ingredients

Feed Ingredient	Mineral content					
	Ca(%)	P(%)	S(%)	Cu(ppm)	Zn(ppm)	Co(ppm)
Oil Cakes	0.12	0.48	0.40	16.6	34.6	0.4-0.56
Cereal grains	0.07	0.04	0.56	10.9	74.0	0.40
By-products						
Brans	0.14	0.80	*	11.0	76.1	0.10
Rice polish	0.24	0.49	*	13.9	10.9	0.10
Green fodder						
Legumes	1.5-3.0	0.14-0.4	*	12.0	50.0	0.48-0.63
Non-Legumes	0.3-0.4	0.12-0.28	*	9.6	*	0.18-0.39
Grasses	0.2-0.3	0.07-0.3	0.06	10.6	*	*

(Source: Ranjhan, 1981; Underwood, 1981)
* not known

CONCLUSION

Animals on straw based diets are likely to be deficient in P, Mg, S, Cu, Co and Zn. When straw diets are fed, there is a possibility of a negative Ca balance due to the presence of high silica and oxalate (binding). Salt should be provided in the diet and minerals may be provided mixed with the concentrates to dairy animals. Supplementing green fodder and concentrate byproducts like brans and oil cakes would be cost effective when these ingredients are available at a cheaper rate than mineral mixtures. The best ingredients are available at a cheaper rate than mineral mixtures. The best source to provide various minerals depends on the feed ingredients fed to the animals, the availability of leguminous green fodder and the type of animal.

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4.4. SELECTIVE CONSUMPTION

Ulhas H. Prabhu, A. Subba Rao, T.K. Walli and Mahendra Singh

INTRODUCTION

The intake of nutrients can be affected by offering animals more feed than they will eat. This enables them to select the more nutritive fractions, e.g. leaves rather than stems. This principle is called selective consumption. A stronger effect of increased allowance on intake and digestibility can be expected in coarser straws, and with plant fractions that exhibit greater difference in chemical composition. Even though it was often thought to be a wasteful practice, it now appears that selective consumption is a strategy to at least partly overcome problems of low nutritive quality of a feed in conditions where enough feed is available. Even where feed supply is limited it may be better not to feed all poor feed. This chapter discusses the effect of type of forage, type of animal and farmers choices on the extent and need for selective consumption.

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TYPE OF FORAGES

The animals' ability to select the more nutritious parts of feeds, and hence the relative benefit of offering excess feed, differs between forages and animals. Selection between different fractions is more difficult with fine forages or slender straws (e.g. rice, wheat), compared with those of coarse fodders or straw (e.g. Napier, maize, millet). Of most forages the leaves are more nutritious than stems, except for rice straw where stems are sometimes more nutritious than leaves (#4.5.; #5.1.). Selective consumption will be more pronounced in plants with a greater quality difference between plant parts like leaf and stem. The practice of chopping reduces waste and therefore the opportunity for selective consumption but, the usefulness depends on the type of feed and the required level of animal output (#4.6.2.). Selective consumption has been found to take place under stall feeding as well as under grazing conditions.

FEEDING BEHAVIOUR OF ANIMALS

Species such as sheep display selective feeding behaviour if offered an abundant ration of straw. Goats are considered to be even more selective feeders than sheep when grazing and browsing and also under stall feeding conditions. Cows are able to select within fine materials, under stall feeding as well as grazing conditions. Within a herd, there is considerable variation between individual animals in their diet selection. However, some general trends occur. A clear effect of amount of feed offered, amount of refusals, intake and digestibility has been demonstrated for example with Kikiyu grass

(*Pennisetum clandestinum*) and barley straw (Table 1), but also for a many other feeds.

Increased intake does not depress digestibility when it is associated with selective consumption, unlike in situations where high levels of feed for high production are fed and when no selection is allowed. Left-overs from good yielding cows are in practical farm conditions often fed to bullocks or other animals with lower nutrient requirements.

Table 1. Effect of level of feeding on intake and digestibility

Feed charasteristic	Feeding level		
	L1	L2	L3
Kikiyu grass for cows[1]			
Dry matter offered (g/100 kg BW/d)	1380	1790	2470
Dry matter intake (g/100 kg BW/d)	1300	1480	1770
Dry matter digestibility (%)	48	50	59
Barley straw for sheep[2]			
Dry matter offered (g/d)	957	2787	4702
Dry matter intake (g/d)	758	984	1171
Organic matter digestibility (%)	29	36	37

[1] Schiere *et al.*, 1990
[2] Wahed *et al.*, 1990

THE FARMER

Not only the animal, but also the farmer plays a role in the selection process. Many farmers like to see a minimum of refusal (leftover of straw), since for them refusal appears to be a waste of feed. However, other farmers encourage selective consumption. They recycle the refusals, by feeding the "waste" to animals at maintenance or by using it as a bedding material for younger stock or for animals during pregnancy. The bedding material impregnated with urine and dung is used as compost, a form of recycling that can be quite beneficial to the farmer.

OPTIMUM LEVELS

It is not yet possible to prescribe fixed levels of required refusal. As more excess feed is given, the amount and type of refusal will also change. Moreover, the farmer's decision on whether or not to allow selective consumption or to maximize intake from straw depends on whether there is excess straw and whether better feeds are available (#4.1.). Other important factors are whether he/she can find another use for the rejected straw, or whether the level of production warrants selective consumption. Generally, the high producing animals benefit most from selective consumption. Due to the variation in feeds and animals as well as in production objective, a general rule about the level of excess is difficult to give. Around 30% refusal can be quite reasonable, mainly depending on desired level of production and availability of other feeds.

CONCLUSION

By giving "excess feed" to animals it is possible to let the animals select the more nutritive parts like leaves. Some animals are better 'selectors', but the principle is observed in all species, whether stall fed or grazed. Selective consumption can be more in coarse than in slender straws. Leaves have generally a better quality, except in rice straws where sometimes the stems are better. Some farmers allow selective consumption if they have plenty of straw and if supplements are expensive. What appears to be a waste of feed may turn out to be a blessing in disguise: the better part can be given to the more valuable animals, refusals are given to unproductive animals, or they are used for non-feed purposes. Concrete guidelines as to the amount to be offered in order to allow for selection cannot be given at this stage, though the farmer's eye can help to judge by looking at the type of feed left in the manger. The optimum level of selection is ultimately determined by availability of roughage and other feed, as well as by the desired level and type of animal production.

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4.5. VARIATION IN THE QUANTITY AND QUALITY OF CROP RESIDUES

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INTRODUCTION

The growth and consumption patterns of the world population necessitate a higher food grain production. As opportunities for the expansion of the total cropped area become limited, for many crops the increase of total production is to be achieved either by increasing grain yield per hectare or the number of crops grown each year. Also traditional grazing grounds in forests and on community lands have become eroded and less productive in terms of livestock feed. Hence, ruminant livestock depends increasingly on crop residues for feed leading to even greater integration of crop and livestock production. Since crop residue based livestock production offers a way to increase income of farm families, continued efforts are needed to improve the quantity and quality of crop residues without sacrificing the grain yield. It is therefore necessary to understand the factors affecting the production and/or quality of crop residues as discussed in this chapter.

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DIFFERENT TYPES AND USES OF CROP RESIDUES

Crop residues comprise of a variety of feedstuffs, some of high nutritive value like brans, broken grains and oilseed cakes, others of low nutritive value like straws and stovers. In many low input farming systems, the latter become increasingly important as a source of feed.

The conversion of forest or grazing lands into cropland affects the availability of animal feed. However, the quantity of crop residues produced with fertilizers and irrigation may exceed that of natural vegetation from natural grazing. In spite of that, the crop residues produced may have alternate uses reducing their actual availability to the animals, e.g. straw may be used for thatching, mulching, mushroom production or fuel. Also, the nutritive value of fibrous crop residues is likely to be less than of grasses and leaves from roadside grazing or forests. The more valuable grain and oilseed byproducts often leave the farm to be sold to farming systems with more purchasing power. Thus, only byproducts which are 'useless' for other purposes are left to be utilized for animal production, especially in small farms. The discussion between breeders / agronomists / nutritionists or farmers on the role of plant in the supply of more and better crop residues to the livestock requires a common language. It is, therefore, important to define some of the most frequently used terminology (see Box 1).

Box 1. Some relevant terminology related to grain production and quantity or quality of straw.

Harvest Index (HI): the ratio of grain (weight) to total above ground biomass weight on dry matter basis. e.g. if the grain production from a millet crop is 100C kg/ha, and the straw production is 1500 kg, then the HI is 1000/(1000+1500)= 0.4, also expressed as 40%. Some HI's for different grain crops are given in the respective chapters like maize, rice, wheat, sorghum, and millets (#5.1. - #5.5.).

Grain/straw ratio: the ratio of grain to straw (weights) in the crop should not be confused with the HI e.g in the same crop with a grain production of 1000 kg and a straw production of 1500 kg the HI is 0.4 (see above), but the grain to straw ratio is 1000/1500 i.e. 0.66.

Straw or stover: these are the stalks/stems and leaves of a crop after harvesting the grain. Stovers refer to the residues with thick stems from coarse grain crops (sorghum, millet, maize), while straws refer to those with thinner/slender stems (wheat, barley, rice).

Stubble: the vegetative parts of the crop left standing in the field for grazing or protection of the soil.

Leaf/stem ratio: the ratio of leaf (blade + sheath) to stem (weights) in straw. This ratio is important because, with the exception of rice and sugarcane, the leaves are generally better digested than the stems.

Texture: the physical feel of straw, being harsh or soft. Farmers use this criterium for judging the quality of the straws along with other characteristics like leafiness, sweetness, greenness.

Short, medium and long duration crops: this relates to crops which have a short period from sowing to harvest compared to those which have a relatively longer period.

Total crop value: the total value realised from both the grain and straw from the crop. e.g. the total value of a crop with grain and straw production of 1000 and 2000 kg, with the price of Rs. 3 and 0.5 per kg respectively, is Rs. 4000, while the ratio of the straw to grain price is 0.5/3 i.e. 0.17.

Ratoon: some crops have the ability to grow again from stubble after harvest e.g. sugar cane, sorghum and even rice. A crop grown this way is called ratoon.

Cell walls and cell solubles: the cell walls provide strength to the plant and they are essentially composed of fibre, which is difficult to digest particularly after they maturate. The cell solubles refer to the cell contents which are highly digestible but translocated to the grain as the plant matures (#3.3.).

Species, varieties and cultivars: the' term 'species' refers to differences between crops like wheat, rice or sorghum. The term varieties refers to differences in type of a crop e.g. IR8 or basmati rice, while the term cultivar refers to a variety that is officially released for cultivation.

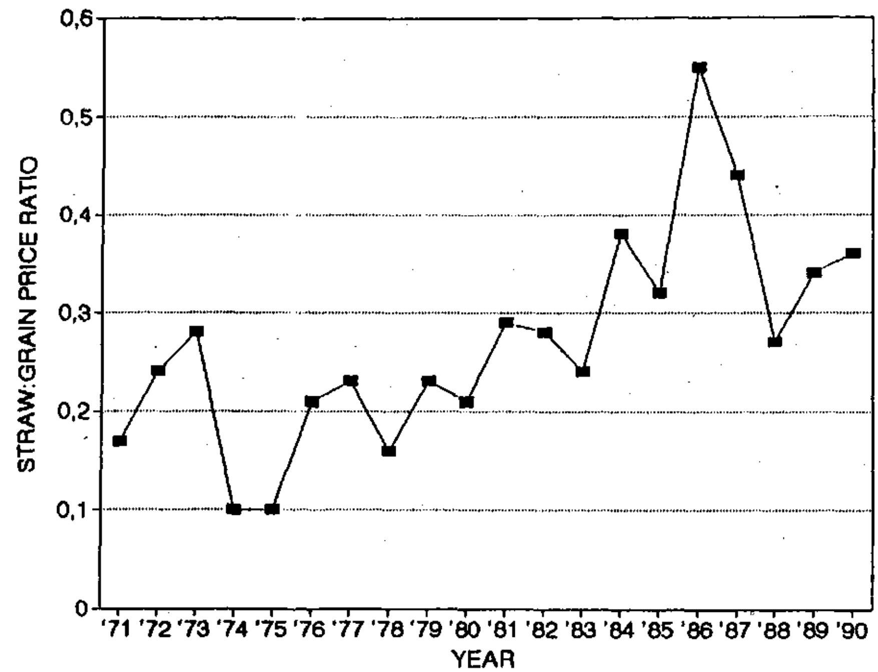
Stay green: is a quality that is used for plants that to some extent remain green up till and after harvest. The condition implies a better quality and it is used common in maize, millets and sorghum, but also known from the slender stemmed grains.

PLANT BREEDING AND STRAW PRODUCTION

Breeding and agronomic advances, including higher fertilizer and water loads in most crops have increased grain yield, total above ground biomass and harvest index. For some crops in India this has led to a decrease in straw availability per hectare (e.g. some finger millet varieties), while in others the increase in total biomass has been sufficient to also result in increased straw yield per hectare (e.g. wheat, barley and rice). A change of HI from 0.2 to 0.3 is compensated in terms of straw yield if the total biomass increases by more than 50%. It has been reported that in Maharashtra the availability of sorghum, pearlmillet and paddy straws has declined while that of wheat is slightly increased.

The availability of crop residues must be maintained at current levels or increased in terms of quantity and quality to sustain the increasing livestock production. Particularly in the more marginal farming systems with unreliable climate. The contribution of grain yield and straw quantity and quality are important in determining the total crop value. It has been shown that many farmers in the semi-arid tropics that cultivate coarse grains (sorghum, millets), prefer 'dual purpose' varieties, giving equal importance to grain and straw production. A study conducted by ICRISAT indicated that during a ten year period the average contribution of sorghum stover to the total value of the crop produced was 40% while in some years (low rainfall and grain production) it rose even higher (Figure 1). The straw value is 100% in case of - not uncommon - crop failure!

Figure 1. Annual sorghum straw:grain price ratio during the period 1971 - 1990.



(Source: Kelley *et al.*, 1991)

The significant contribution of stovers from maize, sorghum and millets to total crop value, compared to straw of wheat and rice, is in part due to the higher amount of the crop residue produced, its better quality, and the lower market value of the grain as shown in the example of Table 1.

There is evidence that stovers from traditional sorghum varieties are more valued than those from modern cultivars. This trend is less clear for cereals like wheat and rice, perhaps due to their higher grain / straw price ratio.

Table 1. A simplified calculation to show the relative contributions of straw and grain value to the total crop value in a high yielding fine grain (rice) for high potential areas, and in a low yielding coarse grain (finger millet) under uncertain conditions *).

	Rice	**Finger millet**
Grain yield (kg/ha)	5000	1000
Straw yield (kg/ha)	8000	3000
Straw/grain ratio	1.6	3.0
Value of grain (Rs./kg)	5	2
Total value of grain (Rs.)	25000	2000
Value of crop residue (Rs./kg) **)	0.4	0.6
Total value of crop residue (Rs.)	3200	1800
Total crop value (Rs.)	28200	3800
Contribution of grain to total crop value (%)	89	53
Contribution of crop residue to total crop value (%) ***)	11	47

Notes: The case is simplified to show the principle clearly

*) The change of this calculation when other cost factors (fertilizer, labour) are included will work to the benefit of relative straw value if straw is considered a byproduct, and unless spraying of chemicals reduces the straw value, or if the use of combine harvester decreases the straw availability.

**) The value of crop residues is difficult to establish. In high input systems, straw can be a nuisance, thus lowering the estimate used (0.4 Rs./kg). In low input systems straw can be highly valuable if it decides the difference between survival and collapse of the farm. Even if straw in such cases is not traded, the value of Rs. 0.6/kg might underestimate its real value in terms of farmer perceptions, thus increasing its contribution in the total crop value

***) If the grain harvest fails, more likely in finger millet than in rice systems, the relative value of straw becomes 100%.

As indicated in Table 2, in areas where rainfall is unpredictable the grain yields alone do not seem to be important in farmers' preference for a particular variety. For example, farmers in rabi sorghum tracts of Maharashtra and Karnataka continue to cultivate the popular cultivar M-35-1. Its relatively lower grain production is compensated by higher stover yields and market value for grain as well as straw.

Table 2. The relative importance of grain and straw production in sorghum and wheat production systems of different agro-climatic zones.

Crop	Agro-climatic zone	Grain yield	straw yield
Sorghum	Low, erratic rainfall	++	+++
	Assured rainfall	+++	++
Wheat	Assured rainfall	++	+++
	Irrigated	+++	+

Source: adapted from Doyle and Oosting (1994)

IMPORTANCE OF STRAW IN DIFFERENT REGIONS

The relative importance of straw and grain differs per region, and per type of grain as already indicated in the previous paragraph. In high potential regions (irrigated), green forages are often available to alleviate shortages and to supplement the lower nutritional value of the straws. However, in the semi-arid tropics with lower grain yields than in the irrigated regions, the higher production of crop residues would enhance the total value of the crop (Table 1). Scarcity of green and dry forage increases the dependence on straw feeding.

Where sufficient straw is available, farmers may allow selection by the animals, thus increasing the feeding value (#4.4.). The straw quality seems to be more critical for semi-arid tropics regions as indicated by differences in prices for straw based on quality attributes. It is important to state that one of the key determinants of price of straw is the farmers' perception of its need and quality. In animal production systems that require relatively lower energy intake by livestock, e.g. for traction, low growth or milk yields, higher quantities of the straws alone would be almost adequate to fulfil the needs. Where nutrient requirements expressed per unit of feed are high, as for higher milk production, the quality of straw fed becomes more important but, may never suffice to meet the higher nutrient requirements of animals in these systems.

As a feed for ruminants, straw has physical and chemical characteristics which limit its utilisation for animals with high production levels. Sometimes however straw is essential, either as a source of fibre for high producing cows or as an emergency feed to help animals survive a lean period. For urban dairies with a high proportion of concentrates in the diet, the poor quality straw becomes a valued product because of its quality to provide fibre to maintain rumen function. In rural areas of most parts of the country the dryness of straw allows good and cheap storage over many seasons.

The quality of straws is expressed in different ways. Farmers are known to refer to the stem thickness, leaf content, sweetness or colour, whereas scientists use terms like crude protein, organic matter, cell wall and cell contents, digestibility and voluntary dry matter intake. Fortunately, these terms often express similar things e.g digestibility and intake are normally related with sweetness and leaf content. The low nitrogen and high fibre (= cell wall) content are the principal factors affecting straw nutritive value in terms of voluntary intake and digestibility.

An important determinant of straw intake and digestibility of straws for most crop species is their leaf:stem ratio. This is because the leaf components are more acceptable to livestock, they are physically easier to chew and also more digestible. Only in rice straw the leaves are sometimes of a lower quality than the stems. The characteristics of a particular straw (leaf:stem ratio, fibre content, nitrogen content) determines its potential value to livestock, how it is used, when fed with supplements, whether selective consumption is possible (#4.4.) or the degree of response to various treatments to improve nutritive value (#4.6. - #4.6.2.).

FACTORS AFFECTING QUANTITY AND QUALITY OF STRAW

The information available at this time indicates that improving straw yields through breeding and/or management is relatively easy compared to increasing the quality of different crop residues. The nutrition characteristics of a straw are determined by its genetic make up, the conditions under which it is grown (environmental and management), and the harvesting, threshing and storage procedure.

Genetic effects

For most crops, the increased grain yield continues to be the primary aim in the development of new varieties, and not without success. To achieve this, the plant breeders have selected for shorter plants which are less susceptible to lodging, and for plants which respond to fertilizers. This has meant that the vegetative parts of crops have changed in terms of improved photosynthetic activity, root systems, disease and pest resistance. Agronomic practices have also changed by sowing varieties according to length of growing season, to apply fertilizers and by introducing crop protection. Denser planting, shorter growing seasons and higher leaf contents can be expected to favour straw quality. In some cases, in addition to grain yield, total biomass production has increased.

The effects of all these interventions on straw yield are not clear cut and vary between crops and farming systems. With higher grain yield, the grain:straw ratio has also generally increased. Data from experimental plots indicate that for some species or cultivars higher grain yield has decreased straw yield (Table 3), while for other crops the increase in total biomass has been sufficient to ensure that straw yield remained the same or increased.

Table 3. Straw and grain yields of different sorghum and finger millet cultivars.

	Sorghum		Finger millet		
	IV	HY	LAND	IV	HY
grain (mt/ha)	3.3	3.3	2.5	3.8	3.4
straw (mt/ha)	9.6	8.0	9.3	8.6	7.2
HI	0.26	0.29	0.21	0.31	0.32
straw:grain ratio	2.91	2.42	3.72	2.26	2.12

IV = Improved selections
HY = Hybrids
Land = Landrace

The effects of advances in crop production on straw yield under less favourable conditions of crop growth and management - as usually seen on farms - are unknown. However, there are clear cases where farmers rejected new varieties, among others, because it negatively affects the grain yield security or even crop residue availability for feeding of their animals.

Laboratory studies with varieties of rice, wheat, barley, sorghum and millets grown under similar conditions have indicated wide differences of in vitro digestibility: as much as 10-15 units. In many studies, straw digestibility has not been related to grain yield, and indications are that higher grain yield does not necessarily mean low straw digestibility.

The genetic effects, combined with those of environment (location and year interactions) on straw digestibility varies between straw species and between studies within a straw type. The effects of genotype are often overshadowed by those of location, year and interactions can occur (i.e. the ranking of cultivars changes between years). Though it may be possible to select or breed varieties which combine good grain yield with better quality straw, this has not been conclusively demonstrated. Evidence available now, however, allows some general statements about the type of criteria that plant breeders, agronomists and/or farmers can take into account.

Some of the differences in quality of straw between varieties can be attributed to the proportion of plant parts, i.e leaf, leaf sheath and stem. Leaf and leaf sheaths are more digestible and have higher degradation rates than stems for most straw types. An exception is rice straw, where the differences are variable. In wheat and barley, selection for grain yield and lodging resistance has led to shorter (dwarf) varieties, but these have often a higher proportion of leaf in the straw. In this instance, selection for grain yield may have actually improved straw quality. In other cases, however, selection may have decreased straw quality, e.g., selection for bird resistance (pigmentation) in sorghum has led to decreased feeding value compared to non-pigmented straws.

Breeding and testing for improved straw quality of cereals seems possible but, it is time consuming and difficult. Current analytical methods for determining straw quality require laboratory facilities for the large scale screening required in breeding programmes. Because of large effects of environment and management on straw quality and quantity it is necessary to undertake such studies over at least 5 years and at a number of locations. This needs considerable resource inputs even if applied only for varieties ready for release. In addition, the quality characteristics measured, such as leaf/stem ratio or digestibility may not always correlate well with intake. For example, bird resistant and non-resistant sorghum have the same leaf:stem ratio, but the non-pigmented varieties are consumed better than the pigmented ones.

Environmental factors affecting straw quality

Factors like soil moisture, light (intensity and duration), temperature, soil nutrients, fertilizer use, and disease and pest incidence affect the growth pattern of crops. Their effects tend to dwarf the genetic effects on straw quantity and quality. Since the nutrient content of the straws is the balance between production and use of photosynthates (growth, respiration, reproduction), it is obvious that environmental factors would have profound effects on straw quality, e.g. by changing in the proportion of leaf, leaf sheath, stem, or by changing of the chemical composition of cell wall and cell contents (#3.3.).

How environmental conditions affect the proportion of plant parts is again not clearly understood. Some factors like nitrogen application and water stress have been reported to increase leafiness in crops, but whether the effects during development persist till harvest is not known. The environmental conditions during growth also affects the fibre content and composition of plant parts. Grain fill affects the translocation of stored nutrients into grain, e.g. the straw quality.

Low light intensity and high temperature can reduce the stored sugars in plants and therefore the digestibility of crop residues. Moderate water stress may increase cell solubles and thus increase digestibility, e.g. in conditions that lead to low grain yield resulting in high straw quality. Nitrogen fertilizer has a variable effect due to antagonistic effects: an increased digestibility due to high protein and low cell wall content, but reduced digestibility due to faster maturation, combined with greater stem development and more flowering. Higher plant populations result in thinner straw, less grain yield and therefore better straw.

Harvest and post-harvest management

Equipment use, harvest facilities, traditional attitudes and climate influence the harvesting, threshing and storage techniques for grain and straw. Harvesting is done either manually or by machine depending on factors like scale of farming, crops planted, availability and cost of machinery and fuel.

Manual harvesting is mostly used by small holder farmers where labour is cheap relative to machines. Variations within manual harvesting are seen depending on crop and region. Separate harvesting of grain (panicle) and straw is done when, at grain maturity, the plant is still in vegetative stage, usually under irrigated conditions. The cutting height of the whole plant above ground level with a smooth or serrated sickle is suited to threshing practices. Cutting height varies, but directly affects the amount of straw available. In some states the stubble is used as fuel while the straw is used as animal feed. Cutting height can influence the straw quality since the digestibility of crop residues changes from the top to the bottom. If the plant is in vegetative state at grain harvest (irrigated crop) the bottom parts would be more digestible than the upper parts. However, the lower part is also more likely to be contaminated with soil, though it may contain young regrowth besides having higher stem content. Uprooting of the whole plant is done for rainfed rabi sorghum in Maharashtra where soils are completely dry at harvest. When fed, the straw includes roots but, these are usually not consumed by animals. There is however contamination of straw with soil, and the effects of this are not known. The roots are generally composted and not consumed by the animals.

Machine harvesting can be done on small farms but its use is mostly limited to irrigated areas. The cutting height can be varied depending on whether straw is required or not. Machine harvesting may lead to loss of leaf (due to lightness) from wheat and barley straws, implying a loss of quality due to higher digestibility of leaves than stems in these crops.

Threshing

Threshing, i.e separation of kernel grain from straw, can be achieved by rubbing, impact or stripping, manually or by machine. Generally harvested plants are allowed to dry in the field for a period of 6-8 days before threshing, depending on labour availability and rains. This may result in loss of cell contents from the plant reducing the straw quality. The loss of cell contents can be due to respiration, microbial/fungal growth, or rains that leach the soluble nutrients from the straw quality. In case of rice and wheat the whole crop is threshed, while only panicles are threshed for sorghum, maize and millets. Threshing methods are therefore unlikely to affect straw from the latter crops.

Treading by human feet or animals or tractors is practised for whole crops/panicles. In case of rice the whole crop is mostly threshed by beating, though machine threshing is done in irrigated areas for crops like wheat. The threshing can also influence straw quality due to loss of variable quantities of leaves. The effect of threshing can also be that the straw is reduced to small particles e.g. by using machines on wheat in Punjab, Haryana and U.P. or by using stone rollers on finger millet in Karnataka.

Storage of crop residues

Baled or unbaled straw is stored in several ways, mainly classified as covered and uncovered. Stacks are made without shade, on the ground or on raised platforms, with shape that facilitates rainwater run-off. Depending on the system followed the losses of nutrients due to leaching and microbial attack following rains would be variable. The use of covers is not common due to bulkiness of the material and the high costs for building or polythene. In many North Indian states straw stacks are mud-plastered to protect the straw from rains. Studies on nutrient losses from straw during storage are limited, and no information is available that compares the cost of storage with the cost of lost nutrients.

CONCLUSION

Farmers, crop and animal scientists should be striving to jointly develop interventions for improved output from the whole farm, particularly for smallholder mixed farming systems. The quality and quantity of crop residues is an important issue in this respect, varying widely as it is affected by genetic make up, environment and post-harvest processing and storage. The effects of environment and management appear to exceed those of genetics. No general recommendations about priorities and criteria for plant breeders can be made, but laboratory measurements like digestibility and intake tally well with farmers' perceptions about leafiness and texture (#3.3.). Depending on the farming system, it is also possible to indicate priorities for either total crop yield, grain or straw yield and quality. The implications of these effects for straws/stovers from different crops are presented in detail in Chapter #5.1. - #5.9. It must be remembered that the amount and quality of crop residues available at farm level will interact with the feeding practices and the level of livestock production.

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4.6. TREATMENT OF CROP RESIDUES: A REVIEW

D.D. Sharma, A.L. Joshi, J.B. Schiere and M.N.M. Ibrahim

INTRODUCTION

Straws and stovers have a low content of digestible organic matter, and they contain low levels of crude protein and essential minerals. The problem is caused by the fact that upon maturation of the crop, the cell contents are removed from the cell and the cell walls become thicker and woodier (# 3.3). Because of their high content of cell wall (= crude fibre), the straws have a particular value in diets with high levels of concentrate or succulent green feeds. When fed as a major part of the ration however, the low digestibility of the fibre is associated with the low intake of feed, and as a result, the intake of energy by the animal remains too low, even to provide sufficient nutrients to maintain the animal. Several ways can be employed to overcome this low feed quality, but the major ones are the addition of supplements in the ration (# 4.3) or the improvement of the straw quality itself, particularly by chemical and physical treatments. The principles and types of treatments are briefly described in this chapter, and the most important treatments will be elaborated in the following chapters.

Handbook for Straw Feeding Systems
Kiran Singh and J.B. Schiere (eds.), 1995
ICAR, New Delhi, India

PRINCIPLES OF TREATMENTS

The basic principle of treatments is that they aim to break or solubilize the chemical and physical bonds in cell walls. This can be achieved by a variation of physical and chemical treatments that either use pressure, heat, chemicals or their combination. All that these treatments do is to "soften" the cell walls, i.e. they add no nutrients except for nitrogen in the case of ammonia treatment. This implies that, even after treatment, the feed still consists essentially only of cell wall. Though some of that cell wall may now be easier digestible, the feed essentially remains only cellulose and hemicellulose with variable quantities of lignin and minerals. It should also be obvious that plant material with relatively low cell wall contents, or highly digestible cell walls will benefit less from treatment. For this reason, maize, sorghum and millet stovers are less likely to show response to treatment than straws from rice and wheat. Also within wheat, rice and all other straws, the effect of treatment will be less pronounced in varieties that have a high initial digestibility, e.g. after a failed harvest, or in fine versus coarse rice straw (# 4.5).

Treatment improves rate and level of digestion, and thereby also the intake, but it does not make the bad feed into a good feed. The combined effect of increased digestibility and intake is shown in table 1 where improved digestibility alone increases the nutrient intake with about 17%. Improved intake alone increases the nutrient ingestion with about 24%, but the combined effect yields an increased nutrient intake of around 45%. With such a combined effect, the feed becomes good enough to allow nutrient intake above maintenance. One should keep in mind however, that treated straw will not become as good as feed, such as green fodder or concentrates. In other words, the production of milk and meat on treated straw alone will never be high and essentially that is true for all types of treated straw.

Table 1. The effect of urea treatment on digestibility, intake and on the intake of digestible dry matter and concentrate supplements.

Dry matter digestibility (%):	
Untreated straw	48
Treated straw	56
% increase	17
Dry matter intake (kg/100 kg BW):	
Untreated straw	2.1
Treated straw	2.6
% increase	24
Digestible dry matter intake (g/100 kg BW):	
Untreated straw	1.01
Treated straw	1.46
% increase	44

Source: Ibrahim, 1986.

The combined effect of increased intake and digestibility brings us to at least three other relevant observations:

- the measurement of digestibility at fixed intake levels explains only part of the treatment effect,
- in order to obtain maximum effects of straw treatments, it is important to have sufficient stock of straw to allow for the extra intake. A common complaint of farmers who try urea treatment is indeed that "the animals eat the straw better, but the straw is also finished sooner, and not enough -

straw remains to manage through the dry season".

- treatment of straw may result in savings on concentrate, though mainly because the animal can eat more straw.

The consequence of this all is a) that where straw is relatively expensive compared with concentrate, there is no point to replace the concentrate supplement with treated straws, b) by measuring only digestibility only a part of the effect is known, and c) treated straw is useful at medium levels of production, but it does not provide sufficient nutrients to serve as major feed resource for high producing animals.

Different crop residues respond differently to chemical or physical treatment. The action of alkali treatment is different in fibrous residues from monocotyledons (straws, mature grasses), than in residues from dicotyledons (tree leaves, legume straw). In fact, the effect of chemical treatment with alkali is well established in cereal straws, but there are reports that it would not work so well with legume straws. Also, the way in which cell walls are built up will affect the treatment result. Sugarcane is reported to have a higher crystalline structure of cellulose than straws, and heat treatment appears to be more effective on such residues.

TYPES OF TREATMENTS

The treatment of straw can be done in different ways, generally classified as chemical, physical and biological methods, or their combinations (Table 1.). Only the most relevant treatments are discussed in the following chapters, and their relevance is determined by the availability of technology, transport, power, access to other feeds and desired level of production.

Table 2. A classification of treatment methods (Source: adapted from Ibrahim, 1983).

Physical	Chemical	Physico-chemical	Biological
Soaking	Sodium hydroxide	Particle size/chemicals	Addition of enzymes
Grinding	Calcium hydroxide	NaOH/pelleting	White rot fungi
Pelleting	Potassium hydroxide	Urea/pelleting	Mushrooms
Boiling	Ammonium hydroxide	Lime/pelleting	
Steaming under pressure	Anhydrous ammonia	Chemicals/steaming	
Gamma irradiation	Urea/ammonia	NaOH/temp.	
Chlorine gas	Sodium carbonate		
Sulphur dioxide	Sodium chlorite		

The application of physical methods like steam treatment is obviously limited to industrial conditions where steam is available, typically the case for steam treatment of sugarcane bagasse. Other physical methods like chopping can employ machines or hand labour depending on the relative availability of labour, capital or other feeds (# 4.6.2). Densification is done with a different purpose in mind. Its main objective is to reduce the volume to economize on storage and transport (# 4.6.3).

Biological treatment, though tried under the BIOCON project, has not proven to be feasible in field conditions, due to a few fundamental and technical problems, leave alone the economics. Those problems include the identification of proper microbial strains, their survival in non sterile straw heaps, possible toxic effects of contaminant organisms and inevitable organic matter losses.

Chemical methods like sodium hydroxide (NaOH) treatments may be effective in a technical sense, but since the chemical is difficult to handle and not widely available there is no scope for its application under farmers conditions in India. The same is true for treatments with chemicals like hydrogen peroxide (H_2O_2), acids or strong alkalis like potassium hydroxide.

The most practical chemical treatment is urea treatment since urea is widely available and easy to handle. Even then, its economic applicability is limited, depending on the level of desired animal production, the relative availability of straws and other feeds, and the possibility to sell milk on the market. It is clear therefore that the applicability of each of these methods is limited to specific situations and seasons, i.e. large scale application of anyone of the methods is unlikely to take place. The treatments have specific feasibility under different feeding systems, as sensitively indicated in Table 3. The terms such as low and high, indicate that, for example in the top row, first column, under condition of low straw availability, chopping is relevant.

As an interesting sideline on the mechanics of physical and chemical treatments it can be said that physical treatment, e.g. the application of heat, can release organic acids that provide an additional chemical treatment. Also, chemical treatments can act as physical treatments where the ions attract water (hydration), producing a swelling action between the fibres.

Table 3. Applicability of treatments under different feeding systems.

Attributes	Treatments			
	Chopping (#4.6.2.)	Soaking (#4.6.2.)	Urea (#4.6.1.)	Steam
Availability of straw	Low	NA	High	High
Cost of straw	High	NA	Low	Low
Availability of labour	High	Med	Med	N.A.
Cost of labour	Low	Med	Med	N.A.
Initial straw quality	N.A.*	N.A.*	see text*	Low
Production level of animal	see text	see text	Low-Med	Low-Med
Availability of greens	see text	N.A.	Low	Low
Cost of concentrate	High	High	High	High
Cost of chemical	N.A.	N.A.	Low	N.A.

* provided not mouldy, here difference stovers/straws; NA: not applicable; Med: medium

CONCLUSION

Several treatment methods are available from the laboratory. Only very few, particularly urea ammonia treatment and chopping and/or soaking have relevance for field application, though each one for different reasons.

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4.6.1. UREA TREATMENT OF STRAW

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INTRODUCTION

Urea treatment of straws is thus far the only chemical treatment with practical potential for farmers' conditions. Urea is available in many parts of the country; it is a relatively safe chemical that is easy to store and also easy to dissolve in water. Urea treatment can be done in different ways, depending on the local conditions and preferences, but some rules can be given regarding concentration of urea, duration of treatment, amount of water to be used and way of stacking. Of all treatments, the economics and feasibility of urea treatment is best understood. Though on a limited scale, urea treatment is done by farmers under practical conditions in different places of the country. All these aspects will be covered in this chapter, and some attention is given to aspects of animal health in relation to feeding of urea treated straw.

Handbook for Straw Feeding Systems
Kiran Singh and J.B. Schiere (eds.), 1995
ICAR, New Delhi, India

UREA AS A CHEMICAL

Urea is a white crystalline solid organic compound, widely used as a nitrogen fertilizer. Pure urea has a nitrogen concentration of 46.6 percent, equivalent to a crude protein content of 290 grams per 100 gram of urea since protein itself has only 16% nitrogen. Urea is easily broken down to ammonia by the urease enzyme that is produced by soil or rumen microorganisms in the following way:

$$(NH_2)_2C=O + H_2O \longrightarrow 2NH_3 + CO_2$$

As an NPN-source urea can replace part of the dietary protein in the ruminant diet. Rumen microorganisms first break down urea to ammonia, which then serves as a nitrogen source for the production of microbial protein, ultimately serving as a protein source for the host ruminant (#4.3.1.).

Urea, when used for treatment of straw enhances the nutritional quality of straw in terms of increased nitrogen content, improved palatability and digestibility of straw. During the treatment process, ammonia is generated from urea, and in the presence of water it forms the alkali named ammonium hydroxide. It has been well-established that alkali treatment makes the cell walls better available for fermentation in the rumen. In temperate climates, anhydrous (gaseous) ammonia or aqueous ammonia (ammonia dissolved in water) is used for the ammoniation of straw. In warmer climates the urea treatment is more feasible because of the easy availability of urea and its quick breakdown into ammonia compounds under higher ambient temperatures.

FACTORS AFFECTING THE PROCESS

Various factors affect the ammoniation process during the urea treatment, ultimately determining the nutritional quality of the treated straw. None of these factors is very critical, but some rules can be given.

Urea concentration

An amount of 4 kg of urea (equivalent to 2.2% ammonia) to treat 100 kg of air dry straw has been found to be an optimum level. Levels lower than 3.5 kg may not produce sufficient ammonia for effective treatment, and levels above 4 kg have not further increased straw quality. Higher levels result in higher digestibility in *in vitro* trials. In practical *in vivo* work however, where it is the combination of increased digestibility and intake that counts, no beneficial effect of higher urea levels is found. A farmer can weigh the 4 kg of urea in a bucket or a cup once, mark the level and subsequently use that measure for further weighing.

Water requirement

The moisture level is not very critical to the process, provided it is not too low. When water availability is a problem, e.g. in arid regions or dry seasons, water usage needs to be minimized. Water however is essential because it helps hydrolysis of urea. It is also required to form the alkali and to act as a vehicle for the ammonia to penetrate the cell walls. A 30-40%

water level has been shown to get the desired effect. For achieving this, 50-60 litres of water can be used to dissolve 4 kg of urea and to spray it over a layer of 100 kg of air-dried straw. A number of straw bundles can be counted to know how many are required to make 100 kg of straw. With chopped wheat straw, the number of baskets required to form 100 kg of straw can be counted. With regard to water measurement, milk cans of 25 kg capacity can be filled with water twice to dissolve 4 kg of urea. In absence of milk cans or any other of these measurement procedures, it is possible to develop locally applicable methods, perhaps more adjusted to the amount and type of straw to be used.

Methods of spraying

For spraying of the urea solution over a layer of 100 kg straw or whatever quantity that is chosen, a gardener's sprinkler can be used to achieve uniformity in urea solution coming in contact with straw. Use of a broom and a bucket has also been found to be effective to spread the water. For chopped wheat straw, some hand mixing after the spray of urea solution is desirable.

Compactness of the stack

Once a layer of 100 kg has been treated, an additional layer of 100 kg is placed on top and sprayed with urea. This process is repeated to make a stack. A compact stack has two advantages. Firstly, the effectiveness of the ammoniation process is better. Secondly, there are less chances of mould growth which leads to spoilage of the straw. Chopped wheat straw compacts very well during stack making. Such a compactness cannot be achieved so easily in loose rice straw, though bundles are better than loose unchopped rice straw. It may be important to know that particularly in the Northern wheat belt the straw comes in chopped form, in other areas, e.g. West Bengal, it is the wheat straw that remains unchopped (#5.2.).

Duration of treatment

Since the temperature of the heap affects the rate of hydrolysis of urea to ammonia, the duration of treatment can be variable, depending on the region or season where the treatment is done (see Box 1).

Box 1. Relation between outside temperature with required treatment time.

In Norway, the outside temperature is reported to affect the ammonia treatment time as follows:

Outside temperature (°C)	Treatment time (weeks)
Below 5	more than 8
5-15	4-8
15-30	1-4
above 30	less than 1

The effect of outside temperature on treatment time with urea is a bit unclear, but urea treatment is not well possible in colder countries/regions with snow and frost like Scandinavia or Scotland and probably neither in the Himalayas or other mountain ranges in the tropics. Usually however the temperature inside the stack is higher than the outside temperature, due to microbial action and/or chemical reactions between urea, water, ammonia and straw. And since it is ultimately the stack temperature that determines the reaction process, it appears critical that the initial temperature is high enough to get the process started. In practice it appears that when straw is treated under conditions with an ambient temperature of around 20°C (during day time), the inside temperature in a urea treated straw stack can be as high as 50-60°C in 1-2 days. In that case the outside temperature is irrelevant to what happens <u>in</u> the stack. Bigger stacks or heaps can control temperature better than smaller heaps.

Source: Sundstol *et al.*, 1978; Tharmarajah and Van Der Hoek, 1986

Ammoniation periods of seven days or less are shown to be sufficient under tropical conditions, as found in Sri Lanka and Southern parts of India. The duration of the treatment can also be decided upon, by considering the local conditions as well as the scale of the treatment. Smaller quantities can be treated on a weekly basis, requiring less labour at once, becoming part of the routine animal feeding practices. In certain farming systems however, especially in northern India, straw is stored in large stacks for many months. In such situations some farmers wish to treat straw with urea at the time of stacking right after harvest, though it involves more labour at that time. Thus, also the duration of the treatment becomes longer. A period of at least two to three weeks has been suggested to be necessary for the treatment of straw in the North, during the winter months, when the ambient temperature is lower. A note of caution however: *longer periods of storage (> three weeks) increase the risk of spoilage by mould growth, especially when the straw is too wet.*

Type of crop residue used

The type of crop residue used and its initial nutritional quality affects the effectiveness of treatment. The poorer the initial quality of the straw or stover, the higher the effect of treatment, possibly because better quality straws have more cell solubles and lower fibre content, the latter actually getting the benefit of ammoniation (#3.3.). Stovers, i.e. coarse straws have generally a higher initial nutritional quality than slender stemmed straws, and they will benefit less from treatment. Furthermore, if mouldy straw is used for the treatment, one can only expect a reduction, rather than an improvement in the quality of straw.

Storage method

A key factor which determines economics and practicability of the urea treatment of straw is the use of storage structures for the treatment. Farmers generally prefer storage methods based on existing traditions, but new ways are found acceptable depending on their cost.

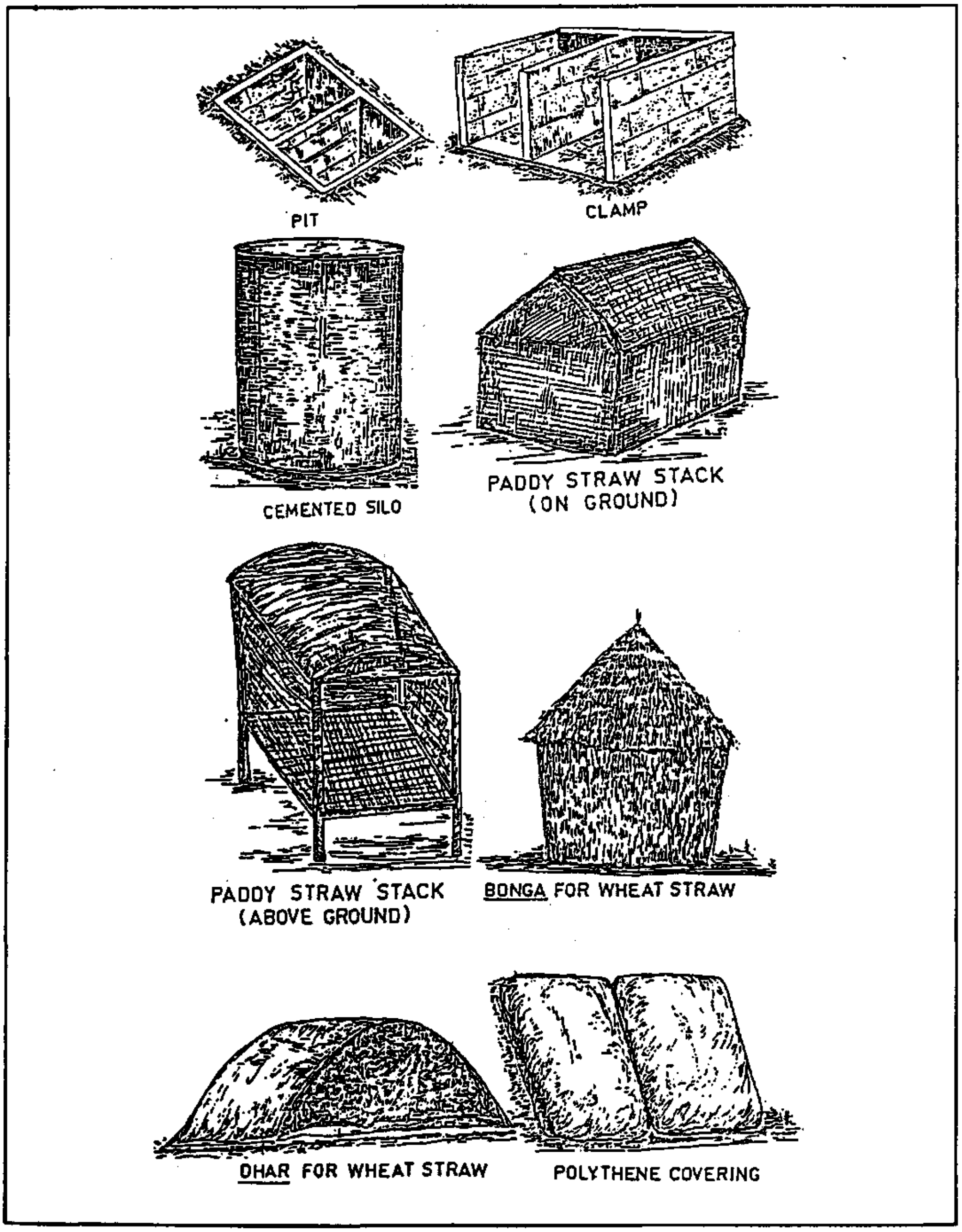
Covering of the stack is important, though particularly the larger, and more densely packed stacks could be open, i.e. covered with only a layer of untreated straw. sealing can be done with materials like polythene, coconut leaves, banana leaves, or empty urea bags stitched together. Farmers also use various storage structures like earthen pits, lined and covered with banana or coconut leaves, wooden or cemented clamps, cemented silos, rings or pipes (Fig. 1). Apart from that, urea sprayed straw can also be packed in sacks made from polythene or by stitching empty straw bags. All these methods have been used in Bangladesh, Sri Lanka and parts of India. No hard and fast rule can be given and local farmers' preference is to be the best guide in this. Particularly when small heaps are treated it becomes important to have the stack adequately sealed.

In Bangladesh, earthen pits or bamboo baskets lined with banana leaves and covered with jute bags, plastered with mud and cow dung have been used during the urea treatment of paddy straw. The pit system, i.e., a hole in the ground, carries the risk of contamination with soil or seepage of rain water through the sides. Loading and unloading of pit is also difficult, and the digging of pits can be a problem in rocky soil. Long straws like rice in Northern India and finger millet and sorghum in Southern India are stored in stacks, whereas chopped straw or 'bhoosa' wheat is stored either in a

room, a 'bonga' or a 'dhar'. Both the 'bonga' and the 'dhar' provide air tight conditions, the latter after mud and/or cow dung plastering. Farmers make 'dhars' essentially to save time, i.e. to allow rapid storage in the field, accepting higher losses of straw in this system than in the 'bonga'.
For a continuous supply of treated straw, a twin pit or clamp systems can be suitable. The size of the clamp depends on the amount of straw to be fed from one clamp (or stack) and on the density of the straw (70-120 kg straw/m^3). Such a clamp (wooden or cemented) is suitable for small dairy owners or landless labourers with a few animals, who treat the straw with the help of family labour on a weekly basis.

The different methods of stacking or storing urea sprayed straw have their relative merits and demerits, but the bottom line about all these methods is that the better the compaction and airtightness of the stack, the better will be the quality of the treated straw. Finally, the farmer has to decide according his/her own preference.

Figure 1. Different storage structures for straw treatment (for explanation of twin pits see text).



Note: a wire mesh can also be used to keep the straw together and to assist compaction.
Source: Rai et al. 1993

EFFECT OF TREATMENT ON STRAW QUALITY

Much work has been done by now to consistently show that treatment improves straw quality in term of digestibility and intake. Also farmers have confirmed that feeding of treated straw positively affects animal production and health.

Nutritive value: scientists' perceptions

Urea treatment improves digestibility, intake and crude protein content of the straw. The extent of response to urea treatment in terms of straw quality is variable, due to variation in initial straw quality, species difference among straws and stovers, and the type of animals used for the experiments. A summary of the effect of urea treatment on the quality of slender and coarse straws, and an average for a number of straw types is given in Table 1.

The increase in crude protein content caused by urea treatment is in the order of 4 to 5 percentage units, due to the addition of ammonia. Crude protein content increases are higher than what would be required in relation to the increased digestible energy availability in the rumen. The higher digestibility and intake is mainly caused by the increased rate and extent of cell wall degradation.

Table 1. The "scientists" perception of the effect of urea treatment on straw quality.

Type of Straw	US/TS	DMI*	DDMI*	DOMI**	DMD	OMD	IVOMD
Rice	US	52-84	35-38	0.86	42-43	47-52	44-47
	TS	64-115	50-76	1.36	44-60	57-61	51-83
Wheat	US	63-64	-	-	39-40	40-41	-
	TS	71-81	-	-	42-50	43-53	-
Barley	US	40	-	-	49	-	-
	TS	53	-	-	65	-	-
Finger millet	US	48-65	32	-	49-52	51-55	-
	TS	60-87	52	-	60-69	63-72	-
Sorghum	US	51	27	-	50	55	-
	TS	94	41	-	55	59	-
Maize	US	3.31***	-	-	57	-	-
	TS	4.09*	-	-	62	-	-

Notes: * $g/kg^{0.75}$
** kg per 100 kg BW
*** kg per day
Abbreviations: US is untreated straw;
TS is treated straw;
DMI is dry matter intake;
DDMI is digestible dry matter intake;
DOMI is digestible organic matter intake;
DMD is dry matter digestibility (in %);
OMD is organic matter digestibility (in %);
IVOMD is in vitro organic matter digestibility (in %).
Source: Prasad *et al.*, (1993)

Animal response and health

The effect of treatment on animal response is more difficult to give. this is because of the variety of animal species and type of produce, and also because farmers often feed less supplements after starting to feed treated straw. Generally, it can be said that by replacing a large amount of US by TS in the ration:

- the butterfat tends to increase with a few decimal points;
- milk yield increases of 0-1.5 litres are reported, but 0.5-1 litres appears to be a reasonable range depending on other feeds fed, stage of lactation and body weight of the animal;
- animals of 100-150 kg body weight will lose 50-100 g/day if fed on only US, whereas they will gain 50-100 g/day when fed on TS alone;
- a milk yield of 2-4 litres on TS alone seems to be possible, of course depending on the quality of straw and the bodyweight of the animal.

All these values have to take into account the animal's body weight, the quality of the straw and the other components of the ration.

Health and reproduction

To assess the effect of urea treated straw on animal health one has to take into account with which ration it is to be compared. As a rule it should be remembered that both urea and straw are compounds that are well known and natural to the animals body, so no harm is likely (#4.3.1.). When TS feeding is compared with feeding of US it can be said that:

- fertility and reproduction remains the same or improves;
- in some cases, the dung gets slightly stickier. No negative health aspect is ascribed to that, but (women) farmers may find it more difficult to clean the animal or to make dung cakes;
- no negative residues of straw treatment are known to enter the milk. The use of pesticides and herbicides should not be overlooked however, though some are reported to be denatured in alkaline environment, and the problem is not confined to the use of treated straw alone;

- provided the straw is not mouldy, there are no reported cases of more mycotoxins due to treatment. In fact, NH_3 is known to inactivate mycotoxins;
- high levels of NH_3 are supposed to occur in the rumen, due to feeding of treated straw, but it is unlikely that they exceed those due occurring for example in berseem feeding. Excessive NH_3 levels in the rumen may depress the absorption of Mg (#4.3.2.), but in practice no problems are known to have occurred;
- a condition termed "bovine bonkers" occurs under a combination of heat, high sugar content and use of ammonia (NH_3) for treatment. It is not known to occur with urea treatment of straw;
- urea toxicity due to feeding of urea treated straw is unlikely or even impossible, because urea and straw are well mixed and the intake of straw is slow (#4.3.1.);
- fungal growth in straw can produce mycotoxins that cause abortion or other ill effects. Fortunately, ammonia produced during treating straw with urea can serve as preservative to prevent mould growth;
- Vitamin A deficiency in treated <u>and</u> untreated straw can cause fertility problems in cows, but this can be prevented by including some green fodder in the ration.

Farmers' perceptions on urea treatment

Many field demonstrations and on-farm trials have been conducted with treatment technology. The feedback collected from farmers who feed the treated straw to their animals suggest that the response has been generally positive, though not always sufficient for most farmers (see Box 2). Farmers report that by feeding treated straw:

- straw consumption increases;
- a better growth performance is observed;
- health improves, i.e. a shiny skin is observed;
- an increase in milk yield ranging from 0.5 1 - 1.5 litres per animal per day;
- butterfat remains the same or increases slightly.

Some farmers have been able to reduce the quantity of concentrate fed to the animals, thereby reducing the cost of production if straw is cheap compared to concentrate. The other advantages of treatment are less wastage of feed and less need to chop the straw.

Box 2. Perceptions of a few women farmers on the treatment of straw with urea in Haryana.

Interview questions	Replies of landholding woman farmer	Replies of landless woman farmer
Have you been involved in the treatment of straw and the preparation of the stack?	Yes.	Yes.
Did your husband discuss the treatment with you, before he agreed to join this trial?	It was a mutual decision.	I was the first one to be approached, but I send for her husband who was in the field and together we agreed.
Which tasks did you perform during the treatment?	Carrying water. Preparing the urea solution.	Arranging the straw bundles. Preparing the urea solution. Trampling the stack. Pumping water into the hose.
Was it difficult work?	No, not at all.	No, very easy.
Was the work dirty or inconvenient?	No.	No.
What are your experiences with the treated straw?	Positive, the milk yield increase a 1/2 kg of milk per day.	Positive. A high increase in milk production, the buffalo from 6 to 8 kg milk, the CB cow from 2,5 to 4 kg increase.

Do the cattle like to eat it?	Yes, first it smells and for a few minutes they do not eat it, then they eat 11 kg instead of 7 kg.	Yes, they eat more.
Which cows were fed the treated straw?	One lactating desi cow and one young cross bred.	One lactating cross bred cow and one buffalo.
Is chaffing easy?	Yes, easier.	Yes, easier, there is no dust because it is wet.
Is the feeding more work?	Not really.	Yes, they eat more, but that does not matter.
Do you process the milk, and is the quality of the milk different?	I make ghee and the fat percentage increased, so there is more ghee; I make dahi (curd) which is tastier.	I make dahi, which is first class, and the milk is also fine.
Is the dung different?	Dung is fine.	It is more work to clean the floor, because the dung is sticky.
Would you like to treat straw again, even if the men don't want to help?	We will convince them, but the money for the urea is a constraint.	I will do it again, even if I have to buy the urea myself.
Do you feed less concentrates now?	Before I gave ready mixed concentrates, now only the treated straw and berseem.	Straw and mustard cake, not much less.
Is this a large farm?	No, a small farm, 0,3 ha, and husband has a job.	No, landless, just 0,5 ha leased land; straw is obtained for free.
Who sells the milk? And to whom?	Milk is for home consumption of 4 persons.	The milk is sold to a vendor, who pays in advance once a month. The husband is the major decision maker on the sale and the income.
Source: adapted from J.G. Muylwijk, BIOCON, consultancy report, Sept. 1994.		

Despite these beneficial effects observed by farmers, the continued use of urea treatment after initial demonstration has been disappointing due to constraints like:

- sticky lung produced by the animals, complicating the (women's) job of preparing dung cakes;

- pungent smell from ammonia;
- fear of fungal spoilage of straw in open stacks;
- where the straw availability is limited, some farmers get discouraged because the stacks of straw get exhausted quickly.

The most important consideration for farmers not to take up this technology is that in most cases the returns are marginal. The suitability of urea treatment in different Farming Systems is now reasonably well understood. From all experiences in on-farm trials and economic calculations it appears safe to suggest that this technology is most likely to work under the following situations:

- when plenty of dry straw is available, free from fungal contaminations;
- where farmers have slender straws from rice, wheat and barley rather than coarse straws;
- when straw is cheap, and available in plenty relative to other feeds, i.e. the straw should be cheap compared to other feeds;
- when there is a shortage of grasses or other green feed;
- when water is freely and conveniently available;
- when the price of urea is not prohibitive;
- cost of polythene covering material should be low;
- labour availability should be good, though small stacks require not as high labour inputs at one time as the large stacks;
- space for storage of treated straw should be available;
- when the animals are low to medium producers (milk or meat);
- a ready market for milk or meat should be available. In other words, the produce should be sold at a remunerative price, allowing the purchase of the inputs.

It should be noted that when the availability of straw is high, it implies that its price is low, the same is true for labour availability and the price of concentrate or the cost of grass.

In principle, both large and small farmers can apply treatment. For poor and marginal farmers, the cost of the inputs like urea and polythene could be a constraint in the use of this technology. For larger dairy farmers, the availability of straw and labour may be a problem, or the production of the animals may be too high to have large amounts of (treated) straw in the ration. For some small farmers, grasses are available at low cost or even free by sending the animals for grazing on roadside and wastelands. This deters them from adopting a technology which costs money. In rainfed and arid zones, water availability can be a limitation to take up this technology.

More factors can be considered. The priority that many farms families put on crop production affects livestock production as a whole, particularly in cash crop areas. A crop farmer who purchases urea on credit or other limited resources, prefers to use the urea on cash crops rather than for the treatment of straw, where the returns are low and marginal. In Northern India, immediately after the paddy harvest farmers get busy in preparing the land for the wheat crop and they do not have time for storage or treatment of straw. Nor do they need treated straw because greens become rapidly available in that season. In order to avoid labour problems, some farmers, e.g. in Sri Lanka and Southern India prefer to treat the straw in small batches of 50-100 kg in pits or cemented rings or clamps, or even polythene bags. Large farmers in Northern India use combine harvesters for the harvest of wheat and paddy, since the cutting height is higher, long stubbles are left in the field, which are simply burned before preparing the field for the next crop. Many farmers also keep a portion of their land for the cultivation of fodder crops and they feed wheat straw rather than paddy straw. There are farmers who on the other hand actively engage in commercial milk production but who possess insufficient greens. Such farmers can apply urea treatment of wheat and paddy straw. However, when the individual animal output is high, and when concentrate is relative cheap, substitutional supplementation becomes more attractive than treatment of straw (#4.3.).

CONCLUSION

Urea treatment improves the nutritive value of straws, in terms of total content, energy digestibility and intake. The crude protein content is also increased but beyond what is needed! Farmers have confirmed these technical results in practical conditions. The effectiveness of the treatment depends on factors such as type of straw, concentration of urea, moisture level, environmental temperature, method of spraying, compaction and duration of the treatment and the method of storage. Some of these factors are governed by local conditions. The technology is technically feasible, yet in practice many farmers feel constrained to adopt the method. The most important constraints are probably the marginal returns from the technology, the non-availability of sufficient straw, urea, or too high levels of animal produce. It is well established however, that the technology can be adopted where:

- grasses or other green fodder are not available;
- straw is cheap and readily available;

- concentrates are relatively expensive;
- water is freely available;
- there is a ready market for milk, fetching good prices to the farmer.

Health hazards of feeding urea treated straw are unlikely. Deficiencies of minerals and vitamin A which can cause fertility problems can be easily overcome by supplementation, and they are due to the feeding of straw, not to the treatment.

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4.6.2. CHOPPING, WETTING AND SOAKING

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INTRODUCTION

In many areas of India it is customary to chop and or soak the straw that is to be fed. The two treatments are restricted to certain regions and this chapter will explain some of their backgrounds. It first discusses chopping and after that it reviews some reasons and ways of soaking and wetting.

CHOPPING

Chopping is done to reduce the size of the feed particles, whether stems, leaves or whole plant parts. The length of chopping is variable, it ranges from 10 - 30 cm. for stovers of millets, sorghum and maize in some parts of the country and to pieces between 1 - 3 cm. for straws of wheat and rice in other areas. The most extreme way of reducing particle size is the grinding of the material to a size of 0.1 - 0.3 cm. or less. Grinding is a very energy intensive process, particularly for straws and stovers. Due to the extreme reduction of size, grinding might affect the surface area of the straw exposed to digestive action in the rumen. It will not be discussed further

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because of its cost, and because the increase in digestibility is likely to be offset by a higher rate of passage resulting in a lower digestibility.

Regional differences

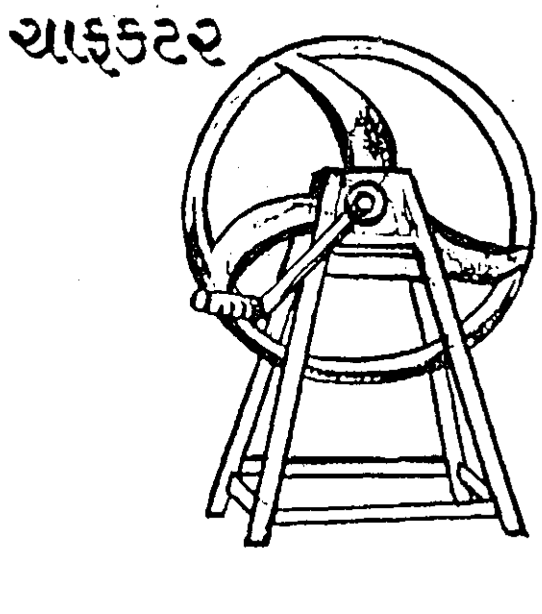
In the North-Western Gangetic plains, the wheat straw is not cut on purpose, but it happens to come in small particles from the threshing machine, the so-called wheat bhoosa (#5.2.). When bullock threshing is in use, the wheat straw is threshed to small pieces by trampling the animals on it. The rice straw is normally stored and fed in its long form, even in farming systems where wheat straw is fed in its short form. In the North-Eastern states, West-Bengal and Orissa however, the wheat straw is kept in its long form and the rice straw is chopped, with a knife (Figure 1). Finger millet straw in some areas of the South is, just like the wheat straw in the North, crushed during threshing, though under a heavy granite roller, and not in a machine. Chopping is quite common in the North-West, usually by mechanical choppers, but mainly on lush green feeds like berseem and the stovers of sorghum and maize (Figure 2).

Reasons for chopping

When all these differences between regions and straw types are taken into account, there must be several reasons for chopping, not solely one. A series of questions remains: does chopping increase the intake and digestibility of straw and/or berseem? Would chopping of stovers to a length of 10 - 30 cm. be done to increase the intake and digestibility?

Figure 1. A women in West Bengal chopping the rice straw by hand over a knife (courtesy J.G. Muylwijk)

Figure 2. A common wheel with knives used in the North-West for chopping of green feed, either hand or mechanically driven. (courtesy BAIF-Baroda)



There is some information indeed from literature that chopping increases intake and or digestibility, but this is countered by evidence to show that there is no or negative effect. Of course, when a long coarse or tough straw is chopped it will be easier for an animal to consume that feed, but will it eat more, and if so, is it (or the farmer) then better off? Why should the farmer force the animal to eat poor quality stems? It appears that chopping can be done to achieve a reduction of the amount of residues and/or waste, i.e. to make sure that the animal will eat what it is offered.

Even though there is not always an advantage in forcing the animal to eat more (#4.4.), it is possible to think of some reasons to do so. First, animals on lush green feed or high concentrate rations can obtain benefit from a certain amount of fibrous material in the feed. It helps to avoid bloat and to improve or maintain rumen function. Second, if stems and other low quality parts are fed the quantity of the ingested feed would increase, though at the expense of the quality. This is a reasonable strategy for farmers that do not aim at high production of milk and meat, but who like to have many animals, if necessary low milk producers, that produce dung and status nevertheless. For farmers with cows that have to achieve high individual productions it is not attractive to feed the animal with low quality stems, unless again the straw is fed as a means to maintain rumen function or for example to increase butterfat content.

Other reasons for chopping can be that it can to some extent increase the bulk density of the straw (#4.6.3.). Also, for making dung cakes it is convenient to use short straw which is easily mixable with the dung.

WETTING AND SOAKING

Water can be added to the feed in two ways, either by soaking the feed for some time, or by moistening it just prior to feeding. The former, soaking, is most common. Mostly farmers, particularly in the farming systems of states like West Bengal and Orissa are used to soak the fine straws. They feed it in a manger with water, quite often mixed with concentrate. Also in this case there are regional differences. Obviously, no soaking or wetting is done where water is scarce.

Reasons for soaking

Regional differences make it also doubtful whether there are any clear and consistent nutritional advantages to the soaking. Though it is claimed that soaking removes excess oxalate, e.g. in rice straw, it still remains to be proven that oxalate is really harmful to a ruminant (#3.5.). In systems where the straw is soaked, it is often done together with the concentrate, cakes or the salt available on-farm, almost in the form of a gruel. In that case, the soaking fulfils a similar function as the chopping, it reduces waste, and it makes sure that the animal is "forced" to eat what it otherwise might not like to consume.

If there is a nutritional advantage from soaking it might well lay in the fact that one may expect the rumen microbes and their enzymes to penetrate quicker in a prewetted feed, or that the wet straw is less abrasive to the animals' mouth. But again here, the evidence from the literature is contradicting. On the other hand, soaking is sure to cause a loss of nutrients by removing a part of the soluble carbohydrates. One would expect therefore that soaking would be to the detriment of straw nutritive quality unless the straw is fed together with the water that it is soaked in. There is a final possibility that when soaking is done in alkaline water from soil reservoirs, some treatment effect, however small, might occur.

CONCLUSIONS

Soaking, wetting and chopping can be done in several ways, but the reasons are not very clear. The literature with regard to the nutritive quality is contradicting, and effects are generally small or insignificant. The major reason for farm men and women to spend time and energy on either chopping and/or soaking might be that it forces the animal to eat what otherwise would go "waste". Less straw is thrown out of the manger, and in this way not more nutrients are ingested on a daily base, and less straw is refused, i.e. more animals can be kept over a longer period of time, but production of milk per animal per day will go down (#3.2.).

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4.6.3. DENSIFICATION OF ROUGHAGE

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INTRODUCTION

The low bulk densities of straws cause problems for storage and transport. Current methods of compaction, here called densification, include baling, briquetting and pelleting. The choice of technique depends on factors such as the type of material, desired final density, cost of processing, available systems of storage and transport, and market value of the densified feed. At present, baling and pelleting represent the two extremes of animal feed densification. Baling is used for fibrous roughages and pelleting for ground material that includes both roughage and concentrate feed ingredients. A disadvantage of baling is that the densification is not sufficient to significantly reduce the volume. Pelleting, in contrast, produces a high degree of densification (particularly of roughage), but requires much energy for grinding and extruding of the material. The third option, briquetting or block making, has until now been largely confined to the production of oilseed cakes and for the production of fuels. The process requires less pre-treatment of the material and less pressure than pelleting, thus reducing the energy requirement. This chapter describes the processes for compaction

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of ruminant feed into blocks (or wafers) or pellets, using fibrous roughage such as straws, stovers, tree leaves, grasses and leguminous fodders, alone or in combination with cereal grains, oilseeds and food processing residues. The state of knowledge is reviewed and the potential use of densified feeds for ruminants is examined.

NEED FOR DENSIFICATION

The bulk density of ruminant feeds ranges from 50-75 kg/m^3 for fibrous roughage such as hay, bagasse and paddy straw, to approximately 500 kg/m^3 for the ground ingredients of concentrate feeds. Baling of fibrous roughage increases the bulk density to a level between 100-150 kg/m^3. An immediate result of densification would be a reduction in required storage space. This may not be an important consideration for the rural farmer, but it is important for the urban farmer, and in particular for the urban dairies. Since the main markets for milk are found in cities and towns, the concentration of high yielding (8-12 kg/d) animals on the periphery of Indian cities is very high. Due to a combination of limited storage space and high transport costs, roughage supplies are scarce, and thus these farmers tend to feed their animals mainly on concentrate, partly also because of the high yield of the animals. A densified feed which also contains the appropriate mix of concentrate ingredients could be further useful as a "complete" feed source.

Problems related to transport of roughage also apply when natural disasters affect animal feed supplies for rural farmers. In the Indian sub-continent, where floods and drought commonly occur, it can be necessary to transport animal feed over large distances, often from one part of the country to another. The most common means of transport at present is by truck. In order to carry more straw, the trucks are stacked up very high, resulting in accidents due to instability and overturning of the trucks on rough roads or in strong cross-winds. Safety and cost efficiency of transport are, therefore, factors to be taken into account when considering densification. Reducing the volume-to-weight ratio would result in improved unit transport costs per kg feed that pay off beyond a certain distance. The use of compaction in rural areas may have a beneficial effect where rains are seasonal and where storage/transport of mature grasses is to be considered. It might facilitate the harvest of the grass in a more nutritive stage. Feasibility studies for village areas are not known however.

BLOCK MAKING

When deciding for a suitable technology for densification of roughage feeds, the following factors play a role:

- capital, operating and maintenance costs;
- ease of use and labour requirement;
- rate of output;
- nutritive value and palatability of the densified feed.

It is not proposed to examine all of the factors here, but in reviewing the block making process in particular, it is useful to compare this technique with the other densification techniques: pelleting or compounding. Pelleting is a commonly used technology, but largely confined to concentrate feeds. Compounding is a process where feed ingredients are mixed in preset ratios. It can be characterized as having high capital and operating costs, since the material must be comminuted or ground before pelleting which is itself an energy intensive process. The block making or wafering process offers a means to reduce operating costs by lowering process energy requirements, leading to lower densities.

Significant reductions in energy consumption can also be made using wafering techniques. The wafering or briquetting process has largely been developed for production of fuels from agro-residues, but its application to animal feeds is not well researched.

DENSIFICATION PROCESSES DEVELOPED IN INDIA

For the densification process through baling, materials like grasses, crop residues and legumes used alone, or they are mixed with other feeds in the desired quantity. As per adopted feeding standard/system, the nutrients are added together with water upto the desired moisture level. These materials are fed into the feeding chamber of the baling machine and compressed. The compressed bales are formed and kept after tying with wire or string.
In case of pelleting, the material is fed into a hopper. The auger inside presses the material and it passes through a desired diameter size of pellet dies forming pellets, that are dried and stored.

Traditionally designed manual and bullock operated hay baling presses were developed and are still widely used in parts of Maharashtra, Gujarat and Rajasthan. In Southern Gujarat, the grass bales of size 114 x 114 x 66 cm weigh around 110-120 kg, and these are prepared with the help of locally manufactured vertical balers. The disadvantage of this baling machine is the low bale density.

Box 1 Some machines and centres relevant for densification

A 7.5 HP, 3 phase electrical operated baler was developed by Gujarat Agricultural University, Anand and installed at N.C. Farm of Gujarat Agricultural University at Chharudi. The weight of each bale is 100 to 120 kg with an output of 12 to 14 bales/hr. The Central Institute of Agricultural Engineering, Bhopal developed a straw baler operated by 3 HP, 3 phase, 1440 rpm electric motor with output capacity of 6-8 bales/hr (C.I.A.E. Bhopal, 1993). The weight of a bale is 20 kg and its density 200 kg/m^3. Power operated ram type stationary balers are commercially manufactured. All these machines were observed to produce bales of 150 to 200 kg/m^3 density.

To overcome the low density problem, IGFRI in Jhansi has developed a stationary type high density baling machine for which the details are available on request (See relevant addresses below). The rectangular shape bales have a size of 30 x 30 x 45 cm, and grasses, paddy straw as well as stover can be processed to a density of 350 to 400 kg/m^3, with a machine capacity of about 1.0 tonnes/hr with 4 labours. A power operated feed pelleting machine for making the feed of concentrate, wheat bhusa, subabool (*Leucaena* leaves) and berseem has also been developed by the Institute. The densification processes using the machines developed at IGFRI, Jhansi can reduce the stack volume of grasses, crop residue and paddy straw by approximately 5 times, i.e., from 14.4 to 2.7 m^3/tonne. As a result, the transportation and handling cost can be reduced considerably depending on the distance. The cost involved in densification may range between Rs.80 to Rs.100/- per tonne, and is expected to be covered by reduced storage space requirement, longevity in storage duration and ease in handling. The cost of feed pelleting comes out to be in the range of Rs.150-180 per tonne depending upon die size.

CONCLUSION

The process of densification by baling appears suitable for areas where feed densities of 100-150 kg/m3 are sufficient. In block making with or without supplementation of concentrate, densities of up to 400 kg/m3 can be achieved. On the other hand, pelleting is suggested for use in concentrate mixtures where mixing and pelleting is necessary to avoid selection or rejection of a constituent of feed. For low quality roughages, there is no great scope for pelleting.

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4.7. FORAGE CONSERVATION, STORAGE AND FEEDING

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INTRODUCTION

Fodders and grasses can be preserved either as hay (dried fodder) or as silage (wet fodder), depending on the weather conditions and the available resources. Silage and hay are fed in some high input farms in India to bridge seasonal scarcity periods. However, silage and hay making have been extended only sporadically to low input farmers. Previous efforts have not given the desired result due to very high losses and reluctance in its acceptance by animals during the initial stages of feeding. Though the technology has been fully standardised and can be easily applied under favourable conditions, even little carelessness in its application results in quality loss or even complete spoilage.

On mixed crop-livestock farms in India, much of the roughage for animal feeding consists of crop residues. Most of the cultivated fodder is grown in the Northern and Western parts of the country, where still only about 8% of the area is under fodder crops. In the Central, Southern and Eastern regions, only 1-3% of the area is used for forage production. Another source of

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fodder is from grasses and shrubs that grow abundantly on the rangeland and roadsides during the monsoon season. Most of these reach their flowering stage during August-September. In irrigated areas of North India, fodder crops such as oats and berseem grow very fast during March and April. During this period, green fodder is available in plenty and many times it exceeds the daily animal requirements. From November onwards, there is a shortage of green fodder which causes animals to loose weight, particularly during the summer months. This situation is more prevalent in the Eastern and Central parts of India, where irrigation facilities are scarce.

Hay making is a suitable method to preserve these fodders and grasses. Leguminous plants, which are a major source of protein, can also be conserved in this way for feeding at a later stage. The low moisture content of hay considerably reduces costs and efforts involved in transportation and handling. Its flavours can be preserved well, especially if the drying process takes little time. Any method of feed conservation involves losses of dry matter in the process of fermentation and handling. Besides that, there is extra expenditure in terms of labour and materials on the processing of green fodder over direct feeding as green fodder.

This chapter deals with methods of conservation, storage and feeding commonly followed for hay, stovers, straws and various other forages. General guidelines for these methods are summarized, with particular attention to prevention of losses and improvement of the nutritional value.

HAY MAKING

The basic principle of hay making is to reduce the moisture concentration in the green forages sufficiently as to permit their storage without spoilage or further nutrient losses. The moisture concentration in hay must be less than 15% at storage time. Hence, crops with thin stems and many leaves are better suited for hay making as they dry faster than those having thick and pithy stems and small leaves.

Harvesting, curing and baling of hay

Leguminous fodder crops should be harvested at their flower initiation stage or when crown buds start to grow, while grasses should be harvested at their pre-flowering or flower initiation stage. Harvesting should be done preferably when air humidity is low. The harvested forage should be spread in the field and raked a few times for quick drying. The dried forage should be collected and baled when the moisture concentration becomes lower than 15 per cent. Baling the hay helps in storage and requires less space.

Artificial drying

Field curing is mostly done during bright sunny days, which causes bleaching of the forage and loss of leaves due to shattering. Nutrients may also be leached out if the forage is exposed to rain. To avoid these losses, forages can be dried in barn by flowing hot air though the forage. Its main benefits are that nutrient losses due to leaf shattering and bleaching can be avoided, and that the forage can be harvested irrespective of the prevailing weather conditions. Although artificial drying results in hay quality approaching that of the fresh forage, it is expensive and beyond the reach of small and marginal farmers.

Losses in hay making

Monsoon grasses and fodder crops come in flowering during August and September. Fast lignification and translocation of sugars in these crops occurs after this due to high temperatures, resulting in a rapid decrease of the digestibility. Considerable losses occur with the monsoon grasses, because they are not harvested and preserved at the stage when their digestibility is fairly high. This may be due to the prevailing weather conditions and the lack of interest and skills for proper preservation and storage. Preservation of any surplus fodder can be beneficial during a scarcity period.

Respiration by living plant cells after harvesting occurs at the cost of carbohydrates. However, this loss is nominal as compared to losses due to shattering, leaching and bleaching.

During the process of drying and curing, there are losses due to **shattering and dropping of leaves**, which are the most nutritious part of the plant. Legumes are particularly sensitive to leaf shattering.

Leaching is caused by rain during the drying period of hay, through which the soluble nutrients are lost. Continuous and excessive rainfall may result in large losses due to decomposition and mould growth.

Bleaching of hay, due to its excessive exposure to sunshine during the drying and curing process causes losses of nutrients, particularly carotene.

High moisture content at the time of storing may lead to **fermentation and moulding** of hay. If the hay is moist at the time of storing, fermentation sets in with a rise in temperature. The overall loss of dry matter and nutrients may range from 15 to 50 per cent, and may lead to development of mould, fungi and undesirable bacteria. A high moisture content at stacking time results in fermentation of forage and a rise in temperature, resulting in overall dry matter and nutrient losses ranging from 15 to 50 per cent. A moisture content above 15% may also lead to the development of mould, fungi and undesirable bacteria, which make the hay unsuitable for animal consumption. General guidelines, and points of attention for hay making are summarized in Box 1.

Box 1. Important points for hay making

- The crop is harvested for hay making at its pre-flowering or flowering stage, when its growth is levelling off and its feeding value is still high;
- hay is best made during rain free days;
- crops with thick and juicy stems should be dried after chaffing and conditioning, which will speed up the drying process and slow down the loss of nutrients;
- hay should be raked only a few times during the drying process in order to avoid the shattering of leaves and the bleaching of the hay;
- legumes should be raked in the morning hours to avoid leaf shattering;
- after drying and curing, baling and/or stacking should be done as early as possible. Storage under a roof is preferred;
- for hay baling, the maximum permissible water concentration is 15%. Storage of hay before sufficient drying may cause fire due to spontaneous combustion;
- storage of hay with higher moisture concentration may result in mould growth, making the hay unfit for feeding;

SILAGE MAKING

The basic principle of silage making is to convert the sugars in the ensiled fodder into lactic acid, this reduces the pH of the silage to about 4.0 or lower, depending on the type of process. In this way, the biological activities responsible for spoilage are inhibited. To attain this, the early establishment and maintenance of an oxygen free, i.e. **anaerobic**, micro-environment is essential.

The term 'silage' refers to any wet and/or green fodder, preserved by organic acids, chiefly lactic acid, that is produced naturally by bacterial fermentation of sugars in the plants under anaerobic conditions. Stored material is highly acidic and has a lower feeding value compared to the original green fodder in the field. Silage making is commonly recommended in most parts of India, but it has not been established for a number of reasons:

- a lack of surplus forage during the rainy season;
- an unreliable rainfall pattern, making farmers reluctant to ensile a forage surplus during the rainy season, since the actual feed shortage during the dry season will then also vary considerably. Often it is possible to bridge the scarcity period in other ways and without great complication.
- the requirement for labour (cutting, raking, collecting, chopping, pit construction and cleaning, ensiling) and materials (polythene, molasses) may be a problem in some areas;
- the organizational aspects (punctual and sometimes fast action is required) may be felt as a complication.

Some of these problems may be overcome if larger quantities of silage are prepared by the cooperative milk unions from the surplus green fodder during the flush season and supplied to its members during scarcity periods. There is also scope to prepare silage near the reserve forest areas by harvesting the forest grasses at a proper stage and ensiling them rather than allowing them to dry and burn. Box 2 lists some important points for silage making.

Box 2. Important points for silage making

- crops and plant material rich in soluble sugars such as maize, sorghum, oats, sugarcane tops, hybrid napier grass and other grasses are highly suitable for ensiling;
- the dry matter concentration of the forage at the time of ensiling should be around 15-30 %, but higher is possible;
- chaffing of the material for ensiling increases its compactness, thus eliminating the air space to the maximum extent;
- green to semi-green forage, which may use the oxygen present for respiration, results in high quality silage;
- the silo should be air-tight after filling;
- fermentation starts within hours after closing the silo, and accelerates over the next 2 to 3 days. It terminates after about three weeks. Organic acids, primarily lactic and acetic acid, ethanol and gases such as CO_2, CH_4, NO_2 and NH_3, are produced during the fermentation process;
- due to the production of acid, the pH of the biomass is reduced to a level below 4, resulting in the termination of all biological activities, after which the material remains conserved under anaerobic conditions.

Advantages of silage making are:

- when harvested at or before the flowering stage, more nutrients (per area unit, time unit and kg feed) can be available for animal feeding;
- losses due to shattering, leaching and bleaching during hay making are avoided;

- the silage making is less affected by adverse weather conditions (or fire), as compared to hay making.

Some disadvantages of silage making are:

- it requires labour for filling of the silo;
- the construction of a silo requires an investment;
- handling and transportation requires more effort as compared to hay, due to the lower dry matter concentration;
- nutrient losses are generally 10% over losses with green fodder, which may be more with smaller quantities;
- slight carelessness at the time of ensiling may result in heavy losses due to aeration;
- the marketability of silage is very low.

Box 3 summarizes general guidelines for preparation and usage of a silage pit.

Losses in silage making

The losses resulting from silage making are the sum of respiration losses, fermentation losses, effluent losses, and losses due to prolonged fermentation and moulding.

The **respiration losses** occur because the plant is normally still active at the time of ensiling. Respiration continues as long as air is available. During this stage, oxygen and sugars are converted into water, carbon dioxide and heat. Therefore, sound compaction and air-tight closure of the silage pit are major factors that inhibit and stop this process as soon as possible.

Box 3. Guidelines for preparing and using a silage pit

Harvesting
High (or medium) quality silage is obtained from high (or medium) quality grasses and fodders containing between 15-35 % dry matter. This is found at the dough stage in maize, at flowering in sorghum, ear emergence in pearl millet, milk stage in oats and at flowering stage in most of the grasses. Partial wilting of legumes is necessary to reduce the water concentration to about 70%. For proper filling and compaction, grasses, particularly those having thick and pithy stems, should be chaffed to 2-3 cm size.

Silo preparation
The structure must be thoroughly cleaned and if the bottom and sides of the silo are kachcha, a 10 cm layer of straw or waste fodder is spread on them. In all cases, such layer is advisable in cemented pits. Chopped fodder should be filled layer by layer of about 50 cm each within a day or two and compacted properly to remove trapped air. If fodder contains little soluble sugars which is the case in legumes, liquid or dried molasses should be sprinkled on top of each layer to increase the fermentation. The entire pit should be filled in the same manner up to a height of about 1.5 to 2 metres above the ground, to ensure that after complete setting the silage mass is well above the ground level, in order to avoid water collection in the pit. Trampling must be more thorough near the sides and edges of a trench silo.

Closing the silo
After properly shaping-up the mass on the top layer (dome shape), the silage pit should be covered as soon as possible with a layer of straw or waste fodder, and subsequently with a plastic sheet of 250 to 275 micron thickness to prevent oxygen from coming in. In trench silos, plastic sheets should overlap each other to avoid the entry of air. Sufficient weight should be put on plastic sheets to keep them intact. A layer of mud can also be put over plastic sheets. During the setting period cracks etc. must be properly closed to avoid the entry of water and air into the pit. The fermentation process will be complete in 4 to 5 weeks and after that the mass becomes stable.

Opening the silo
During the shortage of green fodder, silage may be fed to animals. While opening the silo, the cover should be removed properly and a plastic sheet is taken out in a section of the pit, taking care that the minimum possible surface is exposed to the atmosphere. Some mouldy material may be found on top and also on the side, which should be removed before taking the silage for feeding. A well-preserved silage will be of yellowish green colour, having a pleasant acidic smell, is not sticky, and is free from mould growth. Milch animals should be fed with silage after milking as feeding of silage just before milking may give some silage smell in the milk.

Fermentation losses occur during the fermentation process, because bacteria convert sugars into - mainly - lactic acid. Gradually, this end products create a micro-environment which is increasingly hostile to those bacteria, eventually stopping their activity. Throughout an average fermentation in a silage pit, bacteria use 4-5% of the energy present in the ensiled mass. If the water concentration at the time of ensiling exceeds 75%, juices will accumulate on the pit floor, and may flow out of the pit, causing **effluent losses**. If air is able to penetrate the silage, a **prolonged fermentation** may lead to an additional loss of organic material in the silage pit. This results in the production of butyric acid and moulding, and spoilage may take place.

SILAGES FROM DIFFERENT FORAGES

Silage from cereals like maize, oats and sorghum

Maize, oats and sorghum are important fodder crops, that are rich in carbohydrates. During periods of abundant green fodder availability, they can be chopped and ensiled to produce silage for feeding during scarcity periods. Sorghum and oats should be harvested at flowering stage when 50% ears have emerged, while maize should be harvested at its milk stage.

Silage from cultivated and forest grass

During the monsoon season, cultivated as well as forest grass grow luxuriantly, and there is abundant availability of green fodder. These grasses can be harvested at their pre-flowering or flowering stage when growth has levelled off while their feeding value is still high. If the weather is too humid for hay making, these grasses might be conserved in the form of silage for feeding during scarcity periods.

The main **stovers** used for silage are from sorghum, though also crops like pearl millet and green maize can provide stover for silage. The prussic acid which is present especially in younger sorghum plants or quick regrowth, and which is dangerous if fed to ruminants in larger quantities, is destroyed completely by ensiling. Particularly sorghum plants are green and juicy at the time of harvesting for grain. Normally the ears are removed and the plants are left in the field as standing hay. (See also #5.4.).

Large quantities of **sugarcane tops** are available in sugarcane growing areas during the crushing season. They are rich in soluble carbohydrates but poor in protein. Out of about 80 million tonnes of sugarcane tops, only 30% is used for animal feeding as fresh feed. The rest is partly used as fuel by the sugar industry. The silage is usually offered to the animals as wet fodder during the scarcity period in the summer months.

Tall varieties of **paddy straw** are grown in some traditional rice growing areas in India. They are susceptible to lodging under conditions of high fertilization, in which there is an excessive initial growth of the crop. To avoid lodging, about one third of the top portion of the crop is removed during the vegetative stage. Fresh straw of many dwarf varieties of paddy is quite succulent at maturity, when the crop is harvested and the grain is separated out. A moisture concentration of 50-65% in paddy straw at the time of harvesting is still suitable for ensiling.

In all these situations, the available biomass, including the succulent weeds, can be ensiled and utilized as wet fodder during the lean periods. Paddy straw treatment with urea/ammonia improves the feeding value of straw.

However, ensiling and urea treatment of straw have some basic differences, as presented in Box 4.

Box 4. Differences between ensiling of grass and urea- ammonia treatment of straw (adapted from Schiere and Ibrahim, 1989)

	(grass) ensiling	urea-treatment (of straw)
Basic process	microbiological fermentation	chemical reaction
pH during process	acid	alkaline
Addition of urea	not essential, may even be harmful	essential
Purpose of process	conservation of feed	increase in feeding value
Effect on nutritive quality	negative	positive
Use of pit or other structure	one large batch per season	several small batches per season
Need for airtightness	essential	desirable
Purpose of sealing	to keep oxygen out	to keep ammonia and moisture in
Name of process	ensiling	treatment

Water hyacinth is an aquatic weed, abundantly growing in Eastern India. In its fresh form it is not liked by ruminants. Its leaves are rich in protein but the plant contains 90-94% water. In order to prepare silage from water hyacinth, it is necessary to reduce the water concentration to about 70%. As the leaves dry faster than the petiole and the stems, they drop down during the drying process, and the nutritive value is reduced (#).

Berseem is an important green fodder legume in Northern India. It grows luxuriantly during March and April. However, it is not suitable for ensiling, due to its high moisture and protein concentrations: 85-90% and 14-18% (on DM basis), respectively.

A **mixture of berseem/paddy or berseem/wheat straw** in a ratio of 4:1 can be suitable for ensiling. Addition of molasses (4% of total biomass) further improves the fermentation and quality of the silage. For that purpose, any other material such as crushed maize grain, spent barley from breveries, apple pomace or citrus pulp, can also be used instead of molasses.

USE OF ADDITIVES IN SILAGE MAKING

For grasses, fodders or crop residues that are rich in sugars, sufficiently dried (i.e. above 25% DM) and with a CP-level under 20%, there is no need to use additives. In all other cases, additives do not only upgrade the silage quality, but they also reduce the risk of failure to preserve the forage. The benefits of using additives should be seen in comparison to the costs of applying them. The most common ones are organic acids, molasses and preservatives. Most of the undesirable bacterial activity can be prevented by adding an **organic acid** to the crop. By adding **molasses** to the silage, the pH of the silage can be quickly reduced to a level below 4.0. A standard rule is to dissolve 15 litres of molasses in 15 litres of water, before adding it to one tonne of silage. **Preservatives**, such as salt and sodium metabisulphite are sometimes used for ensiling forages. Salt adds flavour, and it mainly reduces water activity.

STORAGE STRUCTURES FOR SILAGE

A silo is a structure designed to store and preserve high moisture fodder such as silage. The selection of a silo is made on the basis of required capacity, climatic conditions and economic considerations. Different silo types are used to conserve and store fodder:

- horizontal silos, such as trench silos and bunker silos;
- vertical silos, such as pit silos and tower silos.

Trench silos are horizontal silos, commonly used for easy handling of the silage. Trenches of different sizes, with depths up to 4 m are used, but the size can usually be made as per requirement. On an average, 700 kg fresh silage per cubic meter can be preserved. The ground water table should be below the maximum depth of the silo.

Bunker silos are another type of horizontal silos that are used instead of trench silos, when the ground water table is high. The basic difference between trench and bunker silos is only that the former is below ground level, whereas the latter is above ground level.

Pit silos are circular or rectangular vertical pits with a depth of 3-8 m. Usually the required dimensions are prepared, keeping in view that the ground water table is lower than the depth of the pit. Circular pits are preferred as the silage can be compacted much better than with a rectangular pit. Both earthen and masonry structures can be used, but losses are lower and silage quality is higher in the masonry structure as compared to the earthen structure. Pit silos are most suitable and economical for storage of smaller quantities, such as frequently available in Indian conditions. Their cost is lower, and the losses are also lower than with the trench silos.

Tower silos are vertical silos, used instead of pit silos in areas with high ground water tables. They are generally of the so-called 'pacca-structure'. The cost of these tower silos is a major limitation for their adoption.

STORAGE METHODS FOR STRAWS AND STOVERS
(other than for silage and hay making)

Straws and kadbis are a major source of dry matter in mixed farming systems. Proper storage of such material is important. Different structures, including permanent and temporary types, are used for their storage. Different methods are followed to store paddy straw, wheat bhusa and stovers.

Storage of paddy straw is generally done on uplands in the form of stacks. The upper part of the stack is given a conical shape, which prevents the water from entering into the stack. The straw can be kept well for many years. However, improper shaping of the above portion of the stack may allow water to leak into the stack and spoil it. In Southern India, finger millet straw, which has a higher feeding value as compared to paddy straw, is also stored just like paddy straw. Straws of these crops are also used for thatching of structures erected to store crop residues. The intake of stored paddy or ragi straw is usually better than the intake of the fresh straw.

Storage of chopped wheat straw (wheat bhusa) is done after chaffing wheat straw to a particle size of 1-2 cm. Wheat straw is a main crop residue for animal feeding in Northern India. It is stored in permanent or temporary structures, depending on its quantity and the economical condition of the farmer. In Punjab and Haryana, wheat straw is generally stored in open structures, either vertical (called "Bunga") or horizontal (called "Dhar" or "Dhad"). Use of the vertical construction is more common where the heap is properly packed on a platform in a round structure of the required diameter, while the upper portion is given the shape of the cone. Long paddy straw, coarse grasses of *Saccharum* or dry sugarcane leaves, are used to thatch the structure in such a way that rain water cannot penetrate into the heap. The daily requirement is taken out from one side without dismantling the structure. In general, the feeding from such a structure is started only after the monsoon. The horizontal heap is covered with paddy straw or coarse grasses, and plastered with a mixture of mud and cow dung to avoid the entry of raining water. Since the surface area open to the sky is much larger in the horizontal structure, losses are also greater as compared to the vertical structure.

Long, dried **stovers** of maize, sorghum and pearl millet (Bajra) are tied in bundles, weighing about 10-15 kg each. These are called poolies. They are stacked on a platform or elevation in such a way that its slopes are directed on the outside. These structures are covered with paddy straw, sugarcane leaves or coarse and long dried grasses in such a way that rain water cannot enter into the stack. Large quantities of such stovers are stored in drought prone areas for feeding during feed scarcity.

SUITABILITY AND PRACTICES OF CONSERVATION

Feeding strategies based on conserved fodder include feeding of dry fodder (hay, dried crop residues or grazing of dried grasses), silage (preserved green fodder or grasses) and standing hay/stover (standing mature fodder crop or crop residue). Such fodders may been screened for their feeding value for ruminants, as presented in Table 1. Depending on the local availability of labour and other inputs, a particular conservation technique may or may not be suitable on a farm.

Dry feeding

Straws are a major source of roughage for ruminants, particularly after the monsoon, but also during planting and in the early wet season.

Silage feeding

When feeding silage, the following points should be considered:

- Silage should be fed after milking, as silage feeding during or before milking may add undesired flavours to the milk.
- mouldy and decomposed silage, if found on the top and sides of the silo, should be discarded;
- once a silo pit has been opened, it is better to feed it uninterruptedly until is empty. Otherwise, considerable spoilage may take place due to exposed surfaces that are easily subject to decomposition.

Table 1. Tentative screening of different fodder conservation techniques for animal feeding

Parameters	Silage from cereal fodders	Silage from grasses	Silage from fresh stover	Hay from cereal fodder	Hay from legume	Straw/ stover animal	Storage in body
Feed Value Characteristics:							
DM supply	+++	+++	+++	+++	+++	+++	N.A.
CP supply	+	+	+/-	+	++	--	+/-
Energy supply	++	++	+/-	+	+	+/-	+/-
Maint. ration	++	++	+/-	+	++	+/-	+/-
Growth ration	+	+	+/-	+	+	-	--
Medium prod.	++	+	+/-	+/-	+	--	N.A.
High prod.	+	+/-	-	+/-	+	---	N.A.
Farm Management Aspect:							
Peak labour saving	---	---	---	-	--	+/-	N.A.
Total labour saving	--	--	--	-	-	+/-	N.A.
Capital cost	---	---	--	-	--	-	N.A.
Transportability	---	---	--	-	-	-	N.A.
Feed security	++	++	+	+	++	+	N.A.
Farming System and their Suitability:							
Specialized Dairy Farming:							
In arid regions	+/-	+/-	+/-	+	++	+/-	N.A.
In humid regions	++	++	+/-	-	--	+	N.A.
Draft Animals:	++	+	+/-	+	+	+/-	N.A.
Sheep and Goats:							
Arid regions	+/-	+/-	-	+	++	--	+/-
Humid regions	+	+	+/-	+/-	+	--	+/-

+ positive effect. - negative effect. N.A. not applicable

Feeding of standing hay

In many rainfed farming areas, only one crop is grown in a year, generally during the monsoon. In such areas, fodder crops, crop residues or stovers of maize, sorghum and pearly millet are left in the field as standing hay. The plants at this stage dry gradually during the winter season, while their feeding value decreases with time. The daily required amount of stovers is directly harvested from the field and fed mostly after chaffing. This results in utilization of family labour during the lean period when there is not much work in the field. This practice is common in the Bundel Khand region near Jhansi and also in Central and Southern India, where sorghum is an important grain crop.

SOCIAL ASPECTS OF FODDER CONSERVATION

Silage and hay making are labour intensive and heavy tasks, often done by women. Therefore, the gender division of labour should be considered. When the basic fodder for hay or silage making is composed of grass which has to be collected in a short period, family labour will not be sufficient for this task. Possibilities to reduce the work load especially for women during the silage making process, should be explored.

Persons use communal or state land to collect weeds daily, enough for a few animals. How does the community or local leadership react when a farmer decides to employ a number of labourers to collect all the weeds in a short time, leaving the other people without any for the coming weeks ? Communal land is neither considered to be 'nobody's land', nor privately owned land, but there is a limit to freely remove the amount of vegetation one desires. The local rules for using the communal land are therefore to be considered and respected. Regular communication between users, is important, especially when the number of people using the land for their animals increases.

CONCLUSION

To avoid the loss of nutrients from green fodder at the time of abundant availability, and/or to maintain the nutrient supply during scarcity periods, fodder conservation can be useful. In humid areas, roadside/forest grasses and cereal fodders may be preserved as silage. In arid and semi-arid areas, surplus fodder - if any -may be preserved as hay or silage, depending on the weather conditions. Leguminous and other slender fodders such as cowpea, berseem or lucerne are more suitable for hay making but leaf loss is to be prevented. Fresh succulent stovers of sorghum and pearl millet and sugarcane tops may also be preserved as silage for better feeding value during the lean season. Since there are some unavoidable losses in quality as well as in quantity of fodder during storage, and since additional labour and capital is required for fodder preservation, such practices can only be recommended after thorough cost-benefit analysis. Conservation techniques are a standard practice at organised farms, but whether this technology should be extended to farming families for feeding of high yielding animals during the period of green fodder scarcity depends on local conditions.

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SECTION 5

CROP RESIDUES

THEIR USES

5.1. RICE STRAW - ITS PRODUCTION AND UTILIZATION IN INDIA

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INTRODUCTION

Rice (*Oryza sativa*) is the most widely grown crop in India with 43 million cultivated hectares yielding 746 million tonnes of grain. India occupies the world's largest area under rice, grown under a wide range of agro-ecological conditions. Rice straw is a major feed for ruminant livestock in India. The production levels of rice straw depends on variety cultivated, level of fertilization,climatic conditions, holding size, irrigation facilities, soil type etc. This chapter will discuss rice and rice straw production and utilization of rice straw as livestock feed and for other uses.

PRODUCTION

Rice is grown in India mainly as rainfed upland (16%), rainfed lowland (42%) and irrigated land (42%). The average rice yield on rainfed upland is 0.6 MT/ha (1 MT=1000 kg) while on rainfed and irrigated medium lands it is 1.3 and 1.7 MT/ha, respectively. Relatively high grain yields occur in

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ICAR, New Delhi, India

coastal states near the Arabian sea and the Bay of Bengal, some Himalayan as well as sub-Himalayan areas, Punjab, Haryana and Western Uttar Pradesh. Lower yields are obtained in Rajasthan, most parts of Gujarat, Madhya Pradesh and Maharashtra.

The grain to straw ratio varies from 1:1.3 to 1:3. The percentage of rice in paddy varies from 65 to 72 and the percentage of bran in rice husk is 15 to 20%. The grain and straw yields depend on environmental and genetic factors like variety, season, location, plant-height, soil texture and fertility, plant density, available water,fertilizer, weeds and their control, harvesting stage and methods. A brief discussion on the effect of these factors on the yield of rice straw is given below.

Varieties

A good number of varieties of rice has been developed so far. With IR8, Jaya, Ananda and Ratna varieties it is possible to realise a grain yield of 2.5 MT/ha in rainfed uplands, 3-4 MT/ha in rainfed low lands and 5-8 MT/ha in irrigated lands. The rice straw yield can be enhanced even when the ratio of grain to straw is low. Different varieties have different grain:straw ratios ranging generally from 1:1.3 to 1:3. Semi-tall and tall varieties produce relatively more straw than the dwarf varieties. Short duration varieties of rice contain relatively more leaves than long duration varieties.

Location

The yield of grain and straw differs between locations because of variation in agroclimatic conditions, e.g. soil type and fertility, amount and frequency of rainfall and temperature during the growth of the crop.

Upland rice is sown by broadcast at the start of the monsoon. This system is followed in almost all rice growing states in India but, mainly confined to tracts which get either the South-West or North-East monsoon. The major portion of rice crops in India is grown under lowland conditions, that is under submerged conditions.

EFFECT ON STRAW QUALITY AND QUANTITY

Plant density

Proper plant spacing is one of the important factors to obtain a good rice yield, particularly in transplanted conditions. There is a progressive increase in grain and straw yield with increase in plant population up to an optimum level of approximately 15 x 20 cm, though this density depends on the variety used. Plant density beyond the optimum level reduces grain yield but, leads to higher straw yield and better straw production. Spacing is wider in the wet season as compared to the dry season.

Soil condition

Soil fertility, soil texture, salinity, acidity and alkalinity affect grain and straw yield as well as their chemical and physical conditions. Accumulation of certain nutrients (Selenium) in the straw up to toxic levels may take place under adverse soil conditions such as the accumulation of Selenium in some areas of Punjab and Haryana resulting "Degnala" disease of cattle.

Irrigation

Rice is a water loving plant and requires a minimum of 125 mm of standing water in the rice field for its growth. Frequency of irrigation is directly affecting grain and straw yield. Rice cultivation in India is mainly rain based and only 4.3% of the total land area is under winter cultivation where assured irrigation is available. Irrigation if not done at the right time may lead to crop failure and the production of both grain and straw will be affected. The quality of straw will be better but, hardly any farmer will prefer that at the cost of grain production.

Fertilizer application

Fertilization with Nitrogen (N), Phosphorus (P) and Potassium (K) is necessary to maintain good yields of grain and straw.The standard recommended level of N. P, K fertilization is 120: 60: 60 kg/ha, respectively, for high yielding varieties of rice. In most areas in India, the recommended rates of fertilizer N for flooded tall *indica* rice have been limited to 30 to 60 kg/ha. Some trials have indicated that doses of up to 200 kg N/ha, 90 kg P/ha and up to 80/kg K/ha are required for good yield of grain and straw. With additional Nitrogen, plant growth will be higher but, grain production will be reduced. However, high levels of fertilizer use are capital intensive and unsuitable for resource poor farmers. Even resource poor farmers with sufficient water cannot grow high yielding varieties due to relatively high costs of inputs like fertilizer and pesticides. To avoid the risk of crop failure, these farmers prefer traditional varieties which produce relatively less grain and straw but can stand climatic hazards to a considerable extent. This implies a low input oriented farming practice in most situations where the high yielding varieties are not suitable. Farmers in different farming systems have different requirements of grains depending on family size and composition, cattle numbers and availability of inputs. The straw production varies accordingly in terms of quantity and quality.

Weeds and their control

Weeds compete with the main crop for nutrients, sunlight, water and space, thus reducing production of grain and straw resulting in reduced rice yields. Weed control is, therefore, essential for good production but it is labour intensive. Some weeds, however, can be used as cattle feed.

Harvesting

The method of harvesting influences quality and quantity of straw. Early harvest may provide good quality straw (some greenness of straw will remain) but grain quality and production will be negatively affected. Hardly any farmer will prefer to do that. The cutting height affects straw yield, as lower cutting increases straw yield. Harvesting of the plant is done at a certain height for two reasons: (1) The bottom most part is generally waterlogged, coarse and is not easily relished by cattle. (2) It is mixed with the soil to maintain soil texture and soil fertility. In waterlogged land, the plants are harvested at 20-25 cm height from the surface of the land and the plants thus left grow vegetatively, being either utilized as cattle feed or production of another rice crop known as ratoon crop. However, ratooning is not a common practice in rice cultivation and is mostly done in areas where other cropping is not possible.

Threshing

The method of threshing affects quality of straw. Bullock trodden threshing contaminates straw with soil and such straw is less relished by the animals. A hand-beating method or threshing by a Japanese paddle thresher provide good straw which is relished by cattle and easy to store in stacks.

Storage

The traditional method of storing of paddy straw in Indian villages is in circular or rectangular stacks built in open air over a platform (made of indigenous materials like bamboo, wood, jute-sticks, bricks etc.). Storage improves palatability of straw if done properly and if there is no fungal or mould growth. Stored straw is preferred by animals over freshly harvested straw. Wet straw is not stacked to avoid spoilage. Good stack structures avoids percolation of rain water inside the stack and only the outer layer of the stack is spoiled.

UTILIZATION OF RICE STRAW

Rice straw is used as feed for ruminants and for many other uses like manure, thatching, paper pulp, alcohol, mats, poultry litter and mushroom production. Besides the straw, rice also produces rice polish, rice bran and rice husk. On an average, there is 20% husks, 10% bran, 3% polishings, 1-17% broken rice and 50-66% polished rice.

Rice straw as feed

Rice straw is fed to cattle and buffaloes in India since ages. Though rice and wheat straw on average have a similar nutritive value according to laboratory analysis, in some parts of the country like Punjab, Haryana and Western Uttar Pradesh, wheat straw is preferred over rice straw. This is possibly due to "Degnala" disease which is a problem in those areas. Farmers in these areas mostly cultivate green fodder and mix it with wheat straw (which needs not be chaffed and is commonly available in that form) and feed it to the animals which is labour saving, while rice straw chaffing is labour intensive. Rice straw is fed at home as basal diet in most areas where green fodder is scarce. Stubbles and ratoon left in fields after harvesting of rice are also grazed. Rice straw is a poor quality feed in terms of protein and mineral content. It is high in lignocellulose and insoluble ash. The chemical composition on a dry matter basis is presented in Table 1.

Table 1. Chemical composition of rice straw (% on dry matter basis)

Organic Matter	82
Crude Protein	4
Crude Fibre	37
Non Fatty Esthers	43
Total ash	18
Calcium	0.14
Phosphorus	0.05
Neutral Detergent Fibre	75
Acid Detergent Fibre	54
Cellulose	37
Lignin	8
Silica	8

Rice straw is poorly palatable and its intake by animals is low. However, the intake of straw depends on straw type (coarse, fine, long, dwarf, leafy, steamy, fresh, stored, hard, soft), animal species and breed, body weight of animals, other feed in the ration, physiological state, climatic stress etc. In general, fine (slender), soft, long, leafy and stored rice straw is preferred by animals. Dry matter intake and digestibility of rice straw free from dirt and water lodging, in different species is presented in Table 2. The DMI is highest in buffaloes followed by cattle, whereas sheep and goats have relatively low DMI's. However, DMD is similar in cattle, buffaloes and goats but, seems lower in sheep.

Table 2. Dry matter intake (DMI) and digestibility (DMD) of rice straw consumed by different animal species *)

	Cattle	Buffalo	Sheep	Goat
DMI (g/kg$^{0.75}$)	67 (46-87)	83 (60-105)	43 (25-60)	43 (40-46)
DMD (%)	48 (40-55)	47 (44-50)	42 (40-44)	48 (46-50)

*) Figures within parentheses indicate ranges (Prasad *et al.*, 1993)

Different parts of rice straw (node, internode and leaf blade) differ in chemical composition and digestibility as shown in Table 3. Unlike in most other straw types, in rice the stems are preferred over the leaves. Newer short straw varieties with less stem and, therefore, more leaf do always have a better straw than traditional tall straw varieties.

Table 3. Chemical composition (g/Kg DM) and digestibility (g/kg) of different parts in rice straw at 40 kg N/ha

Characteristic	Node	Internode	leaf blade	Whole plant
Crude protein	42	46	40	37
ADF	459	508	478	475
Cellulose	337	375	280	295
OM digestibility	495	418	584	501
NDF digestibility	428	398	522	430
ADF digestibility	380	364	493	400

(Source: Mahendra Singh, 1993)

Other uses of rice straw

Manuring/composting: This can be done in two ways. Either the stubbles are mixed with the soil to maintain soil fertility, a common practice in the rice growing areas of the country. Also unused and spoiled straw (either left by the animals, spoiled during storage or waterlogged and unfit for consumption) is generally kept in a place along with dung and allowed to form compost which is then used in fields for manuring.

Thatching: Rice straw is used for thatching everywhere in the villages in the rice growing areas, particularly in the Eastern Indian States.

Poultry litter: Chaffed rice straw is used for bedding material in deep litter poultry keeping in the Eastern Indian states.

Mushroom cultivation: Rice straw is used for mushroom culture.

Packing material: Rice straw either chaffed or unchaffed is used as packing material for transport of goods to avoid breakage/spoilage.

Industrial uses: Rice straw is industrially used to manufacture paper, straw-board, alcohol, hats and mats, ropes, baskets etc.

FEEDING SYSTEMS OF RICE STRAW

Feeding and use of rice straw vary between farming systems. Since rice straw is poor in nutrients, it is generally supplemented or occasionally treated for better utilization by animals, depending on level and type of animal production. In spite of its low nutritive value as measured in the laboratory, it can also be valuable as an emergency feed to help animals survive a period of feed scarcity.

Supplementation

In low input farming systems, straw is the basic feed supplemented with field or roadside grazing, kitchen wastes, vegetable wastes, fruit wastes or whatever is available throughout the year. In a poor man's farming system (marginal or landless), rice straw is substituted by field grass as much as possible. Supplemental feeding of concentrates is more important with lactating and working animals. The associative effect of low levels of supplementation (field grass/concentrate) results in increased intake and efficient utilization of rice straw by animals (#4.3.).

In high input farming systems, rice straw is substituted by cultivated green fodder or high levels of concentrate. In some parts of the country where high quality green fodder is fed at high levels (Haryana and Punjab) some straw is fed as supplement to improve the consistency of animals faeces. In commercial dairy farms near the cities and towns, rice straw is used as supplement to provide some fibre in concentrate based rations to maintain normal rumen function (#4.3.).

Treatment

Many methods have been investigated of which most are technically sound but economically unattractive. The objectives constitute a mix of improved intake and digestibility of straw, as well as a correction of deficiency by adding proteins and minerals. None of these treatment except for chopping and soaking (#4.6.2.) and to some extent urea treatment (#4.6.1.) has been successful under field conditions.

In low input farming systems of West Bengal, Bihar, Orissa and Assam, the bullock trodden rice straw is generally not chaffed. The texture is soft and such straw is fed as such to the animals. However, straw threshed by paddle thresher/hand beating is chaffed and soaked with water and fed to the animals in the Eastern Indian States. Chaffing reduces selective consumption and wastage by animals and it may improve intake if the particle size is very small. However, increased intake is followed by faster rate of passage and lowered digestibility. Soaking softens straw and possibly has some treatment effect if the water is acidic or alkaline (#4.6.2.). In high input systems rice straw is either fed as such or in chaffed form. Urea treated straw in such systems is not relevant because of high levels of concentrate feeding, high levels of milk production, and often a high price of straw on the urban market.

GENDER ISSUES

Women and children largely contribute in the production and processing of rice straw. However, there is a great degree of variation of women's role in aspects depending on socio-economic and cultural factors (#2.1.). Women in small holder farming systems do most of the physical work themselves, while women in higher caste or income levels also have access to hired labour. The work mostly carried out by women in rice straw production includes:

- transplanting of rice;
- threshing of straw (not always);
- chaffing, soaking and feeding of straw to the animals;
- cleaning of residual straw from the manger followed by composting;
- making of baskets, ropes (not always);
- harvesting (not always).

Work carried out mostly by men includes:

- cultivation of rice which includes land preparation and sowing;
- manuring, intercultural operations;
- harvesting, transporting and threshing;
- stacking and storing of straw.

CONCLUSION

The quantity of rice straw produced per hectare largely depends on the variety used and on the management practices adopted. In addition to these factors, quality of rice straw is mainly influenced by the method of storage. Traditionally, rice straw among its other uses has been a valuable source of feed for cattle and buffaloes in both low and high input farming systems. Other than in most other straws, in rice the leaves are not always better than the stems.

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5.2. WHEAT STRAW - PRODUCTION AND UTILIZATION AS ANIMAL FEED

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INTRODUCTION

In India, wheat is grown on about 24 million hectares, occupying about 50% of the total area under food crops during the winter (rabi) season, and making a major contribution to the total grain production. This chapter describes the production and agronomy of wheat in relation to the quality and quantity of straw produced. It also reviews the effect of environment on straw production, and gives a brief account of the different feeding methods.

PRODUCTION OF WHEAT AND WHEAT BHUSA IN INDIA

Wheat is the major cereal crop in the winter season, particularly in Northern India. Its grain provides a staple food for humans and its straw is a major feed resource for ruminants. The bread type (*Triticum aestivum*) is grown on more than 87% of the area under wheat in the country, on well drained loamy and clay loams in the alluvial plains of Uttar Pradesh, Bihar, Punjab, Haryana, and parts of Rajasthan. The macaroni type (*Triticum durum*) is

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grown on less than 12 % of the area on the black soils of South Rajasthan, M.P., Maharashtra, A.P. and Karnataka. The main wheat producing region is the Indo-Gangetic plain, where the winter is cool and where the crop can be grown for a period of 5-6 months.

Many farmers in states like Punjab, Haryana and Uttar Pradesh separate grain by threshing the crop with power driven machines which yields straw pieces of 1-3 cm in length or finer. This type of straw is called bhusa in those states and it is used as ruminant feed since ages. Wheat bhusa is stored either in a stack or bonga, depending on the availability of space and time. In North West India, wheat bhusa is offered to all categories of ruminant animals throughout the year, either alone or in combination with other feeds, depending on their availability and the type and level of production expected from the animal.

VARIETIES AND THEIR CHARACTERISTICS

For some time the emphasis was on the breeding of disease resistant wheat varieties with a grain quality suitable for "chapaties". Such varieties developed during 1930-1960 were designated under the series as N.P. (New Pussa), Pb.C. (Punjab cross), K. (Kanpur), R.S. (Rajasthan), Hy (hybrid) of M.P. and NI (Niphad). However, these series were fertilizer non responsive and had a tendency to lodge with irrigation and better management. The genotypes are tall, producing numerous long slender leaves (140-150 cm) and the weak straw was accepted as animal feed due to reasons of better digestibility. The major break-through in this respect came after the introduction of the dwarf gene-'Norin 10'. Dr. Norman E. Borlaug, the Nobel laureate force behind the green revolution arranged to supply India with the four most promising strains in 1962. After extensive tests for suitability, a large quantity of seeds of the two varieties 'Lerma Rojo 64A' and 'Sonora 64' was imported in 1965-66. They had desirable attributes in terms of grain yield, e.g. dwarfness, relatively stiff straw, earliness and good resistance to rusts, as well as a high response to fertilization and irrigation. With additional breeding material supplied by CIMMYT, it was possible for Indian breeders to develop the 'Kalayansona' and 'Sonalika' varieties to suit Indian consumers' preferences. Both these varieties became popular in the country and they helped India to achieve new heights in wheat output. From then on more than 160 wheat varieties have been bred and released in India to suit different growing periods and agroclimatic zones.

AGRONOMIC PRACTICES

Wheat is sown in adequately firm and pulverised soils from loamy to clay loamy by broadcasting in rainfed areas, either by drilling or in a furrow behind the tiller. Sowing is from mid October till the first week of January, and all over Northern India the crop is harvested in April / May.

Loamy soils are ideal for wheat cultivation. Under rainfed conditions, farmers try to conserve soil moisture from late rains. They do so by ploughing the land only once for field preparation, followed by 2-3 harrowings with adequate levelling, and with seed rates of 100 kg/ha. If wheat sowings are delayed beyond November 15 grain yield reduces at a rate of 100 kg/day. There is a corresponding reduction in the total straw production also. Partly this is compensated by increasing the seed rate, under late sown conditions to 125 kg/ha. For irrigated timely sown high yielding dwarf varieties, 4-5 harrowings are done to make the loamy soil quite pulverized.

Recommended nitrogen, phosphorus and potash levels are 60:40:30 kg/ha, for rainfed varieties, and 120:60:40 kg/ha, respectively for irrigated timely sown varieties. Out of the total, half of the nitrogen, and full doses of P_2O_5 and K_2O are applied at the time of sowing. The remaining nitrogen is applied in two equal doses at the first and second time of irrigation. The first irrigation is done at about 20-25 days after sowing and a total of 3 to 5 irrigations are done at similar interval (20-25 days) depending on soil conditions and rains. Nitrogenous fertilizer and/or irrigation enhance the production of biomass.

EFFECT OF MANAGEMENT ON STRAW QUALITY AND QUANTITY

Just like in all other straws, the effect of management and environment on straw quantity and quality appears to be important and has an over riding impact on the genetic basis of these traits. The major effects of management will be discussed before proceeding to the nutritional qualities and feeding systems of wheat straw.

Field preparation

Unlevelled land, big soil clods and uneven moisture distribution lead to uneven germination, non-synchronized growth, development and maturity of the crop, with subsequently low yield. Some shoots become ready for harvest while others continue to translocate their soluble nutrients to spike. The secondary tillers remain immature at harvest, they are tender and they contain a high ratio of solubles to cell walls (# 3.3). The result is a reduced quantity, but a relatively good quality straw.

Wheat is sown at 3 - 5 cm depth, along with fertilizers that are kept a little deeper than the seed. As said before, general recommended seed rates are 100 kg/ha. Rich soil can support higher plant densities than sandy and light soil. Late sowing needs a higher seed rate of 125 kg/ha because tillering is poor. During sowing, the control over seed rate is essential to avoid uneven depth and seed pouring. Seed that is sown deep takes more time to emerge and remains immature at harvest time: a loss in terms of grain, a gain in terms of straw quality. Higher seed rates, i.e. plant density, results in thinner and softer straw which splits during threshing, yielding thinner straw particles of relatively better nutritive quality.

Crop management

(Organic) manuring is done at the time of field preparation. Farmers either apply farm yard manure before ploughing, or they grow a green manure crop that is partly fed (e.g. berseem and mustard) and that has stubble and roots to be ploughed under. More organic matter in the soil is believed to result in better nutrient availability. Combined with application of chemical fertilizer and timely irrigation it gives a fast growing bumper crop. The plant stems of the wheat thus grown remain tall, thin and soft with a higher leaf content, resulting in a high grain yield, as well as more straw. Straw obtained from such a crop is also of a better quality, has a better intake and digestibility.

Irrigation and fertilization

Recent results indicate that at levels of nitrogen application from 60-150 kg N/ha, and an increase in the number of irrigations (up to 3) increases yields of both grain and straw. More than three irrigations generally continue to increase the straw quality without further increases in grain yield.

Crops that are infested with insects and other pests give low grain and straw yield. The latter is of inferior quality too. Control by insecticides or pesticides improves both yield and quality of grain, as well as quantity of straw. However, many farmers express apprehension on the effects of these agrochemicals on the animal health and either avoid feeding such straw, or feed it in reduced amounts.

Weeds compete with the wheat crop for soil nutrients and cause the crop plants to be shorter, with smaller spikes. Stunted growth occurs also if the field is poorly fertilized, leading to lower yield of grain and straw of inferior quality. However, in rich soil, a luxuriant crop and high plant population combined with weeds results in thin stemmed straw of low straw and grain yield. Since the leaf content remains low, the straw quality is likely to remain low as well, but together with weeds they provide good stubble grazing.

Rodent attack occurs more in thick bumper crops when the soil contains sufficient moisture for the rats to dig holes. The rats harm the plant and reduce the yield of both grain and straw, though the latter is of better quality.

Straw and harvest management

Wheat is harvested when the grain is dead-ripe about or below 17% moisture and when the straw is golden yellow and brittle. However, a somewhat earlier harvest at physiological maturity does not only yield straw with better leaf content and higher grain yield, but the leaves and stems also remain better digestible and palatable. Unfortunately, threshing by machine requires brittle stems and therefore the farmers allow the harvested crop to remain in the field for sun drying, at the detriment of straw quality. A delayed harvest has the same, negative effect on straw quality. Delayed harvesting causes shedding of spikes and grain loss, because the plant becomes more brittle and fragile. Shedding of leaf leads to reduced straw quality because of the higher nutritive quality of the leaves.

Hand harvesting is generally done at so called ground level (4-7 cm above the ground) by moving while squatting. The lower part of the plant stem is harder, the height of the harvesting is therefore a factor that determines the quality and quantity of the straw. A higher level of cutting would improve the quality, but reduce the amount of straw. Farmers with plenty of straw can cut higher, but not those who have only a small plot of land. Depending on the availability of labour and other feed supplies the farmer can decide the height of cut. Women who tend the animals and/or cut the crop may have a different preference than men in this respect.

Combine harvesting is done at about 25 - 35 cm above ground level. Grain losses are higher in taller, brittle and more fragile matured crops, and also with an inefficient combine. Loose straw that is thrown by the combine contains more leaves, and is of better nutritive value, but the amount of straw thus obtained is hardly one third of the total obtained while cutting at ground level. Stubbles are incorporated by harrowing them into the field to increase the soil organic matter, or simply to get rid of them.

Combine harvesting is done by large and not by small or marginal farmers. The latter category needs more straw due to non-availability of quality feeds and fodders, and also combine harvest is too costly for many of the small farmers. Lately however, even large farmers realize the value of wheat bhusa because it can fetch some money on the market. Nowadays farmers even prefer feeding of straw of a variety containing more leaf content. A moving thresher has now been developed which harvests the long straw, breaking it simultaneously to bhusa and blowing it into the trolly attached to it. Its adoption still remains to be seen. During the combine harvest in brittle crops the leaves are shaken to the ground and their proper collection remains a topic for further work. Even a moving thresher would not be able to collect it. The hard stubble remaining in the field mainly consists of the stem component of the plant and is of an even lower quality.

Post harvest management and quality of straw

Rains after the harvest of the mature crop leads to the spoilage of the grain, the kernels imbibe water, swell and can germinate. A moist crop is also difficult to thresh and there may be a danger of fire due to overheating. The straw quality may be marginally higher because the leaves will be intact.

Threshing by poor farmers is traditionally done by treading under the feet of cattle/buffaloes on a threshing floor. Simple mechanical threshers and winnowers are now used by most farmers. These motor driven threshers blow the straw (bhusa) in the same direction as the wind. Heavy particles of straw fall closer to the thresher and the lighter particles - containing finely broken upper stems and leaves - fall furthest. Straw falling near the thresher contains hard and thick stem portions with nodes of lower quality, while the fraction away from the thresher is of better digestibility and intake. It contains more leaves and is thus softer.

When adequately stored, wheat straw characteristically has good keeping quality. Its surface is smooth and does not allow percolation of water into the heap. The upper wet layer may be removed after the rain and can be fed after sun drying. Storage of wet straw causes the growth of fungi. Animals may consume such straw in larger amounts but, it has a lower digestibility and may have a negative effect on animal health also. The stack of wheat straw can be covered quickly by mud in the field, a so called "dhar" in Haryana, or "bonga" in Western U.P. (# 4.6.1.). Straw losses are higher in the dhar than in the bonga system, because the bonga is a tall stack methodically covered either with soft long wild grass or with long leafless wheat straw itself. The bonga is used by villagers to store straw if sufficient space and time for storage is available near the house.

NUTRITIONAL CHARACTERISTICS OF WHEAT STRAW (BHUSA)

Wheat straw contains on dry matter basis 72-76% NDF; 44-49% ADF; 25-29% hemicellulose; 35-43% cellulose; 7-8% ash; 3-4% crude protein and 6-8% lignin. Leaves are always better than stems, and straw on the average contains 87-93% dry matter when dry, depending on environmental conditions. The digestibility is around 40-43% and intake is 1.5-1.8 kg/100 kg body weight in adult and 1.8-2.2 kg/100 kg body weight in growing heifers, of course depending on the level of production. Even this rate of intake and digestibility usually does not provide sufficient digestible and metabolizable energy to meet the animal's maintenance requirements. In terms of quality as measured in the laboratory, wheat straw ranks lower than - or similar to - rice straw, and it has a considerably lower quality than the stovers from maize, sorghum and millet.

Some farmers feed wheat straw as the main energy staple feed for all categories of ruminant animals throughout the year. Wheat straw is sold and purchased throughout Northern India, and regular wheat straw market can be seen in all small or big cities. In times of feed scarcity the price goes up. Many urban dairies in the North depend mainly on wheat straw as a source of roughage because it can be stored even in the open provided it is protected from rain, even though rain may spoil it to some extent. Wheat bhusa is considered by the farmer as security fodder and is the only fibrous residue transported to and from distant places for marketing. Some differences between paddy and wheat straw are presented in Box 1.

Box 1. Some notes on differences between paddy and wheat straw

Wheat straw in unchopped form is not fed to livestock. No animal is likely to consume wheat straw as such because the stem is hard and difficult for an animal to chew. Therefore, wheat straw is broken or cut to small pieces (1-2.5 cm in length) and then offered to animals. Particularly in the wheat growing areas of the upper Indian states (Punjab, Haryana, Uttar Pradesh), wheat straw is broken to small pieces during threshing, resulting in a material called "wheat bhusa". Separate chaffing as done for paddy straw in paddy growing regions is not generally required. Wheat straw is also stored/stacked in the form of "Bhusa" and not as bundles of long straw as in the case of paddy straw. In West Bengal, threshing of wheat is done differently, and the straw remains long and unbroken like paddy straw. As said earlier, the animals refuse to consume wheat straw in that form, and the straw is either burned or used for thatching. In some areas it is sold to paper mills.

There is a notion in Northern India that chaffing of paddy straw is difficult, but this is only true if somebody tries to cut it by North Indian method. In that case, the chopper reaches the straw but in Eastern India it is the straw, but in Eastern India chopping is done with the help of a foot-knife, running the bundle of straw over that knife. There is also an opinion that urea treatment softens straw and makes it easy to chaff. But to farmers in Eastern India it is the untreated straw which is relatively easier to chop than the softer treated straw.

In the Northern States paddy straw has been introduced relatively recently on a large scale. Farmers are still reluctant to feed it, partly also because of the fear for Degnala disease. Paddy straw is sometimes burned in those states, possibly also because it becomes available in a time when there is not much time to collect/store the straw, or because the feed scarcity is less prolonged. In other States of India, farmers are sometimes reluctant to feed wheat straw, and there it is the wheat straw that is sometimes burned.

Source: R.C. Saha

Table 1. Summary of feeding systems adapted by farmers

Supplementation (#4.3.)	Generally supplemented with either green fodder or concentrate (grain flour), or soaked protein supplements like, groundnut cake, mustard, cotton seed etc.
Chopping (#4.6.2.)	Chopped wheat straw is fed as such by farmers since the straw comes in pieces from the threshing floor
Soaking (#4.6.2.)	In some areas, soaking of chopped wheat straw is a regular practice while in others unsoaked straw is used
Selective consumption (#4.4.)	Animals pick up the softer parts of the straw. The remaining hard particles are left in the manger and either removed to go to the manure pit, or animals may eventually eat it if "sani" is made from it
Urea treatment (#4.6.1.)	Wheat straw can be treated according to various methods, and in conditions similar to all other straws

FEEDING SYSTEMS

Different feeding systems adopted by farmers are listed in Table 1.

Wheat straw in its chopped form is offered in a manger to dry animals (cows and buffaloes) without much supplementation, let alone treatment. Dipping in water is done in certain part of the country (Western U.P., Haryana and Punjab). It is supposed to wash away dust dirt and fine parts that might damage the mucous membrane of the mouth. It is then offered to the lactating and draught animals. Ground wheat flour or dahl chunni is mixed with the straw so that animals consume the left over straw in the manger (#4.4.), and it is believed that this improves the palatability.

Almost all farmers supplement wheat straw with either green fodder, or with homemade concentrate (kitchen wastes also used) while feeding supplements to milking or draft animals depends on the production or work taken of the animal.

Wheat straw feeding to lactating animals generally is done as one-third of the total DM intake, but the ratio decreases as the milk production increases, depending on the availability and type of green fodder. In the months of June to September, wheat straw is mixed with green fodder such as sorghum, maize or guar. In the months of October-November, it is mixed with green fodder and in the months of December to April with green berseem, oats or sugarcane tops, and in the month of May and June with cowpea and maize fodder. Most of this applies particularly to the conditions in the North.

OTHER USES

In the absence of suitable jungle grass, wheat straw is used to cover the straw storage structure (bonga). For this purpose, soaked long straw is crushed a little for making rope. Long unchopped straw is also used as thatching material by poor or landless farmers/labourers. Wheat straw is a suitable material for mushroom production, particularly for *Pleurotus*. Last but not least, left over chopped wheat straw (bhusa) in the manger either goes to the manure pit to make farmyard manure, or it is mixed it with dung to make dung cakes, a common fuel in many farm households.

FARMERS' PERCEPTIONS

Wheat straw is considered to be a major staple feed for all categories of ruminant animals, and it is fed throughout the year. It is also sold and purchased throughout Northern India. Regular wheat straw marketing can be seen in all small or big cities. In periods of feed scarcity the straw price goes up and due to this reason no farmer wants to waste it. Urban dairies depend on wheat straw for their roughage supply, because it can be stored even in the open, provided it is protected from rain. Farmers consider chopped wheat straw as a security fodder and is the only fibrous residue transported for distant places for marketing.

CONCLUSION

Wheat straw is often available throughout the year. It is fed to cattle, buffaloes, sheep and goats after suitable supplementation either with green fodder or concentrate, after treatment or after soaking. It is one of the most widely used staple energy feeds, sold and bought throughout Northern India.

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5.3 FINGER MILLET

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INTRODUCTION

Finger millet (*Eleusive coracana*) is an important staple food in Southern Asia and parts of East and Central Africa. Compared to other cereals, the great merit of finger millet is that it can be stored for long periods (according to some, 10 years or more) without deterioration or insect damage. The grains form a staple food for the farming community and the stover is a source of dry roughage for the feeding of animals in areas with unreliable rains and marginal soils. The production and agronomy of finger millet will be briefly reviewed and after that, the value and use of finger millet straw as animal feed is discussed.

PRODUCTION AND CULTIVATION

In India, finger millet is cultivated in several states, and Karnataka alone accounts for more than 40% of the national production (Table 1). The straw of finger millet is considered to have a higher nutritive value than slender straws such as from rice and wheat.

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Table 1. Production of finger millet grain and fodder in different States (five years average 1981-85)

States	Local names	Grain area (*1000 ha)	Grain production (*1000 mt)	Fodder production (*1000 mt)
Karnataka	Ragi	1056	1208	3268
Tamil Nadu	Ragi	235	327	886
Andhra Pradesh	Ragalu	240	243	659
Orissa	Mandia	281	669	669
Maharashtra	Nagali	225	649	649
Uttar Pradesh	Mandika	162	445	445
Bihar	Ragi	142	225	225
Gujarat	Nagali	46	124	124
Madya Pradesh	Marwah/ Ragi	23	15	15

Source: Technology for increasing finger millet and other small millet production in India (ICAR 1988) Project Coordinating visit. All India Coordinated Small Millets Improvement Project. G.K.V.K. Campus, Bangalore

Finger millet is cultivated on different soil types but mainly on red and laterite soils. Alluvial and black soils are also suitable, provided they are well drained. The crop is cultivated mostly in the rainy season under dryland conditions. Out of a total area of 2.6 million ha, only 0.35 million ha receive irrigation. As a dryland crop, finger millet is sown in July in the southern parts of India. In the North, it is sown in May-June. Men, women and children have specific roles in the cultivation and harvesting depending on class, social status and region. Table 2 shows the gender division of labour and the role of bullocks in the cultivation of finger millet in a village near Bangalore.

The choice of varieties depends on the agroclimatic situation of the region. In the northern states, particularly at higher elevations, early maturity (90-

100 days) types are required. Medium and late duration varieties are preferred in the plains and the southern states because of photoperiodicity of the region.

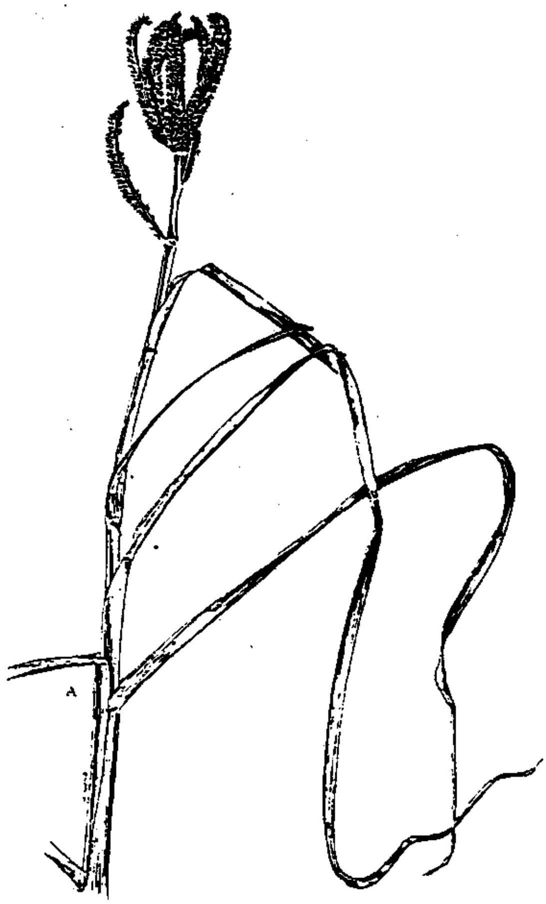
Table 2. Gender division of work in the cultivation of finger millet (adapted from Vijayalakshmi and Seetaramaswami, 1994)

Activity	Men	Women	Bullocks
Cultivation:			
ploughing	+++	-	+++
cold crushing	++	++	-
harrowing	++	-	++
manuring	+++	+++	++
Plant care:			
sowing (dry land)	++	++	++
sowing (irrigated)	+	+++	-
weeding	+	+++	+
thinning	++	+	++
irrigation	++	++	-
harvesting	+	+++	-
Post harvest:			
collection	++	+++	++
transport			
stacking			
threshing	++	+	+++
cleaning	+	+++	-
storage	++	++	-

- = no contribution; + = small contribution; ++ = medium contribution; +++ = large contribution

Under dryland conditions finger millet is often sown by broadcasting the seeds at the rate of 25 kg/ha. After two weeks when the plants are about 2-3 cm tall, they are thinned to reduce the plant density. The thinnings can be used as animal feed. When sown in rows, optimum spacing recommended for best yields is 25-30 cm and a plant to plant spacing of 10 cm for dry land. Denser planting results in less grain but more fodder and thinner steams, i.e. better stover. Generally, in southern India, finger millet is intercropped with crops like fodder sorghum (jowar), field beans, niger, castor and pigeon peas and in some places even with pearl millet (bajra). Finger millet is also rotated with other dry land crops like groundnut, horse gram, other millets, cotton, tobacco and oil seed crops like sesame.

Figure 1. Flowering shoot of finger millet (adapted from Purseglove, 1972)



Under irrigated conditions, finger millet is mostly grown after paddy when the water availability is not sufficient for a next crop of paddy. It is also grown after crops like sugarcane, potatoes, onions, carrots and chillies. However, with the adoption of modern management practices, finger millet is also grown as a sole crop.

Genetic variation in grain and fodder yield

Short duration varieties are semi dwarf, with a lower grain/straw ratio, higher proportion of cell contents, less cell walls, and therefore a higher organic matter digestibility than medium and late duration varieties (see Table 3). The higher harvest index (HI) of the longer duration varieties results in less cell solubles and a lower nutritive value of straw (#3.3.).

Table 3. Grain and fodder yield, chemical composition and *in vitro* digestibility of early, medium and late varieties

Characteristic	Variety		
	Early	Medium	Late
Grain yield (kg/ha)	3800	4900	5500
Fodder yield (kg/ha)	6100	6400	7300
Harvest Index	0.39	0.44	0.44
Height (cm)	89	101	115
Organic matter	90	91	91
Crude Protein	4.4	3.4	3.4
Cell wall content	60	63	65
OM digestibility (%)	62	59	58
Cell wall digestibility (%)	43	41	41
TDN (%)	56	54	52

Fertilizer and manures

The recommended fertilizer levels vary from state to state, but the general dosage (kg/ha) of N:P:K is 50:37.5:25 for dryland and 100:50:50 for irrigated land. Phosphorus and Potassium are applied at the time of sowing, while Nitrogen is ideally applied in two split doses i.e. 50% at the time of sowing, and the remaining 50% at 40-45 days after sowing. Application of farmyard manure reduces the fertilizer requirements and helps to improve the physical properties of the soil.

Table 4. Biomass, height and quality of finger millet straw, some approximate values

Criteria	Rainfed			Irrigated		
	Levels of N:P:K					
	F-I	F-II	F-III	M-I	M-II	M-III
biomass(1000kg/ha)	9	10	12	8	14	16
height (cm)	46	54	58	73	90	95
organic matter (%)	92	92	92	90	90	89
crude protein (%)	5	5	5	4	4	4
cellwall content	67	67	67	62	62	63
IVOMD (%)	59	59	61	61	60	60

Note: Rainfed: F-I(0:0:0) F-II (25:20:13) F-III (50:40:25)
Irrigated: M-I(0:0:0) M-II (50:25:25) M-III(100:50:50)

Source: Technology for increasing finger millet and other small millet production in India (ICAR 1988) Project Coordinating Unit. All India Coordinated Small Millets Improvement Project. G.K.V.K. Campus, Bangalore

The effect of fertilization on straw quality and quantity

In experimental work, the biomass production of grain and fodder per hectare and the plant height increased with the level of application of NPK

(Table 4). The organic matter content (%) remained unchanged with increasing level of NPK application. There is no significant effect of fertilizer application on the organic matter digestibility of the straw.

Effect of location on straw quantity and quality

Finger millet is grown at locations with different rainfall had different stover biomass yields (Table 5). Stovers from higher rainfall areas generally have lower crude protein levels, but higher cell wall contents. There were no differences between locations in organic matter digestibility, whereas the location effect was significant on the cell wall digestibility.

Table 5. Morphological characteristics, chemical composition and *in vitro* digestibility

		Location		
Parameter	**Range**	**Coimbatore**	**Vizayanagaram**	**Bangalore**
Grain yield (1000 kg)	3-6	1.3	1.8	5.0
Plant height (cm)	57-117	73	81	94
Composition(%DM):				
Organic matter	83-90	88	88	88
Crude Protein	3-11	9.5	3.8	6.9
CWC	58-72	64	68	66
In-vitro Digestibility(%):				
Organic Matter	43-62	51	52	51
CWC	26-45	34	37	35
TDN	45	45	46	45

Weeds, diseases, insects and pests

Most of the weeds commonly observed in finger millet belong to the grass family and timely weeding is important, this would provide a source of feed at the same time. Finger millet is affected by fungal and viral diseases, but insects and pests are not so common. Stem borers, aphids and caterpillars can at times cause considerable damage.

Table 6. Difference in harvest characteristics of traditional and improved finger millet cultivars

Cultivars	Total Dry Matter (g/m^2)	Grain:stem ratio	Harvest Index
Traditional	650-1500	26:74	0.21-0.33
Improved	1240-1400	42:58	0.40-0.41

Strategies to improve grain and fodder yield

In spite of its importance, the production of grain and stover is only 1000 kg of grain and 3000 kg of straw per ha. This is low as compared to other food crops, mainly due to marginal methods and conditions of cultivation; finger millet being a crop that thrives when other grains cannot grow well any more. Inputs like improved seeds and fertilizers are used only sparsely. Further, the breeding of finger millet for grain only has decreased the fodder yields. The local cultivars (land races) which are cultivated as fodder types had a low harvest index (HI = 0.21) and improved dual purpose cultivars and hybrids developed for grain purpose have a HI of around 0.40 (Table 6). Since farmers view grain and fodder as equally valuable, especially in conditions where finger millet is grown, it is essential to explore ways to increase both grain and fodder yield, in terms of quantity and quality.

A number of hybrid varieties is not preferred by the farmers since the stems are thicker and animals leave more residues as compared to local varieties (#4.4.). Laboratory studies show that both the land race and improved cultivars have comparable organic matter digestibility, but crude protein content is higher in local varieties. Proper matching of laboratory measurements and farmers perceptions of stover quality and total plant output deserves attention in research and extension (#3.3.).

Harvest

The crop is harvested at grain maturity. The general practice is to harvest the plants 3 cm above ground level and they are left in the field to wither; sometimes they are tied to sheaves and stacked to dry. Under irrigated conditions, the ears do not mature simultaneously. Earheads are gathered as they mature, heaped for 45-60 days to cure. Straw is then harvested on drying. In both cases grains are separated using either bullocks or passing heavy stone rollers. The grains are stored for human consumption.

Straws left in the field after removal of ear heads decrease significantly in nutritive value, probably due to loss of cell solubles. Straws harvested at grain maturity and stored under a roof do not change in quality as much (Table 7). In terms of nutritive value it is therefore worth to consider harvesting straw at grain maturity for subsequent proper storage (dry and protected from sun/rain).

Table 7. Chemical composition (on DM basis) and digestibility of finger millet straw on storing

Stages	Organic matter	CWC (%)	IVOMD (%)	IVCWD*) (%)
Grain maturity	89	66	61	48
10 days after grain maturity	90	68	57	43
60 days on storing	89	71	50	38
150 days on storing	88	70	49	36

*) IVCWD, in vitro cell wall digestibility

Leaf to stem ratio

The high yielding grain type cultivars show less tillering, but larger earheads as compared with fodder types (Table 8). The latter have thin stems with high tillering and small earheads. The modern high grain yielders have thick stems and a low leaf to stem ratio.

Table 8. Leaf to stem ratio of different types of cultivars

Type of cultivar	HI	leaf:stem ratio
Fodder type	0.22-0.25	30:70
Grain type	0.32-0.33	25:75

NUTRITIVE VALUE

Feeding trials on finger millet straw conducted at NDRI (Bangalore), showed considerable variation in chemical composition and in intake (Table 9). The accessions from Indian and African origin differed in organic matter, crude protein and cell wall content, within as well as between origins. Organic matter and cell wall digestibility varied among cultivars.

The cause for such variation in straw composition and digestibility may lie in the proportion of morphological fractions (#4.5.). In finger millet straw, the cell wall content in leaves (66%) is lower than in stems (71%), while cell wall digestibility is higher in leaves (51%) than in stems (33%).

Bullocks consumed daily 4-6 kg, heifers 3-5 kg and milch animals 6-8 kg of finger millet straw when fed without supplements.

Table 9. Chemical composition and dry matter intake of finger millet straw.

Chemical composition (%)	
organic matter	89-92
crude protein	3-5
crude fibre	34-39
cell solubles	10-21
water soluble carbohydrates	3-6
calcium	0.7-1.2
phosphorus	0.05-0.21
Intake (kg DM per 100 kg BW)	
bullocks	1.6
heifers	1.7
milch animals	2.0

Farmers' perceptions on nutritive value

There is a strong belief among farmers that traditional land races are superior in terms of straw quality than the hybrids developed for higher grain yields. Laboratory measurements do not confirm this, and the worst of the traditional varieties might be inferior to the better stovers of new varieties. Hybrids are low fodder yielders; again a general statement that may not be true across the board (#2.2.). Animals leave more residues of thick than of thin stems, such as of land race or densely planted crops. Higher phenolic content present in the straw is believed to give a bitter taste.

Table 10. Feeding systems

Feeding Systems	Remarks
Supplementation (#4.3.)	Supplementation as with all other straws
Chopping (#4.6.2.)	Finger millet stover is fed in the long form only, chopping of straw is uncommon in Southern as well as in Northern India. The method of threshing, under granite rollers, makes that the straw is shredded and chopped to some extent.
Selective consumption (#4.4.)	Feeding of finger millet straw in excess and long form, particularly to milk producing animals is common in many parts of the country. The residue, of lower quality is fed to working animals, low producing animals, and buffaloes. The final residue is used for compost
Urea treatment (#4.6.1.)	Treating straw with 4% urea using max. 100 litres. of water per 100 kg air dry straw in long form, storing it under airtight condition for a period of 1-3 weeks improves palatability, energy and protein content
Soaking (#4.6.2.)	Soaking of finger millet straw as feed is not commonly done in South India, in contrast to the soaking of e.g. rice straw in places such as Tamil Nadu.

FEEDING SYSTEMS

Traditionally farmers feed stovers along with supplements like greens, oil seed cakes, concentrates that are locally available or premixed in the market. Some feeding systems are given in Table 10.

OTHER USES

Due to its high palatability and nutritive value, farmers use the stovers almost exclusively for feeding cattle. Residues left by the cattle are used in the preparation of farm yard manure. In some parts in and near India (e.g. the hill regions of Sikkim, Nepal, Himachal Pradesh and Uttar Pradesh), after 30 to 40 days seeding, the excess seedlings are used for feeding cattle. In other parts e.g., Kashmir, Andhra Pradesh and Tamil Nadu, the animals are allowed a quick grazing to encourage tillering. Finger millet can also be cultivated as forage for feeding cattle and its nutritive value is comparable to any other cultivated grasses.

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5.4. SORGHUM AND PEARLMILLET STOVER

V.C. Badve, P.R. Nisal, A.L. Joshi, M.N. Amrith Kumar

INTRODUCTION

Grain sorghum (*Sorghum vulgare*), popularly known in India as jowar, is an important food crop and source of fodder in Indian dryland agriculture. The area annually sown with sorghum is 17 to 18 million hectares, and it is concentrated in peninsular and central India. The stover can contribute up to 40% of the value of the total crop in dry areas, but in dry years this may increase to 60% or higher if the grain fails to mature. Sorghum stover is preferred to pearl millet stover and rice and wheat straws by farmers. Since sorghum and pearlmillet stover are similar in many respects, a few notes about the latter are added in this chapter.

CULTIVATION, HARVEST AND STORAGE

Sorghum is grown mainly as a rainfed crop in the monsoon (July to October) and post monsoon (October to February) seasons. The on-farm grain yield is higher from monsoon crops (970 kg/ha) than from post-monsoon (590 kg/ha) crops. This difference is partly due to the greater use of hybrid sorghum varieties in the monsoon season, but it is also influenced by the

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different environmental and management conditions under which the two crops are grown. Traditional varieties are more common in the post monsoon season, because their stovers are more valued than those from hybrids or improved varieties, and also because growing conditions are less certain in that season. The yields of sorghum grain on farms are low compared to those obtained in breeding and agronomic experiments. This is because the use of inputs in weed control, soil and water and fertilizer application on farms are lower than in station experiments.

The harvesting practice most commonly used is to remove the panicles manually. The stover is harvested as a separate activity. The height at which stover is cut varies between 3 and 5 cm. For monsoon season crops it is sometimes not possible to harvest the stover without spoilage due to wet conditions in the field or rain during the period of harvest. In some areas where post-monsoon crops are grown, the whole plant (grain, stover and roots) is removed at harvest. The above ground material is fed with the roots attached after threshing.

The stover is stored by stacking bundles in a manner which assists run-off of rain water. However, there are losses in the quantity and quality of stover during harvesting, transport, storage and feeding. In some systems, the stover is left in the field, harvested daily and fed routinely to animals.

STOVER PRODUCTION

There is little information on the amounts of stover (kg/ha) or the grain to stover ratio for crops grown on farms. In research station experiments, the yields of stover and the grain:stover ratio vary widely (Table 1). The improved varieties are found to produce more stover and have a wider grain/stover ratio than the hybrids, although there is some overlap.

Table 1. Stover production (kg/ha) and grain:stover ratio for improved varieties and hybrid sorghums grown in the monsoon and post monsoon seasons in Maharashtra.

	Monsoon season		Post monsoon season	
Type of Sorghum	**Stover yields 1000 kg/ha**	**Grain/ stover ratio**	**Stover yield 1000 kg/ha.**	**Grain/ stover ratio**
Improved varieties				
Mean	7.3	0.39	6.3	0.42
Range	2.5-11.9	0.24-0.42	2.6-14	0.28-0.47
Hybrids				
Mean	6.6	0.47	5.8	0.52
Range	3.7-11.1	0.22-0.54	2.3-12.6	0.38-0.52

(Source: Badve *et al.*, 1993)

The factors causing most variation in stover yield are the growing conditions and the genetic make up of the cultivars. In general, the variation due to year and location for the post monsoon season is greater than the variation due to cultivar. For sorghum, which is currently available for the monsoon season, location effects are largest, followed by variety and year effects.

STOVER QUALITY

Farmers prefer stover from traditional varieties above stover from hybrids. While the reasons for this are neither fully understood, nor substantiated in laboratory measurements, it is believed that traditional varieties have more palatable stover, probably due to texture and sweetness (#4.5.). The factors affecting the nutritive characteristics of sorghum stover have been investigated in a small number of studies. The important characteristics appeared to be leaf and stem proportions and the variability in their digestibility.

Leaf and stem proportions

The proportion of leaf in the stover varies from 19 to 54 percent (Table 2). Available information indicates that the effects of year and location on the proportion of leaf are greater than those of cultivar. The differences between improved varieties and hybrids are small, indicating that the farmers' perception of better feeding value of traditional varieties is not only influenced by differences in leaf:stem ratios, but also by differences within either or both of those fractions. The differences in leaf:stem ratio and proportion of leaf in the stover are more or less similar for the two stover types.

Chemical composition

The contents of nitrogen, cell walls and cell solubles also vary in sorghum stovers and in their leaves and stems. The differences in digestibility of sorghum stovers and their fractions are due to differences in cell solubles and cell wall concentrations, as well as to the microstructure of the cell wall. How these different fractions are affected by changes in growing conditions and genetic make-up of plants is largely unknown.

Table 2. The proportion of leaf(%) in stover from improved varieties and hybrids grown in the monsoon and post monsoon seasons in Maharashtra

Kind of Stover	Monsoon	Post-monsoon
Improved varieties		
Mean	40	37
Range	29-54	22-50
Hybrids		
Mean	42	35
Range	32-51	19-51

(Source: Badve *et al.*, unpublished)

Digestibility

The leaf components of monsoon and post monsoon season stovers are more digestible than the whole stover. However, the differences are small (around 5 digestibility units) compared to the differences found in straw from wheat (#5.2.) or barley. The organic matter digestibility of whole stover is higher for post monsoon than for monsoon crops (Table 3). However, there is a large annual and local variation, with marginal differences between the cultivars studied to date. Sorghum grown in the same location does not have the best stover each year, which indicates important interactions. Also, the ranking of cultivars changes over years, though the ranking over many years tends to be fairly similar. The digestibility of the cell wall fraction of stovers varies even more than that of organic matter (#3.3.). However, the effect of year, location and cultivar on the digestibility of the fibre of different fractions rank the same (year > location > cultivar).

Table 3. Digestibility (%) of whole stover from improved varieties and hybrids of sorghum grown in the monsoon and post-monsoon seasons in Maharashtra.

Type of stover	Monsoon season	Post-monsoon season
Improved varieties		
Mean	55	60
Range	40-64	51-70
Hybrids		
Mean	54	57
Range	43-64	49-69

(Source: Badve *et al.*, 1993)

Pigmentation effects

Birds are a major crop pest that limit grain production from sorghum. Bird resistance is related to tannin contents in grains. Leaf blades and leaf sheaths from bird resistant varieties have higher levels of insoluble tannins and soluble red pigments. High levels of pigmentation are associated with higher levels of lignin and lower digestibility of cell walls. Both genetic and environmental factors affect levels of lignin and pigmentation which could lower the digestibility of cell walls. This effect is more in leaf sheath as compared to leaf blade and stem. Stems contain less soluble red pigments and insoluble condensed tannins than leaves, hence these phenolics are less important in digestion of cell walls from stems.

Pearlmillet stovers do not contain pigments which affect the NDF digestibility in sorghum stovers. The feeding value of pearlmillet stovers is below the maintenance requirements of cattle, indicating the need to supplement the diets based on this feed. There is not much information available on the urea treatment of bajra stovers.

PEARLMILLET

Pearlmillet (*Penisetum typhoides*), locally known as *bajra*, is grown annually on approximately 12 million hectares in the country, mainly as a monsoon crop in arid regions. The harvesting practices of millet are similar to those of sorghum. After sundrying, the stacking methods differ from region to region. The most common method is to stack the bundles of stovers in a circular fashion tapering at the top. There is lack of information on the nutritive value of pearlmillet stovers. Studies from ICRISAT in Niger indicate that the leaves and leaf sheaths have a higher cell wall digestibility than the stems (see Table 4).

Table 4. Range in cell wall digestibility of different plant parts in pearlmillet varieties.

Plant Part	Digestibility (%)
Leaf blade	56 - 62
Leaf sheath	38 - 45
Stem	28 - 35

Source: Reed *et al.*, 1987)

The large difference between plant parts of pearlmillet, which is not seen in sorghum, suggests that leafiness will influence the intake as well as digestibility of pearlmillet stovers.

FEEDING SYSTEMS

Farmers either harvest the stover after the grain harvest and carefully stack it, or harvest it and feed it daily to animals. Because the feeding value of these stovers is low, they can be treated or supplemented in order to improve their nutritive value (#4.3.; #4.6.).

Supplementation

Sorghum and pearlmillet stovers are generally of higher feeding value than rice or wheat straws. However, they still require supplementation to achieve livestock performance well above maintenance (#4.3.).

Treatments

Improvement in nutritive value of sorghum and pearlmillet stovers can also be achieved by physical or chemical methods. In chemical methods, treatment with urea is advocated (#4.6. - #4.6.2.). However, because the nutritive value of sorghum stovers is higher than that of other cereal stovers, improvements due to urea treatment are marginal and perhaps uneconomical. The major bottleneck in applying the urea treatment is that stovers need to be chaffed before treating, not a common practice level in parts of the country. Urea treatment of stovers in their long form is not effective because of run-off problems with the urea solution.

Selective consumption

The prevailing practice of not chopping the stovers in a majority of the sorghum growing regions, makes it possible to adopt selective consumption for improving nutritional value of sorghum stovers. The relatively low difference in the digestibility of leaves and stems suggests that the improvement in digestibility through this approach would be marginal. However, the higher rate of degradation of leaves as compared to stems would mean a higher intake of slightly better feed. For this approach, however, the amount of straw offered to the animals needs to be high, thus limiting its use to conditions with high producing animals and relatively low animal numbers (#4.4.).

Soaking

Due to its long form, sorghum stovers are difficult to soak. Chaffed material can however be soaked to reduce the losses of pith (#4.6.2.).

Chopping

In most southern parts of the country chopping is not practised. In these regions, the stover is first offered to milking animals and the refused part is fed to the less productive animals (dry, draught animals), which reduces the wastage of the stover. This practice also allows more productive animals to select the better parts of the stover. (#4.4.).

CONCLUSION

The nutritive value of stovers from coarse grains such as sorghum and pearlmillet seems to be higher than that of slender straws such as wheat and rice. This is perhaps due to higher cell contents in stovers than in the straws. Variations in the nutritional value of stovers from the sorghum and pearlmillet are caused more by environmental than by genetic factors. In general, leaves have a better digestibility and rate of digestion than stems, enabling a higher intake in varieties with more leaves. The pigmentation of sorghum, especially in its leaf sheaths, adversely affects the intake and digestibility by the animals. Improvement in feeding value of stovers from sorghum and pearlmillet through breeding will have to take into consideration the interaction(s) between genetic and environmental factors influencing digestibility. The feeding systems can adopt chopping, soaking, selective consumption and supplementation, depending on the farming system. Treatment is less effective than in slender straws since the stovers already have a relatively higher nutritive value.

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5.5. MAIZE STOVER

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INTRODUCTION

Maize (*Zea mays L.*) is the third most important crop in the world and it is grown under a wide range of climatic conditions. In India, maize occupies the fifth position in area, it ranks fourth in grain production and third in per hectare yield. Maize is grown on 6 million hectares producing about 9 million tonnes of grain and 18-20 million tonnes of stover. Uttar Pradesh, Rajasthan, Madhya Pradesh, Bihar, Andhra Pradesh and Himachal Pradesh are the major maize grain producing States in North West India. It is also an important crop for green fodder production. The average grain yield of maize in India is 1524 kg/ha. This is among the lowest in the world as most of it is grown in rainfed areas, the majority of which receives low and erratic rainfall. The low fertility status of Indian soils, cloudy weather during the Kharif season, the limited use of fertilizers, weed control, plant protection and water management measures and cultivation of traditional non-high yielding varieties in more than 55 per cent area are also responsible for such low grain and stover yields.

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CULTURAL PRACTICES

Soil and climatic requirements

Maize requires fertile, well drained, loamy soils neutral in reaction, and moist and warm weather. The most suitable temperature for its germination is around 20°C and for growth 32°C. Some 50-70 cm of well distributed rain is conducive of proper growth and yield.

Sowing time

In India maize is mainly grown during the kharif season. Generally, it is sown with the break of the monsoon. The optimum sowing time varies from region to region.

North-Eastern Himalyan Region	:	Mid March to Mid April
North-Western Himalyan Region	:	April to May
Northern Plains	:	Mid June to Mid July
Peninsular India	:	May-June

In irrigated areas to a limited extent, maize is sown from late September to early October in Northern Bihar and Eastern Uttar Pradesh, from mid October to mid November in Punjab and Haryana and during October in Andhra Pradesh, Karnataka, Tamil Nadu and Maharashtra. In the Tarai belt of Uttar Pradesh and in certain pockets in Punjab it is also grown during summer season.

Varieties

Varieties recommended for cultivation under different conditions are as follows:

Monsoon irrigated	: Ganga, Ganga 5, Decan 103, Ganga 11, Ganga, Safed2, Vvikram, Sartaj, Ranji, Ganga-3, Him-123, Kissan, Vijay, Parbhat
Monsoon rainfed	: Ganga 101, Decan, Ranjit, L-54 Ganga Safed 2, Vijay, Ganga 3, Ganga 5
Winter season	: Hi sarch, Partap-1, Vijay, Decan, Decan 105, Trishulata, MCV 508, Comp.
Summer season	: Punjab Sathi-1, Diara 3, D 765, African Tall, J1006

A large number of maize varieties is grown under different agro-climatic conditions. A wide variation exists in yield and quality of maize stovers due to variety, agro-climatic conditions and management practices. This chapter discuss the recommended package of practices of maize cultivation and it highlights the effects of genetic and environmental factors on quantity and quality of maize stover.

Seed rate and plant densities

To exploit the grain yield potential of improved varieties, some 55 to 70 thousand plants per hectare are required at maturity, also in marginal areas. However, under conditions of limited moisture availability a lower plant population is required. An amount of 18-20 kg seed/ha is required during the summer and monsoon season, while 22-27 kg seed/ha is required during the winter season.

Water management

Adequate water supply is essential throughout the growing season, particularly during pre-tasselling and silking stage. Thus, depending on the rainfall in irrigated areas, it should be irrigated to maintain the adequate supply of water. Maize is very sensitive to excessive soil moisture, particularly at a young stage. Therefore, excessive water during the rainy season should be immediately drained out.

Fertilizer requirement

Fertilizer requirement of maize under different growing conditions is given in Table 1.

Table 1. Fertilizer requirement for maize

Season	**kg/ha**		
	N	**P_2O_5**	**K_2O**
Monsoon Season			
a) Irrigated areas	120	60	30
b) Rainfed areas			
i) Sandy Loam to clay loam soils with adequate stored moisture	80	40	20
ii) Loamy sand to sandy soils with low stored moisture	40	20	10
Winter Season	150	60	30
Summer Season	60	30	20

Harvesting

The maize grain is ready for harvesting even at physiological maturity when the stalks and leaves are somewhat green but the husk cover has turned brown. In irrigated areas the plants are harvested along with cobs, stacked and the cobs are removed after sowing of the succeeding crop. In rainfed areas, the cobs are removed from the stalks and stalks are cut near the ground. Around cities, the green cobs are removed from the plant at milk stage and the stalks are harvested and fed to animals. Threshing of dried cobs is done by manual removal of grains, by beating the cobs with sticks, treading under the feet of bullocks or by using maize shellers.

Crop rotations

Important rotation followed in various parts of the country are maize-wheat, maize-barley/gram, maize-potato-wheat, maize-wheat-moong, maize+ cowpea - maize+cowpea (F)-berseem.

Uses

The green cobs are palatable and nourishing, consumed after roasting mature grains are extensively used as food and feed, while stover is a good source of feed for the livestock. It is also grown as a green fodder crop for feeding to the livestock fresh or after conservation in the form of silage. Thinnings or green stalks after removal of green cobs are also a good source of green fodder for ruminants.

Grain yields and quantity and quality of maize stover

A large variation exists between farm and experimental grain and stover yields in different seasons and agro-climatic conditions (Table 2).

Table 2. Comparison of maize grain and stover yield under experimental and on-farm situations

Particulars	Yield Kg/ha			
	Experimental		On Farm	
	Grain	Stover	Grain	Stover
Kharif season				
a) Irrigated areas	30-35	50-60	15-25	30-45
b) Rainfed areas	20-30	35-45	8-15	25-25
Winter season	50-60	70-80	35-45	55-65
Summer season	18-25	30-40	10-15	20-35

The residue of a grain crop of maize after removal of the cobs is called the stover, it forms an important roughage for ruminants. From a nutritional point of view maize stover is better than other straws as it has higher levels of crude protein and has higher digestibility than rice, pearl millet, sorghum, crude protein and oat straw (Table 3).

Table 3. Relative composition (%) of straws in India

Straw	Crude Protein	Cell walls	Silica
Maize Kadabi *)	4.6	67	2
Sorghum Kadabi	4.2	54	4
Pearlmillet Stover	3.5	55	3
Wheat Bhoosa **)	2.6	51	6

*) Stover **) Finely chaffed straw

In the North-Western State the maize stoves are preferred by farmers over rice and pearlmillet. The quality of maize stover depends upon the proportion of leaf and stem fractions of stover. The leaf fraction of the stover has a higher palatability and digestibility than the stem fraction, as well as a higher protein and mineral content. Thus, the stover with higher leaf-stem ratio is of better quality.

A large number of genetic and environmental factors affect the morphological and physiological development of the maize plant. They influence the rate of growth, the amount and ratio of various tissues produced, and the time of grain maturation. Subsequently, these changes are reflected in variation in quantity and quality of grain and stover as well as in the harvest index. A brief discussion on the variability in quantity and quality of maize stoves due to various factors is given below.
Under better management the improved varieties, being more responsive to the application of fertilizers, irrigation and other inputs, produce considerably higher biomass, grain as well as stover yields and harvest index than the traditional varieties. There is also variation in leaf-stem ratio, protein, fibre and mineral content, energy value and digestibility of stover of different varieties.

High temperature coupled with lack of moisture at the critical stage of maize can limit the growth and grainfill and result in a greater reduction in grain yield than in stove yield, leading to a very low harvest index. The lesser grain fill results in retention in the stover of more than the normal amount of carbohydrates and higher digestibility. Thus in rainfed areas under limited moisture supply, a winter season crop produces lower grain and stover yield than the monsoon season crop. However the quality of stover in the former is superior. In irrigated areas the highest biomass and grain yield and harvest index are produced during the winter season followed by the monsoon season, while the poorest performance in this regard is during summer season. More information about the quality and quantity of stover produced during different seasons in irrigated areas and effect of cutting height needs to be obtained. Maize produces higher grain and stover yields in areas with fertile sandy loam soils adequate and evenly distributed rainfall or irrigation water, than in areas with sandy soils of poor fertility and low, or erratic rainfall. High temperature results in stover of lower digestibility. Thus under assured availability of moisture, maize in tropical areas produces less digestible stover than in temperate areas.

Soil conditions

The reproductive stage of maize is most sensitive to adverse soil conditions such as soil salinity, alkalinity and acidity. These conditions adversely affect the grain filling resulting in marked reduction in grain yield and harvest index with little or no effect on stover yield, though stover quality can be expected to increase. The uptake of nutrients from the soil is governed by soil conditions leading to wide variations in chemical composition of the stover.

Sowing time

Early or delayed sowing results in lesser grain yield and a lower harvest index. Being a short day plant, day length plays an important role in its growth and yield. Short days retard vegetative growth and hasten the flowering resulting in lower stover yield. Long days increase the leaf number, plan height and length of growing period, thus encouraging a higher stover production. Table 4 clearly shows that with lack of grain fill, the yield of stover is high, its quality is much better than with good grain fill. This physiological process of grain fill and stover quality holds true for all variations in grain fill caused by any environmental stress or genetic effects.

Table 4. The effect of grain fill on the yield and quality of maize stover

Pollination	DM Yield (kg/ha)			Quality of stover (%)		
	Crop	Ear	Stover	Protein	Cell wall	DCWC
+	18	9	9	8	60	67
-	16	1	15	10	46	67

(adapted from Deinum, 1988)

Plant density

The grain yield of maize increases with plant population up to an optimum level, depending on the variety used. Too high plant densities increase the proportion of barren plants, resulting in a lower grain yield and harvest index. Stover and total biomass yield continue to increase, in terms of quality as well as quantity, provided there is no lodging. The drop in grain yield and harvest index at higher plant density is greater under limited availability of moisture, nutrients and light. Thus under limited water supply, lower plant population and wider rows give more grain and a higher harvest index. In some regions of India, the crop is planted very dense, and thinned as the plants grow. The thinnings are used for cattle feed.

Water management

Water stress adversely affects the growth, biomass yield, harvest index and quality of stover. The effect of water stress depends on the physiological stage. Early water stress reduces plant height and stover yield, while the late stress increases the number of barren plants and causes poor grain-filling. It leads to a lower grain yield and harvest indexes, but it produces higher yield of better quality stover. Stover from dry land areas is generally of a better nutritive value than that obtained from irrigated areas. Maize is sensitive to excessive soil moisture, thus water stagnation even for shorter periods adversely affect its grain as well as stover yield and harvest index.

Weeds and their control

Weeds compete with the crop for essential nutrients, moisture and space. They reduce plant growth and yield of stover and grains and a lesser uptake of nutrients by the plant results in a lower feeding value of stover. The control of weeds may therefore result in higher stover as well as grain yield and better stover quality, but in less weeds for feeding during the growing period.

Fertilizers

Under conditions of adequate moisture availability the nitrogen application increases grain yield and harvest index up to level. Beyond this level the improvement in stover production sill continues with application, leading to lower harvest indexes. Nitrogen application under moisture stress increases the vegetative growth, leads to depletion of available soil moisture before or during grain fill stage and suppress the grain yield and harvest index. In soils deficient in phosphorus, the application of phosphorus improves the grain fill and increases the grain yield and harvest index. Nitrogen application increases leafiness, palatability and protein content of stover, while phosphorus application improves its mineral content. Deficiency of sulphur and zinc reduces stover yield and harvest index.

Diseases and insect-pests

Diseases and insect-pest attack adversely affects the plant growth and grain yield, markedly reduce the stover yield and harvest index of maize. Rusts and mildew make the stover dusty and reduce its palatability. The proportion of the nutritional valuable leaf fraction is reduced by diseases. Thus one expects lower quality stover from a diseased crop than that of a disease free crop. Insects such as grass-hoppers, Japanese beetles, caterpillars feed on leaves during early growth, and on silk at reproductive state. Thus insect attack reduces the grain and stover yield and harvest index and lower the leaf/stem ratio in the stover.

Thinning/stripping

Stripping and topping of maize is followed in some countries, even though there is experimental evidence to show that this practice reduces the grain yield and total biomass. The beneficial effect of this practice depends on the relative value of maize grain and fodder in the particular farming system. In Western Africa, 5-10 per cent of the leaves are removed from the standing crop and fed to goats, while in Punjab province of Pakistan lower leaves are removed before maturity, the so-called stripping. In the Middle East, South Asia and in densely populated highlands of Africa and Latin America, farmers often plant maize by broadcasting seed densely, thinning the stand throughout the growing season and the thinnings are used as fodder. Despite farm demonstrations, farmers in Pakistan rejected the recommendations which enhance grain production, such as a lower seed rate and line planting, they value fodder from thinnning very much. In North-Western India, farmers use slightly higher seed rate than the one recommended for grain production in order to remove the barren plants at silking stage for feeding to animals as green fodder.

Post harvest management of stover

The quantity and quality of stover is negatively affected by the length of period for which the stalks are allowed to stand in the field after harvesting the cobs or stored before feeding to the animals. The reduction in quantity and quality of stover depends on the weather and the protection given to stover from rain and moisture. Rains could leach out soluble nutrients from stover and mould can develop, resulting in reduces nutritive value and acceptability of stover by the animals. The delay in harvesting of the stalks also leads to loss of leaves and a decrease in stover digestibility.

Harvesting stage and method of harvesting

At physiological maturity when leaves are still somewhat green, the palatability and digestibility of maize stover is superior to that at dead ripe stage. There is good evidence that the cell wall content of the stover increases during ripening. Moreover at dead ripe state the leafy portion of stover dries and becomes brittle, and during the process of harvesting and collection some of these leaves which are more nutritious than the stem portion get lost. Removal of cobs from standing crops and the harvesting of stover for feeding to animals results in better stover than when the crop is harvested along with cobs so that the cobs are removed from the plant after drying for a certain period. The later method of harvesting results in loss of leaf and spoilage of stover if it rains between harvesting of crop and removal of cobs.

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5.6. SUGARCANE TOPS

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INTRODUCTION

Sugarcane (*Saccharum officinarum*) is a major cash crop grown in many parts of the country. The crop is popular with farmers in many regions for its ability to withstand extremes of environmental conditions and because of its assured market price. The crop is grown primarily for sugar, but cane tops, molasses, and bagasse form important byproducts. Bagasse, which is produced near the factory, has industrial use like for paper and board, creating a competing demand with its use as animal feed. Systems using whole sugarcane or its byproducts as feed for ruminants or sugarcane juice as feed for ruminants/non-ruminants have been reported from other countries. These are not discussed in this chapter as these systems have little relevance in Indian context. Only aspects related to production, cultivation, storage and the use of cane tops in ruminant feeding systems are discussed.

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PRODUCTION AND CULTIVATION

The potential yield of sugarcane, which is a C_4 plant, is reported to be 250 metric tonnes (mt) fresh weight/ha. However, actual yield in the country is around 65 mt/ha with important yield differences in various parts of the country (see Table 1). In general, the yields are lower in the subtropical regions (50-60 mt/ha) than in the tropical areas (70-100 mt/ha).

Table 1. State-wise area and yield of sugarcane (1990-91)

State	Area (*1000 ha)	Yield (mt/ha)
Uttar Pradesh	1,856	55.8
Bihar	149	52.5
Punjab	101	59.4
Haryana	148	52.7
Andhra Pradesh	182	69.6
Tamil Nadu	233	100.8
Maharashtra	444	86.5
Gujarat	118	89.6
Karnataka	272	77.0
All India	3,686	65.4

Source: Cooperative Sugar, 1992

The area under sugarcane has increased by about 15% between 1981 and 1990 (3.2 million hectares to 3.7 million hectares). Uttar Pradesh has the largest area under this crop (Table 1) and accounts for 43% of the total production in the country.

The yield of cane and cane tops is mainly affected by the agro-climatic conditions and practices followed during cultivation, and the following discussion is restricted to these aspects only.

Soil and climate

Sugarcane grows best on medium to heavy soils. It can also be grown on lighter soils provided adequate irrigation is available. On heavy clays good drainage is required. Sugarcane can withstand a wide range of temperatures (20° - 50°C). The crop grows best in tropical areas with a rainfall of 750-1200 mm. In the high rainfall areas (1200-1500 mm) of U.P, Bihar, Orissa, West Bengal and Assam, the crop is grown without irrigation, while in other parts an assured irrigation is required for growth. In sub-tropical areas with extremes of climate, the growth period is restricted resulting in lower yields than in the tropics. Cool and dry weather is necessary for ripening while warm and moist weather affects ripening of the cane. Heavy or prolonged rainfall adversely affects the quality of the juice.

Preparatory tillages

In India one or two deep ploughings are undertaken at an interval of one and a half months followed by harrowing for clod crushing. Because of the long duration of the crop, it is necessary to plan the crop layout carefully giving due weightage to the slope. The crop is planted in furrows or trenches (100-150 cm apart) depending on soil fertility. Narrow spacings are practiced in Northern India, where yields are comparatively low, while wider spacings are common in southern parts of the country.

Manures and fertilizers

Farm yard manure, compost and other slowly degrading organic materials are usually applied to the soil and mixed thoroughly before planting. Sugarcane requires high inputs in terms of N, P and K for sustained yields. The nitrogen requirement of the crop is high (150-500 kg/ha) and the increase in total yield is in the range of 100-250 kg/ha per kg N, depending on the source of nitrogen and on climate and soil. Phosphorus gives high responses particularly in the deficient regions of Bihar, West Bengal and Maharashtra.

Varieties and planting season

Different varieties of early (11-12 months), medium (14-15 months) and late duration (18 months or more) are recommended for different regions of the country (Table 2). Varieties can also be differentiated on their tillering ability as shy, medium and profuse. The details for specific regions may be obtained from local Institutes and Organizations. Planting of cane is undertaken over a long period (July-March) depending on the climatic conditions and varieties.

Table 2. Recommended seasons for planting of cane

Region	Planting season
Punjab, Haryana	February-March
Uttar Pradesh	February
Bihar	January
Tamil Nadu	December-February
Andhra Pradesh	December-February (12 months' crop)
Maharashtra	October-November (15-16 months' crop)
Karnataka	July-August (18 months' crop)

Under the relatively more favourable environmental conditions of Southern India, cane can be growm more or less continuously, and earlier plantings give higher yields than late planted cane. The latter is also more prone to attack by pests with a setback for growth and production. Since the availability of cane tops is dependent on cane growth and yield, the early planted crop will give higher yields of cane tops as well.

Ratoon

In most states only one ratoon is recommended as repeated ratooning increases the incidence of pests/diseases. The crop to be ratooned is cut flush to the ground and the above ground stubble is cleared. For best results, cane should be harvested as early as possible after the end of the cool weather. Ratoons mature earlier than main crops but, the yields are generally lower. Crops suffering from diseases/pests should not be ratooned.

Irrigation, intercultivation and weeding

The total water requirement for the growth of the crop is 200-300 cm including rainfall for seasonal plants. Wherever soil moisture is inadequate, the crop should be irrigated at an interval of 8-20 days depending on the season and soil type. Due to slow early growth of sugarcane in the initial phases, weeds come up rapidly in the planted field. Good weeding helps early tillering of clumps, and the weeds may be used as animal feed. In fact, they are often part of the wage to the labourers, helping them to keep dairy animals. Weed control is not recommended when a short duration companion crop is sown along with sugarcane.

The slow early growth of cane in the initial stages allows cultivation of companion crops with sugarcane. Suitable companion crops include maize (forage) and vegetables. They can improve the cash flow of the farmer, and the nutrient availability for livestock.

At an age of four months the cane crop is supported by earthing up. This, along with the tying of cane stalks with trash helps to prevent lodging due to winds. It is also common to sow castor/ pigeon pea/sesbania around the cane field which acts as a windbreak to prevent lodging. Some of these windbreak trees are also a source of forage to the animals.

Plant protection

The crop is vulnerable to several pests and diseases and the problem is more severe in the subtropical than tropical regions. Suitable control measures should be undertaken to ensure proper crop growth and yields. The residues of the chemicals are a health hazard for animals and humans and should be used with care.

HARVESTING AND STORAGE

Harvesting of cane is done by cutting at ground level, stripping of dry leaves and removal of tops. A portion of the topmost internode usually goes along with cane tops which improves the yield and feeding value of the material. There is however no deliberate attempt by the farmers to improve the feed quality by adopting this practice since it reduces the cane yield for sugar production. Where farmers are making jaggery on-farm, they may purposely include the top internode to increase the yield and feeding quality of tops. Farmers in other countries are reported to strip the leaves before they turn yellow, in order to have an almost year round feed supply. The seasonal availability of sugarcane tops necessitates conservation of this feed resource for use during scarcity periods. The usual practice adopted by farmers in Maharashtra consists of sun drying the cane tops for future use. Losses of nutrients during drying of tops under field conditions are high. Alternate methods of conservation like ensiling are technically possible but not adopted by farmers due to high costs of silage pit and polythene (# 4.7). Another reason for non-adoption of these methods could be that an active rural market for cane tops exists during the cane crushing season. It may be more economical to sell the surplus at that time, and to buy feeds required for daily use as needed.

YIELD OF CANE AND TOPS

The yields of sugarcane and therefore cane tops differ due to variety, management practices, and environmental conditions. The crop has two main phases; vegetative and sucrose accumulation. Proper soil moisture and aeration result in profuse and early root growth ensuring heavy tillering and vegetative growth. Tillering can be a continuous process or restricted to certain period. In general, tillers formed after 3.5 months do not produce stalk and they are used as feed for ruminants. Table 3 summarizes average yields of sugarcane in different states of India.

Table 3. Yield of sugarcane in different states of India

Type of crop	Fresh yield (mt/ha)	Region
12 month	50-60	Assam, Bihar, Uttar Pradesh, Punjab, Haryana, North Madhya Pradesh
12 month	50-60	Bengal, Orissa, Kerala,
12 month	70-85	Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh
18 month	120-140	Southern Region, Deccan Plateau

The sugarcane plant can be fractionated into the following components (% on dry matter basis) :

Cane - 55-60%

Tops - 15-20%

Trash - 20-25%

The cane top yield is thus 25-30% of total cane yield. The estimated production of cane is approximately 240 million tons/year in India. This means that 60-70 million tons of cane tops are available which are largely used for livestock feeding. Depending on the region, the production of fresh cane tops is estimated to range between 10 and 30 mt/ha (i.e. 2.5-9 mt dry weight).

In Maharashtra and Gujarat, where sugarcane is harvested by labourers employed by sugar mills, these labourers have a right to 20-50% of the cane tops produced in addition to their wages. The labourers use part of these tops to feed their draught bullocks and sell the rest at the local market. Again depending on the region, a cane farmer is thus left with 2-15 mt/ha of fresh cane tops. Quantitatively, the contribution of cane tops as feed is very important during the cane harvesting season (October-April). Village surveys across different farmer categories in Western Maharashtra indicate that sugarcane tops constitute between 20-70% of the dry matter available to cattle during the dry season. In some parts it is common to strip leaves from sugarcane for feeding animals without loss of cane yield. For this purpose the late tillers which are unlikely to form stalk are used.

Trash consists of dried fallen leaves of the cane and these are not commonly fed to the animals. Trash is only fed to animals with tops during scarcity periods. It is also used as fuel in jaggery manufacture. The trash is difficult to collect from the standing crop and is usually burned after the harvest. More recently it is advised to spread the trash in the field as mulch and also as a source of organic matter to the soil.

NUTRITIVE VALUE OF CANE TOPS

Cane tops contain 25 to 30% dry matter and contain (%DM) 4-6% crude protein; 35-40% crude fibre; 8-10% total ash and low levels (<2%) of ether extract. The TDN content of cane tops is about 50% (see Tables 4 and 5).

A part of the variation in cane top composition is due to varying proportions of stem and leaves, which differ substantially in chemical composition, digestibility and rate of digestion.

Table 4. Comparison (%) of cane tops

DM	Ash	CF	NFE	CP	DE *)	ME *)	TDN	some references
30	10	36	46	5	2.24	1.84	51	NRC (1978)
33	9	32	52	5	2.4	1.97	54	McDowel et al. (1983)

*) Mcal/kg DM

It may be seen from Table 4 that, contrary to most other cereals/grasses, leaves of cane tops have lower digestibility than stalks and their rate of digestion is also lower. This lower digestibility of leaves is due to lower content of cell solubles in leaves than stems. The extent and rate of leaf cell walls digestibility is also less than in stems, a fact that is often attributed to the high silica content in the leaves. Lignin does not seem to be important for cane tops due to its low concentration. Stalks are also better digestible than leaves. Sugarcane, contrary to other grasses, retains its nutritional value over a long period. This ability is often used by farmers to use the crop (or part of it) as an emergency feed.

The voluntary consumption of cane tops is between 2 and 2.5 kg DM per 100 kg bodyweight in cattle. The *in vivo* OM digestibility is around 50-55%. The higher rate of digestion for stalks as compared to leaves suggests better voluntary consumption of the former. However experimental evidence for this is lacking. An important factor influencing the cane top quality is reported to be the effect of flowering. No experimental data are available on this aspect, but the lower nutritive value due to flowering is seen in other cereals and grasses and is perhaps due to the translocation of nutrients for reproduction purposes when the vegetative growth of the plant comes to an end.

Table 5. Composition of sugarcane leaves and stalks

Part	OM%	CP%	CW%	Ligin	OMD%	CWD%
Leaf	90.9	4.4	67.8	2.5	60.9	46.5
Stalk	94.2	3.1	45.1	3.5	78.4	54.8

Like for all other fibrous crop residues, the feeding value of cane tops alone is insufficient to support high levels of milk production or live weight gain. A number of feeding systems to cope with this problem is described below.

FEEDING SYSTEMS

Supplementation

Cane tops contain less N than the concentration that is required for optimum fermentation in the rumen. It should be possible to augment the rumen fermentation of cane tops through judicious use of nitrogen rich supplements. Studies on urea supplementation of cane tops revealed that the digestibility of OM can be increased. Tree leaves from *Sesbania, Leucaena* or other crops that are often used as windbreak are a potential source of nitrogen and can be used as supplement for the tops.

Sulphur is also reported to be a limiting nutrient for rumen function. Although direct evidence for beneficial effect of sulphur supplementation of cane tops is scanty, it might be useful to add this nutrient under practical feeding situation. Cane tops are also a poor source of phosphorus (0.1-0.2%). This is perhaps a reason for the reported poor reproductive performance of animals fed large quantities of cane tops without supplementation. (# 4.3; # 4.3.2)

Densification/processing

Processing of cane tops (e.g. pelleting, wafering) has been reported from Indonesia but, these technologies are expensive and impractical, unless they save on cost of storage and transport (# 4.6.3).

Urea treatment

Urea-ammoniation can be useful to upgrade the feeding value of most crop residues. However, only a few studies have been conducted with cane tops. Due to the high content of soluble sugars in fresh cane tops, the treatment process does not always give a well-treated product: the increase in pH due to ammonia generation is countered by the production of acids during treatment, ultimately resulting in unstable fermentation. Urea treatment of dried cane tops is also difficult due to the low water absorption capacity of leaves which necessitates the use of lower quantities of water resulting into non-uniform treatment. (# 4.6.1)

Chopping and Soaking

Chopping of forages is common in the Northern and Eastern states, while in the South it is almost non-existent. Chopping of cane tops is however necessary if it is to be conserved as silage. It may be beneficial to chop the tops together with other forages (particularly legumes) to improve their nutritive value. Since the tops are mostly fed in their green form, it is not common to soak them.

Selective consumption

Selective consumption of leaves is not expected in case of sugarcane tops because of their lower digestibility and digestion rate than stems while preference for stem is difficult due to physical factors. Sheep are reported to eat the leaf without eating the mid ribs. (# 4.4)

CONCLUSIONS

The quantity of cane tops produced is directly related to the growth of the crop. Adoption of all recommended practices for cultivation would therefore also result in higher production of this important feed resource. Sugarcane tops can be supplemented with nitrogen, energy and minerals, depending on the desired production. Protein and mineral supplementation becomes more important when cane tops are fed as the only roughage source for animals that receive no other supplements.

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RELEVANT ADDRESSES

National Sugar Institute, Kanpur, U.P.
Indian Institute of Sugarcane Research, Lucknow, U.P.
Vasantdada Sugar Institute, Manjari, Pune
Local Agricultural Universities
State Departments of Agriculture

5.7. WATER HYACINTH

R.C. Saha, R.B. Singh, and G.C. Banerjee

INTRODUCTION

Water hyacinth (*Eichhornia crassipes*) is an aquatic weed which was introduced to India in 1905-1906 as an ornamental plant. It then spread over the entire country in ponds, lakes and rivers also in other parts of Asia. It spoils water, reduces aquatic animal numbers and pollutes the environment by facilitating mosquito reproduction through reduction of drainage and evaporation. It has become a national problem and some states (West Bengal, Assam, Tamil Nadu and Uttar Pradesh) have legislations to control this weed by hand or by chemical agents like copper sulphate, lead nitrate, sodium arsenite, 2-4-d, methoxone and sodium pentachlorophenate. This chapter will describe how water hyacinth can be used as an animal feed.

PRODUCTION, HARVESTING AND PROCESSING

The production of water hyacinth has been estimated to be as high as 150 tons of wet material per hectare at dry matter content of around 6% to 10%. However, such estimates are subject to large errors and the conditions of climate and water ways would be expected to markedly affect its growth.

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Water hyacinth is mainly harvested by hand and usually left to rot on the banks. Sometimes it is composted or burned after drying in order to be used as a fertilizer. In experimental work, water hyacinth has been fed to livestock in the fresh form, after drying or after ensiling with other feeds.

NUTRITIVE VALUE

As with other feeds, the feeding value of water hycianth depends on the amount of nutrients it contains (chemical composition) and the amount of dry matter the animals could voluntarily consume (#3.2.).

Chemical composition

After harvesting, water hyacinth contains only 6% to 10% dry matter. In the whole plants and the lamina parts, this dry mater contains approximately 85% organic matter, 14% to 23% crude protein, 17% to 26% crude fibre, 15% to 16% total ash, 1.8% to 2.5% Calcium, 0.4% to 0.5% Phosphorus, 5% Potassium, 3.5% Chlorine, 1% Magnesium and 3.3% to 4.4% oxalic acid (see Table 1). The high Potassium and Chlorine concentration are thought to contribute to its poor palatability and are likely to affect mineral metabolism if water hyacinth is fed *ad libitum*. Value estimates for Total Digestible Nutrients (TDN) range from 32% to 41% in dry matter for ruminants. In small amounts, water hyacinth may be a useful source of vitamin A for livestock fed low quality dry roughages. Fresh leaves contain 52 to 58 mg carotene per kg.

Table 1. Chemical composition of Water Hyacinth (% on DM basis)

Organic matter	85
Total ash	15 - 16
Crude protein	14 - 23
Crude fibre	17 - 26
Calcium	1.8- 2.5
Phosphorous	0.4 - 0.5
Magnesium	1.0
Potassium	5.0
Chlorine	3.5
Oxalic acid	3.3 - 4.4

A feeding system based on fresh water hyacinth as the only feed is not possible because of its low intake by animals, and its imbalanced mineral composition. It is common to see buffaloes wallowing in water areas where water hyacinth grows wild. Under such situations, in addition to the normal ration fed to them, they have the chance to consume water hyacinth whenever they like eating. Some research data on the use of water hyacinth in the fresh or processed (wilted, ensiled) form are discussed below.

Intake by animals

The intake of fresh water hyacinth by large ruminants is less than 1 kg dry matter per 100 kg liveweight, possibly due to its poor palatability and high water concentration. Its intake, when fed *ad libitum* with small amounts of concentrates, may increase, but not sufficiently to maintain liveweight. Even when ensiled with paddy straw in a 4 (paddy straw) to 1(sun wilted water hyacinth) ratio, total intake remains low at about 1.2 kg DM per 100 kg liveweight. When fed fresh water hyacinth in large quantities, cattle suffer from diarrhoea. Even when it is fed with paddy straw, the animals loose bodyweight due to low intake of water hyacinth and low digestibility of the paddy straw and water hyacinth mixture.

Farmers' perceptions of water hyacinth as animal feed

Feeding of a restricted quantity of water hyacinth chaffed and mixed with straw is beneficial to cattle and buffaloes. Feeding of large quantity affects health and causes diarrhoea. A large group of farmers feeds water hyacinth at a low level and mixed with straw. Cattle and buffaloes are also found to graze water hyacinth in ponds in villages.

FEEDING SYSTEMS

Supplementation

Many workers have succesfully fed water hyacinth to cattle replacing part of a diet consisting of straw and concentrate or straw and green fodder without any adverse effect on the animal. This was possibly due to the associative effect of concentrate or green fodder in the ration. If fed in excess, it is likely to severely affect mineral metabolism in the animal due to very high potassium and chlorine concentrations. Because it contains 90% to 94% water, the labour involved in collection and feeding appears to make it uneconomical for the commercial dairy farmers as feed. However, the following options are to be considered:

- 3 kg to 5 kg per animal per day to adult cattle/buffalo as vitamin A supplement. Young animals and goats can be fed 1 to 2 kg per day;
- utilization as scarcity feed mixed with straw;
- landless and marginal farmers can daily feed 10-15 kg fresh water hyacinth to adult cattle, after chaffing and mixing it with paddy straw. In this way it helps the animals to survive.

In any case, water hyacinth is not an appropriate feed for highly productive dairy cows, because it may limit or reduce DM intake if other feeds are available.

Treatment

In most situations the whole plants are collected, the roots and rhizomes removed and the shoots are chopped and offered with other dry forage to livestock. Sometimes the plants are wilted for 48 hours under shade or sun before feeding.

Ensilage

Under experimental conditions, water hyacinth silage made of a mixture of paddy straw and water hyacinth (as fresh weight ratio 4 straw to 1 water hyacinth) added with 2% common salt could not improve intake to any significant extent.

OTHER USES

Attempts have been made with varying success to use water hyacinth as a pig and fish feed. Farmers have also found other ways of using water hyacinth in their normal farming or household needs. Use of water hyacinth as an industrial raw material has also been attempted.

Manure

In many areas of Indian villages water hyacinth is used as manure, both as compost and ash. The ash contains (on dry matter basis) 23.4% potassium, 1.3% sodium, 9.4% calcium, 2.6% chlorine and 3.1% phosphorus. The ash is extremely rich in potassic fertilizer which is particularly useful for root crops.

Fuel

Many farmers in West Bengal dry the fresh water hyacinth under the sun and they use dried water hyacinth as fuel, and the ash for manuring.

Industrial uses

Attempts have been made to utilize the plant as a raw material for paper, plastics and other commercial products but so far it has not been very successful. The possibility of using the dried plant for the production of gas and alcohol has been considered but, the commercial possibilities of the processes have not been proven. The high water content of the green plant adds considerably to the cost of transport and drying. Water hyacinth appears to have limited possibilities for use as an industrial raw material.

Human food

Water hyacinth is reported to be used as a table vegetable in Formosa. Fresh leaves contain 52 to 58 mg of carotene per kg and a method seems to have been developed for the production of carotene concentrates from water hyacinth.

Pig and fish feed

Water hyacinth has been used as pig fodder in Central and South China and Malaysia. In China it is cultivated in fish ponds and used for pigs, the piggery washings being drained into the pond to fertilize the growth of water hyacinth. Water hyacinth when fed fresh to pigs as a sole feed resulted in body weight losses. Digestible crude protein (DCP) and total digestible nutrients (TDN) in pigs were 7.7% and 44% respectively, on a dry matter basis. Palatability of water hyacinth for pigs was very poor.

Gender aspects

In most villages of West Bengal and North Eastern India, the drying of water hyacinth for conversion into fuel is a job carried out by women. Similarly, chopping of water hyacinth and straw, its mixing and feeding to cattle or swine is done mostly by women. Manuring kitchen garden crops by water hyacinth compost or ashes is done by both men and women. Removing water hyacinth from the ponds is done by men. Spreading of water hyacinth compost in fields is mostly done by men.

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5.8. JUTE AND ITS BYPRODUCTS

R.B. Singh, and R.C. Saha

INTRODUCTION

Jute (*Corchorus oletorius*) is an annual crop grown mainly for its fibre contained in the stem. Its cultivation is a labour intensive activity commonly produced in the North Eastern parts of the Indian subcontinent and besides fibre, the plant produces sticks for fuel and leaves for feed. The major jute producing tract of the world is located in North-East India and Bangladesh confined mainly to the lower courses of the Ganges and Brahmaputra rivers and their tributaries. Together, these areas produce nearly 80% of the world's total jute output. This chapter discusses the use of jute leaves as cattle feed in the areas where it is grown along with the uses of jute byproducts and gender aspects of jute cultivation.

CULTIVATION AND PRODUCTION

The important jute growing areas in India are found in the following districts:

- Murshidabad, Hooghly, 24 Parganas, Malda, Nadia and Jalpaiguri (West Bengal).
- Purnea (Bihar).
- Goalpara, Nowgong, Kamrup and Darrang (Assam).

Handbook for Straw Feeding Systems
Kiran Singh and J.B. Schiere (eds.), 1995
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- Cuttack (Orissa).
- Kheri (Uttar Pradesh).

About 67% of the annual production of jute fibre is processed by jute mills in India, 7% is retained by the growers for their own use and the rest is exported to western countries. The fibre is used for manufacturing of hessian packing cloth and bags used in the transport and storage of cotton, wool, food-grains, pulses etc. Jute is also used for making rugs, carpets, curtains, upholstery, linings, ropes and twines.

Jute cultivation requires a high labour input and is grown by the farmers as a cash crop. Sowing time of jute is generally done in the period from March to May. Pre-monsoon showers are important and beneficial for the crop. The time of harvest depends on the time of sowing and on the variety grown, generally, from June to October. Delayed harvesting increases fibre yield but results in coarser fibres.

The jute plant produces fibre (in the skin of the stalk), stalks (after been stripped of fibre), leaves, thinnings and seeds. The amounts produced vary according to the length of the growing season and the growth conditions. Fibre production varies from 2400 kg DM per hectare to 3000 kg per hectare and leaf production from 300 to 400 kg DM per hectare, while the yield of jute stalks from 4800 to 6000 kg DM per hectare, and the seed yield from 170 to 500 kg per hectare. A substantial amount of jute leaf is also available for animal feed during thinning done at 18-21 days and 30 days of crop age.

JUTE LEAVES AND THINNINGS AS CATTLE FEED

Leaves are generally available from June to October during the monsoon months. Hence conservation could be considered but, rains frequently disturb the drying of leaves. Sun drying of leaves for one day followed by shade drying for 3-4 days yields good hay with a feeding value comparative with berseem/lucerne hays. Some leaves are available during thinning of the crop, but the quantity available at that time is small. Leaves are not harvested from the standing crop because it will cut down the photosynthetic activity and the fibre production will be reduced. Collection of fallen leaves from the jute fields is labour-intensive and only cost effective when labour is available.

Leaves are available during harvest and prior to the soaking (retting of jute) of the stalks for fibre removal. Immediately after the harvest, the stems are kept standing in large bundles for 3-4 days to cause shedding of the leaves. The amount of leaves available can be 2700-3000 kg per hectare of cropped land on fresh basis. Under experimental conditions, about 5.2% of the total green weight of the plant is in the form of leaves at the time of harvesting. Farmers feed jute leaves to their cattle and the excess is used as green manure. The chemical composition of the leaf is given in Table 1.

The leaves are rich in protein and minerals but, low in crude fibre. Adult cattle fed 2 kg jute leaf hay per day plus paddy straw *ad libitum* could maintain body weight under experimental conditions. The dry matter intake of the ration was 1.9 kg per 100 kg body weight. Balances of nitrogen, calcium and phosphorus were all positive. The digestible crude protein (DCP) and total digestible nutrients (TDN) contents of the hay were 14% and 61%, respectively.

Table 1. Chemical composition of jute leaf (% on DM basis)

Dry matter	6.0
Total ash	12.60
Organic matter	88.0
Crude protein	22.0
Crude fibre	16.0
Calcium	2.8
Phosphorus	0.7
Magnesium	0.5

The use of jute leaf hay as a partial replacer of protein has been studied in Red Sindhi calves. An average daily body weight gain of 433 grams was observed in calves fed jute leaf hay *ad libitum*, replacing 50% of concentrate in the calf ration.

The jute plants and weeds which are thinned out at the third and fourth week after sowing of jute are fed to cattle, either as such or mixed with straw. Thinned out plants are palatable to animals.

After stripping of the fibre, jute stalks are used as fuel, gunpowder-charcoal, as fencing material around houses, and for several purposes in Hindu rituals. During RRA's conducted in villages of West Bengal it was found that in many areas, jute stalks are so essential for these other uses that farmers cultivate jute in spite of low incomes from the fibre. Jute stalks with a dung cover are used as fuel sticks in many villages of West Bengal.

The seeds are used as purgatives in Ayurvedic medicine. Jute leaves shed in the fields decompose into humus, returning organic matter and nutrients to the soil. Tender leaves and twigs are consumed by humans after frying and cooking. The leaves are demulcent, tonic and diuretic. The leaves are also reported in Ayurveda as astringent, they help to cure pain, ascites, abdominal tumours and piles (Kirtikar and Basu,1975).

GENDER ASPECTS OF JUTE CULTIVATION

Women play a major role in extraction of fibre from jute stalks after retting of jute. From aged women to little girls, during the harvesting season, women are found to be busy from morning to evening in extracting jute fibre. Collection and feeding of jute leaves to cattle is in most cases done by the women. Men cultivate and harvest the crop. Thinning and weeding is done by both men and women.

CONCLUSION

Although jute is grown primarily for its fibre, the leaves and young plants that are thinned off and those available at the time of harvest could serve as a supplement for ruminants. Some bulk of the leaves are available at the time of harvest can be conserved them as hay for later use.

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