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EFFICIENCY AND EQUITY CONSIDERATIONS IN THE DESIGN OF AGRICULTURAL TECHNOLOGY IN DEVELOPING COUNTRIES

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The green revolution in developing countries magnified concern about the efficient allocation of agricultural research resources and the distributional consequences of alternative research resource allocation and technology design strategies. These concerns are being increasingly reflected in the planning, management and research activities of the international agricultural research centres. In this paper a description is given of how economists at one centre contributed their expertise to the *ex ante* analysis of some key issues in this complex milieu, such as the determination of research goals and priorities, the small-large farm dichotomy or nexus, income distribution and employment effects, human nutritional considerations and farmer risk attitudes.

Agricultural research in developing countries has had a high payoff, both in terms of the return on the investments required, and in terms of equity. The 23 studies of agricultural research productivity in developing countries reviewed by Ruttan (1980) had an average annual rate of return on investment of 55 per cent. In the studies, research on food crops, livestock and commercial crops such as cotton and rubber was covered. These high rates of return to agricultural research in developing countries suggest that the levels of research investment remain well below what they should be to exploit fully the opportunities for increased agricultural production and enhancement of economic development and human welfare.

Economists have played a key role in assessing the impact of past investments in agricultural research, which is amply displayed in Ruttan's (1980) analysis and in Arndt, Dalrymple and Ruttan (1977). Their role in the *ex ante* analysis of research resource allocation strategies is growing and seems not yet to have reached its full potential.

With the increasing trend toward inclusion of economists in agricultural research institutions and agricultural ministries in developing countries, their scope to contribute constructively to the design of technology options and policies is enhanced. However, *ex ante* evaluation is fraught with many uncertainties, not the least for economists. Considerable subjectivity and intuition is still required and, in these circumstances, use of formal planning models of the type described in Fishel (1971) often only serve to cloud the decision-making environment with an air of certainty and objectivity which can be inappropriate (Arnon 1975, p. 61). Many of the techniques of project appraisal were designed for industry where costs and gains are generally private. In

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agricultural research and development there are usually many externalities, and public funds comprise the bulk of the investments, especially in developing countries. As a result, analysis of the likely efficiency implications of alternative strategies is complex and income distribution and social welfare concerns must be assessed as well.

The theme of this paper is that, at the present time, the most valuable role for economists responsible for research on these issues is in the provision of more economic information to assist policy makers in reducing the amount of subjectivity in their decisions. These decisions are usually made sequentially so that the concept of marginal analysis, so familiar to economists, is appropriate. Rarely is one asked to help identify a complete portfolio of projects. The more common problem is the degree of emphasis to place on different activities in view of budget and scientific manpower constraints.

In this paper the methods and approaches taken by a group of economists at an international agricultural research centre are described under five broad headings. These illustrate how socio-economic information and analysis were used to help in the *design* of technology options for semi-arid tropical farmers. In the recent paper by Hardaker, Anderson and Dillon (1984) the focus is on *assessment* of technologies from a more philosophical standpoint of *what* needs to be done. This complements the '*how* one group did it' *ex ante* approach taken in this paper. The discussion begins with the determination of research resource allocation priorities, the small-large farm dichotomy or nexus, income distribution and employment, human nutritional considerations and farmer risk attitudes, and ends with some comments. The author draws heavily on published and unpublished materials from colleagues' and his own research at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

Determining Research Resource Allocation Priorities

It is evident that, in the past 15 years, economists have accorded increased attention to the design of methods to assist in the planning of agricultural research strategies. The range of approaches is described in the watershed publication edited by Fishel (1971). More recently, Ruttan (1982) discussed the issues with which research administrators are confronted in deciding the allocation of scarce research resources amongst many competing programs and projects. In the ensuing section, the question of setting broad goals in agricultural research is addressed; this is followed by a description of the range of techniques employed at ICRISAT to determine regional and commodity priorities, including consideration of equity-efficiency trade-offs.

Goals and choice of methods

Arnon (1975) discussed the desirable features of a national agricultural research program, including the identification of broad national goals which research is expected to achieve, the formulation of research programs and activities based on these goals and the various techniques for evaluation of research projects. More recently, Berry (1981) provided a review of alternative research resource allocation schemes which have been or are currently employed in developed countries such as the United States, Canada and Australia.

Arnon (1975) delineates three basic types of approaches used to plan, evaluate and select research activities: the economic analysis approach, the operational research approach and the decision-method approach. The latter is probably the least demanding of data and expertise which are scarce in developing countries and is probably to be preferred at this time. In the most recent review of techniques proposed to select research projects, Anderson and Parton (1983) added a fourth category, namely rule-of-thumb approaches.

The choice of planning instruments depends on the level at which the problem of choice is being addressed. The issues may differ for an international agricultural research centre, an international donor agency, a national agricultural research system or a regional research station. Arnon discusses the issues confronting national agricultural research programs where the establishment of goals for agricultural research at the national policy level is seen as the prerequisite to formulation of the precise aims and objectives of a program of research. It is in the setting of goals that government intervention has a particular rationale in agricultural research (Samuel, Kingma and Crellin 1983, p. 15).[1] At the present state of scientific knowledge, economists and other social scientists seem to have a greater comparative advantage assisting in the setting of overall research goals and their translation into viable research programs than in assisting research administrators in selecting a portfolio of research projects to reflect these goals. The approach of the planned programming and budget system in the USDA's National Program of Research for Agriculture described by Bayley (1971) represents a formal technique intended to relate national goals to research programs. The value of such formal techniques is yet to be adequately proven (Anderson and Parton 1983).

Many of the goals set for agricultural research by national policy makers are in conflict and attempts to rationalise them are valid for economists and other social scientists. The most appropriate contribution would seem to be in the provision of more information to policy makers and research administrators on the likely trade-offs implied by pursuing alternative strategies. To attempt more refined approaches, such as those suggested by Pinstrup-Andersen and Franklin in their multiple-goal modelling approach (1977, pp. 423-5), would be excessively demanding of the data base and patience of the clientele in developing countries. Most questions faced by research administrators are of the type involving decisions 'at the margin' rather than those faced when starting a whole new national effort. In such circumstances, simple analytical tools such as the *ex ante* project evaluation techniques described by Greig (1981), supplemented by a suitable dose of intuition, are likely to provide more timely and valuable information than comprehensive analytical frameworks.

In developing countries, sophisticated analytical skills are themselves scarce and it is probably unwise to suggest they be devoted to esoteric modelling of whole programs or institutions. Additionally, as Campbell

[1] This is in addition to the well-known reason that individual agents have little incentive to pursue research where the benefits cannot all be captured by them due to the difficulties of assigning property rights. Economies of scale can also necessitate publicly funded research and development.

(1972) pointed out, there is limited flexibility to move scientists around as new problems and priorities are identified, due to disciplinary specialisation. This limitation further reduces the relevance of operations research methods in determining research strategies. If the existing stocks of commodity, disciplinary and, to a lesser extent, regional competence of scientists are ignored in re-ordering priorities using such methods, there is a real danger that the probabilities of successful research will be significantly reduced. There seems to have been an almost universal ignorance of this in the literature on the determination of research priorities. This is not to say that, over time, the appropriate mix of disciplines could not be achieved by restructuring tertiary education programs. However, these take so long to come to fruition that there is a danger that research priorities will have again changed.

Congruence analysis and regional and commodity priorities

The likely trade-offs between equity concerns of governments and the pursuit of efficiency or productivity gains are of increasing concern in developing countries. In agricultural research these issues are important in the choice of regional and commodity priorities. For example, the green revolution in rice and wheat in developing countries of South and South-East Asia has been confined largely to irrigated regions with adequate water control. These were generally the more affluent parts of the countries before the revolution, so it can be argued that, from a regional perspective, the changes that occurred were regressive. Scobie and Posada (1976) described how the upland rice producers of Colombia were the major losers from the green revolution in rice in the lowland irrigated regions. The upland landowners would lose relatively more than upland rural labour as it is the most inelastically supplied factors of production which bear the greatest burden in such circumstances. Land rents would decline more, or rise less rapidly, than wage rates because some labour would migrate to the prospering region. The implication of this from Quizon and Binswanger's (1983) work is that, as long as landowners cannot stop investment in agricultural research in other regions, they must attempt to achieve rapid technical change in their own regions in order to minimise their losses from technical change elsewhere.

Edwards and Freebairn (1981) provided an analytical framework to explore the implications of externalities in research on export crops for the distribution of benefits between the researching and the recipient country. When a country's (region's) research reduces costs in other countries (regions) as well as at home, a high price elasticity of total demand for aggregate production and a large share emanating domestically is to the home country's (region's) advantage. During the colonial era, emphasis was generally given to research on commercial export crops, to the exclusion of basic food staples in developing countries. With a relatively assured and elastic demand from the colonial power, producers (mostly originating from the same place) were able to capture most of the benefits.

In *ex ante* assessment of international, national and regional priorities, the most valuable starting point is the rule-of-thumb technique of congruence analysis. This was used by Boyce and Evenson (1975) to assess the relative allocation of national program research budgets for various

commodities compared to their relative importance in aggregate production. The rationale for this is that the potential benefits of research are directly proportional to the importance of the commodity or industry and hence, *ceteris paribus*, the share of the research budget should approximately equal the proportion of aggregate production represented by the commodity or industry. Ryan (1978) used this approach to evaluate the congruence between the research expenditures of ICRISAT and the importance of the five crops in its crop improvement budget. He also applied the same approach to assess the extent of congruence of research expenditures within the five crop research programs and the farming systems and economic programs with indexes of their relative importance in the seven functional regions in the semi-arid tropics. By separating national program research expenditures in the seven regions for each crop from those of ICRISAT, it was possible to judge whether the addition of the ICRISAT programs increased or decreased the congruence (Table 1). More recently, Oram and Bindlish (1981) and Salmon (1983) have used a similar analysis, but at a more aggregated level.

The congruence approaches described above are based solely upon efficiency considerations. Many other factors need to be taken into account before final allocations are made. Arnon (1975, p. 83) and Samuel et al. (1983, p. 15) include the following:

(a) technical feasibility;
(b) the urgency and need for different types of research;
(c) the extent to which research meets national and regional goals;
(d) the contribution to knowledge;
(e) the expected benefits of research in relation to costs;
(f) the likelihood that research results will not be available elsewhere;
(g) the ability of infrastructural institutions to transfer technology options;
(h) the ease of adoption by farmers;

TABLE 1

Indexes of Regional Congruence of Agricultural Research in the Semi-Arid Tropical Developing Countries, 1977[a]

Research expenditures	Sorghum and millet	Chickpea and pigeonpea	Groundnut	Farming systems	Economics
Using ICRISAT research expenditures only	0.92	0.93	0.69	0.74 (0.79)	0.61 (0.67)
Using national programs plus ICRISAT research expenditures	0.98	0.94	na	na	na

[a] Each index value is calculated as $1 - [\sum_i (C_i - R_i)^2]$, where C_i is the share of the crops in each of the i regions in total production value and R_i is the share of the respective research budget accruing to region i. For commodity research programs, individual crop values are used as the basis for the C_i calculation. For farming systems and economics, the product of each region's geographical area and population is used (nonparenthetic figures) as well as the region's share of total value of the five ICRISAT mandate crops taken together (figures in parentheses). The closer each index is to 1 the more congruent the budget allocation is with the relative importance of the crop in each region.
na not available.

(i) how soon the cost savings can be realised;
(j) the growth rate of the industry; and
(k) the market parameters and prospects for the commodity.

In recognition of the importance of regional allocations of research resources to both the size and distribution of total benefits, von Oppen and Ryan (1984) suggested a multidimensional scoring model which would address both equity and efficiency concerns. The method expands on the work of Ryan (1978) by introducing nine other criteria to the congruence analysis that he performed to assess ICRISAT's regional research resource allocations. It represents an attempt to make operational some of the concepts for deciding on the *ex ante* allocation of research resources discussed by Binswanger and Ryan (1977). The criteria primarily relate to the desirability of research rather than to any assessment of the technical feasibility or probabilities of success aspects which must also enter the final analysis prior to choices being made.

For a regional analysis of this type to be done, it is necessary to assume that each region is relatively homogeneous or functional from the point of view of the conduct of research and that there are no research spillovers from one region to another. The latter may be a more valid assumption when dealing with biological innovations than with mechanical and chemical ones (Jarrett 1982).

In the model, there are four criteria which relate solely to equity concerns, three relating to efficiency considerations and three which have elements of both (Table 2). Regions with a low per person income should receive the highest priority, other things being equal. The reason is that such regions are poorer and, hence, more in need of research to generate increased income streams on the grounds of equity. For similar reasons more research effort should be devoted to regions in which income is growing slowly. Similarly those regions with the largest populations and highest population growth rates should receive high priority.

TABLE 2

Criteria for Determining Regional Research Resource Allocation Priorities

Criterion	Highest priority	Justification	
		Efficiency	Equity
Income per person	Lowest income		x
Income growth/income per person	Lowest ratio		x
Population	Highest population	x	x
Population growth rate	Highest growth		x
Crop production growth rate	Lowest growth	x	
Current food consumption status per person (calories, protein, fat intake)	Lowest intake		x
Crop contribution to current food status per person	Highest contribution	x	x
Region's contribution to total crop production	Highest contribution	x	
Yield stability (R^2 of trend lines)	Highest instability (that is, lowest R^2)	x	x
Person-to-land ratio	Highest ratio	x	

Regions in which production growth rates have been low presumably could benefit more from research than those in which production growth rates have been high. Hence, on efficiency grounds, the low-growth regions should receive greater research attention. On equity grounds, regions in which the per person food intake is low also deserve greater attention, as do regions in which the mandatory crops of the research centre provide a large proportion of the region's food supplies.

The regions which produce the largest shares of the total production of the research centre's mandatory crops require more research resources because the possible impact of research can be spread over a larger area and production.[2] Regions with more yield instability deserve added research to alleviate the adverse effects on rural populations. In such areas, biological research aimed at alleviating yield-reducing factors such as drought, diseases and pests can be successful, together with policy research on such aspects as trade and storage strategies to alleviate instability in food supplies. Where present population pressure on the land is greater, biological research aimed at enhancing yield per hectare is more likely to succeed.[3] These areas are also likely to be those where the natural resource base is most precarious and where the populations are most at risk and in need of technology to enhance productivity.

An additive multidimensional scoring technique is required to incorporate all ten criteria, due to the complexity involved. The advantages and disadvantages of this method are described in Anderson and Parton (1983). Different weights, based on subjective assessments of the relative importance of equity versus efficiency concerns, are assigned to each criterion in Table 2. A weighted average of the numerical scores for each region generates a composite priority index reflecting its relative priority. When present allocations are compared with those suggested by the composite priority index, the implicit rationale for the current regional emphases can be elicited. By placing different weights on efficiency and equity criteria, the sensitivity of the implied allocations to political economic judgments can be gauged. An example of this, for pearl millet, is in Table 3, which shows that the actual allocations at ICRISAT closely reflected adherence to a straight congruence analysis. A composite index which uses the regional crop shares in column 3 of Table 3 as multiplicative weights, with the weights assigned to efficiency and equity criteria in Table 2, is probably a satisfactory compromise.

The merit of this approach is that research administrators are obliged to analyse the criteria they are implicitly using in allocating research resources. The method is not intended to provide a panacea. It does represent a necessary part of the body of information on which to base

[2] The congruence method does not allow for explicit consideration of the potential for new crops in various regions. It is probably wise for all regions to have a small budget set aside to explore agronomic and market opportunities for prospective crops from which the regional potential can be gauged. Alternatively, risk or venture capital in the form of bilateral or multilateral activities, such as occurred in the introduction of soybeans into India, can be encouraged (von Oppen 1974).

[3] This criterion may work in the opposite direction when considering research on mechanical innovations. The induced-innovation hypothesis of Hayami and Ruttan (1971) would suggest that labour-saving technological changes such as mechanical innovations are more appropriate for areas with low person-to-land ratios. This illustrates the point that there may be different criteria appropriate to different types of research and some may operate in the reverse direction depending upon the type of research being considered.

TABLE 3

Congruence of Various Priority Index Values for Pearl Millet and 1980 ICRISAT Research Resource Allocations

Region	Priority index value using as weights			ICRISAT principal scientist equivalents allocated
	Efficiency 2 Equity 1	Efficiency 1 Equity 2	Region's share of production 1 Other criteria 0	
	per cent	per cent	per cent	per cent
India	21	17	35	42
Eastern Africa	10	13	7	4
West Africa	19	20	49	54
Southern Africa	12	14	3	0
Other Asia	14	12	3	0
North, Central, and Southern America	10	11	2	0
Near East	14	13	1	0
Total	100	100	100	100

such decisions. Factors not explicitly taken into account, such as the history of previous research, present research emphasis and probabilities of mounting successful research programs, are of great importance and must also enter the assessment.

Analyses of the above type are not excessively demanding of data or human capital and can hence be a valuable aid to decision makers in developing countries. Often more sophisticated optimisation approaches, such as those discussed in Fishel (1971) and Arndt et al. (1977) are simply not possible in developing countries and their relevance in developed countries is even doubtful (Campbell 1972; Arnon 1975; Tichenor and Ruttan 1977; Berry 1981; Anderson and Parton 1983). Scoring models of the priority index type involve the incrementalist approach of provision of more information to enhance the decision process. The major constraint to improved *ex ante* decisions remains information because of the necessity of so much subjective judgment in evaluating alternative strategies. Economists can be most useful in conducting research to improve the amount of objectivity in decisions. For example, more research is needed to provide estimates of parameters essential for assessing the likely income distribution and nutritional effects of alternative strategies. The work of Pinstrup-Andersen, de Londoño and Hoover (1976), Freebairn, Davis and Edwards (1982), Quizon and Binswanger (1983) and others has endowed the profession with a rich harvest of models to address such questions. Economists in developing countries can profitably use these, preferably working in close contact with scientists and research administrators, to ensure that they correctly perceive problems as well as the likely effects of research strategies.

One important implication of the Freebairn et al. (1982) model is that aggregate benefits of agricultural research at any phase of the input-production-marketing chain are relatively insensitive to variations in supply elasticities. Also, as long as the cost reduction per unit of farm equivalent output is the same in each part of the chain, the aggregate benefits of research will be the same, regardless of where the innovation occurs.

Contrary to the experience in developed countries, farmers in developing countries receive between 70 per cent and 90 per cent of the consumer's dollar (Raju and von Oppen 1982). This is more than twice the proportion cited by Edwards and Freebairn (1981, p. 5) for Australian farmers (30 per cent). The clear inference for developing countries is that research should largely be focused upon the production stage rather than the marketing end of the spectrum. In this way, improvement in productivity will have a greater effect on the efficiency of supply systems for food and fibre and on reducing consumer prices. The more atomistic nature of farming in developing countries probably dictates an even greater case for publicly funded production research than in developed countries. This, together with the small share of the consumer's dollar going to the marketing and input stages of the chain, strongly suggests that governments should not fund research in these stages but, rather, should rely on the establishment of property rights to innovations as Freebairn et al. (1982) contend.

Small and Large Farms: Dichotomy or Nexus?

Critics of the green revolution such as Frankel (1971), Palmer (1972), Villianatos (1976) and Farmer (1977) claimed the benefits were primarily captured by the large and more affluent farmers. These types of criticisms, although often emotive rather than based on careful analysis, led international donor agencies and policy makers to exhort scientists to design technologies which were appropriate for so-called small farmers. As a result, at ICRISAT there was an active search for technologies that were not just scale-neutral but even scale-negative. Resort to the induced innovation model and a farming systems approach to the conduct of research assisted in rationalising the approach to this problem at ICRISAT.

Induced innovation and factor markets

Ryan and Rathore (1980) used extensive data from village studies in India to test if it was feasible in an *ex ante* framework for research scientists purposefully to design agricultural technology specifically for small farms. The induced innovation hypothesis of Hayami and Ruttan (1971) served as the basis of the empirical tests performed by Ryan and Rathore. Hayami and Ruttan postulated that farmers and research administrators had been induced by differences (and changes) in relative factor prices to search for technological options which would save the increasingly scarce factors of production. Hence, countries such as the United States and Australia with low person-to-land ratios developed their agricultural sector by employing land-using and labour-saving technological innovations. In contrast, Japan with a person-to-land ratio more than 36 times that of the United States relied on biological innovations of a land-saving type. It is not clear whether the induced innovation hypothesis can also be used as a normative tool in an *ex ante* framework but the implication has always been that it can.

The basic premise behind the concern in developing countries that owners of small farms require unique technology options denied them in the past is that their resource endowments differ substantially from those on large farms in the same functional regions. Ryan and Rathore ex-

amined whether this was the case in six villages of Andhra Pradesh and Maharashtra in India. In only one of the villages were there statistically significant differences between mean land-to-labour and capital-to-labour ratios on the small and large farms (Table 4). Variations in factor proportions between regions and within farm-size groups within regions seemed to be much larger than variation between farm-size groups within regions. This result suggests that regional variations in technology and factor ratios may be more important than between farm-size groups within regions. However, more empirical analysis is required to see if this result is true in developing countries generally.

The large coefficients of variation of factor proportions within each size group for the villages studied by Ryan and Rathore suggest that classification of farms based on operational size is not appropriate for delineating the type of technology which is likely to be viable.[4] Unless small and large farms comprise disjoint sets on the factor ratio space, it is not possible to infer that small farms require technologies which, in terms of their basic resource-saving or resource-using characteristics, differ in substance from those of large farms. This is not to say that it is not desirable to have differences in the degree or intensity of use of technology amongst farms of different size. Ryan and Subrahmanyam (1975) illustrated the value of selecting individual components of technology packages to suit differential factor proportions.

Small farms had significantly lower mean land-to-labour *endowment* ratios than large farms in the six villages (Table 5). This was in contrast to the land-to-labour *utilisation* ratios shown in Table 4. In a village or regional context, differences between endowment ratios among farmers can be more easily equalised via the operation of factor markets than is the case between countries such as Japan and the United States. This is no doubt why it was found that the statistical significance of the mean utilisation ratios between the two farm-size groups was much less than the original endowment ratios. Policies which are aimed at enhancing the performance of factor markets and the accessibility by owners of small farms to them are likely to be more successful in achieving a more equitable distribution of the benefits of technological change than are attempts to design basically differentiated technologies for small farms.

The green revolution of the mid-1960s highlighted the importance of accessibility to factor markets, particularly for credit and land, to prospective beneficiaries of technological change. It was only after the new technology options created disequilibria in the Schultz (1975) sense that economists were alerted to the potentially adverse distributional consequences of imperfectly functioning or incomplete factor markets. One might say that, since that time, there has been a substantial amount of what Ruttan (1982) terms induced institutional change in developing countries aimed at improving accessibility of small-farm and landless households to credit and land. One example is the creation of the Small and Marginal Farmers Development Agency in India.

It is clear that early adopters of technologies earn innovators' rents. Indeed, in situations where commodity demand is inelastic these can be the only producer benefits. Operators of large farms will often (but not

[4] Other problems such as differences in the extent of irrigated land on farms further complicate such classifications.

TABLE 4

Land-to-Labour and Capital-to-Labour Ratios in Six Villages of Semi-Arid Tropical India, 1975-76

District/Village	*Small farms*[a]				*Large farms*[a]				*t*-value of difference between means	
	Net cropped area/ Labour used		Total assets/ Labour used		Net cropped area/ Labour used		Total assets/ Labour used		Net cropped area/ Labour used	Total assets/ Labour used
	Mean[b]	CV[c]	Mean	CV	Mean	CV	Mean	CV		
	ha/1000 hr	per cent	Rs/hr	per cent	ha/1000 hr	per cent	Rs/hr	per cent		
Mahbubnagar										
Aurepalle	3.85	50	19.34	72	1.84	44	9.03	37	3.04†	2.26*
Dokur	0.72	15	14.93	55	1.59	78	12.10	21	2.04	0.91
Sholapur										
Shirapur	3.36	94	34.16	104	3.99	56	30.45	55	0.51	0.30
Kalman	5.93	70	25.52	59	5.46	31	22.07	42	0.34	0.61
Akola										
Kanzara	2.43	30	13.37	27	2.55	31	18.27	36	0.34	2.07
Kinkheda	2.29	40	10.67	36	2.44	30	11.47	28	0.41	0.50

[a] Size classifications are based on initial census data for total operated land (cultivable and noncultivable). Households were first divided into three categories—small, medium, and large. Data on small and large farm-size groups are presented here.
[b] Simple means.
[c] Coefficient of variation.
* Denotes significance at the 5 per cent level.
† Denotes significance at the 1 per cent level.

TABLE 5

Land Owned-to-Family Labour Ratios for Six Villages in Semi-Arid Tropical India, 1975-76[a]

District/Village	Small farms		Large farms		*t*-value of difference between means
	Mean	CV[b]	Mean	CV	
		per cent		per cent	
Mahbubnagar					
Aurepalle	1.10	100	3.69	46	4.05†
Dokur	0.64	46	3.25	59	4.24†
Sholapur					
Shirapur	1.73	42	4.64	49	3.88†
Kalman	2.26	51	5.69	34	4.80†
Akola					
Kanzara	1.39	76	6.32	53	4.41†
Kinkheda	1.31	42	6.42	52	4.74†

[a] This differs from Table 4 in that here owned land is used instead of operated land and available family labour supply instead of labour used (family plus hired).
[b] Coefficient of variation.
† Denotes significance at the 1 per cent level.

always) be the early adopters due to potential size economies. Innovators' rents are thus a pay-off to superior information searching and processing capacities, and also a necessary compensation for the risk of failure of new techniques borne by the early adopters who provide later adopters with cheaper and more reliable information. Too often social science research is concentrated on success stories, which may lead to an over-estimation of these innovators' rents relative to the long-run situation which should embrace both successes and failures. An example of this is in India, where early adopters of hybrid pearl millets, which became susceptible to downy mildew disease, experienced substantial income losses before reverting to traditional cultivars. Many of the early pearl millet adopters in this example also would have been the early adopters of high-yielding dwarf cultivars of wheat and would have earned sizeable innovators' rents.

The farming systems approach to research

An important difference between developing and developed countries is the extent to which intercropping is practised. Jodha (1980) found that, in the semi-arid tropical regions of India, intercropping was generally practised to a greater extent on small farms than on large farms and was more prevalent in areas where soils have a lower moisture-holding capacity and/or where rainfall is less assured. The implications of these findings are that intercropping research would have particular relevance to the less well-endowed farms and regions, resulting in considerable equity benefits. Such analyses highlight the benefits of conducting village studies in developing countries within a farming systems research framework.

At ICRISAT, the farming systems approach to research was employed to good effect to address efficiency and equity issues, especially those relating to technology design and the small/large farm nexus. The farm-

ing systems approach to research is judged as being of particular value in understanding the complexities of small farm systems (Norman 1980). However, there is a danger that blind adherence to it could do more harm than good by creating institutional structures which could inhibit rather than encourage the multidisciplinary interaction so important for its success.

There were three strategies employed in ICRISAT's farming systems research approaches—base data analysis, on-station research and on-farm research. Byerlee, Harrington and Winkelman (1982) contend that on-station research is of a longer term nature, whereas on-farm research has a shorter run perspective aimed at incremental change in farming systems. This suggests that they are to some extent subtitutes, whereas in the farming systems approach described here, they are viewed as complements in the process of designing improved agricultural technology intended for relatively homogeneous regions. On-farm research is not simply for testing a subset of potentially viable and relevant technologies from amongst the shelf of prospective technologies emanating from on-station research. It is the dynamic feed-forward and feed-back between on-farm and on-station research which is an essential ingredient in successful farming systems research. These three strategies were used in various combinations in the four phases of the farming systems approach to research at ICRISAT shown in Table 6.

The role of village studies

The village level studies component of the farming systems research approach at ICRISAT involved the intensive monitoring of a stratified random sample of a panel of small, medium and large sized farm households over a number of years. In this manner, close and continuous links between on-station and on-farm research strategies could be maintained and the phases were conducted in the same villages over time.

The village level studies have combined the features of what is now commonly referred to as the 'quick and clean' techniques of rapid rural appraisal with the 'long and clean' methods involving in-depth study of a more limited sample.[5] Many *ad hoc* studies (for example, post-harvest cultivation practices and effects of threshing machines) were conducted using the same villages and households as in the panel data-gathering exercise. Through a supplementary data-gathering exercise in the same study villages, it was often possible within the space of days to address a particular issue which had arisen. One example was the evaluation of the economics of herbicides, where labour use data on weeding already available on farmers' traditional plots were combined with data from diagnostic experiments. Another was the analysis of the economics of wheeled tool-carriers which employed village study data on hiring charges and performance rates for bullocks and traditional animal-drawn implements along with performance data on the wheeled tool-carriers from on-station research.

On a number of occasions, the detailed panel data revealed errors in data collected in earlier rapid rural appraisal instruments. In one in-

[5] For a discussion of the value and desirability of rapid rural appraisal see Carruthers and Chambers (1981), Chambers (1981) and the other papers contained in the special edition of *Agricultural Administration* in November 1981.

TABLE 6

The Conduct of the Farming Systems Approach to Research at ICRISAT

Phase	Research strategy		
	Base data analysis	On-station	On-farm
Description/ Diagnosis	General agro-climatic classification of the semi-arid tropics Socio-economic constraints of the semi-arid tropics: National level Regional level Criteria for village selection	Basic studies: Hydrology of small watersheds Component research on soils, cropping systems, environmental physics, farm implements and power, and agronomy	Village level studies: Resource base and cropping patterns (intercropping and rainy-season fallowing) Labour use and labour markets Fertiliser use and its determinants Incidence and determinants of crop failure Human nutritional status and crop improvement strategies Extent and cause of poor stand establishment in sorghum and millet
Design	Agro-climatic classification using water balance simulation models/analysis Review of anthropological and economic literature and case studies to determine necessary and sufficient conditions for group action among farmers Analysis of cropping system options Adoption studies	Steps in improved technology experiments of soil, crop and water-management options Development of improved animal-drawn implements Field scale research of improved soil, water and crop technology options at ICRISAT Centre Economic analysis of the above elements[a] Simulation modelling of the economic potential for water harvesting and supplementary irrigation of upland crops	Village level studies: Post-harvest cultivation practices Reasons for crop planting directions Human nutritional status and crop improvement priorities Incidence of pests, diseases, and weeds in farmers' fields Scope for rabi-kharif-rabi pigeonpea system Reasons for poor germination of chickpea Effect of contour bunding Economics of herbicides[a] Economics of wheeled tool-carriers[a] Impact of prospective technologies on labour employment[a] Extent and causes of yield gaps[a] Impact of machine threshing Risk aversion attitudes of farmers and genotype selection in crop improvement[a] Risk and choice of cropping systems Yield instability, farmers' risk aversion and supply response

TABLE 6 (continued)

Phase	Research strategy		
	Base data analysis	On-station	On-farm
Design			Village level studies: Food-grain preferences of village consumers Resource endowments of small/large farms and technology design Extent and determinants of post-rainy season fallowing in deep Vertisol regions
Testing/ Verification	Assessment of ability of delivery systems capacity to support technology Analysis of district agroclimatic and socio-economic data to determine suitable locations for further testing/verification	Operational research to test improved soil, crop and water-management options in small watersheds at ICRISAT Centre and in co-operative experiments in national program Activity analysis of scope for prospective technology options to be acceptable to farmers and identification of constraints[a]	Village level studies: Soil, crop, and water management research on small watersheds in original villages with researcher management and in specially selected villages with less researcher management Economic analysis of above research Assessment of scope for group action for: Watershed development and maintenance Shared implement ownership and use Shared ownership and use of irrigation facilities
Extension/ Training	Data needs for pilot project site selection	Seminars for policy makers Workshops for research and extension staff Visits by farmers	Studies of early adoption, its constraints, and farmers' perceptions of technology options Field days for farmers

[a]Most of these analyses were conducted using data from both on-station and on-farm research.

stance, it was discovered that most of the 'landless' households identified in response to the initial census questionnaire actually owned or leased small plots of land. This became evident only because the investigator resided in the village and regularly visited fields where he observed respondents working. By eventually being regarded as legitimate members of the village community, the investigators as well as being able to verify facts, were able to gain insights and understanding that one usually expects only from anthropologists acting as participant observers.

Longitudinal studies clearly entail a trade-off of breadth for depth under situations of limited research resources. Fewer villages and respondents can be included when monthly interviews are required, as opposed to one-time surveys involving either rapid rural appraisal techniques or structured schedules, and resources are committed for longer periods of time. This is the most important disadvantage of the longitudinal approach taken in the ICRISAT village level studies. India, though, is well endowed with a large number of *ad hoc* agro-economic and other surveys which can be and have been employed to help verify hypotheses and findings from the village studies.

Factoral Income Distribution and Employment

The *ex ante* assessment of the effects of research and technological change on the distribution of income amongst factors of production and their owners is complex. As Quizon and Binswanger (1983) state:

> Evaluating distributional impacts of policies which affect factor supplies, output demand, and technical change in agriculture is much more complicated than normally assumed by policy makers (p. 537).

With the recognition by Binswanger and Rosenzweig (1981) and others that factor markets are inextricably linked in developing countries, the problems inherent in assessing factoral distributional consequences of technological change and development are made even more intractable. Nevertheless, these authors provide a framework to assess some of these impacts, of which the drawbacks are the data and parameter requirements. Their analyses show that the real wages of labour will always rise from any neutral technical change where land is in inelastic supply and labour and capital are price-responsive. However, where technical change is of the labour-saving variety, real and nominal wages will fall. The fall will be greater the lower the share of capital in production costs. Hence, in Asia where labour's share is probably greater than in Africa, the implication is that labour-saving technical changes would not be beneficial to labour, whereas the reverse would be true in Africa.

Prospective technologies and labour

A number of studies at ICRISAT have used the village level studies within the farming systems approach to assess the consequences of various research and technology options on employment and labour. Using a combination of data from the respondents in the village level studies and experimental data from ICRISAT Centre, an evaluation was made by Binswanger and Shetty (1977) of the estimated relative costs of three alternative weed-control practices under conditions existing in the Akola region of Maharashtra. The three plans were designed to achieve

about the same level of weed control using (a) human and animal power only; (b) herbicides plus human labour; and (c) herbicides only.

The cost of the pure herbicide treatment was so high that it could never be feasible at existing wage rates. For food-grain crops under Indian semi-arid tropical conditions, even partial herbicide use combined with animal and human methods was two to four times more costly than the traditional animal and human methods due to the low wage rates. On small farms where the opportunity cost of using family labour is generally lower than ruling wage rates, there is even less incentive to use herbicides. In semi-arid tropical Africa, where real wage rates may be two to four times those in India, herbicides may be a more viable proposition.

Unless herbicides make possible substantial yield increments not achievable by traditional methods (such as a pre-emergence herbicide), then widespread use of herbicides will remain out of the question in semi-arid tropical India. Wage rates would have to rise by more than 50 per cent to make the partial herbicide plan attractive in pearl millet. For other crops, the wage rise would have to be even more. Real wage rates in semi-arid tropical India have been stagnant for the past decade or so. Hence such increases are unlikely in the near future. Herbicides may have potential in specific situations such as in Vertisol regions having assured rainfall where perennial weeds may constrain or hinder cropping in the rainy season.

It was found that herbicide research and technology in semi-arid tropical India could also adversely affect income-earning opportunities of one of the most disadvantaged of all rural socio-economic groups—female labourers and, in particular, hired females from landless and small farm households. Between 70 per cent and 90 per cent of the hand weeding is performed by hired females whose wage rates are generally about half those of hired males. The labour displacement that herbicides could cause could be substantial, particularly for crops like cotton and sorghum in the assured rainfall areas. The situation in semi-arid tropical Africa with its higher wage rates and opportunity costs may be different. Landless labourers are rare in many African areas and animal power for intercultivation is often not available. Weed-control problems there seem substantial and would justify a greater allocation of weed-control research resources than is the case for India.

To assess the likely impact of watershed-based improvements to soil, water and crop management, a comparison was made by Ghodake, Ryan and Sarin (1981) of the labour requirements for traditional farms in semi-arid tropical India with those on the small experimental watersheds at ICRISAT Centre. It was concluded that the prospective technologies being evaluated at ICRISAT offer scope for increased employment compared with existing technologies ranging from at least 100 per cent in Alfisols to more than 400 per cent in deep Vertisols. If traditional threshing methods were used, the potential employment increases would be much higher. The intraseasonal variability of labour demand with the prospective technologies would also be greater than with traditional practices. Given the existing availabilities of labour in these villages, the watershed-based technologies would encounter major farm labour bottlenecks for three to four months of the year.

No doubt, such bottlenecks would generate increased wage rates and employment for those relying on daily wages which would be desirable

from an equity point of view. However, such bottlenecks could adversely affect the timelines of operations critical to the success of the prospective double-cropping and/or intercropping technology. If this occurred, one could expect to see increased demand by farmers for selective mechanisation of operations such as threshing, where the major bottlenecks would arise. There was evidence of this in more recent on-farm verification trials of the technology options reported by Ryan, Virmani and Swindale (1982).

A study by Walker and Kshirsagar (1981) was initiated to gauge the effect of the introduction of machine threshers in one of the ICRISAT study villages. One major finding that is widely applicable was that a diversified output mix limits the scope for, and conditions the impact of, mechanical threshing technologies in semi-arid tropical India. Crop diversity and low production encourage machine hiring, as few farmers have enough produce to afford a large investment like a thresher. With present levels of cereal production in semi-arid tropical India, only a few machines per village are economically feasible. A few machines per village do not lead to competitive pricing. Under these conditions, it is questionable whether potential benefits from reduced costs due to new threshing technologies will be passed on to producers and consumers. In addition, the labour displacing effects of introducing mechanical threshing need to be considered.

In a review of empirical studies of the effects of tractors in South Asia, Binswanger (1978) found that there was no evidence that tractors were responsible for substantial increases in cropping intensity, crop yields, timeliness or gross returns. Tractors did substitute for labour and draught power, which are relatively abundant and underemployed resources in South Asia, unlike Africa. The existing and projected human and animal wage rates in the latter are stagnant and the introduction of tractors in such circumstances is unlikely to be a strong stimulus to economic growth. Hence on both efficiency and equity grounds, it seemed desirable not to incorporate tractors in the design of improved technology options in the semi-arid tropics of India.

Human Nutritional Considerations

In general, poor people in developing countries spend a large proportion of their budgets on food. Hence, technological improvement in the production of basic food staples will generally involve a larger proportional increase in their real incomes than in the incomes of more affluent consumers who spend proportionally less on food staples. Research resource allocations designed to benefit the poorest consumers should thus stress commodities with low income and price elasticities. Pinstrup-Andersen et al. (1976) and Pinstrup-Andersen (1981*a*, *b*) illustrate how such effects can be analysed in an *ex ante* framework to guide the determination of commodity priorities in agricultural research.

The increasing concern being expressed about the need to design research and development programs that attain nutritional goals is evidenced in publications like that of FAO and WHO (1976, p. 35) in which it is stated 'Effective nutrition planning needs to start from the identification of people who are malnourished and the nutrients they are short of.' With this requirement in view, the research at ICRISAT on human nutritional needs and crop breeding strategies was initiated.

Nutritional status and crop breeding objectives

Reviews of nutrition studies by Ryan (1977) and a diet, health and nutrition study conducted in the ICRISAT village studies by Ryan, Bidinger, Rao and Pushpamma (forthcoming) have shown that the major nutritional deficiencies in diets in rural India are energy, calcium, β-carotene (a precursor of vitamin A), B-complex vitamins, and ascorbic acid (vitamin C). Proteins and essential amino-acids were not generally limiting, except in particular circumstances. These findings were significant because conventional nutritional wisdom in the 1960s was that there was a 'protein gap' in diets of poor people in developing countries. This lead to policies of protein supplementation of diets and to a stress on improvement of the protein content and quality of grains in crop breeding programs.

According to Ryan (1977, pp. 82-3) there is, in general, an inverse relationship across genotypes between protein percentage and yields and between protein percentage and lysine percentage of the protein. So, in selecting for protein and protein quality in breeding programs, it is likely that progress in enhancing yield potential would automatically be retarded. More importantly, a breeding strategy that emphasises yield and yield stability would be far more effective in enhancing nutritional welfare. Ryan (1977, pp. 83-5) estimated that the effect of an increase of 10 per cent in yield of sorghum on low income rural people in three of the poorest states in semi-arid tropical India would be an improvement of almost 10 per cent in the per person consumption of protein, lysine and energy.[6]

Evidence of the aggregate nutritional impact of a successful yield-orientated crop breeding program is provided by the green revolution in wheat in India. Ryan and Asokan (1977) showed that, had the improved varieties of wheat not been introduced in the mid-1960s, the total production of protein in 1974-75 would have been 10 per cent less, even after allowing for the reduction in the production of pulses, winter rice and barley which were displaced by the increased area of wheat. Energy production would have been down by 13.5 per cent and sulphur amino-acids by 15.5 per cent.

Seasonality in nutritional status

Schofield (1974), Longhurst and Payne (1979) and Chambers (1982) contend that malnutrition and morbidity are greatest in the rainy season in developing countries. This may well be the case when considering the two principal components in diets (energy and protein) and the incidence of respiratory illnesses from wet conditions. Major food-grain staples are generally not harvested until the end of the rains and this means that, in the few months before harvest, grain stocks and food consumption are often lower. However, even though the availability of food grains may be greater in the 'surplus' (dry) seasons, the availability of 'protective' foods such as leafy vegetables is much more restricted than in the rainy

[6] Murthy (1983) has used a complete linear expenditure system to estimate the income and price elasticities of demand for ten rural and urban Indian expenditure groups. These include demand parameters for nine commodities and also calorie demand elasticities. The availability of such estimates greatly enhances the capacity of research administrators to assess the likely nutritional impact of alternative strategies.

season in non-irrigated regions. As vitamins and minerals are major deficiencies in diets, at least in South Asia, directing nutrition programs to the wet seasons may address only half of the problem. It is in the dry season that further development of common property resources such as village forests and fallow lands could play a key role. Jodha (1983) found that common property resources contribute significantly to the income and nutrition of lower income groups in the semi-arid tropical Indian villages he studied. If sources of vitamins and minerals which became freely available primarily in the dry season and which could be grown on common lands could be developed, this could help alleviate a major nutritional problem. Tree crops probably offer the best prospect for this. In the wet season, annual crops on private fields can no doubt provide the answer. The advantage of the provision of foods high in vitamins and minerals from common property resources is that poor people would primarily benefit.

Chambers' (1982) and Longhurst and Payne's (1979) inferences that improved technologies should not exaggerate labour peaks in the wet season lest energy balances be adversely affected, may be a *non sequiter*. To advocate appropriate mechanisation, the use of chemical weed control, and high-yielding varieties which are less time constrained in the wet seasons when the energy balance is apparently negative, as Longhurst and Payne (1979, p. 31) do, ignores two basic factors. First, creation of labour peaks is one of the few avenues whereby labourers can expect to increase their wage rates and employment. With expenditure elasticities of demand for calories estimated by Radhakrishna and Shah (1981) and Murthy (1983) to be around 1.0 for low income groups in rural India, creation of wet season labour peaks could result in a net improvement in nutritional status. It is the landless and small-farm families who rely on wage labour for their sustenance who would benefit from creation of labour peaks. Labour-saving technologies could only make their economic position worse. Second, in situations where soils have a high moisture-holding capacity such as the Vertisols of large tracts of semi-arid tropical India, much of the peak labour activities occurs in the dry season, as crops are grown in the dry season on residual moisture stored in the soil. In such agro-climatic environments and in well-irrigated areas, there is not necessarily a trade-off between additional work activity in the peak labour periods and energy balance. The problem mainly emerges in areas which have soil with a low mositure-holding capacity and little irrigation, where crops are grown only in the wet season which corresponds to the period when food-grain availability is low and labour demand is high.

Risk Attitudes of Farmers

A greater aversion and lesser ability to take risks has often been stated as a primary reason why technology options designed for the owners of small farms need to be different from those of larger farms. As a result, the safety-first principle of choice was regarded as the most relevant for decisions affecting small farms. This was a formidable constraint to scientists engaged in agricultural research aimed at developing attractive technology options especially targeted at small farms.

Using measures of risk aversion in designing technology

In contrast to the interview methods used in the past to elicit farmers' attitudes to risk-taking, such as described in Dillon and Scandizzo (1978), Binswanger (1980) used experimental games of chance with relatively large real payoffs to induce farmers to reveal their risk preferences. The respondents in the ICRISAT Indian village level studies were used as subjects for the experiments. Individuals were allowed choices among risky alternatives where increasing expected returns could be purchased only by increasing the risk or dispersion of possible outcomes.

The main conclusion from this experiment was that, in the three regions studied, the majority of farmers had intermediate or moderate degrees of risk aversion. Few farmers were either risk-neutral or severely risk-averse, despite widely differing income and wealth levels. This ran contrary to the safety-first paradigm. Indeed, when the stakes were high, there were no significant statistical relationships between risk aversion and wealth, farm size, age, sex or tenancy status. Only schooling, salaried employment, receipt of transfer income and the number of winning draws in the experimental sequence were associated with modest decreases in risk aversion. Similar experiments have been conducted in El Salvador (Walker 1980), Thailand (Grisley 1980) and the Philippines (Sillers 1980), and the results are surprisingly similar to those of Binswanger (Binswanger and Sillers 1983).

The above research is important because it enables risk aversion to be explicitly incorporated into choices about the design of technology and development strategies. It also suggests that the risk characteristics of such strategies need not be substantially different for small farms. Instead a rule of thumb which follows from the analysis can be employed in the knowledge that it is likely to capture the *revealed* risk preferences of the bulk of the farming community. The rule is that the average farmer is prepared to incur additional risk, as measured by the standard deviation of outcomes, if it is no more than about twice the size of the mean additional outcome from the decision. If the trade-off exceeds this level, it is unlikely to be attractive to the majority of farmers.[7]

The 2:1 ratio was used by Ghodake (1981) to help explain the gap between present gross returns achieved by farmers in one of the ICRISAT Indian village study sites and the potential return if farmers were technically and allocatively efficient, had no capital or labour constraints, and were not averse to risk. Whole-farm linear risk programming was used. This technique has the advantage of being able to contend with the wide array of intercropping and rotational practices observed in Indian villages and their differential contribution to yield and profit risks.

[7] Binswanger (1981), Quizon, Binswanger and Machina (1984) and Hardaker and Ghodake (1984) have shown that the behaviour of Indian villagers in the risk experiments is not consistent with standard expected utility theory. It is not clear whether the inconsistency arises from violation of the assumptions of asset integration and/or of linearity in probabilities. Expected utility theory is a good normative paradigm but it does not predict the behaviour of farmers facing actual risky choices. If one is interested primarily in designing strategies which are likely to be in line with *revealed* as opposed to *innate* risk preferences, then the 2:1 rule of thumb can be useful. However, it should be employed in full knowledge of the above limitations.

The gap between actual and potential returns in Ghodake's study was around 75 per cent. Capital was the most important single constraint, contributing more than 50 per cent of the gap, particularly on smaller farms. Lack of technical efficiency explained most of the remainder of the gap and was more important on large farms. Risk aversion was significant only on small farms, but it did not explain more than 15 per cent of the gap. This study supports the contention that capital to acquire material inputs such as fertilisers and chemicals, along with varietal improvements and management expertise, are the major reasons why farmers do not achieve the yields and returns which research has shown are feasible under farmers' field conditions. The study is also a good example of combining information from the regular data emerging from the village studies with data from experiments aimed at testing the performance of prospective technology options in farmers' fields within the farming system approach to research described earlier.

The Binswanger trade-off ratio was also employed in an evaluation of genotype performance in multi-location and multi-year nursery trials (Binswanger and Barah 1980; Barah, Binswanger, Rana and Rao 1981). The variance of crop yields was partitioned from the trials into stability and adaptability components. It is stability of performance at particular locations over years that is important to farmers. It is possible to rank the genotypes in the stability analysis according to whether or not they fall on a risk-efficiency frontier such as represented by KFCBA in Figure 1. A genotype is risk-efficient if no other genotype can achieve the same mean yield with a lower standard deviation or of the same standard deviation with a higher average yield. For example, C is preferred to D, E and G and F to G and H. Hence, the choice of genotype is between K, F, C, B and A. By interposing iso-utility lines (P_iR_i) that map the preferred 2:1 ratio of standard deviation and profits, the preferred genotype (B) can be identified.

For the particular sorghum data set which was analysed, three varieties and two hybrids were risk-efficient. Genotype rankings based on risk preferences and yield were highly correlated. Moreover, single-year data predicted adaptability and stability fairly well, and most members of the stability-efficient set also belonged to the adaptability-efficient group. Further analysis is required to determine whether these conclusions hold for genotypes tested in lower fertility and less protected environments.

The shapes of yield and net return distributions are important in evaluating the performance of traditional and improved cropping systems. In a study which exploited the time-series nature of the Indian village studies of ICRISAT, Walker and Subba Rao (1982*a*) found that, in general, both yield and net return distributions in traditional and semi-improved cropping systems were positively skewed, while the improved cropping systems had normally distributed yields and net returns. Intercropping that generates multiple crop products and a high-fertility, rainfall-assured production environment lead to normal yield and net return distributions.

Hence, the assumption made by mean-variance analysis and other methods commonly used to evaluate risky choices that distributions are normal may not be unduly restrictive for improved cropping systems and traditional intercrops. However, when practitioners assess risk in traditional and improved sole-cropped systems, it is likely that the shape of

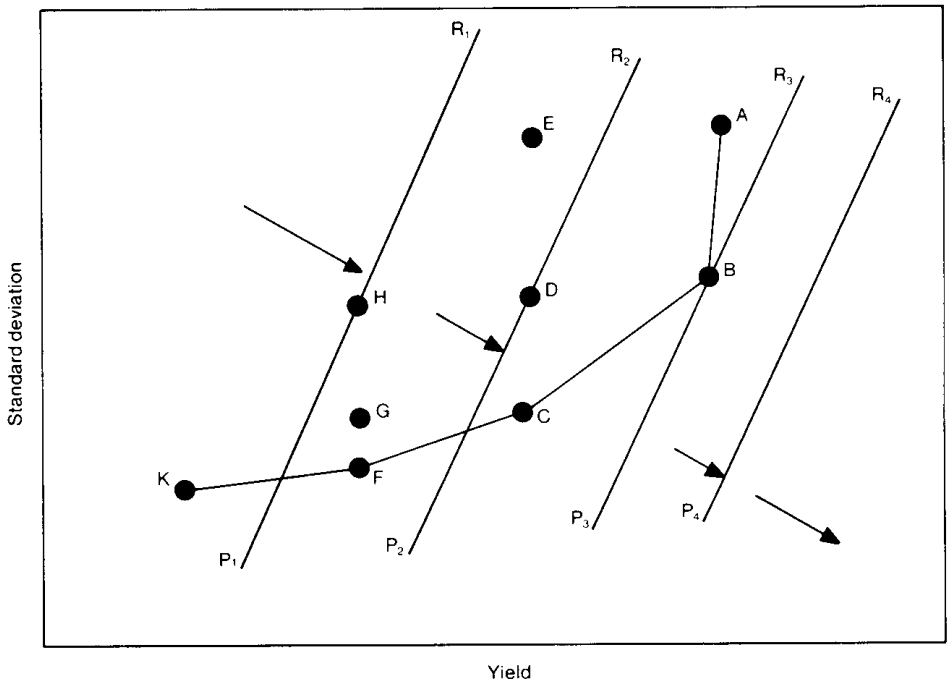

FIGURE 1—Risk Aversion and Preference-Based Choice in Genotype Selection.

the two distributions will differ. Conventional risk management analysis based on the assumption of normality will probably underestimate risk in switching from traditional to improved cropping systems when improved-system yields are normally distributed while traditional yields are positively skewed.

Agro-climatic variability significantly explained yield variation in the nine cropping systems examined, and in most of their components. Farmer-to-farmer differences were proportionally more important in determining yield in the improved cropping systems. The absence of significant farmer-to-farmer differences in yield determination in the traditional cropping systems implies that rearranging practices and inputs will not increase productivity. New technology options are required.

Much of ICRISAT's crop improvement research is focused on incorporating disease, insect, and environmental stress resistances into breeding material to enhance yield stability. Will improved yield stability alone result in farmers planting larger areas to a crop? The research on risk and common cropping systems was extended by Walker and Subba Rao (1982*b*) to look at that question for rainy-season cropping strategies in one village.

It was found that, when farmers substituted hybrid sorghum for the competing traditional cotton-pigeonpea-sorghum intercropping system, mean net crop income increased from Rs500/ha to Rs640/ha, but the coefficient of variation of income also rose, from 58 per cent to 91 per cent. At existing levels of farmer risk aversion, measured by the Binswanger factor, risk is hence a potential deterrent to planting more

hybrid sorghum in the Vertisol cotton-growing region of Maharashtra. The underinvestment in hybrid sorghum production stemming from this farmer risk aversion was estimated to cost society the equivalent of about 80 kg/ha (or 10 per cent of average yield).

Relying on a portfolio analysis, Walker and Subba Rao parametrically reduced the coefficient of variation of hybrid sorghum yield to determine how sensitive area supply response was to increased yield stability. The results indicate that breeding for stability should return handsome dividends. A 30 per cent reduction in the coefficient of variation of sorghum yield, with mean yield held constant, would lead to an initial increase of 46 per cent in area planted to sorghum. The result is particularly encouraging because sorghum hybrids already have a fairly high yield potential.

Conclusion

Economists have an important role to play in *ex ante* evaluation of the likely efficiency and equity implications of alternative research strategies. Because of the tools at their disposal, it would seem their comparative advantage is in assisting in establishing the goals of agricultural research and translating them into research programs at the experiment station and farm levels. In this task, intuition and judgment are important. There are limited benefits in attempting to utilise sophisticated modelling approaches to determine optimum portfolios of research projects in developing countries at this stage of development of such models. They are excessively demanding of the available data and expertise.

There is a premium on the provision of more information to policy makers in developing countries on the nutritional and distributional consequences of alternative research and development options and their implications for growth and employment. As Anderson and Parton (1983, p. 193) suggest, there ought to be a shift in the emphasis from evaluation techniques themselves to information systems within which the techniques are used. In this context, it is pleasing to see that, in their recent publication, Johnston and Girdlestone (1983) developed a socio-economic perspective of the future of agriculture in Australia and suggested areas needing further research; they stopped short of identifying specific research projects or attempting to rank them.

However, information alone is not a sufficient condition for improving the policy process. The information must be effectively extended by economists to policy makers in a form which makes it intelligible. The profession does a good job in communicating the results of research amongst its members. It does less well in extending results to policy makers and to scientists of other disciplines.

Economists working in agricultural research institutions have a unique opportunity to influence the direction of programs as they are close to administrators and other scientists. This enhances their ability to perceive correctly the problems and issues that arise in technology design. If they are prepared to take joint responsibility for planning and executing agricultural research activities within a multidisciplinary framework and to share the plaudits or criticisms of success or failure, the professional and personal rewards can be substantial.

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