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FARMING SYSTEMS RESEARCH APPLIED IN A PROJECT ON FEEDING OF CROP RESIDUES IN INDIA

By J. B. SCHIERE†, KIRAN SINGH‡ *and* A. J. DE BOER§

†*Wageningen Agricultural University, Department of Animal Production Systems, PO Box 338, 6700 AH Wageningen, The Netherlands,* ‡*Indian Council of Agricultural Research, Krishi Bhavan, New Delhi-110 001, India, and* §*Winrock International, 1611 N. Kent Street, Suite 600, Arlington, VA 22209, USA*

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SUMMARY

Increased use of prime agricultural land for cropping and non-agricultural uses in many tropical countries implies that crop residues become more important as a source of feed for livestock. Traditionally, much research on crop residue feeding was done by focusing on laboratory measurements of feed quality but neglect of farmers' perceptions led to disappointing results in the transfer of straw feeding technologies based upon laboratory results. Farming Systems Research (FSR) provides methodologies and concepts that bridge the gap between formal commodity research (including crop residues and by-products) and field application. This paper reports the experiences of a project in India that changed the emphasis from a commodity research approach on improved crop residue feeding to a system approach by using three types of FSR. The paper first reviews the achievements of on-station research on feeding systems for crop residues in terms of treatments (biological, chemical, physical) and in terms of breeding and managing cereal crops for more and better straw. Next, it discusses definitions and problems of FSR as encountered in the project's reorientation of livestock research and development programmes. Finally it summarizes the overall results of the three FSR approaches used in the project.

INTRODUCTION

Increased use of agricultural land for cropping and non-agricultural uses in many tropical countries implies that crop residues become more important as a source of feed for livestock. However, the nutritive value of straw is low in the sense that it does not support high levels of animal production in the form of milk yield, reproduction and liveweight gain. Several methods are available in laboratories, experimental stations and farmers' fields to make good use of straw for feeding purposes (Sundstøl and Owen, 1984; Reed *et al.*, 1987; Doyle *et al.*, 1986; Kiran Singh and Schiere, 1993). The application of these methods is, however, very system specific, in that what is useful in one farming system may not be useful elsewhere. Moreover, use of straw for feed may have implications in other places in

†Email: jb.schiere@binele.nl

the system, for example, on the cropping calendar or on labour demands and income division between men and women. Traditionally, much of the formal research on crop residue feeding focuses on laboratory measurements of feed quality, thus neglecting systems aspects and the use of farmers' perceptions.

Farming Systems Research (FSR) approaches provide methodologies and concepts that can bridge the gap between formal research and issues in field application (Shaner *et al.*, 1982; Simmonds, 1986; Collinson, 1987; Anandajayasekaram, 1997). Today, FSR is part and parcel of many crop development projects in different parts of the world. Application of FSR to aspects of livestock development follows the trend set in cropping research, but often with some delay. As a result, some programmes with technological and disciplinary approaches had to be reoriented and this paper reports the experiences of one such project that was remodelled accordingly. This is the BIOCON project in India that started with a strict technological and disciplinary focus on the use of crop residues for animal feed in India. The paper describes the background and structure of the project, followed by achievement of formal research in crop residue feeding methods. It concludes by explaining how the use of several FSR approaches contributed to the generation of disciplinary knowledge through participatory methods and to a better understanding of system behaviour in general. The practical result was a much better understanding by researchers of farmer problems coupled with specific practices being targeted to specific groups of producers.

THE BIOCON PROJECT

BIOCON is an acronym for the 'Indo-Dutch project on Bioconversion of Organic Crop-Residues' that was run by the Indian Council of Agricultural Research (ICAR) in India and the Wageningen Agricultural University (WAU) in The Netherlands. The project was conceived in the late 1970s and aimed initially to combine knowledge from two technical disciplines (microbiology and animal nutrition) to solve a perceived farmers' problem through development of technologies: the biological treatment of straw (Bakker and De Jong, 1984; Zadrazil, 1984; Gupta *et al.*, 1993; Kiran Singh and Schiere, 1996). The term 'perceived' is emphasized since it is clear with hindsight that the project failed to include attention to socio-economic aspects of technology development. In its early stages BIOCON assumed that (interdisciplinary) work by animal nutritionists and microbiologists had a positive and causal relation with farmers' incomes and welfare. This approach was based on the assumption that (a) better straw quality would improve farmers' incomes regardless of the characteristics of their farming system and (b) new technology could be introduced without having effects elsewhere in the system. Last but not least, the project assumed that laboratory measurements (that is scientists' perceptions) of animal performance such as liveweight gain and feed intake could reflect adequately the perceptions of farmers (men and women) about what was good for their farming conditions. BIOCON was located at five major centres throughout India where work was undertaken on livestock research and development in a range of farming conditions (Kiran Singh and Schiere, 1996).

The original focus on technological approaches to provide quick and general solutions for farmers' problems represented a typical 'top-down' approach to development, that is, a form of technology-driven transfer of technology (Röling, 1989). Initially, most of the original Indian and foreign participants ignored local variation among farming systems, though the fact that farmers have their own perceptions and logic to decide on adoption of new technologies had been well described by Chambers *et al.* (1989). Moreover, both governments expected the project to develop technologies that would directly and visibly benefit large groups of small farmers. This was an unrealistic expectation since, first, most of the counterpart institutions were not well geared to communicate directly with large numbers of farmers. Second, straw feeding methods are typically 'niche' technologies. They are system specific, as will be discussed below. Third, the main application of these methods lies in low-input farming systems where spectacular results are unlikely. After some time the participants began to understand these problems and FSR was introduced to determine (a) which technologies would fit where, and (b) which field problems needed to be taken up to reorient research and extension programmes. BIOCON therefore illustrates the transition from a focus on commodity and disciplinary research to an approach that considers the setting of research and development activities from a systems point of view.

DISCIPLINARY COMMODITY RESEARCH

The original technological focus of BIOCON on the use of crop residues for animal feed led to the refinement of technologies that had already been researched elsewhere (Sundstøl and Owen, 1984; Reed *et al.*, 1987; Doyle *et al.*, 1986; Sansoucy, 1986; Preston and Leng, 1984; Schiere *et al.*, 1988). These approaches are generally classified as biological, chemical and physical treatments, the use of feed supplements and the application of plant breeding and cultivation practices to increase quantity and improve quality of crop residues. The technical results of that work in India and abroad were brought together by Kiran Singh and Schiere (1993; 1995), Joshi *et al.* (1995) and Seetharam *et al.* (1995), and they are further summarized below.

Biological treatment of straw

Work on biological treatment of straw was abandoned by BIOCON in 1987–88 because of the identification of serious technical problems such as difficult process control, organic matter losses, risk of toxic contaminants and only marginal increases in feed quality. Also, the original focus on improved straw digestibility was narrow and ill defined. Only one approach was scaled up to the level of actual feeding trials but its results have remained inconclusive and impractical. New objectives for biological treatment were identified, that is, it appeared possible to increase intake, to preserve moist feed biomass, to increase protein content or to produce mushrooms (Flegel, 1988; Gupta *et al.*, 1993). A systematic attempt at further exploration of these avenues was, however, not within the remit of BIOCON.

Chemical and physical treatment of straw

Chemical and physical treatment of straw aims mainly at increased digestibility and intake of straw. Work from abroad was applied on a variety of straws such as rice (*Oryza sativa*), wheat (*Triticum aestivum*), finger millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*) and sugarcane (*Saccharum* hybrids) bagasse. In summary, the only practical chemical treatment of straw in tropical regions so far has been based on the use of urea. Treatment of slender straws (rice and wheat) is likely to have more effect than treatment of coarse straws (millet and maize (*Zea mays*)), partly because the latter tend to have better initial quality. The only currently applicable physical treatments are chopping and soaking of slender and coarse straws, and the use of steam treatment on sugarcane bagasse (Sharma *et al.*, 1995).

Supplementation

Supplementation with feeds of higher concentration of digestible nutrients is another way to overcome a shortage of nutrients in low quality feeds such as straw. BIOCON studied and reviewed the economics of supplementation or treatment, the application of ration formulation and refinement of work on supplementation by introducing techniques such as response curves obtained on live animals and by use of laboratory techniques. The first conclusion was that it was necessary to distinguish supplementation strategies such as catalytic, strategic and substitutional feeding. Catalytic supplementation refers here to the use of small amounts of supplement that improve rumen function to enhance the digestibility of the basal roughage. Strategic supplementation uses limited feed resources for only the most important part of the herd, for example, lactating, pregnant or working animals. Substitutional supplementation uses large quantities of good feed to satisfy the need of high producing animals, if necessary at the expense of intake of poor quality roughages. Second, it was agreed that supplementation experiments should aim to understand dose-response patterns and interactions between supplements and basal roughages. Nylon bag and gas techniques have proven to be quite useful in this respect (Sampath *et al.*, 1993).

Genetic and management factors

Exploitation of variation in quantity and quality of straw for animal nutrition due to genetic and management factors was the most innovative work in the project. Even this 'variability' work was not new in itself but BIOCON helped to popularize the concept. Joshi *et al.* (1994) and Seetharam *et al.* (1995), along the lines of others such as Kelley *et al.* (1994) and Byerlee *et al.* (1989), have shown that farmers choose between varieties and cultivation practices for obtaining better or more straw. The 'straws' studied by BIOCON included those of rice, wheat, finger millet, sorghum and maize. The first conclusion was that the improvement of straw quality by plant breeding is best done by increasing cell wall digestibility and by aiming to maintain or enhance the 'stay-green' capacity of the crop. 'Stay green' means that some varieties are still green at harvest, providing fodder of better quality than varieties that become entirely yellow. Second, the effects of management tended to dwarf genetic effects on straw quality and quantity, and future research and development work of plant breeders should aim to screen promising varieties and cultivars in relation to agro-climatic conditions and cultivation practices. Third, variability work appeared to be economically more relevant for coarse straws (for example, maize and millets) than for fine straws (for example, rice and wheat), particularly in variable and low-input farming systems with unreliable climate and rainfall. Fourth, and as an important sideline, the work on variability led to the translation of farmers' criteria about crop choice into scientists' criteria, as explained later in this paper.

SYSTEMS RESEARCH IN BIOCON: APPROACH AND PROBLEMS

Much information is now available on technical aspects of straw feeding but application of these methods in India and abroad is constrained by practical conditions which vary between and within the major farming systems rather than by perfection of the method (Owen and Jayasuriya, 1989; Schiere *et al.*, 1988). The low adoption of feeding systems designed in research stations was the main reason to introduce FSR but BIOCON always maintained that FSR should not be used solely to transfer a particular technology. At most, FSR can help to establish under which conditions a technology is useful and what side effects it may have. More importantly still, FSR can establish which other problems need to be solved in the field, that is, it can help to redesign the agendas of researchers and decision-makers.

The introduction of the systems approach into BIOCON was accompanied by problems that were not unique to this project. Foremost, 'the systems approach' was ill defined and for some project staff it implied the use of computers, while for others it implied the design of model farms and for still others it consisted of concepts of participation by farm communities to help determine field problems and research priorities. Second, the use of a FSR approach was rather alien to the existing paradigms at most of the cooperating institutions. At the start only a few of the researchers, extensionists and consultants could grasp the idea of 'participation'. Also, the fact that a technology can be technically and scientifically sound but at the same time uneconomic and impractical was hard to grasp for researchers who assessed technology only by biological criteria, and for extensionists brought up in the tradition of 'lab-to-land transfer of technology'. Moreover, researchers feared that official journals would not accept their work on livestock systems research and the funding governments had procedures and expectations geared to a top down approach and to monitoring of large-scale and easily quantifiable results. Last, but not least, there was an initial feeling of competition and suspicion rather than a spirit of cooperation between the partners in the project.

The problem of defining FSR was discussed and solved by concluding that several types of FSR exist. The classification by Simmonds (1986), which was used to guide the discussions, distinguishes between the following types of FSR:

(1) FSR *sensu strictu*: an academic exercise which can use time-consuming experimentation, questionnaires and data collection to understand how systems function, and how general systems theory can be applied to predict their behaviour.
(2) On-Farm Research with a Farming Systems Perspective (OFR/FSP): an approach that aims at a quick understanding of the farming system to suggest and test innovations. In BIOCON this approach became known as Farming Systems Research and Extension (FSR&E) which employed techniques such as zoning, transects, Participatory Rural Appraisals (PRAs), screening and on-farm testing of technologies (OFT).
(3) New Farming Systems Design (NFSD): an approach that aims to design new farming systems, either on-station or in the field, with or without farmers' participation.

This broad set of definitions seems to be an all too convenient umbrella that serves to cover widely divergent activities. This was a blessing in disguise, however, since most workers could identify a niche to work in, whether they were microbiologists, animal nutritionists, plant breeders, economists or sociologists. Also, the distinction made by Simmonds (1986) and the frequent interaction among project workers through workshops, joint research and publications gave each collaborator access to what BIOCON started to call the basic principles of FSR:

- An intervention in one place of a system affects the functioning of the other parts (Spedding, 1988). Eventually we started calling this the principle of *ceteris imparibus*, an idea that goes contrary to the common assumption of *ceteris paribus* (all other things remaining equal) that is used in many traditional disciplinary and commodity-focused programmes.
- Socio-economic and bio-physical differences between systems imply that interventions have an application only in particular niches, that is, a technology can be useful in one system but counterproductive elsewhere. This principle became known as 'beauty is in the eye of the beholder'. It recognized the divergence of interest and viewpoints of different actors (cognitive agents) according to their context. It represented a break with objectivist tradition, while moving to constuctivism which considers reality to be a combination of perceptions of the different actors (Röling, 1996).
- FSR&E aims to work explicitly for the interests of the resource poor farmers. This was implicit in the project goals and in the choice of work on crop residues rather than on high input approaches.

Acceptance of these principles implies that successful development requires inclusion of a multidisciplinary team of scientists, extensionists and farmers (men and women) and participation by people with different, less biased ideas about the nature of technological interventions and their possible side effects. Typical examples of such professional biases need to be given. The first is that animal nutritionists tried to understand why farmers in the region Haryana fed wheat straw while burning the rice straw. The scientists started by analysing the straws for fibre content, protein and digestibility. After talking with farmers, however, they found that the rice straw was burned because the fields had to be quickly cleared for the next crop whereas wheat straw became available at the start of the dry season without the need for immediate land preparation and with the immediate need for feed. Another example was that plant breeders associated with BIOCON came to realize that farmers rejected grain varieties that were selected for grain yield only, in favour of varieties that combined a reasonable grain yield with a good yield of straw (A. Seetharam, personal communication).

Interdisciplinarity and 'interinstitutionality' in the project were achieved initially through a series of small and large workshops in which project staff had to prepare and present papers that discussed a relevant topic on crop residue feeding. The authorship of these papers was deliberately shared between a mix of people from different disciplines, institutions and regions and no papers on disciplinary researcher-driven work were accepted in BIOCON proceedings. A second way of achieving interdisciplinarity was the intensive visits by consultants and project coordinators who shuttled from one centre to another. A third and critical point was that researchers were assigned, in mutual consultation, tasks that were driven by groups rather than by individual academic interests.

SYSTEMS RESEARCH IN BIOCON: ACHIEVEMENTS

The immediate impact of the project for farmers in the field was modest due, first, to the size and heterogeneity of India, second, to BIOCON's initial top-down approach and, third, to the deliberate choice to work through the cadre rather than directly with farm communities. Nevertheless, some achievements need to be highlighted regarding the use of the different FSR methodologies. Most of the systems work belonged to the FSR&E category, but interesting NFSD and FSR *sensu strictu* was also accomplished, including an unexpected sideline to the theoretical aspects of systems behaviour.

First and foremost, FSR&E methodology made BIOCON partners join in a variety of PRAs for field visits and discussions with farmers. This helped scientists and extension workers to see the complexities of farming and that a new technology often requires or triggers a series of other changes. For example, the introduction of a technically and economically sound straw feeding method may be impractical because it affects the labour division in the family unfavourably, or it may imply that straw becomes a valuable feed, that is, a resource that is no more given 'free' to neighbours or labourers. Similarly, the introduction of a new grain variety or an agro-chemical product may increase crop yields at the expense of the availability of animal feed on the farm. Last, but not least, it was a revelation for many involved with the project to see that animal nutrition, let alone crop residue feeding, was not necessarily the first problem on farmer's minds. For example, while conducting PRAs it was found that some villagers would 'ask' for a speed restriction on the road or that women would suggest action be taken against the local liquor shop. Even when focusing on animal production, there were many issues that ranked higher than crop residue feeding, for example, milk price, animal health or illness in the family. Second, the use of FSR&E methodologies such as zoning, transects, PRAs and on-farm research increased the appreciation among scientists and policy makers of the diversity between farming systems due to geographical location. It also revealed what BIOCON started to call the 'farmers' perceptions' (Rangnekar, 1993; Rao *et al.*, 1995), a terminology adopted from work such as that of Chambers *et al.* (1989). This led to the realization that academic research tended to focus on concepts, such as digestibility, cell wall contents and 1000-grain weight, that were alien to farmers who talked and thought in terms of butterfat content and dung consistency. An interesting point was that BIOCON realized how differences in terminology could conceal similarity in concept. For example, farmers' preference for leafy varieties agreed with the researchers' preference for straw varieties with high digestibility since high leaf content is well correlated with high digestibility.

Overall, FSR&E methodology improved the understanding that application of interventions is niche-dependent, particularly for straw feeding methods. BIOCON avoided deciding in general terms whether a technology was good or bad. Indeed, a standard practice in the agro-ecological and socio-economic conditions in northern India was useless in southern India, or even in the next town in northern India. The need to chop straw was a case in point. Many farmers in the irrigated northern plains fed chopped wheat straw but that practice was not common among the farmers feeding coarse stovers in the upland millet regions of southern India. One likely reason is that in northern India wheat straw tends to be chopped to facilitate mixing with green feeds and to avoid selective consumption. On the other hand, stovers can be fed whole to facilitate selective consumption of the better plant parts.

Another type of FSR, the NFSD, was used very little in BIOCON. When defined as the design of pilot-farms or prototypes, the planned NFSD-work failed due to the institutional problems in implementation. NFSD defined as the use of sensitivity analysis was undertaken to work on 'screening of technology', one of the steps in the FSR&E. It determined under which condition a technology might be useful. For example, the result of screening different supplementation methods concluded that (a) catalytic feeding is useful in conditions of plenty of poor quality feed where herd survival is the main objective, (b) strategic feeding is useful where a small part of the herd needs special attention and (c) substitutional feeding is useful where basal roughage is expensive and where concentrate supplements are cheap in relation to animal products such as milk (Sampath *et al.*, 1993). Many such screenings were carried out, for example, to determine where straw treatment with urea would be useful (Schiere *et al.*, 1988; Sharma *et al.*, 1995), where selective consumption would be useful (Ulhas Prabhu *et al.*, 1995), and how to establish breeding priorities for grain ideotypes (Doyle and Oosting, 1994).

The last category of results worth mentioning lies in the area of FSR *sensu strictu*. The introduction, development and testing of FSR experiences brought together staff from divergent disciplines such as economics, sociology, gender studies, animal nutrition and plant breeding. It helped animal nutritionists to interpret their results on fibre analysis by understanding aspects of plant physiology discussed by agronomists, for example, about the effect of planting density on stem thickness, or about the effect of photoperiodicity on crop choice and plant phenotype. It also helped biophysical scientists to understand the socio-economic and cultural intricacies of development processes. Some workers decided not to bother with 'soft' issues, but for others, such as those involved with plant breeding programmes, it was essential to re-orient. An unexpected sideline of systems theory came from work on the niche suitability of technology based on resource variation ranging from lowland to upland and from straw to concentrates. This work showed that increasing resource flux as a result of feed availability and feeding methods led to higher levels of (animal) system output associated with more intensive use of other resources. This aspect was elaborated for crop and livestock systems in general by using insights from thermodynamic and general systems theory by Schiere *et al.* (1999). It showed the two-way relation between resource flux (nutrients from feeds) and level or type of production. In other words, resource availability determines system behaviour, but also, the targets set for system output determine the demand for resources. The typical example for the BIOCON mandate was that straw feeding allowed (gave rise to) systems with low individual animal output. Treated straw allowed medium outputs and 'good' fodders and concentrates allowed high outputs. Last, but not least, and in terms of integration of systems, the work on FSR *sensu strictu* combined with work on NFSD showed that successful integration of subsystems, here crops and livestock, requires mutual adjustment of the components (Patil *et al.*, 1993). Practically, development of animal production may require agronomists to strike a balance between grain and straw yield (Joshi *et al.*, 1995). At the same time, however, successful rural development can require animal production research to develop adjusted breeds and production processes rather than to focus on high output from individual animals alone. This was a drastic departure from BIOCON's initial reductionist approach which assumed that the simple focus on 'improvement' of straw quality for higher liveweight gain in animals would automatically result in increased farmer wellbeing.

CONCLUSIONS

A systems approach to agricultural research and development is necessary to complement the typical focus on disciplinary approaches and commodities in tropical and temperate regions. The BIOCON project originally adopted a narrow focus on technological solutions to the perceived problem of low nutritive quality of straw. However, the practical impact of these technologies remained below expectations and the project adopted a systems approach to broaden its outlook, to determine the niche suitable for 'on the shelf techniques' and to reassess priorities for laboratory research and extension programmes. The broad set of definitions of FSR helped to assemble researchers and development workers under one common umbrella. More importantly, it gave them access to the common principles of a holistic system approach developed elsewhere. This BIOCON was later called *ceteris imparibus*, and 'beauty is in the eye of the beholder'. They imply a need for attention to the socio-economic and bio-physical side effects of technology, reassessment of research methodology and the use of farmers' participation and interdisciplinarity teams for effective research and extension. The results of commodity research based on Indian and international work, in association with the various FSR approaches, helped to refine a set of straw feeding methodologies and their suitability in 'niches' in the prevailing agro-ecosystems. The project showed that interdisciplinary work can be effective. It was made possible, in no small part, by frequent interaction between workers and by a strong central 'nervous system' consisting of seminars, workshops and participation of ad hoc advisers from outside the project. In this way interdisciplinarity and farmers' participation were found to be both possible and indispensable to make a programme effective and well focused.

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