4.5. VARIATION IN THE QUANTITY AND QUALITY OF CROP RESIDUES

A.L. Joshi, A. Subba Rao, P.T. Doyle, S.J.Oosting, Mahendra Singh, A.S. Harika, B. Deinum and M.N.M. Ibrahim

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.

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

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.

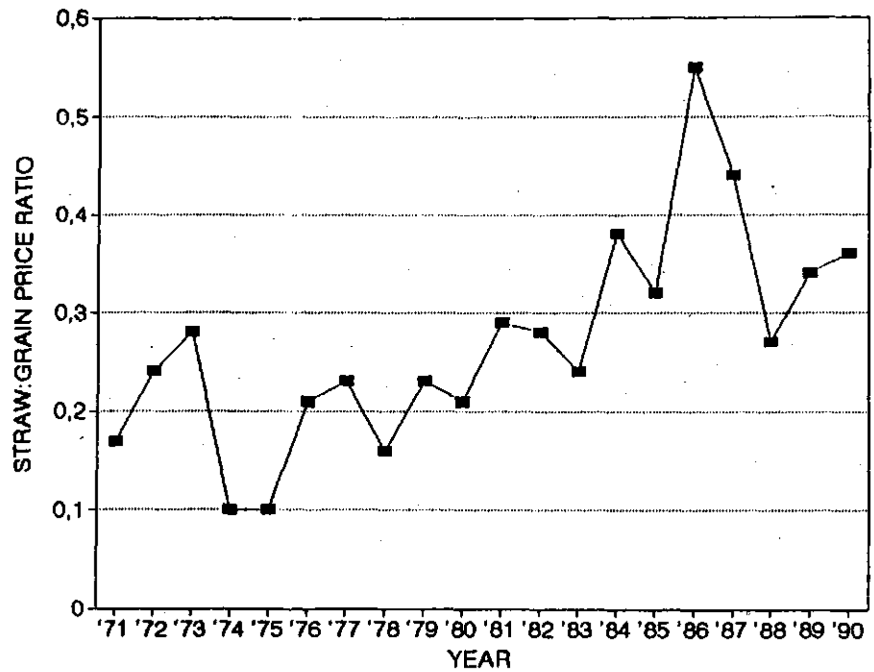
Stay green: is a quality that is used for plants that to some extent remain green up till and after harvest. The condition implies a better quality and it is used common in maize, millets and sorghum, but also known from the slender stemmed grains.

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 ANL 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.

Manúal 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.

SUGGESTED READINGS

Alexandratos, N., 1988. World Agriculture toward 2000, An FAO study. FAO, Rome, Italy; Belhaven Press, London, UK. 338 pp.

Badve, V.C., 1993. Variation in quality of sorghum stover, p 370-377 in K. Singh and J.B Schiere (eds), Feeding of Ruminants on Fibrous Crop Residues, Proc. of an Int. Workshop, National Dairy Research Institute, Karnal, 4-8 Feb., 1991.

Capper, B.S., 1988. Genetic variation in the feeding value of cereal straw, Anim, Feed Sci. Techn. 21:127-140.

De Wit J., Dhaka, J.P., and Subha Rao, A., 1993. Relevance of breeding and management for more or better straw in different farming systems, p 404-414 in K. Singh and J.B Schiere (eds), Feeding of Ruminants on fibrous Crop

Residues, Proceedings of an International Workshop, National Dairy Research Institute, Karnal, 4-8 Feb., 1991.

Doyle, P.T. and Oosting, S.J., 1994. Variation in quantity and quality of crop residues: A Summary Review, p. vii-xv in Joshi, A.L., Doyle, P.T. and Oosting, S.J. (Eds.). Variation in the quantity and quality of fibrous crop residues. Proceedings of a national seminar held at the BAIF Development Research Foundation, Pune (Maharashtra-India), February 8-9, 1994, Pune, India.

Joshi, A.L., Doyle, P.T. and Oosting, S.J., 1994. Variation in the quantity and quality of fibrous crop residues. Proceedings of a national seminar held at the Baif Development Research Foundation, Pune (Maharashtra-India), February 8-9, 1994, Pune, India. 174 pp.

Kelly, T.G., Parthasarathy Rao, P., Walker, T.S., 1991. The relative value of cereal fodder in the semi-arid tropics of India: Implications for cereal breeding programs at ICRISAT, Resource Management Program, Economics Group, Progress Report-105 ICRISAT, Patancheru, Andhrapradesh.

O'Donovan, P.B., 1983. Untreated straw as a Livestock feed. Nutrition abstracts and Reviews -series B 53(7): 442-455.

Prasad, C.S., Sampath, K.T., Shivaramaih, M.T. and Walli, T.K. 1993. Dry matter intake digestibility and supplementation of slender and coarse straws, p 188-203 in K.Singh and J.B Schiere (eds), Feeding of Ruminants on Fibrous Crop Residues, Proceedings of an International Workshop, National Dairy Research Institute, Karnal, 4-8 Feb 1991.

Prasad, C.S., Sampath, K.T., Rai, S.N. and Joshi, A.L., 1993. Physical, chemical and morphological characteristics of slender coarse straws and response to urea treatment. p 320-335 in K. Singh and J.B Schiere (eds), Feeding of Ruminants on Fibrous Crop Residues, Proc of an Int. Work Ship, National Dairy Research Institute, Karnal, 4-8 Feb., 1991.

Reed, J.D, Capper, B.S. and Neate, P.J.H., 1988. Plant Breeding and nutritive value of crop residues. Proceedings of a workshop held at ILCA, Addis Ababa, 334 pp.

Seetharam, A., 1993. Genetic parameters and relation of morphological characteristics associated with fodder yield and quality in finger millet (Eleusine coracana), p 364-369 in K. Singh and J.B Schiere (eds), Feeding of Ruminants on Fibrous Crop Residues, Proceedings of an International Workshop, National Diary Research Institute, Karnal, 4-8 Feb., 1991.

Subba Rao, A., 1993. Genetic and managemental effects on variability of straw quality from finger millet (Eleusine coracana), p 378-387 in K.N Singh and J.B Schiere (eds), Feeding of Ruminants on Fibrous Crop Residues, Proceedings of an International Workshop, National Diary Research Institute, Karnal, 4-8 Feb., 1991.