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The Relative Value of Cereal Straw Fodder in the Semiarid Tropics of India: Implications for Cereal Breeding Programmes at ICRISAT

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Introduction

The role of dual-purpose cereal crops – sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum americanum*), maize (*Zea mays*), wheat (*Triticum aestivum*) and rice (*Oryza sativa*) – in meeting the draught and milk animal feed requirements of mixed crop–livestock farming systems in the semiarid tropics (SAT) has not yet been fully appreciated. Although fodder trees and forage species play an important role in meeting these requirements, their contribution is clearly limited, particularly during the dry season. Farmers cannot afford to allocate much of their limited cropland to forage crop species and few have access to sufficiently large communal grazing areas. Thus, there is a heavy dependence on crop residues in managing fodder requirements at the farm level.

Historically, crop improvement research at ICRISAT and in the Indian national programmes has targeted almost exclusively the use of cereals as food grains. Fodder and dual-purpose fodder/grain varieties are gaining importance in both private and public sector research, but grain yield remains the overriding criterion in national research programmes. Assessing the relative value of cereal straw is a necessary first step in developing a more effective crop improvement strategy; that is, one which considers the contribution of both grain and fodder yield to the total value of production.

Cereal crop residues as a major feed resource in crop–livestock systems in India, the relative contribution by sorghum straw to the total value of production, and their increasing value over time relative to grain are discussed in the next section. Sorghum grain:fodder price ratios are used to illustrate the increasing relative importance of fodder over time. In the third section, cereal breeding strategies is discussed in light of grain yield versus total value of production criteria. The trade-off between grain and fodder yield is examined. [illegible] the evidence on adoption of improved cultivars [illegible] SAT India. Discussion and conclusions follow.

Fodder as a Component in the Total Value of Production

Agroclimatologically, the SAT includes tropical regions of the world where rainfall exceeds potential evapotranspiration during four to six months of the year. India's SAT is vast and encompasses many distinct agroecological zones. The non-coastal regions of Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu on the Deccan Plateau and much of Gujarat and western and central Madyha Pradesh comprise the heartland of the rainfed agricultural belt in India's SAT. Farming systems are characterized by low agricultural productivity, rainfall is low (mean annual rainfall ranges from about 400 to 1,200 mm), erratic and highly seasonal. Soils in these regions are often low in fertility.

The integrated nature of crop and livestock production is another characteristic feature of farming systems in the India SAT. Crop production is typically the most important component in these systems, but animal production activities are by no means insignificant. Indeed, the two are difficult to separate. Livestock provide draught power and fertilizer to the crops in the form of manure; crops and crop residues provide fodder for draught and milk animals. While more specialized systems of production are likely to evolve, this change will only come about gradually. For the time being, most farmers continue to produce forages and use cereal straw for their own livestock with little surplus left for marketing.

For this reason, farmers in SAT India are concerned not only with grain yield but grain and fodder yield. Both are important components in the total value of production. The value of cereal straw is derived from its use in meeting the feed requirements of bullocks and milk animals. Indeed, crop straw and stover constitute a major feed resource for ruminants, more important than cultivated forages because of competition for land. Except where a specialized market has developed due to a strong diary industry, i.e. around large cities, cultivated fodders such as maize, sorghum, napier grass (*Pennisetum purpureum* Schum) and lucerne (*Medicago sativa*) are not yet widespread. Grazing is also limited, and becomes increasingly so as upland encroaches on communal pastures, fallow areas and forest (Jodha, 1985). Most of the sorghum and pearl millet grown in India is characterized as dual-purpose (grain and fodder).

Observations from recent village surveys conducted by ICRISAT in western Rajasthan show that crop residues (pearl millet, sorghum, and wheat straw) contribute more than 50% of the total dry weight of the diet of milk animals on an annual basis (ICRISAT, 1992). Data from a village survey carried out in western Maharashtra indicated that dry roughage (mainly sorghum stovers) contributes between 20 and 45%, depending on the season, of the total dry weight feed fed to dairy animals by small farm owners (Thole *et al.*, 1988). High seasonal dependence of crop residues is supported by a study in south India. Among small dairy and cattle owners in Tamil Nadu, dry fodder provided 13% of the dry matter animal feed from August to October and more than 50% from January to April (McDowell, 1988).

The key role of crop residues is probably in the maintenance diets of breeding stock; diets for lactation or work require higher energy concentration (Nordblom, 1988). Nevertheless, even in urban areas crop straw and stover constitute an important fraction of the diet of milking animals.

Crop residues are also important for draught animals. In central Andhra Pradesh and eastern Maharashtra, fodder — predominantly dry sorghum, pearl millet and paddy straw — constitutes a major share of the cattle feed. Dry fodder contributed approximately 60% and 45% of total dry weight feed during the dry summer season in the Andhra Pradesh and Maharashtra villages, respectively; during the rest of the year, the contribution of dry fodder (and green when available) varied between 20 and 50% (Motavalli and Anders, 1991). Sandford (1987) reported that in various parts of semiarid sub-Saharan Africa, cattle derive up to 45% of their total annual feed intake from crop residues, and up to 80% during critical periods.

Field data on sorghum grain and fodder yields and associated prices were used to assess the average contribution of fodder to the total value of production (ICRISAT, 1991a). During the 10-year period from 1975 to 1984, traditional sorghum straw's contribution to the total value of production averaged 40% in two ICRISAT study villages in central India (Table 6.1). In some years the average contribution rose to 60%. Sorghum straw's contribution averaged only 18% in a third village, reflecting a relatively lower price of sorghum straw in this particular region of Maharashtra and a high harvest index of modern cultivars (MCs) grown there.

The same field data indicate a strong negative association between grain yield and fodder's contribution to total value of production. That is, lower-than-average grain yield is correlated with a relatively higher percentage contribution from fodder. This suggests that grain yield is more vulnerable to environmental stress than fodder yield. If so, areas with

Table 6.1. Sorghum straw contribution to the total value of production, selected villages, SAT India, 1975 through 1984

Year	Straw's mean % contribution to total value of production[a]		
	Aurepalle (local)	Shirapur (local)	Kanzara (hybrid)
1975	[illegible]	[illegible]	12
1976	[illegible]	[illegible]	21
1977	[illegible]	[illegible]	19
1978	[illegible]	[illegible]	24
1979	[illegible]	[illegible]	12
1980	[illegible]	[illegible]	17
1981	[illegible]	[illegible]	17
1982	[illegible]	[illegible]	16
1983	[illegible]	[illegible]	20
1984	[illegible]	[illegible]	20
Average	[illegible]	[illegible]	18

[a] Figures based on an average of [illegible] observations per year at Aurepalle, Shirapur and Kanzara, respectively.
Source: ICRISAT Village Level Studies.

lower-than average grain yields, such as Andhra Pradesh and Karnataka, should give relatively more weight to fodder yield considerations than areas with higher grain production potential, such as Maharashtra.

On the other hand, straw prices are considerably more variable than grain prices over time (Fig. 6.1). The occurrence of drought in 1972, 1984, and 1986 plainly had a greater impact on sorghum straw prices than on sorghum grain prices. Unlike grain markets, fodder markets are 'thinner', and not as integrated either spatially or temporally. The bulky nature of the commodity and its associated high transportation and storage costs account for this fact. The up-and-down nature of fodder prices suggests a cyclical pattern of alternatively strong and weak demand years, perhaps in response to bullock and milk animal divestment during drought periods when fodder sources dry up.

Date from the All-India Coordinated Sorghum Improvement Project (AICSIP) Advanced Varietal and Hybrid Trials likewise demonstrate the importance of dry fodder in the total value of production of coarse cereals in the SAT. In the Advanced Varietal Trials using the All-India Average data for between 16 and 20 varieties tested each year from 1987/88 to 1989/90, the average contribution by fodder to the total value of production was 49% (Table 6.2). The highest average contribution (53% in 1988/89) is associated with a relatively poor production year (excessive rainfall and waterlogged soils). In the Advanced Hybrid Trials, the average

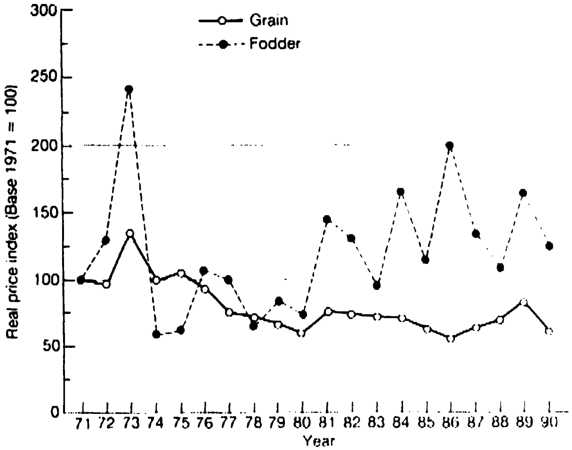

Fig. 6.1. Sorghum grain and fodder, real price indices, Solapur, Maharashtra, 1971 to 1990

Source: State Marketing Cooperative, Solapur, Maharashtra.

contribution represented 43% of the total value of production. Once again, the highest average contribution (48%) occurred in 1988/89.

Some variation in the contribution from fodder is observed when inter-state comparisons are made. More favourable environments, such as Maharashtra with its deep, fertile soils and higher and more assured rainfall, have a relatively lower percentage of contribution from the fodder component (45%). In Andhra Pradesh, a less favourable environment, the average contribution of fodder was higher (57%). For hybrids, the fodder contribution was lower, but similar differences were observed across environments.

The contribution of fodder to total value of production depends on relative fodder and grain prices. This ratio has been increasing over time. The longest and most credible time-series data on fodder prices comes from a wholesale fodder market in Solapur, Maharashtra, located in the heart of the post-rainy season sorghum tract. Wholesale sorghum straw prices rose eightfold, from Rs 12 per quintal in 1970 to Rs 94 per quintal by 1990. In real terms, i.e. after making the adjustment for inflation, the value of straw rose by more than 25% (Fig. 6.1). Grain prices also rose, from Rs 90 per quintal in 1970 to Rs 280 per quintal in 1990. But of greater importance, the real value actually declined by about 35%. Thus in 1971, the sorghum grain price was almost six times that of straw. By 1990,

Table 6.2. Average sorghum grain and fodder yields and associated value of production All-India, Maharashtra, and Andhra Pradesh, India, 1987–1989.

Location	Average yield (q/ha)[a]		Average value (Rs/ha)[b]		Total value (Rs/ha)	Fodder's contribution (%)
	grain	fodder	grain	fodder		
All-India						
Variety	31	110	4,920	4,730	9,650	49
Hybrid	38	106	5,980	4,540	10,520	43
Maharashtra						
Variety	38	112	6,040	4,810	10,850	45
Hybrid	43	102	6,820	4,380	11,200	39
Andhra Pradesh						
Variety	22	108	3,680	4,860	8,540	57
Hybrid	34	110	5,520	4,940	10,460	47

[a]Average of 16–20 'improved' genotypes from at least 30 locations each year for All-India, 14 locations for Maharashtra, and 5 locations for Andhra Pradesh (units = quintals per hectare).
[b]Based on hybrid grain and fodder post-harvest (December) prices, Rs 156 and Rs 43 per quintal for All-India and Maharashtra, and Rs 165 and Rs 45 for Andhra Pradesh.
Source: AICSIP Advanced Varietal and Hybrid Trials (ICAR, 1988, 1989, 1990) and local market prices in Maharasira and Andhra Pradesh.

grain prices were less than three times those of straw prices.

There are several factors associated with rising prices of dry fodder. First, and most significantly, rising incomes over the last two decades have resulted in a marked increase in the demand for milk. Milk production doubled in the last 15 years. This in turn, via linkages to input demand for dairy production, has resulted in a steadily increasing demand for and price of fodder. Another factor has been the increasing number of ruminants in India. Total numbers of cattle, buffalo, sheep, goats, and camels have increased from 340 to 430 million head in the last 20 years (FAO, 1970, 1990), a more than 25% increase, despite some falling off in the numbers of cattle and buffalo used for draught as use of tractors has increased. Other supply factors come into play, including declining common property resources (Jodha, 1985) and stagnating area under forage production in India (Singh, 1989). These trends are likely to continue into the near future, making the fodder value component ever more important to crop producers.

Meanwhile, as incomes rise, per capita demand for cereal foodgrains – and especially for coarse cereals – declines. Empirical evidence for India confirms this. Using data from the latest round of National Sample Survey data for India, Walker (1990) found that per capita consumption of sorghum and pearl millet, the two major coarse grain cereals in India, declined for all but the lowest income groups from 1976 to 1986. A study by Radhakrishna and Ravi (1990) shows that for some income groups, the elasticity of demand for coarse cereals is negative. On the other hand, milk and milk products have one of the highest expenditure elasticities in India. Radhakrishna and Ravi's study projects the per capita demand for milk to increase at 2.3% per annum until the year 2010, higher than for any other food group.

Criteria for Selecting Modern Cultivars

Modern cereal cultivars have a grain yield potential that is two or more times that of traditional varieties. Because improvement in crop grain yield potential has come about largely by raising the grain:total biomass ratio, i.e. the harvest index, gain in grain yield has come at the cost of reduced non-grain plant yield. This effect may have been obscured by improved crop management (fertilizer application and plant protection) which raises total plant biomass. In environments where improved crop management practices are not adopted, cultivation of new genotypes would result in higher grain but lower fodder yields.

Data are available from an experiment which examined the effect of planting date and irrigation on grain and stover yields of two sorghum genotypes (Ahmed, 1987). Total dry matter did not differ between a hybrid (CSH 5) and a traditional variety (Pacha Jonna) under either irrigated or rainfall conditions except when planted very late (after 15 July). Grain yield, as expected, was significantly higher for the hybrid in every scenario. At the earliest planting (17 June), grain yield was 80% higher for the hybrid than for the traditional variety. Stover yields, however, were 36% higher for the traditional variety. Most researchers would agree that traditional varieties have an advantage with respect to fodder yields; however, more experiments are needed to accurately assess fodder yield differentials between various traditional and improved cultivars.

Must breeders choose between grain yield and fodder yield? Is it a question of partitioning a fixed amount of biomass between grain and stover, or can both be increased by selecting genotypes with greater total biomass? If it is the former, then what are the trade-offs between total grain and total fodder value for a given set of genotypes being evaluated?

For the varieties and hybrids under evaluation in the AICSIP trials, there was no visible trade-off between grain yield and fodder yield. Neither a significant negative nor positive relation was borne out. Using all All-India Average data for 1987/88 through 1989/90, the average correlation between grain and fodder yield in the Advanced Varietal Trials was −0.09

Table 6.3. Correlation coefficients between grain yield and total value of production, fodder yield and total value of production, and grain yield and fodder yield, All-India, Maharashtra, and Andhra Pradesh, India, 1987–1989

Location/year	Grain yield × total value of production (r value)	Fodder yield × total value of production (r value)	Grain yield × fodder yield (r value)
All-India average			
1987/88	0.78	0.96	0.05
1988/89	0.54	0.93	0.19
1989/90	0.13	0.80	−0.50
Average	0.48	0.79	−0.09
Maharashtra			
1987/88	0.86	[illegible]	0.07
1988/89	0.72	0.95	0.46
1989/90	0.21	0.91	−0.22
Average	0.59	0.81	0.10
Andhra Pradesh			
1987/88	0.94	0.81	0.57
1988/89	0.30	0.85	−0.20
1989/90	0.64	0.54	−0.31
Average	0.65	0.73	0.02

Source: AICSIP Advanced Varietal Trials (ICAR 1988, 1989, 1990) and local market prices in Maharashtra and Andhra Pradesh.

(Table 6.3). The comparable figure for hybrids was 0.05.

Does this mean breeders need not compromise when selecting for genotypes with superior grain and fodder yields? When there is a positive correlation between grain and fodder yield, the identification of high grain-yielding genotypes necessarily implies selecting genotypes with superior fodder yields. In the absence of a correlation between grain and fodder yield, there will be a smaller sample of higher-grain-and-fodder-yielding genotypes from which to select. A negative correlation implies a clear trade-off. In the last two situations, some system for assessing overall performance is required.

There is another aspect to consider. As mentioned earlier, the 20 varieties and hybrids under evaluation have already gone through a series of selections based on superior grain yield. The question is not so much whether a correlation exists between these advanced varieties and hybrids, but whether any correlation exists between the thousands of lines and accessions from which the more advanced genotypes have been selected.

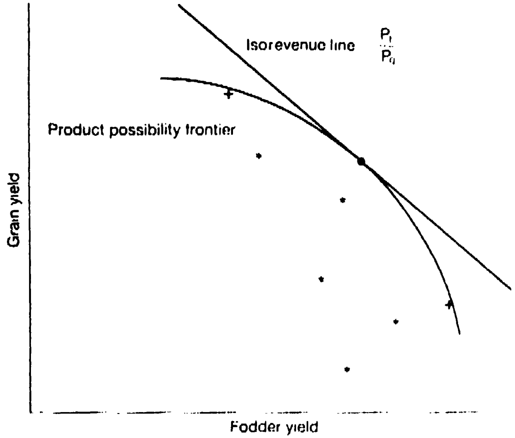

Fig. 6.2. Grain yield and fodder yield production possibility frontier for sorghum genotypes. * indicate technically inferior genotypes; + indicate technically efficient genotypes; • indicates technically and allocatively efficient genotypes when the prices of fodder and grain are P_f and P_g, respectively.

One would have to explore the entire range of existing genotypes (or a sample thereof) for grain and fodder yield trade-offs to establish that fact. Since the fodder yield component has not, until recently, received any consideration, such an exercise has never been carried out.

The obvious alternative to the single-focus selection criterion used is to broaden the focus to include fodder yield. This is not always a straightforward exercise, since high-grain-yielding genotypes are not synonymous with high-fodder-yielding genotypes. Selection of the best lines will therefore require a trade-off between grain yield and fodder yield. Some implicit or explicit weighting procedure is necessary. One alternative is to use respective market prices, or farm harvest prices if available. The advantage of this procedure is that it introduces criteria consistent with the actual value of the total crop, considering the contributions from both grain and fodder yield.

Very little work has been done using the economic value of production as a measure for evaluating and selecting cultivars in breeding programmes. Traditionally, breeders have made their selections without reference to the economic value of crops. This has some justification: when there is a one-to-one transformation between grain yield and value of production, grain yield is the only product of value.

In the two-product case, however, the problem must be analysed within a joint-product economic framework (Fig. 6.2). Farmers who grow dual-purpose cereal crops seek to maximize grain yield for a given level fodder yield, or vice versa, for a fixed level of inputs. More accurately, farmers seek to maximize returns per unit of the most valuable resource applied. A production possibility frontier for fodder yield (horizontal axis) and grain yield (vertical axis) for a group of genotypes is estimated. All technically inefficient genotypes, i.e. those not on the frontier, are eliminated. The technically and allocatively efficient genotypes are those close to the tangent of the frontier and the fodder/grain price ratio line. In a more simplified economic analysis of joint production, grain and fodder market prices are used to assess each genotype on the basis of its total value of production.

The AICSIP data show that grain yield is not a good predictor of varietal performance, as measured by total value of production. Rather, fodder yield is better. In the Advanced Varietal Trials, the average correlation coefficient for grain yield and total value of production is 0.48, compared to an average correlation coefficient of 0.79 for fodder yield and total value of production (Table 6.3). State data for Maharashtra and Andhra Pradesh display a similar, but smaller, superiority of fodder yield as a predictor of total value of production.

In a poorer production year, the differential increases: e.g. in 1988/89, correlation coefficients were 0.54 and 0.93, respectively. This suggests that under conditions of stress, grain yield suffers proportionately more than fodder yield, i.e. fodder yields are less variable. The importance of the fodder component is probably even higher than the average contribution to total production value would suggest, since farmers generally place a premium on income earned in a poor production year.

One generally associates higher grain yields with higher total value of a crop. There are two reasons why this is not always so. First, grain yield contribution to total value of production may not be high enough to completely dominate the picture. Indeed, in some years it may in fact be less than fodder yield's contribution (e.g. 1988/89). Second, the varieties selected in the trials condition the kind of correlation responses observed. These varieties were largely selected for high grain yield, and thus one observes consistently high grain yields with little variability. Relatively more variability in fodder yields is observed for those varieties. These differences in fodder yield, a trait not selected for, translate into differences in the total value of production.

How often are the highest-grain-yield ranked varieties also the highest-total-value-of-production ranked varieties? Varieties tested in 1989/90 were ranked according to their performance with respect to grain value and overall value (grain value plus fodder value), using 1989 market prices (Fig. 6.3). Several varieties initially ranked high by virtue of grain yield

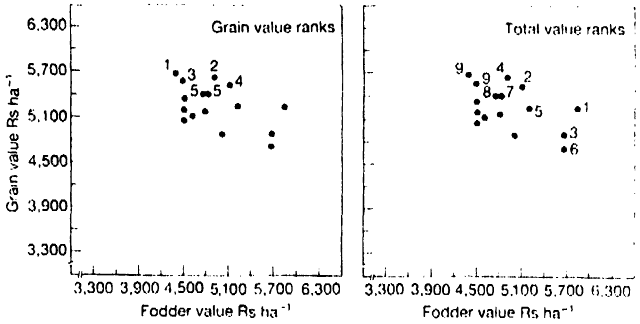

Fig. 6.3. Sorghum grain and total value of production rankings based on AICSIP trial data, 1989, using 1989 market prices.

Source: ICAR (1990)

were poor total value performers. For example, the varieties ranked 1 and 3 by grain-yield criterion ranked 9 and 9 (tied) when measured by total value of production. Not only are inferior varieties ranked higher than they ought to be, but four of the six top-ranked total value of production varieties were excluded from the grain-yield ranking selection. When 1970 price are used, the distinction between grain-yield ranking and total-value-of-production ranking is relatively less important. With a declining grain:fodder price ratio over time the discrepancy between these two criteria becomes more apparent. The strength of the relationship between grain yield and total value of production is highly dependent on the grain:fodder price ratio (Table 6.4). When the price ratio drops below about 3.0, the correlation actually becomes negative. Clearly, the basis for using the grain-yield criterion has continued to erode over time as the grain:fodder price ratio has declined.

Some inferior grain-yielding varieties were quite respectable with regard to total value, while some superior grain-yielders did not perform well overall. One variety in particular, SPV 819, which performed best with respect to overall value in both 1988 and 1989, did not even make it among the top five ranked varieties in those years. Promising lines are being eliminated at the advanced trial evaluation stage, and others probably earlier.

Highest-grain-yield ranked hybrids and highest-total-value-of-production ranked hybrids seem to correlate better than the varieties. But the strength of the correlation depends on the location and on the particular year.

Not only fodder yield but also fodder quality affects the total value of

Table 6.4. Simulated correction coefficients between grain yield and total value of production and fodder yield and total value of production, All-India average

		Correlation coefficient	
Grain : fodder price ratio	Year	Grain yield × total value of production	Fodder yield × total value of production
10.0	1975	0.802	0.122
6.4	1978	0.546	0.457
5.0	1980	0.359	0.632
4.4	1983	0.261	0.709
1.7	1986	−0.239	0.962
3.6	1989	0.130	0.796

Source: Yield data from the 1989/90 AICSIP Advanced Trials (ICAR, 1990); grain and fodder prices from the State Marketing Cooperative, Solapur

production. Fodder quality differentials may be detected by price comparisons. Monthly data on prices of MC and traditional varieties of sorghum straw are available at several locations in Maharashtra. These data were collected from fodder markets in Ahmednagar, Pune, Nasik and Solapur districts from 1985 to 1989 (Government of India, unpublished data). Fodder price variations and differentials were, as expected, observed across districts. Traditional variety dry fodder carried a mean 41% price premium over MC dry fodder. This differential varied between 21 and 70% for Ahmednagar, 30 and 90% for Pune, −3 and 34% for Nasik, and 35 and 50% for Solapur, across the five-year sample.

These results are consistent with a study by Parthasarathy Rao (1983), who examined fodder prices over time using data from markets in Hyderabad city. Only a small fraction of the sorghum fodder received by those markets was from MCs, indicating a strong preference for traditional types. This preference was reflected in a fodder price differential of 30%. Results from both of these studies correspond to expectations based on informal discussions with local farmers and milk producers who say that cattle and buffalo have a strong preference for traditional straw varieties. In some cases, animals will only accept MCs which are green, or if dry, only when chopped and mixed with other feed.

Effects on Adoption of Modern Cultivars

There is evidence that acceptance of new cereal cultivars is related to fodder yield and quality. Pearl millet MC adoption has been very successful in some areas such as Gujarat. On the other hand, adoption of pearl millet

MCs in Rajasthan, the major pearl millet producing state of India, is quite low, about 25% on average and negligible in many districts. Preliminary results of a fodder management survey carried out in western Rajasthan indicate that most farmers perceived MCs to have lower fodder yield (particularly in dry years) and poorer fodder quality than traditional types (ICRISAT, 1991b). Pearl millet breeders regard poor fodder quality as an important factor in the low adoption of MCs in Rajasthan. Survey data collected from the major pearl millet growing zone of central Maharashtra show that farmers make clear distinctions for straw quality between traditional and improved cultivars, as well as between various improved cultivars (Kshirsagar *et al.*, 1987).

Sorghum MCs have been mainly confined to the assured rainfall and high production potential regions of central Maharashtra. MCs have had less impact in other regions, such as the post-rainy season sorghum tract in western Maharashtra and Karnataka, the predominantly fodder growing districts of northern India (Madhya Pradesh, Uttar Pradesh, Gujarat, Rajasthan), and some rainy season growing areas in Andhra Pradesh, Karataka and Madhya Pradesh (Walker, 1990). One of the explanations given for the non-adoption of MCs of sorghum during the post-rainy season is lower fodder yield associated with them. By some estimates, MCs have only about 60 to 70% of the fodder yield of the popular traditional cultivar M-35-1 (Jansen, 1988).

Discussion

Sorghum and pearl millet breeding programmes at ICRISAT have focused on increasing grain yield potential through incorporating resistance to major biotic and abiotic yield reducers and by selecting genotypes responsive to good management. At the same time, major efforts have been undertaken to tackle some serious pests (shoot fly, stem borer, and midge) and diseases (grain moulds, downy mildew, ergot, and leaf diseases) for these two cereals. Within this problem-oriented framework, the thrust was always towards improving the efficiency with which plants convert energy into grain yield – usually at some cost to non-grain dry matter. Breeders selected against the traditional tall, multi-culm, dual-purpose plant types in favour of the short-statured, mono-culm, single-purpose types. This strategy appears to have been successful, particularly in central Maharashtra, where production potentials are high. Significant benefits in terms of grain yield have been achieved.

It is questionable whether this strategy will be successful in the future. As the importance of sorghum as a food grain in India declines, its value as animal fodder increases. Both ICRISAT and the national cereal breeding programmes are re-examining their current objectives and strategies.

Results from ICRISAT study villages, farmer surveys, adoption studies and the AICSIP trials in India are not unique as examples where the crop straw or 'by-product' registers such a large share of the total crop value. Nordblom and Halimeh (1982) in Syria found that the market value of harvested lentil by-product equalled the value of harvested grain. Cowpea hay represents a significant share of the total value of the cowpea crop in the Sahel (Bandu Forson, 1990). A similar observation was made by Sallam *et al.* (1986) in Egypt with respect to wheat straw.

Quantity and quality of straw can affect adoption. New and 'improved' higher-yielding varieties of wheat failed to replace traditional varieties in Egypt due mainly to lower straw quantity and quality associated with the improved varieties (Reed *et al.*, 1988). High-yielding varieties of cowpea in northern Mali have had low acceptance because of low forage yield (Reed *et al.*, 1988). Farmers in Syria rejected an improved barley variety because its straw was less palatable to sheep than straw from a barley landrace (Nygaard, 1983).

The value of crop residues to farmers in the SAT is significant and should not be ignored in breeding programmes. Social scientists can assist breeders in several ways. Of critical importance is eliciting information from farmers about production objectives, perceived risks associated with climatic variability, advantages and disadvantages of MCs, single versus dual-purpose plant type preferences, and the relative importance of grain *vis-a-vis* fodder yield and quality. Farmer surveys are underway in target regions to collect such information. In a collaborative spirit, crop improvement scientists have had considerable input in the design of the questionnaire and have participated in some of the farmer interview sessions.

It seems likely that sorghum and pearl millet improvement programmes will give increased emphasis to fodder considerations in future breeding and selection efforts. Since 1990, ICRISAT's sorghum breeding programme has been recording fodder yields on many of its on-station experiments. The pearl millet breeding programme too, perhaps more conscious of fodder's importance in an area such as western Rajasthan, has for several years been collecting data on both grain and fodder yields in its trials. Evaluation methods will depend to some extent on results of the farmer surveys, including how farmers value fodder with respect to grain. It seems reasonable to expect that regional preferences will emerge. This would provide the basis for a multiple strategy approach, developing distinct improved 'groups' of genotypes based on region-specific evaluation criteria. Fodder considerations may dominate a regional-based strategy for areas such as Andhra Pradesh and Karnataka where sorghum fodder's relative contribution is so much higher. It may also dominate a development strategy for risky or marginal production zones where, again, fodder plays a relatively more important role. A not-too-unlikely scenario for the future would be a three-pronged strategy consisting of:

1. A hybrid development programme targeting regions with high management responsiveness (e.g. central Maharashtra for sorghum and Gujarat for pearl millet) and with primary interest in grain yield.
2. A varietal development programme emphasizing dual-purpose types which targets a spatially wider area where both grain and fodder production are relevant (initially, more emphasis may be on yield and quality of crop straw).
3. A hybrid development programme emphasizing single-purpose fodder types for those interested mainly in commercial fodder sales or those who have many animals in the farm system.

The most direct way to evaluate fodder quality differences among genotypes is by laboratory analysis, measuring quality characteristics such as total digestible nutrients and crude protein. Genotype fodder quality differentials could also be measured through animal trials. Animal preferences (amount of intake) and digestibility (weight gain) could be assessed. To our knowledge, however, neither laboratory analysis nor feed trials are being used by breeding programmes to evaluate fodder quality, the costs being too high.

Conclusions

The focus of ICRISAT's cereal programmes has been on increasing grain yield potential through incorporation of resistance to major biotic and abiotic yield reducers and selection of genotypes responsive to good management. Straw yield and straw quality have received little emphasis. Where farmers have begun to specialize and animals play a less significant role in the farming system, single-purpose cereal grain types are justified. But the vast majority of farmers in the SAT practice in mixed crop–livestock production systems. In order to maximize the potential of the SAT, new cultivars must be such that both grain and fodder objectives are satisfied.

One important contribution the economist can make is in providing an accurate estimate of the true value of alternative varieties being grown by the farmer. In doing so, the roles of both grain and fodder components are assessed and the rationale for breeding exclusively high-grain-yielding varieties can be examined. This is all the more pertinent in view of the changing relative importance of fodder over time, a trend which is likely to continue into the future.

In addition to these aspects, the economist can contribute useful information to the breeder along two other lines: first, by examining the trade-offs between grain yield and fodder yield (or grain value and fodder value) for a given set of genotypes. This could help breeders in assessing

the relative importance of fodder based on market prices. Second, by providing information on farmers' rationale for growing particular cultivars and thereby determining the importance farmers place on crop straw yield and quality.

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