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1986 FARMING SYSTEMS RESEARCH SYMPOSIUM

FARMING SYSTEMS RESEARCH & EXTENSION: FOOD AND FEED

Edited by Cornelia Butler Flora & Martha Tomecek

Paper No. 13a October, 1986

FARMING SYSTEMS RESEARCH PAPER SERIES

KANSAS STATE UNIVERSITY
MANHATTAN, KANSAS 66506 U.S.A.

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Kansas State University's Farming Systems Research (FSR) Paper Series is supported by the U.S. Agency for International Development Title XII Program Support Grant. The goal of the Program Support Grant is to increase the University's ability to implement Title XII agricultural and nutritional development assistance programs in less-developed countries. This series is maintained by the FSR Program Associates — a multidisciplinary team of professors who are aiming their activities at applied research on farming from a systems perspective.

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Vernon C. Larson
Director

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COMPLEMENTING PLANT BREEDING WITH A FARMING SYSTEMS APPROACH

Kenneth L. Buhr*and Daniel L. Galt**

Sources of Agricultural Improvements

There are several sources for agricultural improvements which reach farmers. At the international level, there are the multinational corporations which develop and disseminate technology in the form of agricultural inputs such as fertilizers, pesticides and equipment. There is also the network of international agricultural research centers (IARCs; Appendix) which are funded by a number of donor agencies and governments. These international research and training centers, under the coordination of the Consultative Group for International Agricultural Research (CGIAR), have been assigned primary, and sometimes secondary, responsibilities to conduct research and training in major food commodities, often in specified regions of the world (CGIAR, 1985).

At the national level, a governmental agency generally has responsibility for agricultural research and, often, extension. These national agricultural research services (NARS) contain a mixture of political appointees, usually including the Minister of Agriculture, and civil-service based administrators and researchers. In addition, private enterprise may be represented by local entrepreneurs and outlets which sell seed, chemicals, and/or equipment, either of local or international production or manufacture. In addition, funds and a mixture of expatriate and host country human resources may be mobilized around given projects. Such projects -- which may incorporate a given approach to agricultural improvement or may simply help to focus more money on a given region (or regions) -- are either funded by bilateral donors or multilateral donors. The latter group includes the World Bank Group, various regional banks, and some pilot seed-funding organizations (such as the Inter-American Foundations).

Within a given country, agricultural improvement often falls under regional directors (or committees). National funds for research, extension, or both, may flow from the Ministry through the regional director to the regional experiment station or sub-station and to the local extension level. Finally, some agricultural development projects may only be present in a given region or area of a country. These projects may either be of the pilot (experimental) nature, or directed to focus on an area or group given higher than normal political priority.

While regional and national coordination of agricultural development in general, and agricultural research and extension in particular, are major issues which contain many unresolved dilemmas for both host country administrators and bilateral and multilateral donors, this paper focuses on a sub-sector of this general problem. Specifically, what can plant breeders do, in the development of new varieties and technology, to make the technology more appropriate to small farmers and to reduce the variety development time?

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Making Agricultural Research Relevant to Farmers

Agricultural research and extension organizations in Third World nations have been targets of criticism. Two recurring criticisms are that either research is inefficient, or, extension of the technology -- dissemination -- is too slow. Green Revolution advances in agricultural research went a long way toward eliminating both of these criticisms for the groups of farmers whose circumstances -- biophysical, agronomic, and socioeconomic -- allowed Green Revolution technological packages to be effective in increasing yield levels in their specific situations. However, mainly due to deficiencies in these same three circumstances a sizable portion of farmers in Third World nations have not benefited from Green Revolution technology. The conditions under which small farmers operate are not always understood. Traditionally, researchers evaluate yields or profit potential to measure the success or potential relevance of new technology. These may not be the criteria by which limited input farmers evaluate technology

Many reasons have been advanced to help account for the incomplete transfer of Green Revolution technology to Third World farmers. In fact, the Farming Systems Research and Extension (FSR/E) approach began, in part, as a response to this lack of significant impact. FSR/E evolved in the post-Green Revolution era with the growing perception of the failure of agricultural research and extension institutions to generate and disseminate technologies adopted on a wide scale by farmers. FSR/E explicitly addresses the first criticism leveled at agricultural research and extension. It attempts to make agricultural research more efficient by developing technology tailored to, and based on, the major problems or constraints of limited resource farmers. However, FSR/E has done less to address the other criticism, the issue of slow progress in conventional agricultural research. Ways must be found through which the FSR/E approach can contribute to progress in agricultural research.

Advances in the area of biotechnology address the issue of speed and efficiency in agricultural research. Applied to plant breeding, techniques in biotechnology can allow the generation of more breeding material more rapidly than was possible through conventional crossing of selected parents and subsequent genetic recombination. No longer is sexual incompatibility of potential parents a limiting constraint. The use of tissue culture eliminates the need for fertile and compatible parents in propagation of new genotypes.

Regardless of the rapidity with which biotechnology can create and advance new genotypes, the screening process of potential cultivars remains relatively unchanged and tedious. Often, initial generations of genetic material produced by non-traditional and/or non-conventional means must be screened simply for the ability to survive. Next, surviving cultivars are grown under decreasingly controlled situations (from pots in greenhouses to experimental plots at the experiment station to trials in farmer's fields), and screened for such agronomically important factors, such as yield, palatability, grain type/seed color, resistance to lodging, resistance to shattering, and resistance to major pests.

Techniques in plant breeding undergo continual evolution. For example, plant selection at the International Rice Research Institute (IRRI) in the Philippines has evolved from development of short, stiff-strawed, nitrogen fertilizer-responsive varieties to the systematic search for sources of pest resistance, currently brown plant hopper resistance. Plant breeding in the Maize component of the International Center for Wheat and Maize Improvement (CIMMYT) in Mexico has evolved from a process of selecting the highest yielding maize genotypes to one of improving maize yields under a variety of ecological conditions with special consideration given to host plant response to pests and to consumer acceptance of the improved genotypes. Just as the IARCs have evolved plant breeding strategies to help solve globally important crop problems, so too must the national agricultural research services move potentially improved crop and livestock materials out to major groups of farmers who have yet to benefit substantially from the efforts of breeding programs.

Integrating FSR/E into the Early Stages of the Breeding Program

To have an impact on the technology and production packages used by farmers one must understand what the farmers do and why they do it. One way to achieve impact on these groups of farmers is for the researcher, in this case the plant breeder, to interact with the farmers in their fields. This should be done as early in the breeding program as possible, certainly prior to the final stages of testing and evaluation of improved lines. One of the greatest gains from this activity is the impact on the breeder's thinking -- impact on the criteria used by the breeders in their selection of genetic materials to use in their breeding program and on the criteria used in the selection of segregates. When breeders are knowledge-able of the factors which affect the performance of the plants in the farmers' environment they can be expected to make good choices of parental materials and select desirable segregates for that environment when and where those options exist. The limiting factor may be the breeders' knowledge of the variable environments in which limited input farmers produce their crops.

In those cultures where the sons and daughters of those who gain their livelihood from tilling the land are formally educated and accept jobs in agricultural research and extension it is unlikely that breeding programs are producing inappropriate lines for testing and evaluation. Unfortunately, there are environments (cultures) where it is unlikely, or certainly a rare event, for the offspring of farmers to achieve a position as research scientist or extension specialist with the experiment station. It is in these environments where FSR/E can have its greatest impact on plant breeding, by opening lines of communication between the researcher and the farmer.

Technology cannot be developed in a vacuum. To be relevant and adopted, it must take into account small farmers' socio-economic circumstances, production goals, and the constraints limiting production. The most effective way to do this is to bring small farmers into the research process. On-farm experimentation establishes the context for collaboration between farmers and researchers and fosters a deeper under-standing of the farming system among researchers. It also provides for the evaluation of technologies under the environmental and management conditions in which it will be used. Attempts to breed improved varieties for small-scale farmers who use low levels of inputs are likely to be self defeating if selections are made under high-input conditions on experiment stations.

Depending upon the objectives of the breeding program, and the diversity of the genetic materials going into the breeding program, there are plant breeding programs whose breeding progenies would benefit from earlier exposure to farmers' fields. Regardless of how early generation materials are developed, whether by techniques in the area of biotechnology, or by more traditional plant breeding methods, the proposal suggested here will allow breeders to screen materials much earlier in the varietal development process to assess their appropriateness under different sets of resource-limited farmers' conditions.

While the FSR/E approach to be described here may not be practical at IARC's (because of their broad germplasm development mandates), they cannot afford to ignore it altogether. Because of the inherent location-specificity of farming systems research, the modified approach should logically be implemented by national research programs. IARCs' role may be limited to that of guidance and assistance in the development of the farming systems approach and implementation. International agricultural research and training centers such as CIMMYT, CIAT, IITA, ICRISAT and IRRI are strategically located to demonstrate the technique within Mexico, Colombia, Nigeria, India and the Philippines, respectively. However, the major emphasis of combining PSR/E with conventional breeding research must be placed at the level of national agricultural research programs.

To achieve efficiency in on-farm testing, farms which represent categories of environments can be selected to supplement normal experiment station screening. Such an approach may allow for divergent populations to evolve, based on conditions faced by farmers. This is an approach followed by the breeding programs at the International Centers (IARCs). Segregating populations are produced by crossing parents which have been identified as having desirable traits and will be advanced to the equivalent of the P4 (fourth filial generation following the original crosses). Increasingly, multiple parents contribute attributes to a progeny by crossing the offspring of different parents. These segregating populations are distributed, upon request, to national programs, where national program breeders grow the segregating populations and select those genotypes which possess the traits and perform well under the local conditions. This concept could be extended one step further, where national breeders allow populations which are still segregating to be grown by a select group of farmers whose farms represent one or more distinct environments. The example which follows is intended to clarify this potential process.

Breeding Efficiency Augmented With an FSR/E Approach

Plant breeders traditionally began crop improvement with selected parental genotypes. Most breeding texts discuss the importance of the principles and techniques involved in improving the breeder's ability to select proper parental material to make better crosses and to improve the breeder's ability to select superior genotypes. The successful prediction of which individual parental lines are most likely to make good parental genotypes in a specific crossing situation is still much more an art than a science (Allard, 1960; Briggs and Knowles, 1967). Consequently, breeders must continue to produce and test recombinants, looking for the superior genotypes.

Before discussing a way in which some time can be saved from the time of the initial cross to the release of tested varieties, a few definitions are in order. Plant breeders use terms which should be explained. First, a breeding "pipeline" is here defined as the flow, through time, of successively decreasing numbers of possible cultivars, following one or more initial crosses to combine genetic material from two or more parents, under given conditions and at a specific pressure (or intensity) of selection. "Selection intensity" is defined as the percent of distinct lines in any generation which are selected to continue advancement in the subsequent generation. For example, if a breeder uses a selection intensity of twenty percent, and if the breeder's pipeline started with 2,000 distinct lines in the F2 (or second generation following a cross), by F3, or the third generation, 400 lines ([2000] X [0.20]) will remain in this particular breeding pipeline. Similarly, using the same selection pressure, the breeder can expect to still have only 80 lines ([400] X [0.20]) the following generation (the F4 generation).

A Review of the Pedigree Method of Plant Breeding

The pedigree method of breeding is commonly used in the improvement of self-pollinated species such as wheat and dry beans. Selection pressure varies by generation. In the first generation (F1) following a cross, no selection is practiced as all progeny are genetically identical (homogeneous, and heterozygous for those alleles governing traits which differed between the parents.) Homozygosity is defined as "having like alleles at corresponding loci [on the paired chromosomes]" (Allard, 1960). No selection is practiced as there is no variability upon which to practice selection. Planting the seed produced on the Fl plants results in F2 progeny, the first generation in which segregation occurs, following a cross of two unlike, homozygous individuals. Selection can begin in the F2 and usually does in the pedigree method of plant breeding for qualitative, highly heritable traits such as plant height and length of growing season. For those traits which are not highly heritable, such as grain yield per unit area, further generation advancement is needed to reduce the percent heterozygous loci remaining. If plants bearing many heterozygous loci were to be selected, it would be difficult to predict the performance of its progeny as it is not known which of the alleles (alternative form of gene) an individual progeny will receive; for this reason, breeders "advance generations" to the point where few heterozygous loci remain in the individual plants. To illustrate, if we start with 100% of the loci (in which the parents carried different alleles) being heterozygous in the Fl, self pollination (which occurs without breeder assistance in self-pollinated species) results in a reduction of heterozygosity to one-half of what it had been in the previous generation, or 50% of the loci. By the F4, 25% of the loci are still heterozygous. Generation advancement via self pollination to the F8, a value lower than 1% (specifically 0.78%) heterozygosity is attained. As this level of homozygosity (99.22% for an F8) is reached, the reliability (repeatability) of yield trial results improves to the point that no further gain in reliability can be anticipated from further generation advancement. Any failure to repeat the results of a previous experiment must be placed on the researcher's technique, or on environmental interaction.

Each E2 plant is the progenitor of a "family" among which and within which selections can be made during generation advancement. It should be apparent that greater variability exists among families than within families. During subsequent generations, enough plants must be present to represent a family. Allard (1960) suggests, as another rule of thumb, that between 10 and 30 entries per family should be retained until testing. Breeders generally proceed through the F6 and/or F7 generation of advancement prior to yield evaluations of the selections made beginning as early as the F2 generation. Preliminary yield trials may begin as early as the F4 generation in those progenies whose parents were not greatly different from each other, and certainly by the F6 or F7 generation. By this time, the breeder will have reduced the number of families. Up until yield tests are begun, potential lines are grown in small one row plots. However, for an analysis of variance (the statistical technique to test the hypothesis that there is no difference between treatments) to be conducted, yield plots must be replicated (identical treatments repeated in space and/or time). Further, to get better estimates of the yield potential of the various lines, (and reduce error variance in order to detect smaller differences) the experimental lines must be planted in larger plots.

To complete the process of varietal development and release, a rule of thumb given by Allard (1960) is for the new cultivar to prove to be a superior line for five years in trials at each of five representative areas in the region of intended use. Thus, a minimum time frame for release of a superior variety under the pedigree method (as traditionally used) in the U.S. is 14 to 15 years under the certified seed program (Figure 1). This is assuming that a minimum of three years will follow the fifth set of regional evaluation trials, seed increase and distribution (Allard, 1960). With the use of winter nurseries in the early generations of generation advancement toward homozygosity (and with selection, homogeneity), breeders have been able to reduce that figure somewhat. Further, through natural or breeder selection in different environments (e.g., winter nurseries), resulting genotypes may be more broadly adapted, as was shown by Nobel Laureate, Dr. Norman Borlaug of The Rockefeller Foundation, in the wheat-breeding program in Mexico.

Integrating FSR/E into the Latter Stages of the Pedigree Breeding Method

The authors suggest that the traditional pedigree method of breeding procedure may be shortened by complementing a pedigree breeding program with the FSR/E approach several generations earlier than is traditionally the case. A normal breeding pipeline is represented in Figure 1. Continuing with the example begun earlier, it has been assumed that the breeder started with approximately 2,000 potential cultivars in the pipeline.

As noted above, breeders discard much genetic material through successive generations of selection. That they might be discarding "good" material often is of concern to those who are not plant breeders. On the other side of the issue is the unnecessary waste of resources to save and maintain genetic material of limited usefulness. The key to the process of discarding can be found in the definition of the breeding pipeline itself. A careful reading of the definition reveals that whatever the level of selection pressure applied, it is always applied "under given conditions." Traditional breeding has focused much of its attention on selecting the best cultivars under environmentally optimal conditions: those of adequate fertility and moisture and controlled pest incidence found on most experiment stations. Given these conditions, it is correctly assumed that there is more likelihood of making progress too slowly (by retaining too many "promising" lines in the pipeline) than of discarding too many promising lines too early (Allard, 1960).

Selection is interpreted as the selection of the "best" lines which perform (express their genetic potential) in a consistently superior manner under conditions which often are as close to the agronomic ideal as possible. Variation in soil attributes of plots is one of the factors which underlie the failure to get identical yields from plots receiving identical treatments. In an effort to reduce the error variance due to this "unexplained variation", researchers are tempted to fertilize and irrigate to an extent impractical for most limited input producers. Reasons that researchers do this usually fall into two areas: to give the lines the opportunity to express their genetic potential and, to keep unexplained variation (error variance) in plots receiving identical treatments to a minimum so as to be able to detect real differences. This is understood when we look at the F-ratio, resulting from statistical analyses of variance. The error variance, when divided by the degrees of freedom for the error term in the analysis of variance, becomes the denominator in the "F-ratio" used to determine if treatments are significantly different from each other at a given level of significance. The numerator in this F-ratio is the treatment (breeding lines) mean square (sums of squares of differences between individual treatment values and the treatment mean divided by the treatment degrees of squares). The smaller the error variance (the unexplained variation among plots) the greater is the probability of detecting differences between treatments (the breeding lines). If not careful the breeder may be selecting material which performs well under above average conditions . . . definitely not the environment of the small farmer. Most farmers, especially the limited input farmers around whom our interest as supporters of the farming systems philosophy is centered, operate their farming systems subject to conditions which often do not approximate the agronomic ideal (Hildebrand and Poey, 1985).

Using FSR/E as an approach to complement the traditional breeding pipeline at a point prior to F6 or F7, breeders should be able to save time in the development of improved varieties. Further selections can be tailored to major groups of farmer's relatively homogeneous constraints. There are three major keys to this modified breeding process. These are:

1) First, breeders must be interested in and willing to do broad-based, problem-solving research. It is not common for young plant breeders to understand the many factors affecting crop production and it is easy to restrict research objectives to lesser, more defined aspects of genetics. Exposure to, and experience in, the farmers' realm of production problems must be a priority for young scientists.

2) Breeders must become knowledgeable of what the yield-limiting constraints are and the best means to attain that information is to interact with farmers and those working with farmers, the farming systems team. Team work requires investments in the development of open communication and interaction with others whose job and/or interests are with the farmers. The returns on these investments come when other team members provide input (and possibly desirable germplasm encountered in travels and/or farmer contacts) into the knowledge base upon which the crop improvement program is built. When team members are speaking the same language, the breeder will be hearing requests for specific genetic material. This communication and these requests will help shape the selection criteria, and possibly the conditions imposed on the segregating progenies, making

the selection process more appropriate to the needs of the farmers.

3) Farm environments and conditions must be grouped according to major constraints affecting crop growth and productivity as well as specific needs of the household. Failure to group farms may negate any gains derived from earlier testing on farmers' fields. Environments may be categorized based upon such factors as soil type (affecting fertility and moisture retention), slope, length of growing season, rainfall, etc. Specific household considerations may include such aspects as the need for stover as bedding materials for livestock or construction material. On-station selection and testing of high-yielding, short-strawed small grain types may not meet with widespread acceptance among small farmers, raising the question as to whether the breeder had discarded material at the station which was more desirable for the small farmer than was selected.

Figure 2 contains a hypothetical schematic sequence showing how a combination of FSR/E farm-level specialists and breeders, working in a meticulous, scientific manner, may eliminate three years from the traditional breeding pipeline. At the same time, such a process should allow the breeder-FSR/E practitioner teams to develop improved varieties specifically suited (or tailored) to a set of homogeneous conditions representative of one or more groups of farmers who operate their farms in conditions substantially below conditions found on most research stations.

Specifically in this example, it is assumed that, at the F5 generation, breeders evaluate materials at both the research station and at the farm level of two distinctly different, and each relatively homogeneous within itself, groups of farmers. These groups of farmer collaborators may be designated as farming in research domains 1 and 2, respectively (Wotowiec et al., 1986). It is further assumed that the breeder has carried 100 lines (families) into the F5 generation for further screening. These 100 families may be randomly assigned to five possible groups (combinations) consisting of 20 families each. Thus, combination 1 will contain lines 1 through 20, and combination 2, lines 21 through 40, etc. Finally, it is assumed that 15 collaborating farm households can be randomly selected to host these trials. This provides the breeder-FSR/E team with three farms (or replicates) to host evaluation/ selection trials for each of the five combinations of lines. In Figure 2, "F1-F15" indicates one of the 15 farm households selected to collaborate in the farm-level trials in each research domain, "L1-L100" indicates a randomly selected line from the 100 total lines, and "C1-C2" indicates both the individual farmer's variety (control one) and the most prevalent variety of the crop grown in the research domain (control two).

At each farm, the 20 (or fewer, if so desired) improved lines will be compared with the farmer's own variety (C1) and the most widely-grown, locally-available variety of the crop (C2). Control (or check) two will also be used as the common check across all 15 farms of the research domain for purposes of analysis. Analysis of the reaction of the 100 lines on the 15 farms of each research domain should allow the team to select anywhere from one to ten superior lines to move into further trials next season (F6). Verification of superiority (superiority across seasons) may occur as early as the following year (P7), in the case where very few (one to three) lines were advanced from F6 to F7. If more lines had to be advanced from F6 to F7, statistical superiority will probably not be attained for one or two lines until generation 8. When and where such superiority is difficult to verify -- and under typical, rainfed farmer conditions, the genetic superiority of any given line may be a substantially less than that found on-station -- farmer reaction and evaluations of the lines from both years should enter the considerations used to help the breeder-FSR/E team select superior cultivars for seed multiplication for use in the region or area.

One result of the process described above is less dependence upon a national-level seed multiplication industry or governmental body, with more dependence on local collaborating farmers for production of smaller quantities of any given genotype. Farmers will be involved actively in both the systematic evaluation of genetic material in the split breeding pipeline and in the production of breeder, foundation, registered and/or certified seed for use in the extended dissemination domain which represents their homogeneous conditions (Wotowiec et al., 1986). Another result will be the systematic use of the modified stability index for comparing results from the two research domains with each other and with experiment station results (Hildebrand, 1984; Hildebrand and Poey, 1985).

Concluding, farming systems research has long been used by insightful researchers, and is not a new, independent science. However, where the philosophy is not prevalent in the planning and research activities, research directors or leaders of crop improvement research in national agricultural research systems should be encouraged to incorporate FSR/E methodology and/or cooperate with FSR/E teams to promote FSR/E input in the planning of the breeding objectives and encourage earlier evaluations on farms. Critically needed improvements in local germplasm can be made under <u>more relevant screening conditions</u> and <u>quicker</u> than ever before.

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Figure 1. NORMAL PROCEDURE AND THE REQUIRED FOR THE PEDIGREE BREEDING METHOD

Traditional Pedigree Method Breding Pipeline

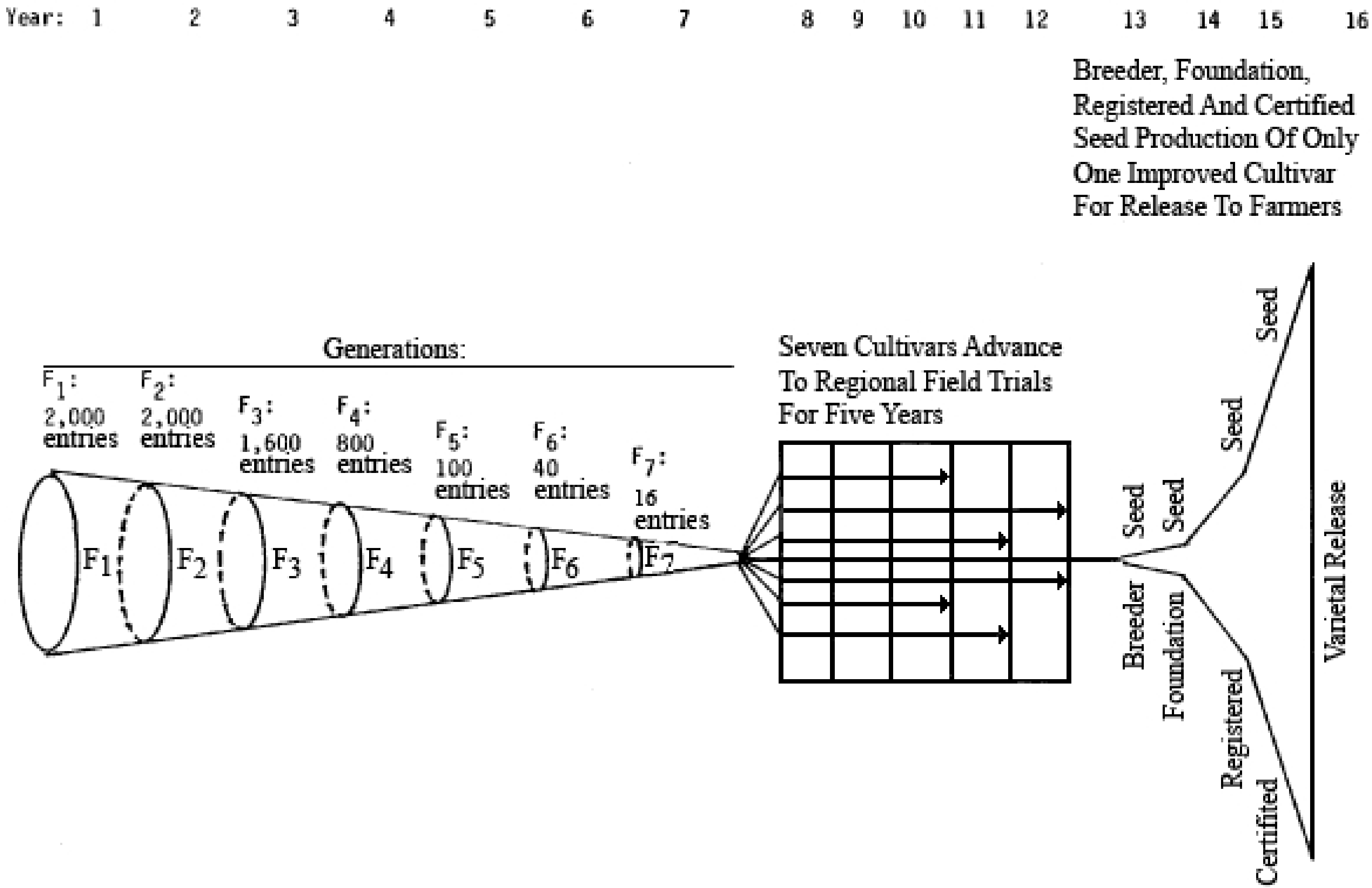
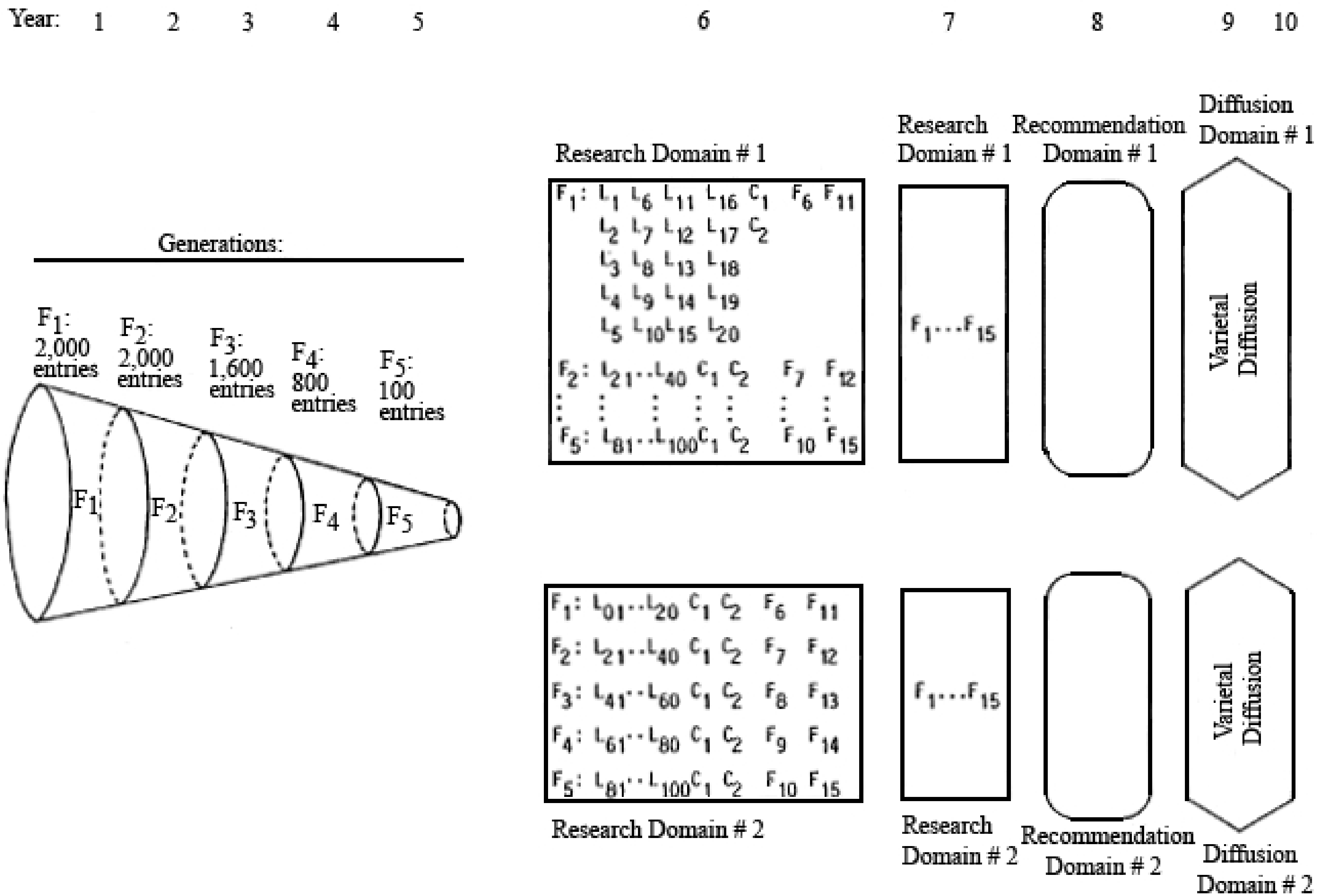


Figure 2. ADDING FSR/E TO THE PEDIGREE BREEDING METHOD SEQUENCE



Appendix

The CGIAR* Centers

CIAT	-	Centro Internacional de Agricultura Tropical Apartado Aereo 6713 Cali, Colombia
CIMMYT	-	Centro Internacional de Mejoramiento de Maiz y Trigo Londres 40 Apartado Postal 6641 06600 Mexico, D.F., Mexico
CIP	-	Centro Internacional de la Papa P.O. Box 5969 Lima, Peru
IBPGR	-	International Board for Plant Genetic Resources (FAO - Food and Agricultural Organization of United Nations) Via delle Terme di Caracalla 00100 Rome, Italy
ICARDA	-	International Center for Agricultural Research in the Dry Areas P.O. Box 5466 Aleppo, Syria
ICRISAT	-	International Crops Research Institute for Semi Arid Tropics Patancheru P.O. Andhra Pradesh 502 324 India
IFPRI	-	International Food Policy Research Institute 1776 Massachusetts Avenue, N.W. Washington, D.C. 20036
IITA	-	International Institute of Tropical Agriculture Oyo Road, PMB 5320 Ibadan, Nigeria
ILCA	-	International Livestock Center for Africa P.O. Box 5689 Addis Ababa, Ethiopia
ILRAD	-	International Laboratory Research for Animal Diseases P.O. Box 30709 Nairobi, Kenya
IRRI	-	International Rice Research Institute P.O. Box 933 Manila, Philippines
ISNAR	-	International Resource for National Agricultural Research P.O. Box 93375 2509 AJ The Hague, The Netherlands

WARDA - West Africa Rice Development Association
P.O. Box 1019
Monrovia, Liberia

* = CGIAR →Consultive Group on International Agricultural Research Secretariat
WORLD BANK
1818 H Street N.W.
Washington, D.C. 20433

Linking Farming Systems Research/Extension (FSR/E) and Commondity Research:
FSR/E Team Identification of Horticultural Research Priorities in the Gambia, West Africa

John S. Caldwell,[1] G. O. Gaye,[2] and Isatou Jack[3]

Farming Systems in The Gambia

The Gambia is a small country on the West African coast, located along the Gambia River and surrounded entirely by Senegal. The climate is semi-arid (800-1400 mm precipitation yearly), with distinct dry (November-May) and wet (June-October) seasons. Precipitation is higher in the southeast. Monthly mean air temperatures are less extreme along the coast (18.0°C - 30.5°C range) than in the interior (14.5°C - 41.0°C range) (Tattersall, 1978).

Important ethnic groups in The Gambia include Wollaf, Mandinka, Jola, Fula, and Serehuli. While Wollofs predominate in the urbanized capital area and in northeast villages, Mandinkas predominate in villages south of the river. Jolas are largely concentrated in the southeast corner of the country. There are pockets of Fula in the west and Serehuli in the northeast.

A major determinant of farming systems in The Gambia is the alternation of vet and dry seasons. Staple cereals are planted in the wet season, while horticultural crops are planted in the dry season. The main exception to this pattern is some irrigated rice production along the river in the east.

As in many other parts of Africa, both crops and animals are divided by gender. Rice is the main women's wet season crop, while men's wet season crops include millet, sorghum, and maize. Dry season vegetables are a women's crop, but orchard fruit, especially citrus, are predominantly a men's crop. Cattle are largely owned by men, whereas goats and poultry are more frequently owned by women.

The economy of The Gambia is almost entirely agricultural, with export of groundnuts providing the main source of foreign exchange. Considerable formal and informal trade in agricultural inputs and products also occurs across the borders with Senegal. Often this trade is based on kinship networks, especially among the Wollof ethnic group.

Vegetables in The Gambia are divided into "indigenous" and "exotic" types. The distinction is based primarily on seed source: farmers save their own seed of "indigenous" vegetables but depend on imported seed of "exotics." Important indigenous vegetables are bitter tomato (Solanum incanum), sorrel (hibiscus sabdariffa), eggplant, hot peppers, and local tomato cultivars. Onions are also important. Common "exotics" are cabbage, lettuce, carrot, and introduced tomato cultivars.

Major fruit crops include citrus, papaya, avocado, mango, and banana. Production is both in orchards, especially in the more humid southwest, and in backyard plantings.

Vegetable production is typically organized in a semi-communal manner. Wet season rice fields become common garden areas with common wells and fencing serving many small individual

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plots. The small plots vary in vegetable type and cropping pattern (monocrop versus intercrop), producing a mosaic of different vegetables. Sometimes papaya and young citrus seedlings are all interplanted in the gardens.

Urbanization and the development of a tourist industry have increased market demand for vegetables in recent years. Dry season vegetable production is largely market-oriented and includes both "indigenous" and "exotic" vegetables. Wet season production, in contrast, is less market-oriented. It consists mainly of scattered backyard production of "indigenous" vegetables.

FSR/E and Revitalization of Agricultural Research in The Gambia

Agricultural research in The Gambia has been criticized for its failure to improve productivity, increase income, or address the deterioration in the national balance of payments. In response to these criticisms, the Ministry of Agriculture has established a long-range plan to revitalize agricultural research. A major element in the plan is The Gambia Agricultural Research and Di versification (GARD) project. The GARD project places emphasis on FSR/E as a means of improving research management (allocation of resources to priorities) and productivity (generation of acceptable technology). FSR/E concepts and skills have been introduced to Gambian research and extension personnel through training supported by the Farming Systems Support Project beginning in 1984.

At the same time, the Ministry has also placed special emphasis on horticultural crops. This is because they are a potential source of revenue through import substitution in local urban markets and export to European winter markets. One of the first activities of the GARD project is to link these two elements (FSR/E and horticulture) of the Ministry's research revitalization plan. From January 1986, an FSR/E multidisciplinary team was organized in the western half of the country. The first task of this team was to reorient the research program of the horticulture unit, by carrying out a reconnaissance of western villages. This paper reports on the organization of this team and how it planned the initial reconnaissance. It discusses both decisions that the team made and results of the reconnaissance in terms of how best to link FSR/E and commodity research.

Team composition

Organization of a multidisciplinary team is one of the first steps in FSR/E. Teams may vary in size. For example, the Centro International de Mejoramiento de Mais y Trigo (CIMMYT: International Center for the Improvement of Maize and Wheat) uses a two person team: an agronomic scientist and an agricultural economist (Beebe, 1985). At the other end of the spectrum, the Instituto de Ciencia y Technologia Agricolas (ICTA: Agricultural Science and Technology Institute) in Guatemala uses a 10-person team (Shaner et al., 1982).

Team size was an issue at the start of planning. The question was, is a small team more efficient when there is a predetermined commodity focus for the reconnaissance, or is a larger team advantageous?

The horticulture unit considered the above variations in the FSR/E literature, and chose a larger team size for three reasons:

1. Horticulture is a part of a larger farming system in each village.

2. Reconnaissance and description of farming systems in the western half of The Gambia is a new activity for the horticulture unit and the Ministry of Agriculture.

3. Involvement of representatives of non-governmental organizations (NGO's) is essential. This is because of their key role in support and dissemination of technology for horticultural (especially vegetable) production.

The result was a 12-person team representing the following disciplines and organizations: horticulture (fruit and vegetables), plant pathology, entomology, soil and water management, livestock production, home economics and nutrition, extension, two NGO's, and rural sociology. Fig. 1 shows in terms of a generalized model (Caldwell, 1984; McDowell and Hildebrand, 1980; Zandstra, 1980) how the different disciplines and organizations represented on the team covered different parts of the whole farming system.

Choice of informal survey method

The first activity of the team was to plan the initial survey in a three day planning workshop. The team weighed two contrasting informal survey approaches: the "topic guidelines" approach used by CIMMYT and others, and the ICTA "blank mind" approach (Beebe, 1985; Caldwell et al., 1984; Shaner et al., 1982). The issue here was: to what extent should the team start with questions based on the predetermined commodity focus, and follow linkages out to other parts of the farming system? Conversely, to what extent should the team start with more "open" questions about the overall farming system, and follow linkages in to the commodity focus? The first approach would favor the "topic guidelines" approach. The second approach would favor the "blank mind" approach.

The team weighed the advantages and disadvantages of the two approaches in terms of two risks that it saw as likely to occur in the interview process:

1. The risk of forgetfulness: That the flow of spontaneous conversation might result in farm household members forgetting to discuss a part of the farming system that information is needed on, because of interrelatedness of components (for example, soil-pest relationships).

2. The risk of imposing problems: That asking a question about a part of the farming system which farm household members do not mention may cause them to think that the should come up with a problem related to that question (for example, because they may think that a question implies that interviewers may be interested in offering assistance in the area focused on by the question).

The team judged that the risk of imposing problems was the greater of the two risks. The team recognized that while a "mental checklist" of topic guidelines would be one way to reduce the risk of forgetfulness and loss of completeness, it would increase the risk of imposition too much. The team consensus was, there fore, to use an "open" approach in an initial reconnaissance survey. The word "open" reflected the fact that none of the tea; members would really go in with a "blank mind". This is because all had some prior knowledge (and hence some preconceptions about horticulture and the farming systems of the western half of the country. "Open" thus meant a "pretend blank mind," that is, not reinforcing prior knowledge and preconceptions by developing a topic areas checklist beforehand.

The team decided, however, to try to reduce the risk of forgetfulness through Judicious probing of points mentioned by respondents that showed linkages to other parts of the farming system. The team recognized that the difference between probing a respondent's response and imposing a new problem would be a fine line that could not be specified in advance. Each team member would have to Judge where that line was in the context of conversation in each interview.

The team saw the "open" approach, with probing, as part of a 2-step process. Stage I would be an "open" reconnaissance. This would result in a description of selected farming systems and hypotheses for a guided informal survey in Stage II. The output of stage II would be the research agenda and on-farm trial designs for the horticulture unit in the 1986-87 dry season.

<u>Choice of villages</u>

In the planning workshop, the team initially identified 16 characteristics for grouping farm households into domains (Harrington and Tripp, 1984; Wotowiec et al. 1986). The team began to rank these characteristics on the basis of importance for horticultural production. However, midway through this process, the team decided that it did not know enough about the villages to rank characteristics or group households or villages. The team also recognized that the ranking was likely to bias team members' questioning, contrary to the team's decision on planning workshop day one to use an "open" approach. The team thus abandoned the initial attempt to distinguish domains before the reconnaissance.

The team instead decided to do a broad reconnaissance of all 23 districts in the western half of the country, in order to determine characteristics for identifying domains. The team then reduced the 23 districts to 11 groups of broadly similar districts. One or two villages were then chosen from each district, based primarily on the extension team member's judgment of representativeness (Figure 2).

Administration of the reconnaissance

The team conducted the interviews in sondeo interview pairs. Each interview pair consists of a biological and social scientist (Shaner et al., 1982). In this reconnaissance, only one person was formally trained as a social scientist. Team members from extension and the NGO's were considered, however, to have more social science perspective, because of their greater experience at the village level. The nutritionist was also considered to have greater social science perspective. This is because home economics works with the whole farm household, rather than with a specific crop or animal production enterprise. Extension, NGO, and nutrition team members were therefore placed in social science positions in the interview pairs. Members were then rotated each day, maintaining pairing of biological and social scientists each time (table 1).

In each village, the whole team first met with a group of villagers for formalities and explanation of the purpose of the visit. The visit was presented as a kacaa (conversation) about farming. Each interview pair then went with a group of men and women for their interview. In some cases, a group would go directly to the garden. In most cases, the interview would begin in the village and then move midway to the garden, sometimes when the interview pair picked up on a response which they would then ask to see.

Processing of information

A key element of the sondeo method is the pooling of information at the end of each day (Shaner et al., 1982). In this reconnaissance, one interview pair took the lead in describing what it learned from a given village. Each of the other pairs then added new information and indicated information, observations, or hypotheses that were different from the first pair or other pairs. One person (usually from the lead pair) also took notes on the additions, differences, and group consensus. A different pair would then lead for the next village. The discussion for each village took approximately one hour.

One week after the survey, the team met again for an overall appraisal session. The team pooled the information from all the villages on constraints in resources and different types of production by placing each constraint in one of three producer-type columns: female producers, male producers, or joint male and female producers. This involved indicating with code letters such items as: local vs. concrete wells for women; types of fruit crops grown by men, women, or jointly; presence or absence of fertilizer use on women's vegetables; and so forth. Constraints given by respondents as priorities were starred. The number times an item was starred as a priority in each row was then counted up across all 39 columns (three producer types times 13 villages).

Ranking of priorities across villages

Based on the number of times a priority was starred across all villages, overall wells and implements were ranked highest with both having counts of 11. Within fruits and vegetables, vegetable marketing was ranked highest, with a count of 4.

Based on this result, the team looked more closely at the information obtained from the villages on the vegetable marketing problem. The information was discussed with the manager of government-sponsored private company who was present in the appraisal session. This company has major responsibility for marketing and processing of horticultural commodities. The conclusion of this discussion was a tentative agenda placing emphasis on testing technical solutions to the marketing problem:

1. Planting date and staggered planting trials, to reduce concentrated production leading to gluts.

2. Cultivar trials, to identify better-storing cultivars or cultivars with differing times of maturity, to spree production and utilization over a longer period of time.

3. Trials with new crops, to reduce farm household risks associated with a glut of one or two existing crops.

4. Testing different storage techniques.

5. Identification of consumption patterns and quantification of consumption and production over the year, to identify potential "windows" to develop production technology.

The team considered this agenda to be a working hypothesis to be tested in stage II of the survey.

Identification of domains

Reflecting the village-based semi-communal nature of vegetable production, the team first grouped farmers on a whole-village basis into preliminary research domains (Wotowiec et al., 1986). The team first identified five characteristics based on the reconnaissance and scored each as either more or less favorable for horticultural production (table 2). Next, the 13 villages were scored for each characteristic, but there was not a clear pattern of association among the characteristics. The team therefore added up the number of favorable scores and grouped villages into those with a higher (count = 3-4) versus lower (count = 0-2) total number of favorable scores.

The team also looked at the count of favorable scores for the first three characteristics as representing higher potential for horticultural production. On this basis, all the villages with higher total favorable scores also had higher potential scores (count = 2-3). Those in this group with a higher level of management were termed domain A-l (higher potential, high achievement), and the one village with a low level of management was termed domain A-2 (higher potential, low achievement). Among the villages with lower overall favorable scores, two had higher potential scores (count = 2) and were termed domain B-l (intermediate potential, low achievement). The remaining villages were termed domain B-2 (low potential, low achievement) (table 3).

Stage II follow-up: survey results and trial designs

Six villages were chosen for the stage II survey: all four villages in the A-l domain, and one village each from the B-l and B-2 domains. The A-l domain villages were chosen to obtain as much information as possible on villages with a higher management level. The objective here was to identify farmer innovations and practices which might be tested in villages with intermediate potential but lower management level.

Team organization and administration of the focused stage II survey was similar to that of the stage I survey, except that topic guidelines were developed in advance. After the survey, the information from the notebooks of each interview pair was summarized into 9 charts:

1. Planting dates.
2. Farmer ranking of area and importance of major horticultural crops.
3. List of all horticultural crops grown.
4. Markets at which produce is sold.
5. Preservation techniques.
6. Sources of information.
7. Priority problems.
8. Sources of inputs.
9. Management practices:
    a. Nursery practices.
    b. Beds, fertilizer, spacing, water, and weeding.
    c. Mulching, trellising, and staking.
    d. Crop protection.
    e. Rotations and intercropping.

The team next divided itself into three working groups. Each group developed a treatment objectives statement, treatment options, and a final treatment subset (Caldwell and Walecka 1986) for two villages. These steps had been introduced in three-week farming systems workshop held after the stage II survey but prior to trial design (Walecka et al., 1986).

The resulting trial designs incorporated several FSR/E principles: use of farmer knowledge (indigenous pesticide intercropping); incremental changes in existing practices (frequency of watering); taking into account other linkages (rejection of groundnut hay as a mulching treatment because use as animal feed, inclusion of economic evaluation criteria and application of scientific knowledge to farmer problems (new lettuce cultivar with thicker leaves less susceptible to wilting and loss between harvest and market sale, plant density theory Altogether, 13 trials were proposed in the six villages (table 4-7).

From this point, refinement of trial designs was turned over to the horticulture unit. Decisions on implementation at the village level were referred to a 5-person steering committee responsible for organizing field teams based at district extension centers (DEC). The field teams would include the district extension supervisor; a research associate; a livestock assistant; and two other persons (an NGO active in the area, an agro forestry person, or a socio-economic survey enumerator, depending on needs and available personnel at each DEC). In addition dry season horticultural trials, the field teams would also have responsibility for implementation of wet season trials for agronomic crops.

The state II survey and design work also had an effect on choices for station research in the horticulture unit. Given the importance of water as a farmer priority, three irrigation trials were designed, one for vegetables, one for fruits, and one combining live lime fencing with vegetables (fencing was another frequently-mentioned farmer problem).

<u>Questions for assessment of implications</u>

The work reported here represents one of the first full-scale applications of FSR/E with a horticultural focus. In assessing the implications of this work, three questions arise:

1. What principles of FSR/E were reflected in horticulture unit and team decisions?

2. How did the conclusions reached by the team compare with assessments made within the horticulture unit?

3. How could the team approach be used for all the different units and programs of the Ministry of Agriculture?

The paper concludes with consideration of these three questions.

Principles of FSR/E reflected in unit and team decisions

Seven principles of FSR/E were reflected in decisions made by the unit and the team. First, the unit decided which persons to ask to serve on the reconnaissance team. It was the decision of the unit to choose a larger team. This decision was made in spite of some administrative reservations about the need and workability of a large team. The unit nevertheless considered the larger team necessary. This was because the unit saw a need both for input into its priority setting and for support for its research from each of the disciplines and organizations represented on the teem. In other words, the unit saw the problems and the solutions for their commodities as being multidisciplinary in nature.

Second, once assembled in the planning workshop, the team decided on an "open" approach over a "topic guidelines" approach for the initial reconnaissance. The concepts of "risk of forgetfulness" and "risk of imposition" were terms coined by the team itself. The team decision provided confirmation of the principle of "open" learning from participants. This principle, derived from anthropology, is a key element of the informal survey method of FSR/E (Rhoades, 1984).

Third, the team recognized that "open" learning requires skill and effort on the part of interviewers. The term "pretend blank mind" was also coined by the team. An informal survey may superficially appear to be facile, but in fact it requires considerable interviewing skill and effort. The skill and effort lie in not allowing interviewer preconceptions and prior knowledge to influence interviewee responses.

Fourth, the team divided the survey process into two stages. It recognized that the "blank mind" and "topic guidelines" approaches were neither mutually exclusive nor self-sufficient. Rather, it recognized that the two approaches can complement each other in an iterative process.

The same iterative process was also reflected in the results of stage I and stage II. The research agenda at the end of stage I was not yet village-specific. Stage II was necessary for village-specific trial designs. The team recognized that another visit by the unit researchers would be needed to check and refine treatment choices and develop cooperator-specific plot layouts.

Fifth, learning from participants was also reflected in the trial designs. By picking up on innovations in one village and using them as treatments in another village, the team acted as a "broker of knowledge" (figure 3: Caldwell, 1984). As a "broker of knowledge," the team combined indigenous and scientific knowledge (Compton, 1983) both conceptually (in treatment arrays) and spatially (from one village to another).

Sixth, the team decided to explore more complex irrigation techniques on-station while testing simpler modifications in watering rates using existing techniques on-farm. This shows the complementarity of on-station and on-farm research (Franzel 1984).

Seventh, FSR/E seeks to increase the "menu" of option: available to farm households (Ferguson, 1983). The unit approached the FSR/E process itself on the same basis. In facilitating team planning decisions, the unit did not suggest that one or another FSR/E technique was preferable. Rather, the unit presented alternate options to the team. It then encouraged the team to weigh advantages and disadvantages of the alternative options at each point. This allows an option not chosen at one point to be considered again at a later point. This happened when the team did not use "topic guidelines" in stage I, but did in stage II.

Comparison of team conclusions with commodity-based assessment

The team reached two major conclusions at the end of stage I identification of marketing as the priority problem of the sample villages, and grouping of villages into four domains. When compared with a preliminary commodity-based assessment done within the horticulture unit prior to the reconnaissance, the first conclusion confirmed the unit's prior assessment. The second conclusion, in contrast, resulted in changes in its understanding of how villages differed.

The preliminary assessment had also identified marketing as a priority constraint. Since the unit no longer has its own marketing specialist, the results of the survey now give the unit a stronger basis for seeking cooperation from other agencies in addressing the marketing problem. One such agency is the socioeconomic unit (Program Planning and Monitoring Unit).

The preliminary assessment had used three characteristics to group farm households: predominance of "exotics," onions, or "indigenous" vegetables; presence or absence of organized citrus orchards; and ethnicity. This had resulted in eight different domains, reflecting varying hypothesized combinations of the three characteristics (unpublished data).

The domains identified by the reconnaissance resulted in a different classification of variability. Ethnicity was not found to be a determining characteristic. Likewise, the presence or absence of citrus orchards was not a determining characteristic. "Exotics" were widespread, and differences in level of management among villages were not necessarily correlated with their relative predominance or absence.

Thus, the greatest value of reconnaissance for the horticulture unit was to increase its understanding of variability among villages. This can only be done through actual direct conversation with farm household members and direct observation of what they are doing. At the same time, doing this as part of a team reduces the risk of preconceptions within the unit predetermining the conclusions of the reconnaissance.

The team approach and commodity research

In this work, a team of research and extension personnel from different agencies all supported the horticulture unit. Never-the-less, the team sustained high motivation throughout the five months of this work. Administrative support was also high. The work was the first application of FSR/E in the western half of the country. It was also done with concurrent training support in trial design (Walecka et al., 1986). Thus, many unusually favorable conditions supported this work.

How can this effort be sustained over the long run? Two questions arise:

1. How can team assessment of priorities be done efficiently for all commodities and support agencies?

2. What tasks are best done on a team basis, and what tasks are best done by commodity researchers separately?

The high motivation throughout this work was likely due to it being new. The reconnaissance and trial design focused on horticultural crops. It did not directly help set priorities on result in trial designs for other crops or for animals. Thus there was no direct benefit to non-horticultural programs. One can hypothesize that the high motivation reflected a desire on the part of the other team members to use this opportunity to gain experience in FSR/E. In the long run, however, they will also want to see direct benefits to their own programs.

Likewise, administrators will also want to see benefits to all programs. The team reconnaissance was expensive in terms of person time and logistical support (vehicles and fuel). The team approach needs to yield multiple, rather than single-program benefits to justify its cost after an initial learning phase.

To achieve multiple benefits from team reconnaissance requires a clear delineation of which tasks benefit most from interdisciplinary team interaction. Other tasks may benefit less, and some tasks in fact may be better done separately by commodity researchers.

This separation of tasks is still in the process of development in The Gambia. Nevertheless, this work suggests a few guidelines:

1. Team reconnaissance can help all units see where their work ranks in terms of their clients' (the farm households') priorities. This is a powerful tool for "democratizing" research decisions. In this study, for example, horticulture recognized that support from the socio-

economic unit was critical for its work. Both the horticulture unit and the socioeconomic unit have a better understanding of how resource allocations to the other unit can complement their own work. Administrative decisions can thus be made with more consensuses among all units.

2. Team input into trial design is most critical in treatment selection, to avoid conflicts with other enterprises. The example here was the deletion of groundnut hay as a mulch treatment because of use as animal feed.

3. After treatment selection, selection of cooperators and details of plot layout can be left to each commodity group. This was also the decision of this team at the end of the stage II appraisal session. Thus, first the whole team can set overall priorities among commodities and choose treatment arrays for each commodity selected for trials. Then it can break into commodity-based groups for completion of trial specifics. Each commodity-based group might have some overlap from support disciplines depending on trial type. For example, crop protection might assist in completion of the design for trials 4-5 in village K, domain A-l, and village B, domain B-2 (table 6). Crop protection personnel might at the same time assist in completion of the design for an agronomic crop trial also focusing on a pest problem.

4. Implementation requires field-based teams. While extension personnel play a lead role in field-based teams, researcher input is also needed. This was reflected in the decision to assign a research associate to each DEC field team.

5. Team input is also needed for assessment of trial results, for two reasons. First, team assessment gives a better assessment of the systems (as opposed to purely commodity) output of each trial. The example here was the need for economic analysis of several of the proposed trials. Second, concurrent team assessment of all trials in terms of systems output gives the team important information for reprioritizing in the next season.

Working out the separation of team and commodity-based tasks will take time. Both the process and the results of this work in The Gambia will likely be worthy of another report in the future.

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Table 1. Examples of interview pair rotation

Day	Pair				
	A	B	C	D	E
1	Entomology	Pathology	Soil & Water	Horticulture	Horticulture
	Extension	Extension	Nutrition	Sociology	Extension
	Livestock				
2	Entomology	Pathology	Soil & Water	Horticulture	Horticulture
	Extension	Nutrition	Sociology	Extension	Extension
		Livestock			Horticulture

Table 2. Characteristics used for distinguished domains for horticultural production

Characteristic	More Favorable	Less Favorable
1. Water availability	L: low-lying land (high water table)	H: high-lying land (low water table)
2. Access to market	N: near	F: far
3. Climate	H: humid	D: dry
4. Level of management	H: high (good crop appearance; special practices such as manure, chemical fertilizer, trellising, or mulching; more diversity of crops)	L: low (poor crop appearance; no special practices, less diversity of crops)
5. Rice	NR: no rice (thus, vegetable production not delayed in good rice years)	YR: yes rice (thus, vegetable production delayed in good rice years)

Table 3. Identification of domains by Scoring

		Characteristics[y]					Favorable Scores	
Domain	Village[z]	Water	Market	Climate	Management	Rice	Potential[x]	Overall[w]
A-1	S(K)*		N	H	H	NR	2	4
	K*	L	N	H	H		3	4
	SJ*	L	N		H		2	3
	SK*	L	N	H	H		2	3
A-2	S	L	N				3	3
B-1	N*	L	N				2	2
	T	L	N				2	2
B-2	B*	L			H		1	2
	S(J)	L					1	1
	J	L					1	1
	NK		N			NR	1	2
	KJ		N			NR	1	2
	K						0	0

[z]Village abbreviations starred with an asterisk were chosen for a follow-up stage II survey to design on-farm trials.

[y]Letter indicates favorable scoring, and blank indicates less favorable scoring, for each characteristic.

[x]Sum of the number of favorable scores (letters) in the water, market, and climate columns.

[w]Sum of the number of favorable scores (letters) in all 5 characteristics columns.

Table 4. Designs for On-farm Trials in Village S, Domain A-1

Trial No.	Farmer Problem	Crop	Factor	Treatments	Notes
1	Water, postharvest Losses	Lettuce	-Cultivar	-Farmer	
				-Introduced	-Thicker leaves for less loss in transit
			-Mulch	-None	-Researcher control
				-Grass	-Farmer practice; results in weeds
				-Rice straw	-Less weeds but not used as animal feed as is groundnut hay.
2	Market diversification need	Shallot	-Intercrop	-Cabbage -Hot pepper -None	-Cabbage and hot pepper intercrop was farmer innovation observed in another village
			-Planting date	-September -October -November -December	-Assess economics of different dates

Table 5. Designs for On-farm Trials in Village SK, Domain A-1

Trail No.	Farming problem	Crop	Factor	Treatments	Notes
1	Marketing	Tomato	-Cultivar	-Farmer -New	-Comparison of market acceptance of small vs. large fruit size cultivars
			-staking	-Without -Without	-Assess value of staking
2	Improvement of intercropping systems	Cabbage/ Onion/ hot Pepper Intercrop	-Intercrop spacing combinations	-To be determined after another visit to village	-Will test different spacing combinations (farmer and introduced) to determine optimum overall combination of plant densities, recognizing trade-offs between individual plant yield, sole crop yield, and intercrop yield
			-Mulch	-With -Without	-Assess value for reduction of water use

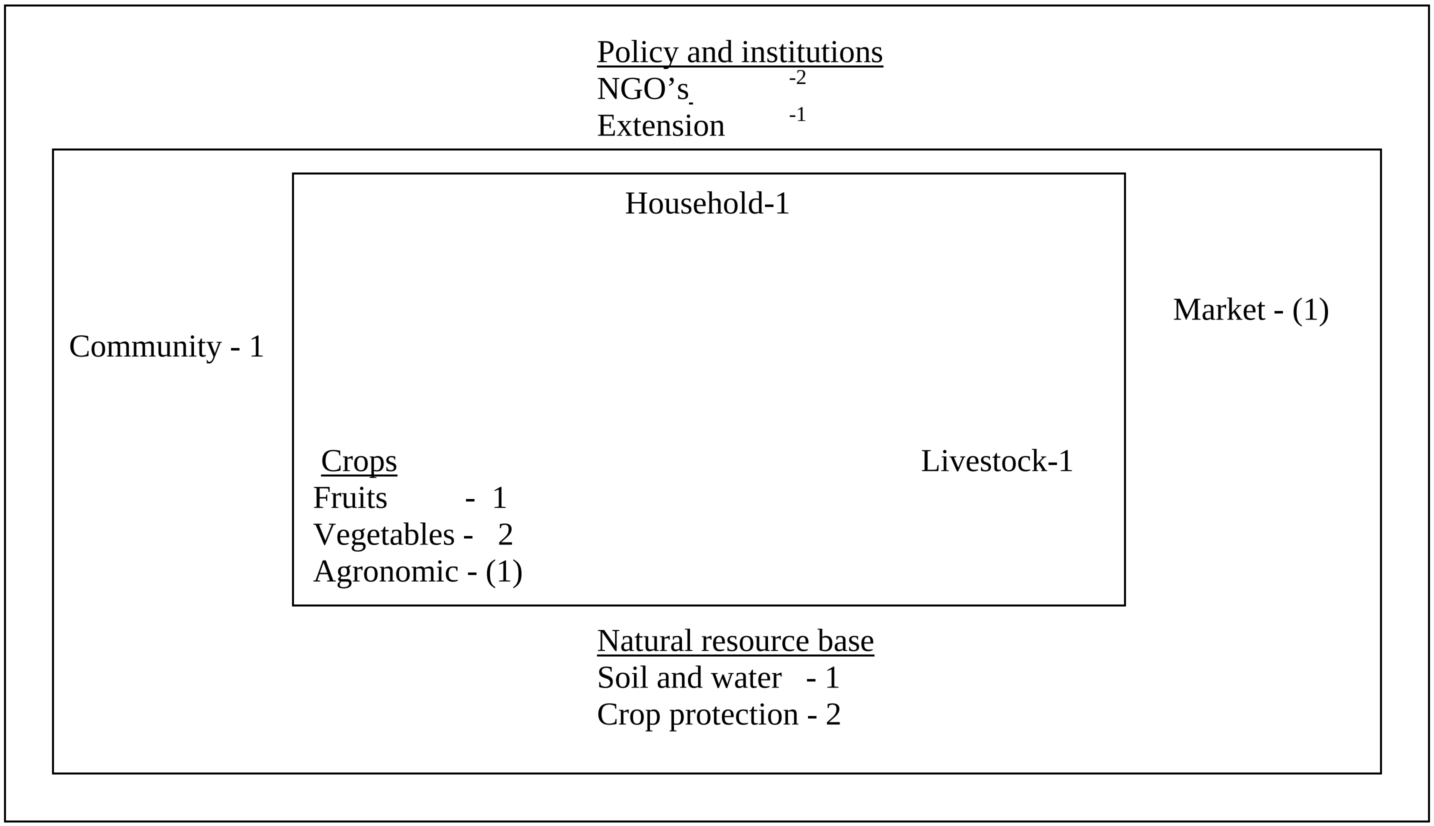
Table 6. Designs for On-farm Trials in Village K, Domain A-1, and Village B, Domain B-2

Trial No.	Farmer problem	Crop	Factor	Treatments	Notes
1-3	Water	Tomato, Onion, Cabbage (1 trial each)	-Mulch	-With -Without	-Assess value for reduction of water use
			-Frequency	-Once per day -Twice per day	-Farmers appear to be overwatering
4-5	Pests	Cabbage, Tomato (1 trial each)	-Pesticides	-None	-Farmer control
				-Ash	-Farmer innovation to be introduced from other villages
				-Neem	-Indigenous wild plant material which can be collected in rainy season and crushed; shown to have insecticidal properties
				-Tobacco	-Cabbage trial only
				-Chemical Pesticide	-Researcher control

Table 7. Designs for On-Farm Trials in Village N, Domain B-1, and Village SJ, Domain A-1

Trial No.	Farmer Problem	Crop	Factor	Treatments	Notes
1-2 (Village N)	Water	Onion, tomato (1 trial each)	-Watering rate	-5 rates	-Assess economic watering requirements
			-Watering time	-Morning -Evening	
			-Mulch	-With -Without	-Assess value for reduction of water use
1-2 (Village J)	Marketing	Onion, cabbage (1 trial each)	-Planting dates	-To be determined	-Assess production capability at times that evade glut periods

Figure 1. Team members' coverage of different parts of farming systems structural model[z]



[z]After Caldwell (1984). Numbers without parenthesis are members who participated in sondeo. Numbers within parenthesis are members who participated in parts of the planning and/or appraisal sessions only.

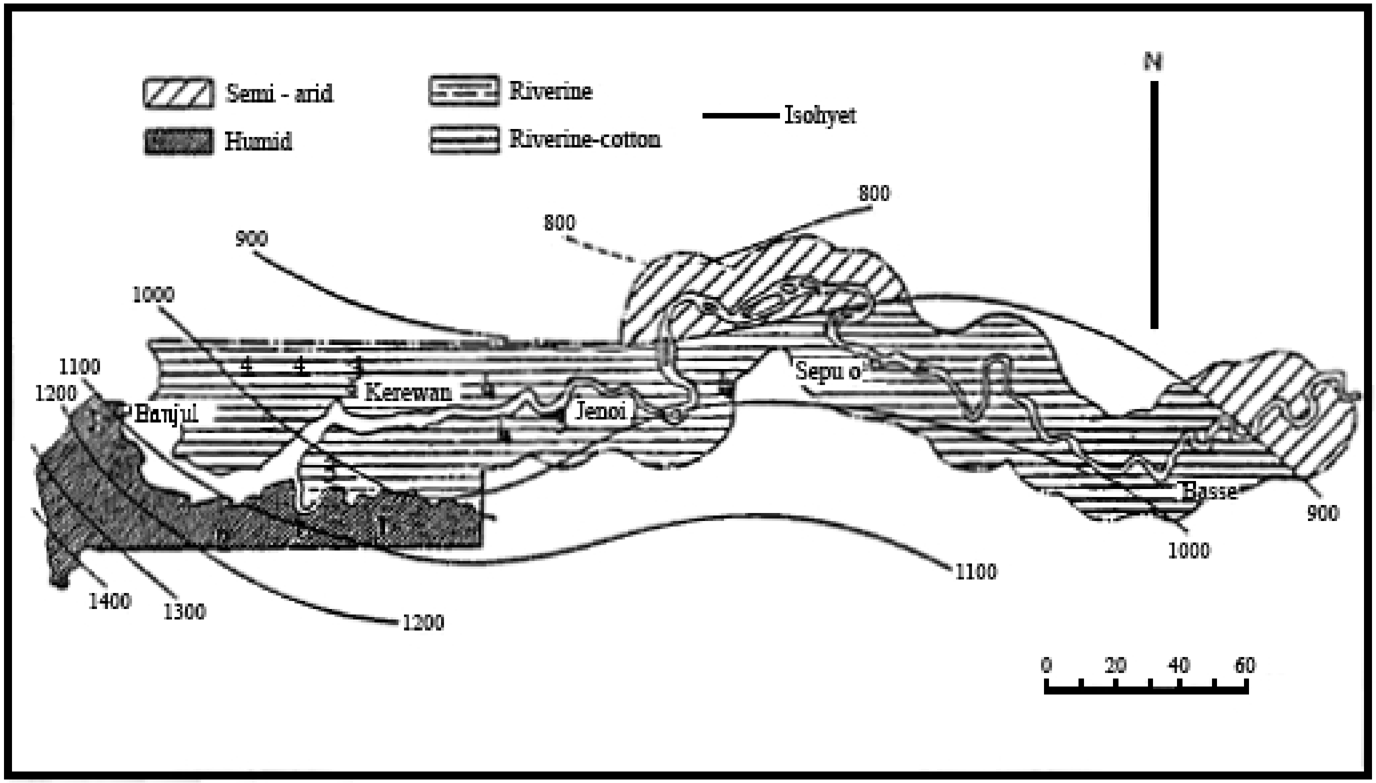
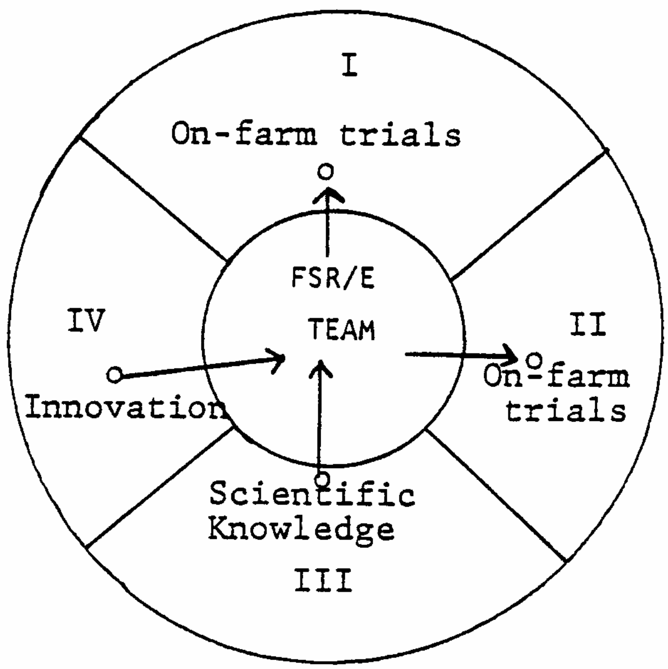


Figure 2. Location of survey villages, classified by domains:

1 = A - 1 (higher potential, high achievement)
2 = A - 2 (higher potential, low achievement)
3 = B - 1 (intermediate potential, low achievement)
4 = B - 2 (low potential, low achievement).

Map based on P. Hutchison, 1983. The Climate of The Gambia.

Figure 3. Role of a farming systems research/extension team acting as a “broker of knowledge” to combine farmer innovation and scientific knowledge in trials in different locations.



The 1986 Gambia/West Africa
Farming Systems Research/Extension (FSR/E) Workshop:
Diagnosis, Design and Analysis

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The West Africa Fanning Systems Research/Extension (FSR/E) Regional Training Course was held in The Gambia, April 7 through 25, 1986. The Gambia Agricultural Diversification Project (GARD) of the Ministry of Agriculture of the Government of The Gambia hosted the course and supported its activities. Farming Systems Support Project (FSSP) member institutions in the United States which participated in delivery of the course were Virginia Polytechnic Institute and State University (VPI), Iowa State University (ISU), and the University of Florida (UF). The workshop was attended by thirty-one participants from The Gambia and five other African countries (Sierra Leone, Nigeria, Ghana, Mauritania, and Botswana).

The Gambia has been the site of two previous FSSP workshops. In 1984, a ten day workshop was held on Diagnosis (Poats, 1984). A one week workshop addressing On-Farm Experimentation was held in 1985 (Walecka, 1985). Based on feedback from participants and trainers in these and other workshops, FSSP decided to take a slightly different approach for the 1986 workshop. Ensuring that participants of the workshop on Design and Analysis had previously attended the Diagnostic workshop, and that the participants at the Diagnostic workshop would have the opportunity to attend the follow-up workshop on Design and Analysis, was often difficult and limited the effectiveness of the both workshops. Therefore, it was decided to lengthen the time for this workshop to include both groups of material at one time. The course included one week devoted to general diagnostic methodologies and two weeks to on-farm trial design and analysis methodologies.

In the subsequent pages, this report describes the day-to-day program of the workshop. It also presents participants' perceptions and trainers' evaluation and recommendations for each day or logical segment of the workshop. In this way, this workshop may provide suggestions to other trainers as they plan similar FSR/E training programs.

PRINCIPLES OF WORKSHOP DESIGN

The decision to hold a three-week workshop resulted from experience and feedback in previous workshops. The previous workshops had been held separately for different stages of FSR/E: one on diagnosis, followed by a second workshop on on-farm experimentation. The pro's and con's of sequential workshops have been addressed in evaluation reports on The Gambia 1985 workshop (Walecka, 1985), as well as the evaluation of other previous workshops. Evaluation of the three week combined workshop format will be discussed later in this paper.

At the beginning of the workshop, 13 overall objectives for the workshop were presented (Table 1). Each objective was identified relative to the specific week in which sessions would be directed toward the objective.

In designing the workshop, the trainers were sensitive to the need to establish a routine structure for feedback, reinforcement, and direction for participants. Recognizing the principle that training is iterative in nature, a short (5-15 minutes) period each morning was used for participants to provide feedback on specific sessions occurring the previous day. In cases where activities lasted for a period of days, this evaluation feedback was not carried out until the logical closure of the activity.

Often the importance of allowing time for the processing of the specific content of the training session is overlooked because of time constraints. Leaving time to bring closure to sessions, by summarizing and highlighting the major points, was another training principle of the workshop.

In keeping with the principle of continual reinforcement and processing of the content being covered, a short period of time each morning was used to ask participants for any terms which they felt needed clarification. A list of these terms were then written on a flip chart, briefly discussed, and displayed throughout the workshop.

Another principle in the planning and execution of the workshop was that of flexibility in the content and sequence of the material to be covered. As the activities progressed, and it became apparent that the original time estimations for particular sessions were too limited, reassessment of activities, tasks, and processing was done. A number of modifications in the original agenda were implemented. Spec examples of this will be discussed throughout this report.

WEEK 1: DIAGNOSIS

Week 1, Day 1 (Monday 4/7/86)

Program

The Director of the Project Planning and Management Unit (PPMU) of The Gambia gave welcoming address to begin the workshop. This was followed by introduction of the trainers and resource persons present at the workshop. The participants were then asked to spend a few minutes first getting to know someone they had not met previously, before introducing that person to the group as a whole. Specific information on participants' disciplines and language capabilities was also requested on paper at the time, to be used as a basis for forming the teams.

The introductions were followed by a General Orientation to the Workshop. The basis of how the three weeks were going to be structured was presented by considering a number of key questions that would be addressed in the FSR/E approach. Based on information specific to The Gambia, participants were asked to try to think about the different perspectives of research and extension: how many divisions of districts, villages, farm households, and farm household members does each serve, and how? Key questions were developed based on this discussion, and the stages of FSR/E which address each were identified (Table 2).

The experiences of the farming systems research approach in the Basse Casamance, Senegal (The Djibelor Experience) were presented in Wollof, a language common to both The Gambia and Senegal followed by a summary in English (Sall, 1984).

Before the lunch break, a Technical Overview of FSR/E was presented. The overall objectives and sequencing of the workshop were discussed.

Following lunch, free time for reading was given. Readings were divided into priority and background readings. After dinner, slides of an overview of FSR/E were presented. The overview was based on the same Gambian examples from which the key questions had been developed in the morning.

Evaluation and Recommendations

In a group discussion, the participants were asked to think about their expectations of the workshop and to consider their own criteria for evaluating the workshop. They were asked to define criteria for answering the question, "What is a 'good' workshop/session/day?" In response, participants gave the following criteria: content, usefulness, sharing information, learning a new approach, "networking" and sharing new ideas, meeting colleagues, gaining helpful techniques, and relevant information for one's job.

Following this discussion, a number of questions and comments arose that made it apparent that the group differed in level of understanding of what would be presented in the workshop. Individuals were encouraged to seek out further information from resource persons on an individual basis. Several questions also arose about the overall design of the workshop. The participants' questions were:

1. Should the specifics of FSR/E be presented first, followed by illustration of application (deductive approach), or examples of the general problem presented first and principles of FSR/E drawn from the examples, leading to specifics (inductive approach)?

2. What do the workshop organizers expect from the participants?

3. How do I as an individual begin to implement the FSR/E approach? How do I follow-up on the workshop?

In future workshops, it may be useful for trainers to address these issues at the beginning.

Week 1, Day 2 (Tuesday, 4/8/86)

Program

This day began with an evaluation of Monday's activities and a review of terms, and presentation of detailed objectives for the first week of the workshop. Then a second resource person from Senegal presented a discussion of Recommendation Domains and Leverage Points, using examples from the Casamance (Fall, 1986).

This was followed by a discussion of Formal and Informal Survey Techniques, conducted by the leader of the Yundum FSR/E team. First, the characteristics of the two types of surveys were presented. This was followed by comparison of the differences between them. Finally, the advantages and disadvantages of each were discussed.

Following a break, another member of the Yundum FSR/E team presented an Introduction to Sondeo Techniques. Two approaches to the informal survey were presented to the participants: the "open" or "blank mind" approach, and the "topic guidelines" approach. The advantages and disadvantages of each were elicited from the participants: the risk of forgetfulness with the "blank mind" approach, and the risk of imposing problems with the "topic guidelines" approach (Beebe, 1985; Caldwell et al., 1984; Caldwell et al., 1986; Patton, 1980; Shaner et al., 1982).

The next presentation, Modelling the Farming System, was again by the leader of the Yundum FSR/E team. Two types of modelling used in FSR/E, the process model and the structural model, were introduced (Franzel, 1984).

Just before lunch, the field activity which would require the rest of the week was explained. The participants were divided into teams based on discipline and language capability. Each team was assigned to a particular village. The villages were selected based on the sondeo work already carried out by the Yundum FSR/E team. Since the villages had been surveyed previously by the Yundum team, the Yundum team felt that the workshop's activities would in part act as a verification survey. Furthermore, trials developed for the villages by the workshop teams would aid the Yundum team in the development and implementation of actual on-farm trials.

The task given the four participant teams at this point was to plan their interview strategies for interviews with village farmers to be held on Wednesday and Thursday. The "open" approach was to be used on Wednesday, with a more structured interview to follow on Thursday.

After lunch and a break for reading, trainers from UF and The Gambia presented several tools for summarizing information: cropping calendars, and a summary tool used by the Yundum team in compiling information from their original sondeos called an activity-by-producers chart. This technique involved listing all resources and activities and indicating who had access to each resource or carried out each activity. All constraints were then circled, and priority constraints starred.

Before dinner, logistics for the village visits were discussed, and expectations for summary of information were listed. Instructions were again given to use the “open mind” approach on Wednesday and the "topic guidelines" approach on Thursday. There seemed to be some confusion about the distinction between the two approaches. Participants were also told that when summarizing information from their surveys, they were to use at least three different techniques or tools. The techniques should include:

1. Structural model
2. Activity-by-producer chart.
3. One other tool (depending on the needs of the group): cropping calendar, food calendar, or feed calendar.

The ISU trainer also indicated specific units in Volume I of the Training Materials (Franzel et al., 1986) which would be useful for preparing for this activity: Unit II, p. 33; Unit VII, p. 141; Unit IV, grouping farmers; and Unit IX, setting an agenda.

At this point, the PPMU enumerators who would accompany the teams to the villages we introduced. On the way to the workshop, the PPMU enumerators had stopped at each village to speak the Alkallo (village head) in order to arrange for the field work.

It became apparent at this time that the participants were still unsure about the planned sondeo exercise. In order to address this, although not previously scheduled, the trainers did a short exercise simulating farmer interviews with the PPMU enumerators being the farmers. After the "interview', the teams discussed the interviewing techniques and the pros and cons of good and bad questions.

After dinner a UF resource person presented a comparison of Integrated Pest Management (IPM) and FSR/E. He discussed the relevance of IPM as part of an FSR/E program. He stressed the similarities in the two approaches.

Evaluation and Recommendations

The sessions introducing informal survey techniques were delivered by two Gambian resource personnel who had been involved in a GARD sondeo activity in February. This proved to be an excellent opportunity to take advantage of local expertise as well as provide them with experience in conducting training. However, it would be more useful if an experienced trainer provided direct support and interaction as needed during the presentations. A team teaching effort might be quite effective.

A slightly different sequence of the topic presentations may have helped to give clearer direction to the participants in preparation for the field sondeo exercise. Some recommendations include:

1. "Modeling the Farming System" should be presented before informal and formal surveys and specific sondeo techniques. Use of diagrams and working through an example would be useful.

2. When discussing informal and formal survey techniques, a clear understanding of both should be established before advantages and disadvantages are discussed.

3. When introducing sondeo rapid rural appraisal techniques, clear direction should be given on how to approach a "blank mind" survey, and how to develop "topic guidelines". Some useful questions to participants are: What is the major objective of doing the informal survey? What do you most want to know? How will you get at least that information? Contrasting non-structured and more structured techniques and indicating the importance of gathering sufficient information from different parts of a farming system (referring back to a structural model) would be helpful.

4. Specific presentations should be made about interviewing techniques and types of questions. A practical activity (such as mock interviews suggested in the Training Units Vol. I, (Franzel et al., 1986) should be formally included in the agenda.

5. Presentation with examples of others summary tools (such as crop, feed, or food calendars; activity-by-producer charts; etc.) should also be made prior to the field exercise.

These recommendations can also be compared to the format of the 1984 diagnosis workshop (Poats, 1984), and to assumptions underlying the changes made from the 1984 diagnostic training format in 1986. In 1984, two days were allocated to preparation for the sondeo exercise. One day was on modeling techniques, including both presentations and working through examples. The next day was on interview techniques and included mock interviews with feedback by PPMU enumerators. Then, only one day was spent in the field.

In contrast, in 1986, a decision was made to reduce preparation time to one day, in order to allow for two days in the field. The assumption here was that the first day of interviewing in the field would also serve, in part, the learning function of mock interviews. Moreover, it would be a more realistic way to learn than in a mock interview. Another assumption was that the participants would learn how to apply the modeling techniques with real data. Both assumptions were based on "learning by doing." The results of the 1986 workshop suggest, however, that practice with examples and mock interviews is necessary for participants to have confidence in going to the field.

Another objective of the change in diagnostic training format in 1986 was to introduce participants to the iterative nature of diagnosis, through the return visit on the second sondeo day. Embedded in this design was also the objective of giving participants experience with both "open" and "topic guidelines" approaches. For a one week workshop on diagnosis, however, having both two days for sondeo preparation and two days in the field means that the field exercise would not be finished until the fifth workshop day (assuming workshop day one is spent on introductions, workshop objectives, and a case study). A sixth day would be needed for processing oral reports, but participant fatigue would likely be high at that point. The results of this workshop thus suggest that the objective of training in iterative diagnosis cannot be accommodated within a five day format.

Alternatively, trainers may want to consider a one-and-a-half week format for training in diagnosis. In this format, participants would leave the weekend and Monday of week two to prepare for oral presentations. Tuesday of week two would then be used for the actual presentations.

Week 1, Days 3-6
(Wednesday 4/9/86 to Monday morning 4/14/86)

Sondeo Field Exercise and Processing

The four teams began their sondeo activities Wednesday morning. The teams differed in their approach to group versus individual respondent interviews. However, participants in all teams worked in pairs and changed pairings each day, following the sondeo technique (Shaner et al., 1982).

Wednesday evening was spent processing the information within each group and developing more structured guidelines to gain additional information and verify initial findings on the return visit to the villages on Thursday.

Thursday interviews were held as originally scheduled, and Thursday evening was left open for group work. The trainers, after discussing the time constraint facing the groups, decided to alter the schedule for Friday and Monday. The teams were originally scheduled to deliver their oral reports on Friday. After discussion among trainers, an evaluation session planned for Friday morning was moved to Monday. That morning time on Friday was then allocated for continued small group work needed to prepare the summary oral reports of the sondeo exercise.

More direction was needed to help the groups prepare for their oral as well as written reports. The tasks were outlined once again on Thursday evening. It was decided to have the participants include copies of the summary data tools that they used for their oral reports in the written reports. In giving guidelines for the written reports which were to be completed over the weekend, the groups were told that before the final report was written, each 'contributor" needed to present their work to the other members of the group and they needed to agree on content. The reports were expected to be finished and handed in by Monday morning.

Monday's schedule was also altered. The first 15-20 minutes were set aside for evaluation of the first week's activities. Following this, 30-40 minutes were allocated for discussing the methods used in the sondeo activity. During this session, the participants voiced concerns that their interviews might have raised the expectations of the farmers in the respective villages. Ways to deal with this problem were then discussed. Also discussed were sources of possible discrepancies in respondents' answers on Wednesday versus Thursday. These discrepancies were a source of some frustration and confusion in the working groups. Types of questions were discussed as well. The group exercises of developing research priorities based on case studies (Yundum sondeos) were moved back until Tuesday. The evaluation framework presentation originally scheduled for Tuesday morning was moved forward from Tuesday to Monday.

This marked the conclusion to the previous week's content on the Diagnosis Stage in FSR/E.

Evaluation and Recommendations

The Wednesday through Monday morning sequence of sessions was overall rated above average. The lowest rating occured on the time appropriateness, with a few participants feeling that not enough time was available for the exercise. This is somewhat surprising considering that compared with the original schedule of a half of a day had already been added. The problem may have been less one of lack of time, and more one of lack of clear definition of tasks so that participants know how to set priorities for their work tin Both the written and oral reports were done in great detail also causing the time problems. On the other hand, the written reports provided a wealth of information that has been used by the Yundum team subsequent on-farm trial design and implementation (C. Taal and G. O. Gaye, personal communication, August, 1986).

In addition, the Wednesday evening processing took more time than anticipated. The "discovery" time (i.e., that time spent experientially learning what possible approaches could be used to summarize the information) could have been reduced by having presented more examples and techniques for summarizing information earlier. The longer time spent in learning by doing" approach may have caused some frustration in the teams.

On the other hand, a more "cookbook" approach might have resulted in more or less internalization of techniques. The oral and written reports prepared by the four teams indicated that the techniques we very well internalized, despite the initial frustration with the learning by doing' approach. For example two teams added a map of the village, although this was not suggested in the trainer presentations (Gibba et al., 1986; Janha et al., 1986). Another team made a feed calendar, although this was only referred to as being analogous to a cropping calendar, but an actual example not given in the trainer presentations (Jallow et al. 1986). The structural models of all four teams went far beyond the simplified examples given in trainer presentations. This indicated both the study of the reading materials (Shaner et al., 1982; Franzel et al., 1986) and thought given to the sondeo information. An example is shown in figure 1 (Gibba et al., 1986 Both crop calendars and producer-by-activity charts showed team modifications made to the format presented by the trainers. For example, one team used bar coding in the crop calendar (Jack et al., 1986 Rather than having producer genders on one axis, and crops and tasks together on a second axis, one tear separated tasks on the second axis from crops on the first axis, and used female and male symbols in the intersection cells (figure 2: Jack et al., 1986).

Future trainers might thus weigh the advantages and disadvantages of "cookbook" versus "learning by doing" (or “discovery”) approaches. The best combination of the two may vary depending on participants' familiarity with "discovery" learning and time available for the workshop.

When preparing the participants for the field exercise, it is important that the tasks be detailed from the on-set of the activity through the expected output. A suggested outline of tasks determined through discussions with trainers and feedback from participants would be:

A. Preparation for village visit:

1. Decide on team composition and pairing.
2. Brainstorm on possible types of information necessary for defining the farming system(s) in the village.
3. Determine the method of dividing farm household members for interviews and number of farm household members to interview.

B. Visit village and conduct interviews.

C. Meet to discuss preliminary information; at this point, preliminary versions of structural model(s of the farming system(s) and the summary tools should be made. Areas for clarification/verification should be identified as a basis for the return visit interviews.

D. Return visit to village.

E. Meet to discuss findings; complete structural model and summary tools.

F. Prepare oral report; summary tools should be prepared as visual aids.

G. Prepare written report; include summary tools.

In a training activity it is important to indicate the length of the report expected as well as a time due It is important that the activity not take such high priority that it detracts from the following week's: activities by taking more time than anticipated.

The session on bringing closure to the Sondeo exercise which was included on Monday morning should be included as part of the entire exercise. This was a very important step and is often overlooked in short course workshops because of time constraints. Such a session, not only reinforces but also addresses unanswered concerns and sets the stage for new activities.

WEEK 2: DESIGN

Week 2, Day 1 (Monday, 4/14/86)

Program

First was a review of the overall objectives and presentation of the specific objectives for the second week. In laying out the specific objectives, the coordinator also displayed a "roadmap" of the week. He explained the layout of the FSSP training manual, Techniques for Design and Analysis of On-Farm Experimentation (Caldwell and Walecka, 1986). The "roadmap" for the week progressed through the units of this manual. First were units on alternative pathways to research (Units I, IIA, and IE), covered in the Monday session. These would be followed by What Treatments to Test (IIC and IID), Where to Test (IIB and IIF), and How to Design Trials to Obtain Analyzable Data (III), as the week progressed.

In the two hours prior to lunch, the ISU trainer discussed the concept of an Evaluation Framework. This discussion was originally scheduled to follow an exercise using case studies of the four sondeo villages based on earlier sondeos by the Yundum FSR/E group. During this exercise the teams would be comparing their sondeo findings with the case studies and based on both, establishing research priorities. However, since the case studies would not be ready until Tuesday, the evaluation framework session was moved up.

The discussion of the evaluation framework centered around what biological, economic, and social criteria a team would need to establish to evaluate trials. The criteria would be chosen in terms of a research objective which the trials would be designed to address. At this point, however, due to the above schedule change, establishment of research objectives had not been covered. Therefore, the group exercise of establishing an evaluation plan based on social, economic, and biological criteria appeared somewhat academic, and the teams had difficulty relating it directly to the previous week's sondeo activity.

As a result of the difficulty the teams had, after the evaluation framework session, the trainers felt it was necessary to address the step of establishing research priorities. Another "closure" or processing session was added the following morning in order to tie the evaluation framework back to the establishment of research priorities and objectives.

Following lunch, the participants were given free time for reading.

Evaluation and Recommendations

More time should be allocated to "setting the stage" of the upcoming week and walking the participants through the "roadmap" for the week. This was an effective method, but too much was covered in too short a time.

Skills in problem identification and establishing research priorities need to be introduced prior to the beginning of the design activity. Short practical exercises and readings should be developed for this purpose. An expansion of Unit IX of the Diagnosis is manual is needed.

Presentation of the evaluation framework needs to build on the established research priorities. Specific examples should be given. The practical exercise in the evaluation framework session would have been more effective if the research priorities had been established.

Week 2, Days 2-3 (Tuesday 4/15/86 and Wednesday 4/16/86)

Program

Following an evaluation of Monday's activities, and an updating of the list of terms, the ISU train gave a presentation on establishing research priorities. During this time she showed how to bridge initial diagnosis and design by discussing five steps for establishing research priorities indicated in Unit IX of the diagnosis volume (Franzel et al., 1986).

This discussion was followed by a presentation on priorities for design, treatment selection, an treatment specification. From the manual (Caldwell and Walecka, 1986), the VPI trainer covered the sections on Defining Treatment Objectives (II,C,l); What to Consider in Selecting Subsets of Treatment (II,C,2); Choosing Control Treatments (II,C,4); and Specification of Experimental Variables (II,D,1).

Following this presentation, the VPI trainer outlined the tasks for the teams' design exercise schedule for Wednesday afternoon through Friday. The case studies (village sondeo results of the Yundum FSR/E team) and summaries of Gambia research results (Walecka, 1985) were distributed at this point. The task were as follows:

A. Using information from the team's sondeo as well as the information in the case study, determine the top priority for on-farm trials by following the five steps presented at the start of Tuesday's sessions:
   1. list the principal problems,
   2. determine the causes of each problem and interactions among problems,
   3. rank the problems in terms of importance
   4. identify possible solutions using your own ideas as well as information from the summaries of Gambia research results,
   5. screen and re-rank the problems based on the identified possible solutions;

B. Take the top priority and develop a treatment objective statement.

The teams were not yet asked at this point to begin task C, development of a treatment subset although this material had also been covered Tuesday morning.

After defining the tasks, but before beginning the design exercise, the VPI trainer had the participants do two exercises from the manual (II,C,1 Activity One) and (II,C,2 Activity One). In each activity, the participants were asked to develop treatment objectives, options, and subsets based on an example. This short practical exercise was completed individually but discussed by the participants as a whole.

On Wednesday, following an evaluation period, the ISU trainer went over new terms, and conducted a summary and review of the previous day's activities. Then, the VPI trainer continued the design discussion by covering manual sections on What Kinds of Fields are Available for Testing (Unit II, B) Trade-offs Between Treatments and Replications (II, F); How Objectives Change (III, A); and What Designs Can Do (III, B).

To close out the morning sessions, before lunch, a resource person from ILCA Nigeria discussed Alley Cropping.

Following dinner, the tasks for the Thursday field activity were defined, prior to preparation for the field work. Originally, at this point the trainers had hoped that the teams would be able to proceed to and complete task C, development of a treatment subset. This task involved the following steps:

A. List all treatment options.
B. Reduce number based on agronomic, economic, and social criteria (from treatment objectives statement).
C. Check with farm household members.
D. Write treatment specifications.

The trainers had also hoped that the teams would be able to begin tackling task D, assessing fields. This task involved the following steps:

A. Determining how to replicate the trial (site-specific or regional).

B. Determining differences in land areas (total, proportions for trial).
C. Comparing land area with plot size based on treatment subset.
D. Determining the number of blocks per farm (1/farm or > 1/farm, equal or unequal numbers across farms).
E. Determining block size per farm (equal or unequal size).
F. Following a decision free to examine treatment, replication, and design option trade-offs.

However, an assessment at this point of the four teams' progress indicated that only one team had begun task B on Tuesday. That team's progress reflected special circumstances. The Yundum FSR/E team had given that team its (Yundum's) choice of priorities (lettuce), reflecting the results of the Yundum team's sondeo work prior to the workshop. For the other villages, the Yundum team did not indicate its choices to the workshop teams.

The remaining three teams were having difficulty ranking and reducing the number of possible priorities (steps 2-5 of task A). Hence, the trainers reviewed these steps again, using an example from one of the teams (figure 3). The trainers then suggested that the teams' goal should be completion of task B during the Wednesday planning and Thursday field work. The trainers also indicated that some teams might possibly also reach task C, but that the trainers did not expect any to reach task D.

Evaluation and Recommendations

These two days led to a near-crisis point in the workshop, for two reasons. The first was the difficulty the teams had with task A. Task A itself, and the sequence of tasks B, C, and D that followed, were all developed in response to the difficulties the teams were having in moving from diagnosis to design. On Monday, the trainers first presented a scheme developed for the 1985 Gambia workshop (figure 4). This scheme was based on identifying a couple of key "leverage points" in a structural model and comparing those with available research. Four possible outputs (extension recommendation, on-farm testing, station research, or policy recommendation) could result. The difficulty with this scheme was that the teams apparently did not know how to identify leverage points". This term needed to be better defined on an operational ("how do you do it") basis. Task A, in essence, was an attempt to show how to find the "leverage points" of the 1985 scheme.

The second reason for a near-crisis at this point was inadequate time to cover the material for task D. The material for tasks B and C were covered in the Tuesday presentation carefully, comprehensively, and with examples. In contrast, the material for task D was covered incompletely. The decision tree of unit II,B of the manual (Caldwell and Walecka, 1986) was explained step-by-step, but the possible outcomes of the decision tree in unit III,A were only referred to. Likewise, the logical rationale for statistical designs in unit III,B was explained fairly carefully, using some of the examples in the unit, but technical explanation of the different designs was essentially not covered at all.

In the 1985 workshop, many design options were presented in a normative scheme based on three stages of on-farm experimentation. One recommendation by reviewers at the International Rice Research Institute of the 1985 preliminary edition of the manual (Caldwell, 1985) was to show how different choices could be made among the design options (R. Bernsten, personal communication, 1985). In essence, this recommendation suggested that the authors of the manual spell out the criteria and process by which they had arrived at the norms indicated in the 1985 manual. Spelling out those criteria and process also meant showing trade-offs among design options, and allowing for decisions different from the original norms, depending on differences in circumstances. The decision tree of unit II,B and unit II,F were prepared in response to those suggestions.

Between the 1984 and 1985 workshops, the technical editor of the manual had been involved in a training needs assessment in the Philippines (Zuidema and Caldwell, 1985). During that work, Clive Lightfoot described ways in which the Eastern Visayas project had sought to put statistics on a practical and understandable basis. Lightfoot emphasized the importance of explaining the basic principles of science in concrete, practical terms. Later, in 1985, he also provided a set of training notes used in the Eastern Visayers project (Lightfoot, 1985). Unit III,B was prepared based on those training notes, with modification and augmentation.

All of the above discussion leads to the conclusion that three days is inadequate to cover the material in units II,B through III,C. In reality, only about two-and-a-half days were acutally used, because of spill-over of "closure" sessions from Diagnosis on Monday morning, and the presentation on alley crop-; on Tuesday.

In the end, as explained in the next section, the material in unit III,C was covered on Friday, and another schedule change.

Week 2, days 4-6
(Thursday 4/17/86 to Monday 4/21/86)

Program

The teams spent Thursday in the villages fine tuning their designs. Between Thursday night and Friday morning, the trainers decided that the teams did not have enough time to process their design work. Therefore, their oral presentations were moved from Friday morning to Monday afternoon. Thursday night through Monday morning was used to finalize their designs, prepare materials for their oral presentations, and complete their written reports.

During the extended preparation time, the trainers worked closely with the teams. Most worked with one team, but the VPI trainer with the most agronomic design and analysis training moved from team to team. In working with the team from which the example of figure 3 had been generated Wednesday, the trainer saw a way to introduce the material in unit III,C. A spontaneous, interactive lecture resulted. Participants from all the teams responded actively, applying statistical background to the concrete problems of the example.

The oral presentations were completed Monday afternoon. Contrary to expectation Wednesday evening, all the teams were able to complete through task D in their reports.

Evaluation and Recommendations

In contrast with the near-crisis situation, and consequent reduced trainer expectations, Wednesday evening, the results of the field exercise and oral and written reports exceeded trainer expectations. The example given Wednesday evening (figure 3) not only enable the teams to get over the “hump” of task A but also to see their way through task C and enter into task D during their planning and field work. The additional time on Friday also allowed for a highly successful lecture. Building on that same example Friday enabled them to make decisions on specific designs.

WEEK 3: ANALYSIS

Week 3, Day 1
(Tuesday 4/22/86)

Program

After a session for evaluation of the design exercise, the remainder of the day was spent on issues relating to farmer participation, trial implementation, and data collection. Resource persons from the Philippines and Latin America conducted this session. The Philippines resource person drew upon his experiences in the Philippines to present many insights on working with farmers. The Latin America resource person concentrated on the logistics side: implementation and data collection. He had the participants lay out the logistics of the trials they had designed in the previous session. Each team identified their specific materials needs (down to labeling seed packets for plots) and developed the structure of the field book they would use to collect information from the trials.

Evaluation and Recommendations

The linkage with the previous design exercise made the logistics exercise more realistic. Both resource persons have had long experience in farming systems implementation. Both are also from developing country backgrounds themselves. At the same time, the two countries where they have their longest farming systems experience (Guatemala and the Philippines) are also two origins of FSR/E (Plucknett, 1980; Waugh, 1980). The Philippines is, at the same time, the original home of the Green Revolution for rice. It also has successfully created a strong university system, first at the University of the Philippines at Los Banos (Villareal, 1986) and now increasingly at regional universities like the Visayas State College of Agriculture (Zuidema and Caldwell, 1985). The Philippines' experience in developing FSR/E within the context of strong commodity research and university development is in close accordance with the emphasis of the new strategy for assistance to Africa of the U.S. Agency for International Development (1985).

Week 3 Days 2-3
(Wednesday 4/23/86 and Thursday 4/24/86)

These two days were devoted to presentation of biological, economic, and social analysis concepts and techniques. On Wednesday, after a period to evaluate the precious day's activity, the ISU trainer lead a session which developed a conceptual framework for analysis. The framework listed resources, indicated who had access to each resource, and who controlled each resource.

Following this, the VPI trainer introduced biological analysis concepts. The focus was on how to set up a combined analysis across farms. An example from Hildebrand and Poey (1985) was used, and the analysis table compared with Hammerton and Lauckner (1984). Calculations were done using simple hand-held calculators.

In the afternoon, the participants were introduced to an assignment which they would be working on for the rest of the workshop. The exercise was based on data collected from actual on-farm trials carried out in the Gambia under the extension program. The objectives of the exercise were:

A. Set up a combined analysis table.
B. Calculate values for the table and treatment means.
C. Set up economic analysis.
D. Calculate values for economic analysis.

After the participants were introduced to the exercise, the VPI economics trainer presented concepts of economic analysis. The fundamentals of economic analysis were discussed in general terms relying as much as possible on examples used in the biological analysis section. This session sensitized the participants (many who had never had any background in economics) to the relevant questions to ask in terms of making recommendations. Given the limited time available, the choice was made to stick to general conceptual understanding rather than actual calculations.

Thursday morning began with tan exercise using a case study from Zambia (Chabula and Nguiru, 1986). In this exercise, participants applied the social analysis tools presented Wednesday morning to results of on-farm trials. The session also introduced a procedure, called the economic dependency quotient, for converting qualitative social analysis data to quantitative data.

Following the case study exercise, the VPI horticulture trainer presented several methods of means separation analysis, including modified stability analysis, analysis of factorial experiments, planned single-degree-of-freedom orthogonal contrasts, and linear and quadratic trend analysis.

The afternoon was devoted to continuing work on the extension data sets.

Evaluation and Recommendations

These presentations presented the greatest difficulties in the workshop. First, time available for the analysis presentations had been reduced by one day, as a result of moving the oral design reports from Friday to Monday. As a result, the presentation on economics analysis suffered most, with actual calculations sacrificed. None of the CIMMYT workbook (1986) exercises could be used. Second, both biological statistical analysis and the economic analysis material were the most abstract and difficult content of all the material covered in the workshop. Third, different examples were used in the social analysis presentation, making it more difficult to show how to integrate the three types of analysis (biologic economic, and social).

On the positive side, the presentation of the economic dependency quotient illustrated how social analysis is not limited only to qualitative analysis of observations.

Prior to the workshop, data sets with a description of social conditions affecting interpretation results were sought from Gambian colleagues. Many socio-economic studies have been conducted in The Gambia, but these have not been linked to on-farm trials or agronomic research. On-farm research is receding in The Gambia. Considerable progress has been made in including economic analysis of the data (H. Boughton and J. Kristenssen, personal communication, 1985-1986). However, social analysis for interpretation of trail results is limited by the fact that there is only one rural sociologist in the Ministry Agriculture.

The case study from Zambia includes some excellent summary results of agronomic analysis However, the case study would be even more useful for integrated analysis if trainers were provided with the raw data on a per treatment, per block, per farm basis. Then, the raw agronomic data and relevant economic data could be given together with the social background information already in the case stud; and workshop participants asked to do an integrated analysis. The summary results could still be included in the trainers' notes, to be given out to participants after the exercise.

Week 3, Day 4
(Friday 4/25/86)

Program

The morning was spent on completion of the calculations using the extension data sets. After the mid-morning break, the teams presented the results of their analyses.

The final session before lunch was spent on an oral evaluation of the workshop.

Evaluation and Recommendations

The exercise with the extension data sets proved frustrating to the participants. The exercise was designed based on use of simple hand-held calculators lent to workshop participants by extension. Only a few participants had scientific calculators with statistical function keys, and not all who had those calculators knew how to use them. Nevertheless, participants were aware of the power available in scientific calculators and mini-computers. Some participants questioned the value of carrying out the tedious calculations by hand.

On the other hand, the fact that the workshop had to use simple hand-held calculators reflects the same conditions that many research and extension personnel will face in the field. In spite of efforts prior to the workshop to locate adequate numbers of scientific calculators, there simply were not enough available for all the participants. Hence, the decision was made to go to the lowest common denominator, simple calculators with arithmetic functions only.

The spread of personal computers (PC's) may change this situation in the future. Not every researcher need have one, but all could be trained in how to set their data up for entry into PC's, what analyses to request, and how to interpret the results. Obviously, the numbers and types of PC's available for analysis of on-farm trials will vary from country to country. To what extent a regional workshop could be designed with a common format would have to be determined based on a survey of existing and planned availability of PC's in the different West African countries.

The above contrasting observations and discussion based on this workshop closely parallels the debate over what level of hardware is most appropriate that was held during the FSSP meetings in 1984. The results of this workshop suggest that there are reasonable arguments on both sides of the debate, but that the situation is fluid. Certainly, learning the mechanics of analysis procedures can deepen understanding of their principles, and can be essential when more sophisticated hardware is unavailable, or becomes unusable. On the other hand, it would seem desirable to focus as much valuable FSR/E training time as possible on participants' learning how to interpret the results of analysis in terms of systems output, of which biological analysis is an essential part, but not the only part.

OVERALL PARTICIPANT EVALUATION

Participants overwhelmingly felt that the workshop was a success in helping them to reach the majority of the stated objectives. Out of 22 respondents in the written evaluation, only one respondent gave "no" as an answer to the question, "Do you feel the workshop was successful in reaching its objectives?" Nine respondents gave a qualified "yes, but..." response, and 12 give an unqualified "yes" response. The vast majority of participants would recommend this workshop to co-workers.

Diagnosis, design, and analysis were all mentioned by participants as the most valuable aspect of the workshop. The majority were split between design and analysis. However, more respondents cited analysis alone, whereas all but one respondent who cited design as most valuable did so in combination with another part of the workshop.

The majority of workshop respondents agreed with the allocation of time among types of activities, with two exceptions: inadequate reading time and free time. Three special dinners (two at restaurants) and two social events (at nearby discotheques) were arranged for participants, but much evening and weekend time was used for slide presentations and formal or informal group interaction.

The most frequently-cited needs for change in course structure were increased length of time and assorted other improvements in course mechanics. Among the three main parts of the course (diagnosis, design, and analysis), suggestions focused on the analysis part, but opinion was not completely uniform. Among topics to add, livestock and analysis (primarily statistics) were most frequently cited. On the other hand, statistics was the most frequently cited topic to shorten or omit. It was also the most frequently cited single-item least valuable part of the workshop.

Time appeared to be the main cause of dissatisfaction with the analysis part, because analysis was overwhelmingly most frequently cited as the part of the workshop which should be expanded. More respondents asked for an expansion of biological analysis than for expansion of social analysis (table 3). This may have reflected a combination of three factors: biological scientists predominated among the participants, (21 out of 30) the material on social analysis was presented well, and statistics appears to be inherently the most difficult material covered in the workshop.

Approximately two thirds of the respondents to the question on follow-up activities desired suggested participant-focused follow-up, primarily in the form of follow-up workshops. Approximately one third suggested farmer-focused follow-up, primarily implementation of the trials the teams had designed. The Yundum team planned to implement at least some of the trials coming out of workshop, depending on decisions made by a committee in the Department of Agriculture responsible for establishing FSR/E field teams.

CONCLUSIONS

This workshop represented the culmination of three years of training in The Gambia. It was essentially a combination in one workshop (for new participants) of the two previous workshops offered in 1984 and 1985. The combination was in both content (1984 diagnosis plus 1985 design and analysis) and time (1984 seven days plus 1985 six days plus expansion of analysis = 1986 three weeks). In the intervening time, training materials were developed and revised both for diagnosis and for design and analysis.

The results of this workshop presented in the preceding pages suggest that the combination of diagnosis and design in one workshop was a significant improvement, but that analysis might better be covered separately. As discussed in the evaluation and recommendations sections of both the diagnosis and design weeks, more time allocated to each would improve their effectiveness. Also, the linkage between diagnosis and design is critical. This was a source of near-crisis in the workshop, but the near-crisis resulted in valuable on-the-spot improvements in training materials.

A diagnosis and design workshop logically should precede the season. If possible, trial designs resulting from workshop exercises should then actually be implemented, in least by those workshop participants from the country or region hosting the workshop. In contrast, an analysis workshop has follow the season if it is to use data from trials designed in the diagnosis and design workshop.

Splitting analysis from diagnosis and design has the added advantage of allowing more time to be devoted to each, while permitting total workshop time at each point to be no more than the three wee of this workshop. One possible sequence of formats, incorporating recommendations discussed earlier for each part, could be:

Diagnosis and design workshop (before season)

M	Introduction, overview, and case study.
Tu	Modeling the farming system.
W	Interview techniques and practice.
Th	Village sondeo and team discussion.
F	Village sondeo and team discussion.
Sa, Su	Informal team interaction.
M	Completion of preparation for oral and written sondeo reports.
Tu	Oral sondeo reports.
W	Overview of design. Determining a design priority, establishing an evaluation framework and developing a treatment objectives statements.
Th	Establishing a treatment subset.
F	Assessing field and livestock diversity for replication of treatments.
Sa, Su	Informal team interaction.
M	Design principles and specifics of design types.
Tu	Village design visit.
W	Preparation of written and oral reports.
Th	Oral design reports. Wrap up and evaluation.

Analysis workshop (after season)

M	Introduction and review of diagnosis and design workshop.
Tu	Evaluation framework as basis for integrated analysis. Introduction to hardware to be used in exercises.
W	Biological analysis principles. Analysis of variance for combined analysis.
Th	Treatment separation.
F	Biological analysis exercise.
Sa, Su	Free time.
M	Economic analysis principles. Partial budgeting.
Tu	Economic analysis exercise (same data sets as biological analysis)
W	Social analysis principles and techniques. Combining results of all three types of analysis using evaluation framework for design, extension, and policy recommendation.
Th	Exercise in social analysis and combining results of all three analyses (same data sets for all three). Preparation of written and oral reports.
F	Team oral reports. Wrap-up and evaluation.

The analysis part of the workshop was overall the weakest. This reflects the development of training materials and training experience. The 1984 workshop built on the 1983 domestic FSSP orientation workshops, which emphasized diagnosis. The 1985 workshop added new training materials (Caldwell, 1985) which conceptually covered both design and analysis. The 1985 training materials were stronger in design, and the 1985 workshop focused largely on design. The revised 1986 training materials greatly expanded the design portion, but the time prior to the 1986 workshop was inadequate for much expansion in analysis from the 1985 version. Thus, a second revision of the training manual in on-farm experimentation should focus on analysis.

The FSSP has been very aware of the need for the development of both training materials and training approaches for analysis. What exists should be built on. What is needed in terms of training is an attempt to integrate all aspects of analysis, biological, economic and social. Why are they all important, and how can they be done? What kinds of data need to be collected? Examples of biological, social and economic analysis applied to specific data sets should be developed. The data sets should include livestock-based examples and materials currently under development. Better integration of livestock into diagnosis and design is also needed as a prerequisite for integration into analysis.

In a short course, time is usually the major constraint, and given such a constraint, decisions on core content and priority objectives need to be made. The balance of the content is very important. Specific objectives need to be stated relative to priority and the time available. Expecting to be able to teach (or review) calculation, use and interpretation of a variety of statistical analyses is unrealistic in a short workshop. Trainers need to determine what is absolutely essential and narrow the objectives to fit the time available. Different levels of audience need to be identified and perhaps separate sessions addressing specific needs can complement plenary sessions. What is absolutely essential for the participants to leave the workshop with in order to be better able to practice FSR/E effectively? Participants in short courses cannot be expected to walk away with a full education in statistical analysis (especially in cases where formal statistical background is negligible). However, they should be much more aware of the need for all types of analysis and how to interpret results to provide useful information for future activities.

A task force and scope of work is therefore needed to improve the analysis training materials. It is important that the focus of the task force be on developing practical examples and exercises for training. Some key outputs of the task force should be:

1. Identification of materials for economic analysis of on-farm trials, with examples. Specific information on some of the techniques of economic analysis of on-farm trials is provided in the CIMMYT manual (Perrin et al., 1976) and workbook (CIMMYT, 1986). (The latter is included as supplementary material in Volume II of the FSSP Training Units (Caldwell and Walecka, 1986)).

2. Development of a core topic list of information considered to be 'absolutely essential" for each areas of analysis.

3. Construction of a table or chart that clearly indicates the types of analyses available, when they are most useful, and what type of data is needed in order to perform each.

4. Development of an integrated analysis framework based on the above information. During this workshop one of the intra-household case studies developed by FSSP/Population Council was used (Chabala and Nguiru, 1986). The ISU trainer used the "Conceptual Framework" from the case study to introduce the analysis portion of the workshop. This "conceptual framework" should be referred to in developing the integrated analysis framework. A framework used in the 1985 Gambia workshop should also be referred to (Walecka, 1985).

5. The integrated analysis should be presented at the beginning of the design sequence and continually referred to for reinforcement in diagnosis and design workshops. Thus, this output of an analysis task force would be used in both diagnosis and design workshops, as well as in analysis workshops.

6. Specific application exercises using all aspects of analysis should be developed. The intra-household case studies may also provide the basic information for a number of these practical exercises and should be considered as a potential basis for exercises.

7. The task force should not be large but should include at least one economist, one social scientist, one biological scientist, and a training materials development specialist. Each of the individuals should have training workshop experience.

The above work outlined for a task force would be the final step needed in synthesizing the experience of this workshop and the two that preceded it. Seen from this perspective, the results of this workshop represent a third but still intermediate step towards development of an integrated set of training materials for FSR/E diagnosis, design, and analysis.

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Table 1. Overall Workshop Objectives

Code	Content	Completion Target Week
General	To explain what types of research and extension problems facing farming systems FSR/E is designed to address.	1-3
A.1	To group farmers for developing recommendations	1
A.2.1	To gather information needed for grouping and developing recommendations.	1
A.2.2	To process information for grouping and developing recommendations.	1
B.1	To determine what types of testing to do.	2
B.2.1	To determine what treatments to test on-farm	2
B.2.2	To develop an on-farm trial evaluation framework	2
B.3	To determine where to test on-farm	2
B.4	To combine treatments and locations in a design to obtain analyzable on-farm data	2
C.1	To implement and monitor on-farm trials.	3
C.2.1	To evaluate on-farm trial results by carrying out biological analysis.	3
C.2.2	To evaluate on-farm trial results by carrying out economic analysis.	3
C.2.3	To evaluate on-farm trial results by carrying out social analysis.	3
C.3	To use on-farm trial results by combining biological economic and social evaluation for extension and policy recommendations.	3

Table 2: Key questions asked at the start of their workshop and their relationship to the stages of FSR/E.

Key Question	Stages in FSR/E
1. How do we group farmers to develop recommendations?	Diagnosis
2. What is the basis for grouping?	Diagnosis
3. Given groups and priorities, how do we develop recommendations?	Design / Testing (trials) (implementation)
4. How do we determine what is accept able to farmers from on-farm trials?	Extension

Table 3. Topics to Expand

Category	No. of responses (value)			Mean
	Full	Half	Total	value[y]
	(1)	(0.5)[z]		
Diagnosis	1	1	2	0.75
Design	1	2	3	0.67
Analysis	19	3	22	0.93
Biological	8	8	16	0.75
Social	2	8	10	0.60
Not specified	4	0	4	1.00
Other	1	0	1	1.00
None	1	0	1	1.00
Total responses	23	6	29	0.90
Total respondents	23	3	26	

[z]Responses in which respondents cited 2 parts of the workshop as equally most valuable
[y]Mean value = no. of full responses +0.5 (no. of half responses)/ no. of total responses)

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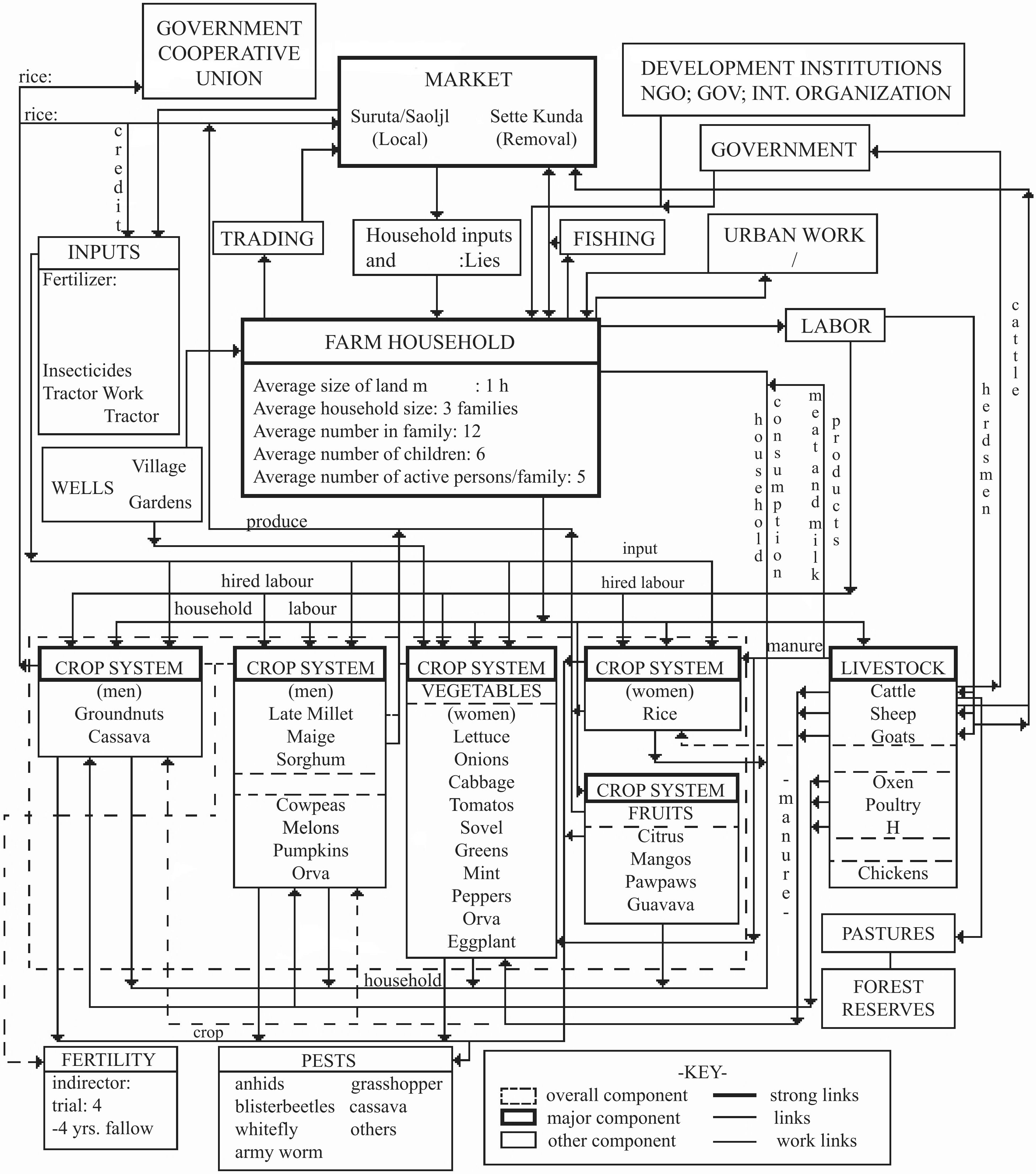


Figure 1. Example of a structural model prepared by a workshop team.

ACTIVITIES / CROPS	Land Clearing	Ploughing	Planting	Weeding	Spraying	Fertilizer Application	Bird Scanning	Harvsting	Processing	Storage	Marketing
MAIZE	♂	♂	♀ ♂	♂	♂	♂	♀ ♂	♂	♀ ♂	♀ ♂	
FINDO	♂	–	♀ ♂	–	–	–	–	♂	♀	♀	
U. RICE	♀ ♂	♀ ♂	♀	♀	♂	♂	♀	♀	♀	♀	
LATE MILLET	♂	♂	♂	♀ ♂	♂	♂	♂	♂	♀ ♂	♀ ♂	
SORGHUM	♂	♂	♂	♀ ♂	♂	♂	♂	♀ ♂	♀ ♂	♀ ♂	
G/NUT	♂	♂	♂	♀ ♂	♂	♂	–	♂	♀ ♂	♀ ♂	♂
CASSAVA	♂	♂	♀ ♂	♂	♂	♂	–	♀ ♂	♀	♀	
VEGETABLE	♀	♀	♀	♀	♀	♀	–	♀	♀	♀	♀

COMMENTS:
Findo is the least labour intensive crop. The women cultivate upland rice and vegetables and assist the men in weeding and processing in paricular. Besides groundnuts and vegetable marketed by male and female respectivly, all other crops are produced for home consumption.

Figure 2. Example of modified producer-by-activity chart prepared by a workshop team.

A: Ranking Priorities

Priorities	Upland rice	Lowland rice	Tomato	Livestock
Ranking	2	1	3	4
Solution [z]	H	L	M	M
Reranking	1			

B: Treatment Objectives

Factor A:
Time of maturity

Factor B:
Time of planting

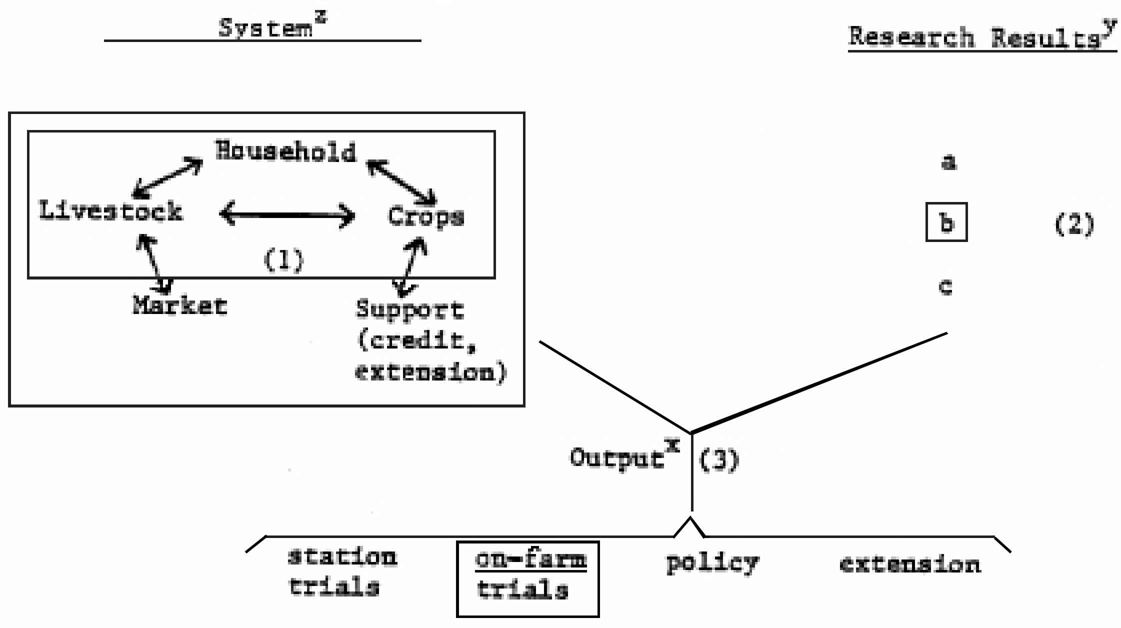
C: Treatment Subset [y]

Farmer	Sapu	Senegal		Weeks before rains			After rains
5	4	4		3	2	1	Farmer
	13		x =52		4		

Farmer	Sapu	Senegal		Weeks before rains	After rains
1	2	2		2	Farmer
	5		x =10	2	

[z]Probability of successful solution: H = high, M = medium, L = low.
[y]Number of varieties (factor A) times number of planting dates (factor B) = number of treatment combinations.

Figure 3. 1986 example for moving from diagnosis to design.



[z] 1 = Crop-livestock interaction identified as leverage point.
[y] 2 = Possible technical solution (b) identified.
[x] 3 = Possible solution has adequate potential for testing in on-farm trials.

Figure 4. 1985 Scheme for identification of "leverage points" for determining a research priority.

DYNAMIC INTEGRATION OF RESEARCH AND EXTENSION: IGNITING THE SPARC

Charles A. Francis*

Abstract

The integration of research activities carried out by producers, extension specialists, and researchers is described through implementation of a model called SPARC (System for Producer/Ag-Extension/Research Cooperation). Conceived as an adaptation of farming systems research and development methodology to the unique resources and people in the Midwest U.S. and the land grant system of universities, this model sorts out researchable questions into those most logically answered on experiment stations and those most efficiently studied on farms. Such questions as optimum crop densities, planting dates, row widths, fertilizer levels, and variety adaptation to specific cropping systems are likely candidates for testing on the farm. Other research areas such as developing models of water movement through soils, nitrogen cycling, crossing and evaluating early generation progeny of crop varieties are logically carried out on station. There is a range of questions between these two extremes which could be studied in either location or both. By combining resources of farmers, county extension offices, and state level researchers, a number of these questions can be addressed quickly and efficiently through on-farm research. When a portion of the total research activity is accomplished on farms with producer collaborators, there is a strong chance for the results to be understood and accepted by these collaborators and moved to other clients in the area. A large part of the extension work will already be done during the research phase. This model needs to be tested further, fine-tuned to each environment, and adapted to the available resources and interest of researchers, extension specialists, and producers in the Midwest.

Introduction

Three major revolutions in the recent past have caused dynamic changes in agriculture and other human activity (Naisbitt, 1982):

- The Agricultural Revolution introduced row planting, simple machines, and new technology to the growing of crops and raising of animals;

- The Industrial Revolution brought much more sophisticated mechanization and products of industry to increase productivity per hour of labor and to further dominate the natural environment; and

- The Information Revolution in which we are all key players today. Many of us in agriculture, including people from the commercial sector, from the research community, and in farming, do not realize the overwhelming influence which the information age has on our industry. In today's farming environment, the ability to access and sort out information can make or break a producer. There is an incredible amount of data and many recommendations available to the producer, from industry, farm press, and university, and tools are needed to help the farmer and rancher sort this out. In addition, we need to seek new and imaginative ways both to conduct research and to move results from where they are derived to where they can be used. It is important to empower the producer

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with the capacities needed to develop farm-specific recommendations which are consistent with the farm's biological potentials and the family's economic resource base. The System for Producer/Ag-Extension/Research Cooperation provides a series of practical models to achieve these objectives.

Research/Extension Environment

Our conventional approach to research and extension in the land-grant system is to delegate responsibilities to specialists. Research is conducted by investigators at the main campus and by specialists located in branch stations located around each state. Some of these specialists may have extension responsibilities as well, although most extension activity is delegated to county staff people who are in direct contact with producers in their area. The transfer of informal from researcher to extension agent to producers follows traditional channels, bulletins, workshops, conferences, radio and television programs, and field visits to demonstration plots, often located at stations or with participating farmers. In the past, this university information has been a principal source of production recommendations.

In today's environment, however, the producer is faced with a multiplicity of sources of ideas and recommendations for commercial products and production practices. These often are connected with a specific product, a corn or sorghum hybrid, a starter fertilizer or non-traditional soil amendment, a new herbicide or insecticide to control a perceived problem in the field, and objective data from a non-commercial source may not be available. With the exception of unit variety or hybrid tests which are conducted by the land-grant institutions, there often is no comparative data with which to evaluate the commercial claims, testimonials, and recommendations from the supplier. It is within this complicated information environment that the producer needs to make practical and profitable decisions on the production practices to employ and products to buy each year

These information channels in university and industry generally have been considered to be a one-way transfer mechanism. Although there is some feedback from producers during workshops, and there are progressive farmers who call researchers directly for information, this is not the rule. We have the concept of researchers setting priorities, conducting experiments, and then providing the results to extension, which then moves this information to the farm. Commercial products likewise are promoted in the same way, although there is certainly some feedback from clients through dealers to researchers in each industry about the success or failure of a given product. Both in the public and the private sectors, there is a lack of formalized use of information from producers to help influence the direction of research. Perhaps a new model is needed to facilitate this process?

On-Station Versus On-Farm Research

One of the first steps in the process is to examine researchable questions and decide which can be logically and cost effectively studied on the experiment station and which on the farm. This decision involves the nature of the problem, the degree of environmental control needed, and the types of research generally considered meaningful by researcher and by producer. Each question is explore in some depth.

By the nature of some research questions, the control and equipment needed, and the frequency with which technical people need to visit the experiment, certain trials are best conducted under experiment station conditions. Crosses of soybean parents or maize inbreeds could be accomplished in either location, but it is much more convenient to the plant breeder to have control over the breeding nursery and to have ready access to the field every day. It may be important to irrigate the plots so that valuable genetic material is not lost, to protect the nursery from birds, or to harvest ahead of commercial maturity to produce quality seed. Studies of nitrogen cycling in soils may require expensive equipment and electricity, so that proximity to a power source and availability of plots to the researcher are prime questions. Measurement of water movement through the soil profile or use of a rhizotron to study root growth often require special installations which would disrupt a normal commercial field operation, and must be located on the station. These are examples of experiments which must be carried out under controlled experiment station conditions.

Another category of research is what we call "on-farm" testing, currently used for variety trials of commercial or advanced varieties and hybrids, validation of soil test results, and some agronomic work on tillage and residue management. These trials are a part of existing research projects, and depend on the farmer collaborator for conducting most commercial farming practices on the crops. The researcher generally determines the treatments, and will plant the trial in the case of a uniform variety test or apply the specific rates in a fertility trial. Harvest is usually accomplished by the researcher or technicians from the university, with or without the participation of the farmer. Extension agents sometimes become involved with these trials, and may conduct similar experiments with farmer collaborators in their counties. More frequently, these agent involvements with growers tend toward the non-replicated demonstration plots, used for field days or other events in the county. Little repeatable or analyzable data is collected from most of these plots.

Between these two extremes is a large category of research which could be conducted either on station or on farm, but which currently is largely confined to the experiment station. These experiments include studies of crop densities, row widths and planting dates, comparisons of fertilizer levels and sources, variety adaptation, alternative crops for a region, options in weed control -— both tillage and comparison of chemical products, tillage alternatives, and cropping system questions such as rotations, strip cropping, relay cropping, and double cropping. Because of the location specificity of some of the results from these types of trials, there could be a strong case made for conducting these experiments on multiple locations with producers. The more locations included, the more reliable will be the information from the tests, and the better our knowledge about how applicable the results will be to a range of farming situations.

Another dimension of the question is the types of "research" which are considered meaningful to farmers versus those which are acceptable to researchers in the university or industry. Farmers tend to believe trials which have these characteristics:

- plots one width or multiple width of standard equipment
- plots long enough to cross an entire field
- plots large enough to make a visual impact
- minimal changes needed to existing equipment
- practices with a minimal change from current farming system
- changes which focus on cutting production costs preferred
- yield a prime concern, as well as crop quality and economics
- important to have involvement of producer with trial.

Trials or demonstrations with these characteristics tend to attract farmer interest, even if not replicated or subjected to statistical analysis.

Researchers, on the other hand, often view the world from a different perspective. Through training and experience, those in research have come to define "experiments" in a very different way. Here are some of the criteria which are relevant to the researcher:

- replication of treatments at least three or four times
- randomization of treatments within each replication
- uniformity of field within blocks or replications
- relative uniformity of treatment variances
- accuracy in planting, imposing treatments, and data collection
- use of an accepted experimental design
- accessibility of field or site to researcher
- capability of running trials over years or locations
- representative conditions on site, so results can be extrapolated.

These conditions usually are present on the controlled sites we designate as experiment stations, and on-farm trials often meet only a few of these criteria

We find that the criteria which are accepted by researchers and those which are recognized by producers are quite different, and this is one reason why there are communication problems between the two groups —- often barriers which extension specialists cannot bridge. What is the middle ground? Is it possible to rationalize these two sets of criteria and expectations, and to design relevant work on farms which will also meet the criteria of the researchers? There are a number of possible models which could be tested. Some of these are described within the context of the SPARC approach.

Igniting the SPARC

Here are some models which could be used in a "System for Producer/Ag-Extension/ Research Cooperation". They include examples from plant breeding and variety improvement, soil fertility, weed control, tillage systems, and other specific disciplines. More important, there are some general models which could be used with a wide range of systems-related questions, particularly those which would best be studied by farmers on their own fields (Francis, 1986).

1. Plant Breeding Model:

Today, crosses are made and generations advanced in the wheat and soybean projects until promising new selections can be tested, generally in the F_6 to F_8 stage, in multiple locations, but all on experiment stations. Before release, there are multiple tests after seed is increased, and these may be both on and off station. With identification of close potential collaborators, it should be possible to accomplish several of these early steps on farmers' fields. This would require an increase in project travel budgets, but drastically reduce the area needed on station fields and other operating costs. Several of the advancing generations could be conducted on farms, as well as the advanced generation seed increases and most of the uniform testing. Commercial breeding programs currently conduct much of their seed increase and virtually all of their testing with key producers. This gives a valid test of materials, early in the development steps as well as before release, under the conditions which they will face as released varieties. Multiple locations could logically be used as a substitute for multiple years, and this could speed the release of new varieties from university programs. An analogous program could be designed for testing new hybrids from cross pollinated crops such as corn and sorghum.

2. Soil Fertility Model:

Much of the testing of fertilizers —- sources, rates and dates of application, value of starters —- is currently done with farmer collaborators. This is a good approach, although it does involve careful planning and difficult logistics for the research and extension programs. Putting a series of rates in farmers' fields, where all other management is carried out by the producer, makes good sense in a practical soil fertility program. Greater involvement of the producers in discussing potential treatments, choosing rates which are within the range of economic interest, and participation in the evaluation of results would all help to strengthen this program even more. Use of longer strips and drive-through designs would eliminate the need for careful hand harvesting of small plots and add credibility to the trials.

3. Options in Weed Control:

One substantial cost in crop production is weed control, and a complete reliance on broadcast chemical treatments has resulted in both increased costs and environmental problems as the residues accumulate in the soil and even in the groundwater. Use of broadcast herbicides also reduces the options for use of legumes later in the season, and for some replant decisions if there is a loss of the crop in early stages. Farmers are concerned about cutting costs and increasing their options, and most have the current equipment capability to apply broadcast, band, or rescue treatments for weed control, as well as a cultivator and rotary hoe to supplement or substitute for the chemical control. Once the crop is planted, it is relatively easy to apply long strip treatments across the field, or to accomplish a cultivation in the same way. Treatments can be fit to the width of the cultivator or rotary hoe, and each method replicated several times. Data can be analyzed as a paired t-test, or using standard randomized complete block designs. The plots are large and manageable, provide a good visible comparison of treatments, and serve as both research and demonstration units. Several years of experience have been reported by Thompson (1986). Prototype trials of corn and soybeans are in the field at Mead, Nebraska this year.

4. Tillage and Rotations:

Erosion continues to plague farmers in Eastern Nebraska and Western Iowa on hilly lands, and conventional tillage is gradually giving way to reduced tillage systems to maintain substantial amounts of residue on the soil surface. The use of expensive terracing systems has come under question. One alternative is the use of contour planting, ridge tillage, and strip cultivation of corn/soybean or sorghum/soybean combinations to diversify the fields and prevent erosion through management. Pilot demonstration projects in Johnson County, Nebraska and elsewhere have begun a technology transfer process, and results are encouraging. Nevertheless, there has been an absence of replicated experimental data from these demonstrations. Such data would make the results more powerful and convincing to producers, researchers, lenders, and managers of federal programs. Use of credible designs which also include factors important to farmers would allow much more data and more solid conclusions to be drawn from this experience. There is already an investment in this project, and some thought given to redesign would pay untold dividends.

5. Team Research Model:

An approach which involves farmer, extension agent, and researcher in the research process from identification of problems through field experimentation to analysis and interpretation of results would make the greatest possible use of ideas from the entire group. This is called "farming systems research and extension" in the international community (Gilbert et al., 1980; Byerlee et al. 1980; Shaner et al., 1981). In our context, a key problem could be identified at one of the Crop Focus or Conservation Tillage Workshops in Nebraska, and a researcher and four county agents identified who are interested in this problem. Each agent would then recruit five farmers (for example), and this team of 25 people would meet to discuss the problem and come up with some potential solutions. They would talk about options, types of designs for testing, and data/information needed to solve the problem. In the next cropping season, the researcher would fine tune the design, the agents would assist farmers in putting out the trials, and the farmers would be in charge of crop management throughout the season. The agents and researcher would assist the farmers in collection of data, and all would begin to explore reasons for the observed results. At the end, the researcher would analyze the data, and reduce it for presentation to the entire team. As a group, they would interpret the data and develop potential recommendations. After the trials were repeated two years and the data confirmed, this information could be written up in the form of a NebGuide or other fact sheet for use in extension. The authors would be the four agents and researcher who conducted the work, giving credit for their involvement within the university system. The NebGuide would also list all of the farmer collaborators with their home towns on the front page. This would not only recognize their contributions to the project, but also provide them with an incentive to participate in another project and encourage them to distribute the leaflets to neighbors and others interested in the results. This would initiate the extension effort in a new way, and spread the credit and the credibility over a large number of people from all three groups. The process could be initiated again by anyone in the group. It is not difficult to imagine a fairly extensive library of materials for extension, derived from this type of on-farm testing and producer involvement, after a period of five years of such trials.

6. Researcher or Agent-Managed Trials on Farm:

Using the farm environment and producer managed crops to impose treatments has been used for some researcher-designed and managed trials. This is possible if the treatments are such that they can be imposed onto a commercial planting after seeding, and in a way which will not interfere with continued farmer management of the crop through the season. An example would be additional fertilizer, use of growth regulators, or thinning to a series of specified densities. One example would be the seeding by several farmers of one acre of sorghum at an exceedingly high density, perhaps 10 pounds of seed per acre. The researcher or county agent would thin specific plots to a number of densities in a randomized block design with replications, and they would continue to monitor the trial through the season, including the harvest of the plots and analysis of the data. With an additional travel budget but no funds for field operation, each technical person could supervise five to ten or more of these sites in a given season, thus multiplying the total information available on density response from this series of sites. If five persons were collecting this data, on five sites each, it would be more valuable than several years on the experiment station in one location. Again, interpretation of results should be a team effort, and every effort made to recognize fully all those who participate in experiments, including the farmers. Publication and extension of the information could be as described above.

7. Farmer-Initiated Research:

One approach which takes maximum advantage of farmer creativity would be "farmer-initiated research". In this model, a question would be identified by researcher, extension specialist, or farmer, and the question directed back to a moderate number of farmers for solution. It might work this way -- there is a recommendation from the university to plant 3 to 5 pounds per acre of sorghum, yet an article appears in the Nebraska Farmer with a testimonial from a respected producer that shows success year after year in planting at least ten pounds per acre. We would reproduce both the NebGuide from the university and the article from the Nebraska Farmer, and send them with a letter to 200 sorghum producers in the state. We could say, "This question is one of concern to producers; it involves cost of seed and stability of production in a variable rainfall environment such as Nebraska. What do you think about this discrepancy in recommendations? And how would you test the differences, to find out what density really is best for your farm?" We would get in a series of responses and opinions from producers, and would encourage them to both test their hypotheses as well as supply us with the procedures they are using for the test and the results at the end of the season. There would be a wide variation in type of design used, procedure for evaluation, and method of measuring yield, yet from this diversity of approach there may be some new and exciting methods emerge. Given a large enough number of trials or experiences on the farm, some reasonable recommendations could result from this test, at a very low cost for the university, and the results would have a high credibility because they were developed by farmers.

Conclusions

This is just a start in developing a SPARC Model; the more people who are exposed to the concept and begin to try out other variations, the better idea we will have about its potential for producing good results and a credible approach to extending information. It is highly participatory, involves everyone on the team in the formulation of questions and design of experiments, and most important calls on the collective experience of farmers, researchers, and extension specialists to interpret the results from several different points of view. Implementation of such a program on a wide scale would help sensitize producers to the importance of information, and to the need to fine-tune systems and adapt results for their own specific farms and farming systems. It would in essence create a new generation of farmer-researchers, highly skeptical of what they read and hear, sincerely motivated to improve their operations by taking charge of their, own recommendations. We would essentially be helping our producers to empower themselves with information that is currently available. Farmers would have a healthy respect for science and the data which comes at them from all sides, but would be ready to challenge that data and to decide for themselves what is best for their farms. The direct and in-depth participation of both producers and extension specialists at the county level in the research and recommendation process would help to develop a new paradigm in research and extension, a participatory model which we might call SPARC: a System for Producer — Ag Extension — Research Cooperation.

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INFORMATION INTENSIVE CROPPING SYSTEMS

Charles A. Francis* and James W. King**

We are living in a dynamic information age. Naisbitt (1982) describes the current information revolution as being more sweeping in its influence on our lives and our productivity then the two preceding revolutions, the agricultural and industrial.

Those of us in agriculture —- in research, extension, industry, or farming —- often don't realize how pervasive this information revolution is, nor how it affects the way we conduct our work, how successful we are, and whether we can stay in business as producers. Specialists in communication can be key catalysts in the interface of information with prime users. We can have an enormous influence on how information is chosen, packaged, and made available to others in the industry.

Cropping systems or farming systems which make intensive use of information, translated into management skills and decisions, are as old as agriculture —- yet as new as the latest available technology and expert system. Current interest in this approach to management centers on the use of information and farmer skills to substitute where possible for fossil-fuel based production inputs.

The intelligent use of resources internal to the farm, and the reduction of purchased external inputs to the minimum level possible, can lead to systems which are both more profitable in the short run and more sustainable in the future. We will discuss information-intensive cropping systems as they relate to farm productivity and profitability, and present specific examples as evidence that this approach could be a key to development of systems for the future.

Internal versus External Resources

We could view crop production as a system which uses a mix of resources, some of which are internal to the farm and community and others which are purchased from outside. These are called "internal" and "external" resources, and a detailed list appears in Table 1.

Adapted from Rodale (1985), this list contrasts the sources of nitrogen, water, and other elements needed to successfully produce a crop and to maintain a system. Also included are characteristics of systems, weed and other pest control measures, and sources of labor, capital, and management expertise. In every case, the internal resource list reflects what is available on the farm or nearby, including rainfall and fixed nitrogen, family labor and creative management. These are low-cost resources, and effective use of these internal elements can result in sustainable cropping systems which are in tune with the available resource base and can be manipulated to meet the objectives of the farm family. Traditionally, these are resources which have been used by farmers through the centuries.

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In contrast, production systems can be designed to use high levels of external resources which must be purchased or otherwise obtained from off the farm. Synthetic fertilizers and chemical pesticides, irrigation water, hired labor and crop consultants are examples of this type of resource. Since many of the external resources are dependent on fossil fuel energy, use of this approach is both expensive and perhaps less sustainable in today's economic climate. In this type of production system it is possible to achieve and maintain high yields only as long as these external resources are available, the farmer has cash or credit to purchase them, and the entire operation is profitable. With high inputs of fossil fuels and chemicals, production systems based on external resources represent a dominance over the natural environment.

Most current farming systems include a mix of these two sources of inputs. Even the most isolated of subsistence farms has some input of new varieties or ideas coming from neighbors or visitors. The most sophisticated, high-technology operation depends on sunlight for crop growth and on rainfall for a part of the water needs of the crop.

Yet the contrast is useful. Information about efficient application or exploitation of internal inputs can be used to increase their relative importance in a system. This information can promote a shift in reliance from external to internal inputs and perhaps a more profitable alternative production system.

It is important to design a logical mix of the two types of resources. Few would debate the value of maximizing nitrogen fixation as a substitute for purchased nitrogen fertilizer, an obvious advantage of the internal nitrogen resource for most systems. Most farmers would prefer to purchase and plant quality seed of improved hybrids or varieties, since this is a relatively small part of the total production cost and produces a high payoff for that investment.

The principle remains -— it would be desirable to shift the emphasis from external purchased inputs to internal resources in order to increase both the profitability of a farming operation and its long-term viability. This is the role for information-intensive cropping systems.

Practical Field Examples

Any theory such as the one we are describing has limited value unless it is illustrated by some practical and relevant examples. Below, we list several examples of information intensive cropping systems - in variety selection, soil fertility, crop protection, cultural practices, and total cropping systems. We want to illustrate specific situations where information can be used as a substitute for more expensive inputs.

These examples are based not only on agronomic information but on what we know about adult learning (Knowles, 1973). To communicate effectively, our information must be practical and appropriate to be incorporated immediately by producers. We must structure our information so producers can relate it to previous knowledge and we must target our information to fit the experiences of highly diverse audiences. Let's look at these examples.

1. Choice of Maize or Sorghum Hybrids:

In order to maximize cereal yield per hectare in the appropriate zone, farmers have been urged to plant maize or sorghum as early as possible in the spring in order to use as much of the potential growing season as possible. This strategy has been successful, when the season is long enough to mature the crop. The past two years have been exceptions in Nebraska, however, and some of the longer-season or late-maturing hybrids have not reached maturity by time of frost. Even those cereals which matured required substantial inputs of propane to dry the grain to an acceptable moisture level for safe sale or storage.

If hybrids are chosen based on their maturity and ability to complete grain fill well before frost, all or most of this drying can occur in the field before harvest. Information on precise maturities of each variety and predicted lengths of the growing season for each region as well as other meterological data can thus substitute for fossil fuel associated with the drying process. There is some reduction in potential yield by using an earlier hybrid, but this may be more than offset by the reduced production cost.

2. Rotation of Maize with Soybeans

There are a number of good reasons to include legume rotation in a cereal production system -— one of these is the nitrogen contribution from a legume to a cereal grown the next year. Soybeans produce enough excess nitrogen in a growing season to provide about 50 kg/ha on the average, to the succeeding maize crop. There is an additional 10% boost to yields of both crops due to other effects of the rotation, many of which are not fully understood.

The nitrogen provided by soybeans can replace an equal amount of nitrogen which would otherwise be applied to the maize crop as chemical fertilizer. An alfalfa crop will provide as much as 150 kg/ha to succeeding maize, although not all of the nitrogen will be available during the first year. Information about the contributions of these legumes can thus lead to designing of cropping systems which require less purchased nitrogen, reducing production costs without changing maize yields.

3. Weed Control through Rotations and Tillage

One of the principal costs of crop production is weed control. There are also additional off-farm costs to society when leaching of herbicides or the breakdown products into the groundwater causes contamination of aquifers. Some of these effects are not known or expressed for many years, yet we often pro-cede with new practices without taking into account the long-term effects or costs.

There are many options to control weeds in an Information intensive cropping system. We could provide information to help farmers better understand the life cycles and seed production mechanisms of predominant weed species. As a result, farmers could include use of rotary hoe and cultivator, banding applications together with cultivation, and crop rotation. Each of these options is less fossil-fuel intensive than a broadcast application of herbicide and each has less off-farm effect in terms of herbicide drift, residual effect in the soil, and potential for leaching into the groundwater. Information about these weed control options could be an integral part of an information-based production system.

4. Conservation Tillage Practices and Strip Cropping

Substantial losses of topsoil and nutrients occur each year due to erosion from hillsides which are clean-tilled and planted to corn or soybeans in Eastern Nebraska and Western Iowa. Much of this erosion and soil loss can be prevented by contour terraces, an expensive but effective way to reduce run-off.

Another conservation option is reduced or zero tillage, based on information about the effects of residues and how they help to break the fall of raindrops and minimize erosion before planting. With the new generation of mechanical planters which can effectively penetrate the previous year's crop residue, it is possible to establish a uniform depth of planting and good stand to get a crop off to a good start.

If an additional dimension is added to the system –- use of alternating strips of maize and soybeans on the contour on hilly lands -– erosion can be reduced even more. Although there will still be soil loss from the soybean strips, this soil will be trapped by the maize stubble in the next strips. Total soil loss from the fields will be minimized. Such a system would conserve water and nutrients, two of the highest cost elements in crop production, and would minimize the off-farm effects of cultivation and production. Other multiple cropping systems have been described in a recent book (Francis, 1986).

5. Pest Control through Rotation of Crops

The corn rootworm does untold damage to the maize crop in the Midwest each year. This can be controlled through planting application of soil insecticide, and there are blanket recommendations for preventive treatment from the major insecticide companies.

However, during the first year after rotation, corn rootworm often does not harm the crop. The farmer who has this information could save a substantial cost per acre by using crop rotation, in effect, to control most rootworm problems. Where experience has shown that first year maize does have a corn rootworm problem, soil insecticide applications could be used. Otherwise, this part of the chemical recommendations can be eliminated through use of information about the insect and the effects of alternative cropping practices. With continuous maize, there will likely be an ongoing problem with corn rootworm.

6. Progressive Biological Sequencing

Cropping systems can be viewed two ways, as both linear –- changes take place from one year to the next in a given field -– and cyclical –- as rotations of crops create repeating cycles of weeds, insects, and pathogens in the field. Increased information about how these cycles occur and on the nature of changes which occur as we manipulate the cropping environment can help producers design new and more sustainable production systems which maximize use of internal resources.

This is illustrated in Figure 1 (from Francis et al., 1986). A stark comparison can be drawn between continuous culture of maize, and the attendant weed and rootworm problems plus the nitrogen inputs necessary to sustain the system, and the rotation of maize with soybeans. The latter provides a significant portion of the nitrogen needed for both crops while controlling major pest problems though breaking their reproductive cycles through rotation.

7. Integrative Farm Structuring

Each field on a farm is a unique micro-environment which can be manipulated by the farmer, dominated by chemicals and other inputs, or sequenced in a more sustainable way as outlined above. Yet no field on the farm operates in isolation from other fields or from the animal enterprises.

The way information is used to more efficiently fit these several activities together can be called the integrative farm structuring of an operation (Figure 2, from Francis et al., 1986). Complex as the interactions may become, it is the careful study of these inter-relationships on the farm which can lead to new and improved combinations of practices and inputs to give a more regenerative total farm system and one which can both meet the objectives of the farm family and minimize the chemical pollution effects off the farm.

These are all examples of how information can be used and manipulated by the producer to substitute for some of the expensive purchased production inputs which are currently a major part of our agricultural recommendations. Alternative technologies and approaches do exist!

Challenges in Communication

Accepting the hypothesis that information can, in some cases, replace more expensive inputs in crop production systems, we can move on to the challenges of communicating this information.

We know that communication is important. Our purpose in agriculture is to "share meaning", the meaning of our research and of producers' experiences. We understand the communication models which include examining the sources, messages, channels, and receivers, as well as less used and studied concepts of feedback and system noise. Three basic theories about communication are understood and we accept and use them. We communicate to influence the behavior of others; we believe that meanings are in people not in words or visuals; and we believe that reality is subjective, that is, we create our own realities from our experiences (Bettinghaus, et al. 1973).

Whether we work in research, extension, or communications, one of the primary concerns we have is the sorting of information, packaging it for the media, and deciding how best to reach our clients. Mechanisms of information transfer have been developed and tested and we feel reasonably comfortable with the traditional and even some new media now available to help reach producers (Prowl, et al. 1984). These include print media (newspapers, farm magazines, bulletins, special topic books, commercial product pamphlets), broadcast media (radio, television), newer media (video cassettes, interactive programs on video discs), and combinations of these (including the slide shows and slide tapes used in extension). We assume that these communication methods are well-known to most of us and that packaging information with what we now have at hand is a relatively simple step.

But today we know that our audiences are becoming more fragmented, split into groups with special interests and needs, and that communication technologies themselves will not be the solution (Scherer, 1986). We need to apply innovative and special techniques to reach these ever diversifying audiences as well as restructure and redesign our messages.

Let's explore some rather non-traditional methods which have been used with some success —- or have been proposed for moving information and how audiences have interacted with these methods.

1. Computer Networks:

On-line information bases or sources currently are used for market reports of crops and livestock, for soil analysis, and for economic analysis of enterprises and programs such as the federal set-aside acres. These services are available to all farmers, but to date have been used by only a fraction of the more progressive managers. Such computer networks as AGNET in Nebraska provide a wide range of management tools to the producer and can be accessed from the county extension office or directly through a home micro-computer.

Virtually unexplored are the potentials of the micro-computer as a daily tool for farm analysis, for comparison of strategies and production decisions, and for long-term planning. The ability of interactive programs to give producers access to a wide range of expertise likewise have been little used. The technology is available for many advanced applications of computers, including interpretation of aerial photographs for fertility and pest control practices, fine-tuning fertilizer recommendations, and comparison of alternative crop mixtures and production strategies.

It is likely in the future that agricultural information flow and farm management will become much more efficient through use of the micro-computer as a networking and communication tool.

2. Farmer's Own Network for Extension (FONE):

Initiated by the Regenerative Agriculture Association and The New Farm magazine, the network of producers linked through the "FONE" system is providing another source of expertise to the individual farmer. Conceptualized as a system for linking farmers with questions to other farmers with answers, the "FONE" network now has more than 900 participants.

When functional, the system will allow an individual to dial the 800 number, to provide an estimate of farm size and crop mix, and to present the specific question at hand. This call will be referred to another farmer with a similar farm who has volunteered to answer questions about a certain crop. In addition to the farmers communicating directly between each other, the conversation will be recorded and later transcribed so the information can be made available to others through The New Farm magazine. A similar system is being used in the Northwest by farmers producing wheat and other dryland commodities.

We have observed that farmers have credibility with other farmers —- at times more credibility than university or industry specialists.

3. Farmer Field Days:

Use of demonstration plots or twilight field days on producers' fields has been a mainstay of extension programs for some years. Yet the model being used by Dick and Sharon Thompson of Boone, Iowa, in collaboration with the Regenerative Agriculture Association, takes the demonstration a large step farther.

In each of the past three years, the Thompsons have hosted a field day on their 300-acre integrated crop/livestock operation, and each year there have been between 500 and 600 visitors. Perhaps due to publicity in New Farm and the Thompson's unique applications of ridge tillage and innovations in swine feeding, there have been many questions during the field days and the associated workshops which the Thompsons have conducted across the state.

From this beginning has grown the "Practical Farmers of Iowa", a farmer group which sponsors workshops and other information sessions for producers.

With a strong religious motivation, the Thompsons feel that their calling includes a commitment to tell others about the success they have found with non-chemical farming. Their farm and its obvious productivity illustrate that information and good management can substitute well for purchased, external production inputs.

4. The Nebraska AGRONINDEX:

Finding that most of the county extension offices and even specialists in the University of Nebraska-Lincoln's Department of Agronomy had difficulty finding internal publications, two specialists created a data base AGRONINDEX, covering all the information published in an extension format during the past five years (Waldren and Francis, 1986). In addition to the title, year, authors, and source, the data base includes a series of key words with each entry. Publications can be accessed by one or more key words including combinations of words; examples are "soybean", "soybean fertility", and "soybean fertility irrigation". Requests to the data base are recorded so that the total usage can be evaluated, including the most popular topics.

AGRONINDEX also has capacity to record the "zero hits", or requests that cannot be filled by the data base. Thus future priorities can be built around items and combinations of items which are requested by users but not available in existing publications. It is envisioned that this data base could be expanded beyond the information prepared in the Agronomy Department and developments may include ideas and results from on-farm trials.

5. On-Farm Research: the SPARC Model:

A "System for Producer/Ag-Extension/Research Cooperation" has been proposed for use in the programs of the Univeristy of Nebraska (Francis, 1986). This model takes advantage of the unique resources and talent that each of the three groups has to offer, including creative ideas about how to reduce costs in crop production. In general, the SPARC approach helps to pool these resources for the greatest possible progress through research and testing.

In one model, producers and county extension specialists provide the impetus for problem identification and initial treatments to be tested. Meanwhile the researcher designs experiments which will allow application and capability for statistical analysis of the results. Research designs are chosen which are consistent with constraints of the farmer, including the need for large plots and the use of normal field equipment. When the data re collected by county agents and farmers, the researcher assists with analysis and data reduction. The entire team interprets the results, and all share in the recognition when the research is written for wider distribution. County agents participate as authors and farmer-collaborators are identified by name and home town on the extension bulletin. With this type of credibility, we anticipate that the results will be easily accepted by other producers. There are a number of other models in the SPARC concept, and these are discussed elsewhere in this Farming System Symposium (Francis, 1986).

6. Campaign Approach —- the Time Dimension:

We generally think of extension interventions and specific communication approaches as single shot activities —- a workshop, a bulletin, or a television special. There are some types of information which would more logically be communicated to producers over an extended time frame.

One example is the Kenya maize scheme which posted signs in small shops where farmers purchased inputs or came to drink coffee. Information included (1) time to prepare lands with the rains, (2) time to purchase high quality seed, (3) time to keep weeds controlled, and so on. Colorfully designed, these signs were posted in an obvious place in each shop and everyone in each village became acquainted with the optimum time for each cultural practice.

Analogous models in the Midwest would include timely information about soil sampling and test interpretation, benefits of reduced tillage and leaving residue on the surface, choice of hybrid or variety to reduce late season risk of not maturing, alternatives for replant after hail or other crop loss early in the season, and alternative crops for a specific area. Perhaps repeating a message at several appropriate times and through a variety of media channels during the season would have a greater impact than a single exposure - particularly in the complex area of finance and farm management. Other approaches to campaign planning would include complex multi-year, multi-media agricultural information efforts, similar to industrial advertising programs (Evans, 1985; King, 1984).

7. Developing an Interactive Information Network:

Similar in concept to the FONE network above, a group (farmers, extension agents, and researchers, for example) with a common interest could establish a bulletin board or other interactive approach to sharing information rapidly by micro-computer. This would vastly accelerate the exchange of information compared to our laborious writing and press releases of today, and especially compared to our normal publication channels. This interactive information network could be accessed by key word, by author or source, or by a combination. In this interactive approach, key contributors will become well known to the network participants, whether these key people are research or crop specialists at a university or particularly good farm managers who have expertise in the given area. These key people could be encouraged to provide information in a more formal way so that it could enter the printed diffusion routes or other pathways which could reach large numbers of people.

Such bulletin boards are currently used for a wide range of special interest groups and the technology could be easily applied to specific user groups in agriculture.

8. Assignment of a Professional Communicator to Department:

Another way to accelerate the collection and packaging of information in a specific area of production would be the assignment of a communication specialist to each of the large departments in a university. Perhaps seconded by the Communications Department to Agronomy, for example, this person could prowl the hallways and fields, talking to researchers and digging out information that would not normally reach producers through traditional communication channels.

A researcher whose rewards are built around technical publications may well be stimulated to provide practical information if it does not require time to interpret this data and write it into an extension format. This model could be tested in a large department, using existing communications persons to see if the approach is cost effective in moving more information from the file drawer and laboratory to the farm.

9. Producers as Key Sources of Information:

Several of the above models recognize that the active farmer can be a key source of production information. We generally think of research and extension as a unidirectional activity: university experiment station to county extension office to farmer. The only discipline and industry which has taken full advantage of the farmer as a resource has been agricultural engineering through the design and manufacture of new implements for industry. In fact, many of the popular ideas in machinery today came from designs that farmers have conceived and tested through the farm shop.

Recognizing that ideas can come from anywhere in this network of participants in this industry, the entire spectrum of agriculture becomes a stage on which different actors play different roles at a given point in time. Each brings certain skills and experiences to the performance which is dynamic in both space and time. The traditional roles of research, extension, and farming are blurred during the evolution of the industry. Such a concept makes maximum use of the creative talents of everyone who is active in agriculture, including and emphasizing the producers.

Conclusions

Information is power. It can be used to promote the expanded use of resources internal to the farm, as a partial substitute to the purchase of external production resources needed to efficiently produce crops. The communications specialist has a unique role to play in this program, and to effectively play this role, the agricultural communications specialist will have to reconceptualize and redefine the process of communication to be more broadened, more involving, and more decision oriented (Evans, 1985).

We have made the unfortunate assumption in the past that this specialist performs a service role in the university or industry, providing slides, editing written texts, or reporting results through traditional channels to producers and others in the industry. We now recognize information as an important component of the production system. There are more and more sources of conflicting information which the producer has to sort through to make relevant management decisions. Thus, the potential role of the communications specialist can be broadened and expanded. While this paper has focused on many techniques and channels for improved communication, there are also advances in message design and content presentation that we acknowledge, but have not included (Fleming and Levie, 1979; Rice and Paisley, 1981). We encourage communication specialists to study and apply these emerging message design principles.

Future success in agriculture depends greatly on the way in which information is interpreted, packaged, transmitted, or otherwise provided within the industry. This means that the professional communicator must become a key player on the team —- and can participate as an equal in the formulation of policy, the setting of research and development priorities, and the decisions on how and when to make information available. Given the increased importance of non-traditional sources of information —- farmers, industry, other disciplines - the communications specialist can play a role as integrator and catalyst in the total system. This is a great challenge, but could be one of the important dimensions of communications in the future.

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Table 1. Resources with description of principal internal and external sources (adapted from Rodale, 1985).

INTERNAL	EXTERNAL
SOIL	HYDROPONIC MEDIUM
SUN - source of energy for photosynthesis	ARTIFICIAL LIGHTS - used for greenhouse food production
WATER - mainly rain and small irrigation schemes	WATER - large dams, centralized water distribution systems, deep wells.
NITROGEN - collected from air through fixation and recycled in soil organic matter.	NITROGEN - primarily from synthetic fertilizer, leached through profile.
OTHER NUTRIENTS - released from soil reserves and recycled in soil on farm.	OTHER NUTRIENTS - mined, processed, and imported into farm.
WEED & PEST CONTROL - biological, cultural, and mechanical	WEED & PEST CONTROL - with herbicides, insecticides, & other chemical means.
ENERGY - some generated, collected, and used on farm.	ENERGY - dependence on fossil fuel for mechanical devices.
SEED - Some produced on-farm as open pollinated varieties.	SEED - all purchased as hybrids or certified varieties.
ANIMALS - produced synergistically on farm with locally grown fields.	ANIMALS - feed lot production at separate location from farm.
CROPPING SYSTEM - rotations and diversity, intercropping.	CROPPING SYSTEM - monocropping, one crop per year.
LABOR - most work done by the family living on the farm.	LABOR - most work done by hired labor, machines substituted.
CAPITAL - source is family and community, with accumulation of wealth reinvested locally.	CAPITAL - source is external indebtedness or equity, while accumulation flows mainly to outside investors investments.
MANAGEMENT DECISIONS - by creative farmers and local community.	MANAGEMENT DECISIONS - provided by suppliers of inputs, crop consultants.

Figure 1. Conceptual pattern of dynamic cyclical changes in one field crop environment as a result of successive crops and management decisions. (From Francis et al., 1986)

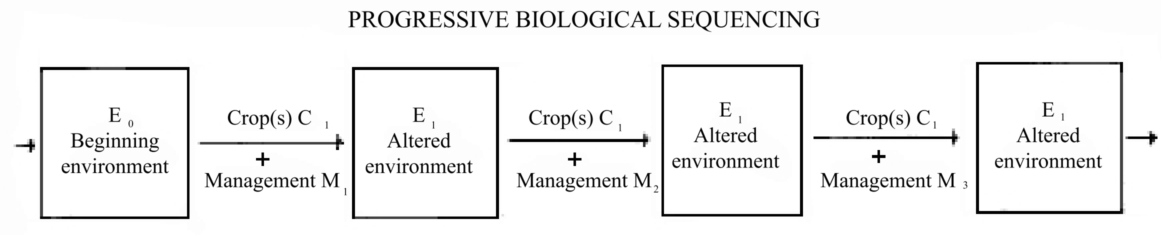
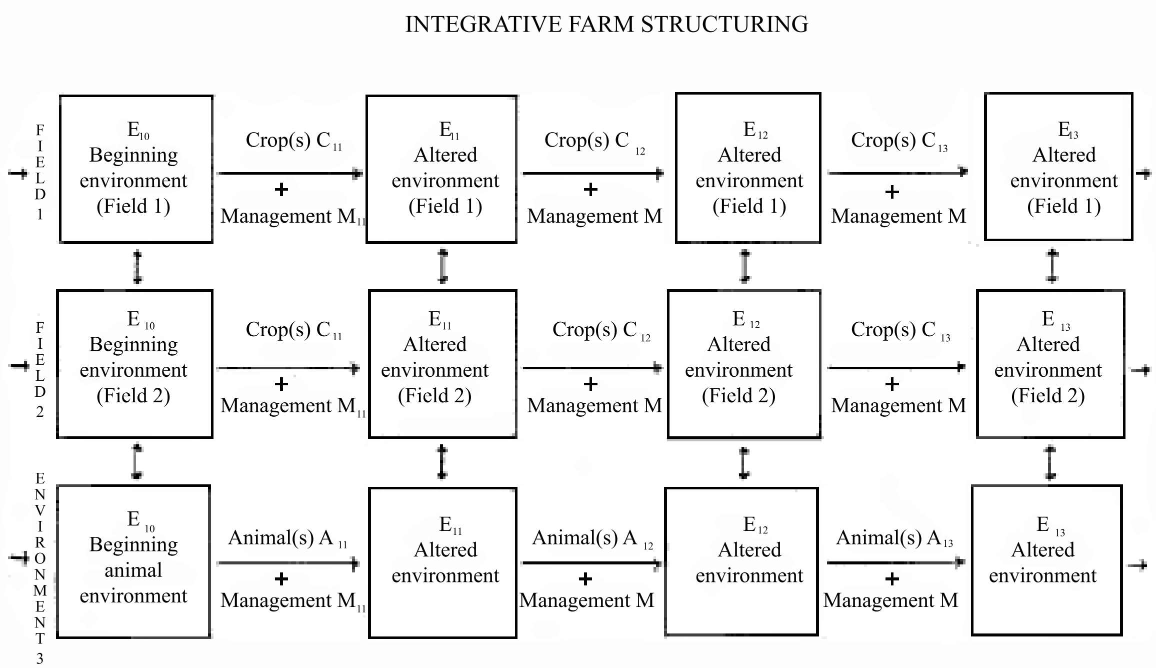


Figure 2. conceptual pattern of interactions of primary crop and animal enterprises on a resource efficient farm. (From Francis et al., 1986)



Sustained Improvement in Nutritional Status After Small-Scale Intervention in Poultry Production

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The targeting of agricultural development projects to specific nutritional or food consumption deficits in the population is theoretically attractive but often dismissed as too remote in the chain of production, consumption and health to be of practical importance. More usual approaches to integrating agricultural development and nutrition focus on short-term nutritional interventions coupled with activities to generally improve production and income generation. Particularly in the case of multi-nutrient deficits, solutions based directly on food production are usually categorized as difficult and requiring a long period of time for effect. In this paper we present data from a project which started with these assumptions, but in which a direct and sustainable impact on nutritional status may have occurred. Post hoc analysis of the characteristics of the intervention may provide a basis for more systematic planning of production targeted to specific nutritional problems.

The More and Better Foods (MBF) project, undertaken by the National Research Center in Egypt, was part of a broadly-based science and technology project whose goal was to bring academic knowledge to bear on problems of development. MBF was a demonstration project designed to illustrate to the farmer the potential impact on

1-National Research Center, Cairo, Egypt.
2-University of Arizona, Tuscon, Arizona, U.S.A.

production of simple, low-resource technologies applied to particular crops. A potpourri of technical assistance was offered, including new seed varieties, wires and string for staking tomatoes, fertilizers, etc. In one of the study communities, there was simultaneous attention to the health and nutritional status of village children.

There was no specific linking of nutrition information or interventions to households who chose to participate in one or more of the agricultural projects, since there was no specific hypothesis about nutritional improvement. However, it happened that the most successful of the commodity-specific production projects involved a product which had the potential for substantially improving the quality of the diet. At the same time, a sustained improvement in nutritional status occurred which can not readily be attributed to other factors.

The Nutritional Problem: Iron Dedficiency Anemia.

Iron deficiency anemia has been documented repeatedly to be highly prevalent in Egypt, affecting more than half of preschool children (NNS, 1979) and pregnant women (Galal and Solim, 1983). Dietary iron intake is low, and mostly from unfortified whole wheat bread, in a form with relatively low biological availability. Further, the diet is low in animal protein, which facilitates iron utilization. Thus it was logical that iron deficiency received attention in the initial nutritional evaluation for the MBF project. In the study community, a baseline survey of 422 school children (all present in the village elementary school) in 1982 revealed an anemia prevalence of almost 26%.

Iron deficiency is a common nutritional problem in many countries; the International Anemia Consultative Group (INACG 1977) has classified effective interventions. Targeted supplementation is effective in the short run, but requires an expensive delivery system and above-the line expenditure. Long-term, sustainable interventions involve dietary change and are classified as difficult and requiring a high degree of community participation.

The Study Community

Kafr El Khadra is a village of about 5000 population, located in Menoufia Governorate in the Nile Delta 35 km. north of Cairo. Agricultural activities predominate in the village economy, with the major crops including clover, wheat, maize and vegetables. Irrigation is by canals which bring Nile river water to the fields. Animal husbandry is significant, with more than 1000 head of cattle and water buffalo. Sixty families engage in fishing from a nearby lake.

The total land area is less than 1000 acres and the average per capita land holding is about 3 feddan (1 feddan = approximately one acre). The average household size is 6.0 persons, and per capita income in 1980 was about 200 Egyptian pounds ($1= 1.3 L.E.). About 70% of the household budget, on the average, was spent on food (Galal et al., 1986). Reliance on on-farm production for staple foods was significant (see Table 1).

The household food supply was assessed by interview with the male and female adult household head. Based on these data and household composition adjusted for age and sex, the household food supply was compared to estimated requirements (WHO, 1985). An estimate of dietary adequacy was derived from household supply as a percent of total estimated requirement for energy, protein animal protein, and iron. Except for iron, the average household had a relatively adequate food supply, meeting more than 100% of requirements. For iron, the mean adequacy level was 44%. Discriminant function analysis indicated that those with relatively more adequate energy supplies were distinguished by larger land holdings; household income was a predictor of dietary quality (protein, animal protein, iron). Household production of poultry was significantly associated with all four indices of dietary adequacy.

The Poultry Project.

Included in the portfolio of agricultural activities was a poultry production effort. Building on this already important household production activity, farmers were offered technical assistance in acquiring, growing, feeding, treating diseases of chicks. The project proved to be popular, beginning in 198 with two families and expanding to more than 100 by 1985. Of particular significance but not appreciated at the beginning of the project, poultry production takes place in the house and it therefore is, more than other agricultural crops, under the control of women. More than one half of the participants in the poultry project were housewives. The success of the project demonstrated in the following data:

By 1985 almost 100,000 chickens/year were produced for sale and local consumption. The average expenditure on the part of the household was L.E. 121/100 chickens and the economic profit 74%. The change in poultry consumption by participant families and others was not documented but chicken is a well-liked and culturally important food, and it is safe to say that poultry consumption increased, not only in participants' households but in the village as a whole.

Changes in Iron-Deficiency Anemia

Figure 1 shows the chronology of the iron status project, which focused on schoolchildren. After the baseline anemia survey in 1982, a supplementation program was begun in the school, with feeding of an iron-fortified biscuit as a snack during the school day. A follow-up survey several months later showed a decrease in anemia prevalence. In the following school year the supplementation program was stopped without further plans for institutionalization.

In the fall of 1985, another school-wide anemia survey was undertaken. The anticipation was that the prevalence of anemia would have returned to the previous level. Instead, a dramatic difference was seen. Homoglobin levels were significantly higher than in 1982 (Table 2), for both sexes (Table 3). More important, the prevalence of low hemoglobin levels (<11 gm/dl) was only 7% (Table 4).

While the data do not permit attribution of the improvement to the poultry project per se., there is no apparent alternative cause. Data collected in 1984-1985 in similar villages for other projects demonstrate that the improvement is not a country-wide phenomenon.

Conclusions:

The identification of nutritional impact from agricultural development is a challenge, due to the complex nature of the relationships involved.

Usually, we focus on food consumption or other indices nearer to food supply such as household expenditure for food. However, the data we have presented here suggest that some nutritional status indices may be sensitive enough, under certain conditions, to be of direct utility. In the case of the MBF project, iron deficiency was highly prevalent, a relatively sensitive indicator (hemoglobin) was available, and a highly successful production project increased the intake of limiting nutrients. When such indicators are available, their use can be justified in that they demonstrate direct impact on health.

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Figure 1

Timeline of Poultry and Iron Status Projects in Kair El-Khadra

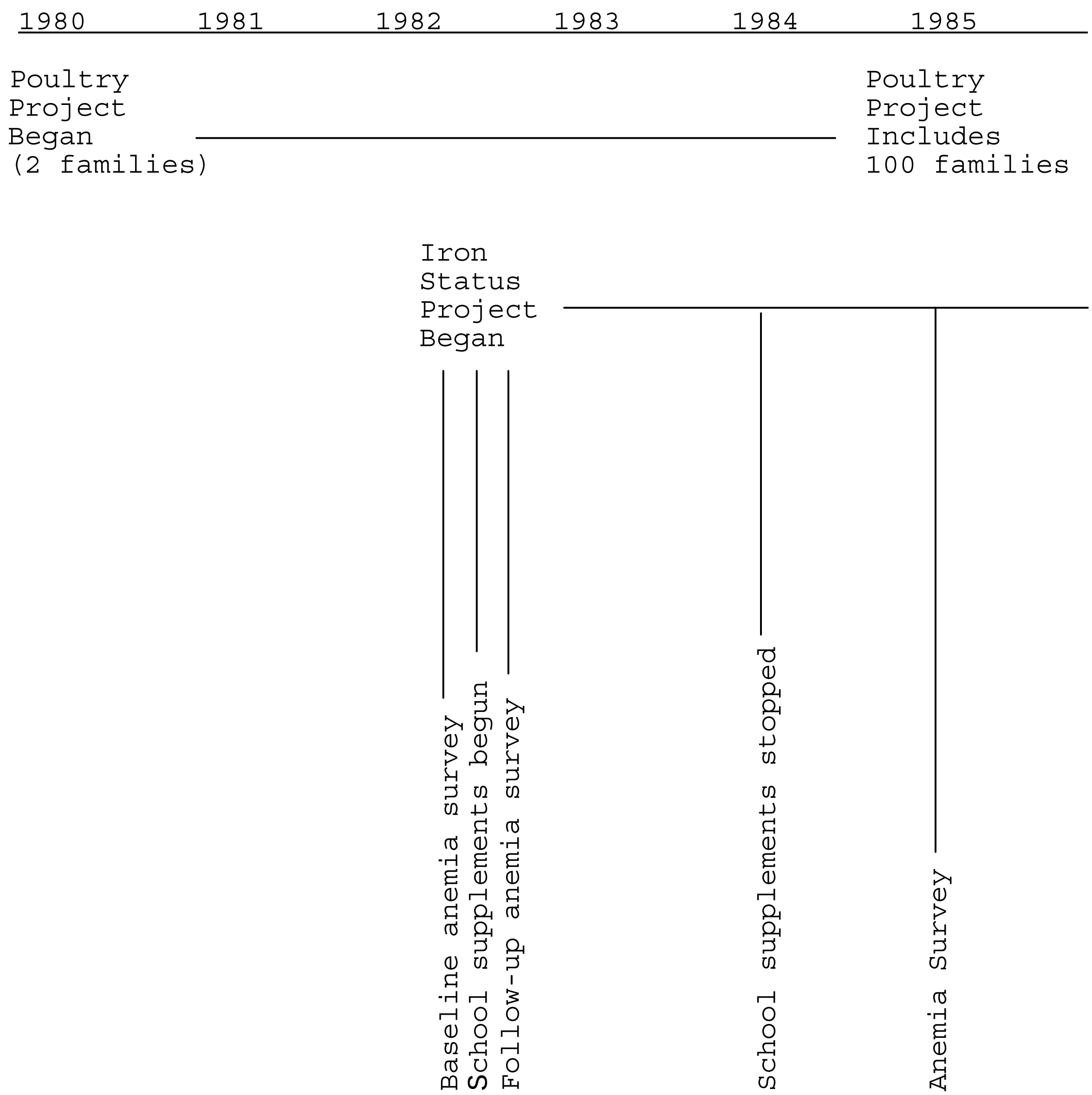

Table (1).

Household Food Consumption from Own Production for Selected Staples, %, 1980, Kafr-El-Khadra.

Product	Amount From Own Production		
	None	Some	All
Wheat	39	19	42
Corn	46	2	52
Rice	99	1	0
Dairy Products	51	0	49
Poultry	77	6	17

From Galal et al., 1986, p-12.

Table 2

Hemoblogin (g/dl), Kafr El-Khadra School Children

x ± s.d.

Fall 1982	11.83 ± 1.56	(N=422)
Fall 1985	13.22 ± 1.43	(N=436)

ANOVA significantly different at p<.00001

Table 3

Hemoglobin (g/dl) by Sex, 1982 and 1985

			Mean ± s.d.	F	p
BOYS	1982	(N=220)	12.01 ± 1.47	98.7	<.00001
	1985	(N=224)	13.32 ± 1.37		
GIRLS	1982	(N=202)	11.64 ± 1.67	85.0	<.00001
	1985	(N=192)	13.09 ± 1.49		

Table 4

Percent of School Children with Anemia (Hb<11g/dl)

1982	27.3%
1985	6.7%

Strategies Used in Designing the Second Year of On-Farm Vegetable Trials in Virginia

Thomas J. Kalb II,[1] John S. Caldwell,[1] C. C. Lewis[2]

INTRODUCTION

The planning and design of applied agronomic research should be a dynamic process. Just as the needs of farm families continually change, so too must strategies in applied research change in response. Research designs often begin exploratory in nature, screening many different variables affecting farm production systems. But as initial research is completed, its results noted, and the interaction among researchers and farm families increases, subsequent research should become more focused in its direction and even more valuable in serving the needs of its particular clientele.

Virginia Polytechnic Institute and State University, Virginia State University and the Virginia Cooperative Extension Service are working together on a Farming Systems Research and Extension (FSR/E) project in Nottoway and Lunenburg Counties of Virginia. The goal of the project is to utilize FSR/E methodology in improving the welfare of limited resource farm families. To this date its research has concentrated on developing cost-effective vegetable production practices for an area whose farm economy is depressed due to its dependence upon a slumping tobacco market. This paper shall illustrate how strategies in the project's vegetable research plan have evolved from the first year of on-farm trials to the next.

DESCRIPTION OF TARGET AREA

Nottoway and Lunenburg Counties are located in East Central Virginia, located in the Southeastern United States. Its climate during the summer growing season is hot and generally humid, with average daily temperatures of 22°C, and average daily highs of 29°C. Precipitation is evenly distributed throughout the growing season in amounts that are usually adequate for the commonly grown crops, including tobacco, maize, soybeans and hay. The area's soils are typically well-drained, strongly acidic and low in natural fertility. The terrain is gently sloping (McDaniel, *et al*., 1981).

INTERVENTION STRATEGY, YEAR 1

A. Diagnosis of Area Problems

In March 1984, project personnel interviewed over 40 farm families from the target area, learning of their farming practices and concerns. Using the *sondeo* technique, the informal survey team consisted of research and field extension staff (Shaner, *et al*., 1982). Disciplines represented among inter-

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2-Department of Chemistry, Virginia State University

viewers were agricultural economics, agronomy, animal science, home economics horticulture and sociology. Interviewers did so in teams of two, with partners matched such that different institutions and disciplines would be represented. All interviewers assembled each night for an exchange of information and development of hypotheses. These interviews indicated that the area was principally made up of small-scale, owner-operated farms, with tobacco production as the major farming enterprise.

The tobacco-producing farm families of the area typically grew their tobacco on only a small portion of their land, but they were nevertheless very dependent upon the cash receipts they received from this high value crop. The security of their income from this federally-subsidized crop relies heavily upon the powerful tobacco lobby in the United States Congress. Recently, however, motions have been made in Congress to significantly change or even eliminate the existing tobacco allotment program. The tobacco-producing farm families who were interviewed expressed fear that if the allotment program is lost, than they might not be able to survive unless they diversified quickly. As is, the existing program is decreasing tobacco production profits as allotments are being reduced due to increased foreign competition and a decrease in consumer demand for tobacco products. The development of alternative agricultural enterprises was clearly needed for the area, and this topic dominated discussions in the designing of intervention strategies.

Project personnel categorized the family farms of the target area into preliminary research domains, based on commodities produced and approximate farm income (Caldwell and Walecka, 1986; Hildebrand and Poey, 1985). Families at either end of the income scale were first eliminated from design considerations. These included families who were rich in resources, and those families who were so lacking in resources, including land, that they were not likely to become viable farming units. The remaining strata of families, including middle-level farm households and those limited resource farms with farmland, had often mentioned vegetable production as an alternative to tobacco production. Cultural practices for vegetables and tobacco are indeed relatively similar, and a local cooperative had recently been established to market vegetables.

B. Experimental Design, Year 1

Experienced vegetable growers of the area were subsequently interviewed to learn of their current cultural practices and to detect those areas where research was most needed. Since most of Virginia's vegetable production is done along its coast, the state's vegetable research efforts have concentrated in that geographic area, serving the needs of that area's farmers, who operate primarily large scale and highly mechanized farms. Most of the other vegetable research in the state is done at Virginia Polytechic Institute and State University, located in the Blue Ridge Mountains at the opposite end of the state. Since no research had been done for farmers located in the central part of the state, with their own particular climate, terrain, soils and farming systems, it quickly became apparent that many production factors needed to be studied.

Two types of potential vegetable farmers emerged from the sondeos, those with overhead irrigation and those without. Experiments were designed to improve cultural practices for bell pepper and cherry tomato, the two vegetables principally marketed by the local vegetable cooperative. The bell pepper experiment was designed to suit the needs of farmers with overhead irrigation. A 3 x 2 x 4 x 3 factorial design was used to evaluate the effects of cultivar, black plastic mulching, plant population and nitrogen rate.

A promising high-yielding cultivar, 'Cadice', was tested against the two commonly grown cultivars of the area, 'Keystone Resistant Giant #3' and 'Lady Bell'. Black plastic mulching is reported to increase pepper yields (Locascio, et al., 1985), and despite fears from local extension personnel that the plants would burn up under the black plastic, its effects were also studied. Plant population effects were evaluated utilizing both single and twin row systems. For the single row systems, plants were spaced 38 and 23 cm apart, creating plant population levels of 25,000 and 43,750 plants per hectare, respectively. Twin row systems had twin rows separated 30 cm apart, with plants within each of the twin rows spaced 42 and 30 cm apart, creating population levels of 43,750 and 62,500 plants per hectare, respectively. Both the single and twin row systems were planted on 105 cm row centers. Three nitrogen rates, 80, 160 and 240 kg/ha of nitrogen, were also tested, the middle rate recommended to area growers at the time. Phosphorous, potassium and boron fertilization was done following recommendation rates based on soil tests (Va. Coop. Ext. Service, 1985).

For the second research domain, those families without irrigation, a 2^6 factorial was designed to test the effects of cultivar, plant population, black plastic mulching, staking, nitrogen rate and soaker hose irrigation for cherry tomato. 'Cherry Challenger' and 'Cherry Grande' cultivars were recommended for evaluation by extension due to their superior performance at trials done at the coastal vegetable research station. In the plant population treatment, plants were spaced 45 and 30 cm apart on 122 cm row centers, giving plant populations of 13,625 and 18,125 plants per hectare, respectively. Previous studies have shown plastic mulching, staking, and irrigation all to have increased production efficiency of tomatoes in the Southern U.S. (Geraldson, 1975), with plastic mulching improving the soil moisture conditions and efficiency of nitrogen use (Jones, et al., 1977). A separate study reported only mixed benefits for these three cultural practices, depending on climatic conditions and soil type (Karlen and Robbins, 1983).

To evaluate staking, the Florida String-Weave System was utilized. In this system a stake is placed every 2 meters and strings are run horizontally, weaving from the side of one plant to the opposite side of the next, wrapping the string completely around each stake. Additional layers of strings are woven between plants at 30 cm intervals as the plants grow, creating a "wall" of tomato vines supported by horizontal strings. In the study of nitrogen rates, 85 and 170 kg/ha of nitrogen were applied for evaluation. As in the case for the pepper trials, the N fertilizer was applied pre-plant in the form of ammonium nitrate, the other half side dressed after fruit set in the form of calcium nitrate. Phosphorous, potassium and boron was applied following recommendation rates based on soil tests.

Perhaps the most important treatment in this experiment was the soaker hose irrigation. The soaker hose was made up of a porous, canvas-like material that when filled with water emits a slow and steady supply of water, similar to that of a trickle irrigation system. Unlike trickle irrigation, however, soaker hoses are inexpensive and easy to manage. They simply need to be attached to a family's well.

For both the bell pepper and cherry tomato experiment, an incomplete block design utilizing confounding was used. Such a design was needed in order to accommodate the large number of variables tested and their interactions. Across-farm replication was done in order to keep the plots at a manageable size, approximately 300 m^2. Select treatments were replicated on each farm to obtain a farm by treatment interaction component (Hildebrand and Poey, 1985; Hammerton and Lauckner, 1984).

These trials were set out as researcher-managed regional trials (Hildebrand and Poey, 1985). Eight farms within the two counties were chosen for the cherry tomato trial and five were selected for the bell pepper trial. Farm families were responsible for the management of the plots after planting, including the harvesting and recording of yields. The project supplied all necessary inputs for the plots, including plants, fertilizers, mulching and staking materials. Yields off the plots were the property of the families, who then could either market the crop or utilize the vegetables for home consumption. Researchers were available throughout the summer for assistance, and a technician from Bach county was hired to work closely with the families.

RESULTS, YEAR 1

A. Bell Pepper

Differences among the cultivars were highly significant, and the effects of all treatments were significant at the 25% level (Table 1). Tests for significance went up to the 25% level as researchers felt that this level of significance would be sufficient enough for farm families to seriously consider the treatment differences in determining their future farming practices.

'Cadice' consistently out yielded the two traditional cultivars. Black plastic mulching, higher plant populations and higher nitrogen rates also increased yields and economic returns. The principal benefit of the plastic mulching appeared to be in moisture conservation as clear differences were visually apparent during the midday heat in the turgor of the mulched versus non-mulched plants. Although the higher plant populations increased yields, the families were uncomfortable with the twin row system. Time-consuming adjustments had to be made on their equipment to cultivate the twin rows. The families also expected that adequate spray coverage for their insecticides and fungicides would be more difficult with the denser plantings. However, contrary to this expectation, the data collected from the plots showed a lower percentage of cull fruits from the highest density planting, perhaps due to increased shading in these plantings and therefore greater protection from sun scalding. Sun scalding and to a lesser extent, blossom end rot were the major reasons for culling of fruit. Marketing of the peppers went fairly well, all plots were well managed, and farm by treatment interactions were insignificant.

B. Cherry Tomato

Black plastic mulching and the higher plant population led to significantly higher yields and economic returns (Table 2). Higher yields under the black plastic were attained despite the fact that many plants, particularly of the 'Cherry Challenger' cultivar, were burned on the plastic when they underwent transplanting shock, lost turgor and laid on the plastic. Staking and the higher rate of nitrogen did not significantly increase yields.

Farm by treatment interactions were significant only for the soaker hose irrigation. The significance of this interaction is due to the unexpected inability of the vegetable cooperative to market the tomatoes. The tomatoes could not be marketed during the middle of the harvest season and those families with tobacco plantings chose to concentrate their labors on their tobacco crop instead. Harvests in these plots were done irregularly and in some cases only out of a sense of obligation to the project. On the other hand, those families without tobacco continued to regularly irrigate and harvest their tomato plots, thus attaining higher yields. Contrasts between these two groups of growers showed significant yield differences at the 1% level.

The soaker hose irrigation system itself was not without its problems. Some families felt that it was too time consuming to move the 9.14 meter hose from row to row. In order to conserve time, two farm families substituted their own garden sprinklers for the soaker hoses. Another identified problem with the soaker hose was that the end attached to the garden hose emitted more water than the distal end.

INTERVENTION STRATEGY, YEAR 2

A. Marketing Concerns

A major obstacle to success in developing a successful vegetable production industry for the area are problems in marketing. The local vegetable cooperative had management difficulties in 1985, leading to dissatisfaction by the families. Marketing of the bell peppers and especially the cherry tomatoes were neither predictable nor profitable for many of the growers. This resulted in significant cutbacks in production of these two vegetable crops during 1986, the second year of the project's on-farm trials. In this unpredictable marketing environment efforts are being made by the project in working closely with the cooperative in producing higher quality, more marketable vegetables, as well as indicating alternative means of marketing to the farm families.

B. Design of On-Farm Trials, Year 2

In the 1986 on-farm trial work the project is emphasizing cost-efficiency in vegetable, production. The project in 1985 successfully introduced more productive, and more costly, production inputs, hoping to increase net economic gains. However, the farm families expressed less concern over net economic gains for any given year as compared to minimizing economic risks over several years. The initial and absolute amount of cash required for inputs were also expressed as constraints. Therefore in the second year of on-far trial work the project has changed its emphasis to the minimization of both input costs and farmer risks in vegetable production.

Extensive cultivar testing was proposed for bell pepper since the only introduced cultivar out yielded both traditional lines. Emphasis in cultivar selection would be placed on those cultivars which produce large and blocky fruits, which are more marketable. Since the open-pollinated cultivar, 'Keystone Resistant Giant #3', out yielded the F_1 hybrid cultivar, 'Lady Bell', special attention would be placed on open-pollinated cultivars, whose seed costs are significantly less.

The strongly acidic soils of the area raised a concern as one plot which was insufficiently limed showed magnesium deficiency, symptoms and produced significantly lower yields. In direct response to the acidity problem: an on-farm demonstration plot was set out in each county to show the benefits of liming. Sites selected had strongly acidic soils and were limed at 0, 50 100 and 150% of recommended rates. A variety of vegetables, including bell pepper, cherry tomato, snap beans and muskmelon were planted.

Another experiment came about this year when one farm family approached the project with the idea of testing for the effects of sulfur fertilization in bell pepper. The project, also aware of the magnesium deficiencies in the area's soils, designed an experiment comparing the traditional potassium fertilizer, potassium chloride, to a potassium fertilizer supplemented with magnesium and sulfur. The fact that solanaceous plants are chlorophobic adds hope for the beneficial qualities of this new potassium source (Mengel and Kirkby, 1982).

For the 1986 on-farm cherry tomato trials, the benefit of plastic mulching despite the heat stress on newly-transplanted plants was encouraging. Families, however, expressed genuine concern over the high initial costs of the mulching (Rojas, et al., 1986), estimated to be $750 per hectare for the plastic and over $1200 for the plastic laying device (O'Dell, 1985). In response to these concerns the project this year is investigating the use of straw mulching. This mulching is readily available to even the most limited resource farm families who have pastureland. Straw mulching has shown to significantly increase yields over both black- plastic mulching and no mulching (Estes, et al., 1985). Black plastic mulching will continue to be studied this year. Using higher quality transplants and widening the holes in the plastic for the transplants has all but eliminated the burning problems.

Non-significant differences between the two nitrogen rates have led the project to look at even lower nitrogen rates. The project is also investigating the interaction of these low nitrogen rates with the straw mulching.

In 1985 the two new cultivars tested produced larger tomatoes that the locally-used cultivar, 'Small Fry', often to the point that the cooperative would not accept the larger tomatoes. These introduced cultivars did not produce such large tomatoes at the coastal experiment station, indicating the value of doing this on-farm research in the local area. Despite the differences in fruit size among the cultivars, farm families were impressed in the productivity of the new cultivars versus their traditional line. Extensive variety testing was proposed, especially since cultivar selection in itself does not necessarily add to input costs. Due to the preference for small-fruited cultivars by the cooperative for marketing, the selection of cultivars to be evaluated emphasized those lines producing small fruit.

C. Trial Location and Experimental Design

Eight of the thirteen families the project worked with in the first year of testing were asked to participate this year, all families accepting the invitation. Of these eight families only three decided to grow vegetables on their own for marketing. The other five families shied away from vegetable production due to increased off-farm employment demands and/or dissatisfaction with the marketing situation. Nevertheless, all participating families showed an active interest in vegetable production. Families also expressed their enjoyment in participating in the project, and those families with children especially thought that their participation served as a valuable educational experience. Making up for the families who were not invited for the second year of trials were three new families.

The extensive cultivar trials for bell pepper (29 cvs.) and cherry tomato (10 cvs.) were planted off-farm, at the Nottoway Teaching/Demonstration Farm. This farm, run by the Virginia State Board of Corrections, grows vegetables to be served to inmates throughout the state and also provides inmates with agricultural training. The farm serves a useful role to all area farmers by providing them with demonstrations of various vegetable cultural practices. In addition to this location for cultivar testing, selected cultivars were set out on farms in order to test these cultivars under different environmental and managerial conditions. These on-farm trials also permit the comparison of on-farm and on-station performance, and tests the transferability of on-station performance with that on farms.

Since fewer treatment combinations need to be tested this year, the plots will be laid out in randomized complete block design. This design is much more readily understood by the farm families, enhancing the educational utility of the trials. In most experiments at least two replications are being set out on each farm in order to gain a farm by treatment interaction component (Caldwell and Walecka, 1986; Hildebrand and Poey, 1985).

CONCLUDING STATEMENTS

For applied agronomic research to be effective it must be designed and redesigned to suit the ever changing needs of the farm families. This project' trials in 1985 were rather conventional in their intent, as they introduced new and costlier inputs in order to increase yields and net economic returns. These trials for the most part were successful in satisfying their original intent, however, these introduced inputs are only of value when marketing is assured, which was not the case for the target area.

Trials in 1986 reflect a valuable year of experience in working with the farm families and evaluating the vegetables under a whole spectrum of different treatments. The one year of experience also led the project to redefine its on-farm research strategies to one which emphasizes risk management, trying to develop practices which will produce marketable crops while undertaking the least economic risks. This, however, is far from a perfect solution, and the project is active this year in gaining an even clearer vision of the farm families' needs so that these needs may be effectively met.

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Table 1. Yield and economic returns for bell pepper treatments.

Treatment	Difference among treatments[z]	Yield (boxes/ha)	Gross return ($/ha)[y]	Treatment costs ($/ha)	Net treatment effect ($/ha)
Plant Population	*				
25000 single row[x]		878	5265	1125	4140
43750 single row		798	4785	1970	2815
43750 twin row		900	5400	1970	3430
62500 twin row		938	5625	2813	2813
Plastic Mulching	*				
None[x]		653	3915	0	3915
Black		1103	6615	938	5678
Nitrogen Rate	*				
80#/ha		753	4515	50	4465
160#/ha[x]		893	5355	103	5252
240#/ha		985	5910	155	5755
Cultivar	****				
Keystone R.G.#3[x]		923	5535	0	5535
Lady Bell[x]		765	4590	0	4590
Cadice		950	5700	0	5700

[z] ****,***,**,*,[NS] Significant at the .01, .05, .10, .25 levels, and non-significant

[Y] One box = 1.11 bushel of marketable pepper. Assume price of $6.00 per box.

[X] Traditional cultural practices.

Table 2. Yield and economic returns for cherry tomato treatments. Non-significant treatments were not economically analyzed.

Treatment	Difference among treatments[z]	Yield (flats/ha)	Gross return ($/ha)[y]	Treatment costs ($/ha)	Net treatment effect ($/ha)
Plant Population	**				
13625 plants[x]		5983	23930	613	23317
18125 plants		6575	26300	815	25485
Plastic mulching	****				
None[x]		5548	22190	0	22190
Black		6888	27550	933	26617
Irrigation	NS				
None[x]		5570			
Yes		6848			
Nitrogen Rate	NS				
85#/ha		6040			
170#/ha[x]		6368			
Staking	NS				
None[x]		6160			
Fla. String weave		6398			

[z] ****,***,**,*, NS Significant at the .01, .05, .10, .25 levels, and non-significant.

[y] Assumes price of $4.00 per flat of 12 pints.

[x] Traditional cultural practice.

RESPONSES OF WHEAT TO DIFFERENT ENVIRONMENTS AND AGRONOMIC PRACTICES IN THE CONTEX OF THE CROPPING SYSTEMS IN PAKISTAN*

BY

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ABSTRACT:

This paper summarizes research findings from over 200 environments from two years of on farm farming systems research (OFR/FRS) with a cropping system perspective in irrigated an rainfed environments in Pakistan. Those on farm trials were conducted on clayey clay loam soils with PH ranging from 6.5 to 8.5. The major cropping systems in Pakistan are Wheat-sugar cane, wheat-rice and wheat-flour.

Climatically both the 1983-84 and 1984-85 seasons were hot dry years in which moisture stress occurred at various critical growth stages influencing the responses of wheat to different agronomic practices. tillage, variety land type, weed control, cropping patterns and addition of nitrogen and phosphorous fertilizer significantly influenced wheat yields. N and P incomplete factorial fertilizer experiments provided response surface data which allowed the calculation of economy recommendations N and P fertilizer application level using multiple regression co-efficients.

Deep ploughing with a moldboard plough as a primary tillage gave 52% (1.3 t/ha) and 36% (0.76 t/ha) higher yields than shallow ploughing with a traditional cultivator under rainfed conditions in the 1983-84 and 1984-85 seasons respectively.

New high yielding wheat cultivars gave more than 20% higher wheat yields over the variety Lyallpur 73 which is widely used by farmers.

Differential responses to fertilizer application within different crop rotational systems was evident for wheat. Economic optima from response curves varied from 103 Kg N/ha for wheat after maize to 136 Kg N/ha for wheat after sugar cane in the NWFP and 155 Kg N/ha for wheat after Rice in the Punjab.

Weed control using chemical herbicides increased wheat yields by up to 22% in the irrigated maize-wheat cropping system in the NWFP

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INTRODUCTION

Wheat is one of the most important staple crops in Pakistan and occupies a pivotal position in the countries economy. In the 1984-85 season wheat was grown over an area of 7.33 million hectares which amounted to 36 percent of the total cropped areas and gave a production level of 11.69 million tones of grain. This wheat growing area is wide spread in Pakistan and includes several different agroecological zones and can be purely rainfed, supplementary or fully irrigated.

An increase in wheat production has been made through the evolution of new high yielding semi-dwarf varieties but wheat yields nationally are low in line with most of the Asian countries. The yield gap between 'potential' and Actual farm yields is still wide and prompts the attention of researchers and planners to identify which are the key factors responsible for this gap and to decide in what manner future strategies can be desired to bring farm yields in line with their demonstrated potential. Limited moisture, late planting, low yielding cultivars, imbalance and inadequate rates of N and P fertilizer and poor weed control are the major factors limiting wheat yields (averages are less then 1600 Kg/ha). However yields above 5,000 Kg/ha can be achieved by using the presently recommended production practices (Hobbs et al. 1986).

Moisture is one of the major limiting factor responsible for low yields in the rainfed areas of Pakistan. However by using proper primary tillage implements for moisture conservation, through improved water infiltration, significantly higher wheat yields can still be achieved under limited moisture conditions (Hobbs et al. 1986, Khan et al.1985 and Reddy et al. 1983).

Recent work by Khan et al. (1985) showed that deep ploughing with a moldboard plough prior to the onset of the monsoon rains has resulted in significantly higher wheat yields than with the use of conventional ploughing with a cultivator (P 0.001) improved root grow, reduced soil compaction, better water infiltration, less disease (root rot) and less weeds were the major yield determining factors resulting from use of moldboard tillage.

In Pakistan as in many Asian countries there is a tendency for recommendations to be too general to be of much use to farmers as there is more land type, moisture and cropping pattern effects. Differential responses to fertilizer from land type, moisture supply and crop rotation has been observed in Pakistan for wheat (Byerlee et al. 1986; Khan et al. 1986).

Kasana et al.(1975) have shown significant wheat responses to the addition of N and P fertilizer. Furthermore in both rainfed and irrigated environments in Pakistan.

Hepworth (1979) has reported 15 to 25% reductions in grain yields of wheat in Pakistan due to weed infestation. Shad et al.(1986) have similarly reported that chemical weed control through herbicides improved wheat yields substantially. Buctril-M, Banvil-P and Dicuran-M were the most cost effective herbicides.

The research described in this paper was conducted on farmers fields over a range of different environments and cropping systems in order to assess the contributions and potential of these agronomic factors and environmental factors specifically on wheat yields under farmers conditions. By using this approach it is hoped that more realistic recommendations attended to farmer condition can be formulated in order to allow farmers to approach closer to the potential yields that have been demonstrated.

MATERIALS AND METHODS

This paper presents a summary of the data from more than 200 on-farm wheat trials conducted in farmer's fields in different environments and cropping systems during the wheat growing seasons of 1983-84 and 1984-85. Studies were conducted on tillage, variety, fertilizer and weed control in farmer's fields under their circumstances and with their participation in the rainfed and irrigated areas of Pakistan. The areas in which rainfed studies were conducted had averaged rainfall of approximately 250 mm in wheat growing season.

	ENVIRONMENT(S)	MAJOR CROPPING SYSTEMS
A	IRRIGATED	
	1. NWFP	a) WHEAT-MAIZE-WHEAT
		b) WHEAT-SUGAR CANE-WHEAT
	2. PUNJAB	a) WHEAT-RICE-WHEAT
		b) WHEAT-COTTON-WHEAT
B	RAINFED	a) WHEAT-FALLOW-WHEAT
		b) WHEAT-MAIZE-WHEAT

The results of these on-farm research experiments were not only the source of information which was used in the formulation of recommendations as the observations and insights of specific farming systems gained by the research scientists during the condition the experiments under farmer conditions and with farmer participation were also important in isolating problems and refining proposed technological solutions.

Site Selection

Fields were selected where the previous crop was either maize, sugar cane, or rice where irrigation was used. In rainfed areas the fields selected were following fallow or maize. Two major groups of land are found in the rainfed areas of Pakistan "Mera" land which is at some distance from the homestead and receives less attention and inputs, especially farm yard manure, and "Lepara" land which is closer to the homestead, receives more farm yard manure, and is more intensively cropped and managed. Wheat is usually planted after fallow on "Mera" and after fallow or maize on Lepara land (Khan et al. 1983). Soils are generally deep and of a clayey loam to loamy texture PH's range from 6.5 to 8.5.

a) Tillage:

In both cropping seasons the primary tillage use carried out either prior to the onset of the monsoon rains or just after the first rains in July. In 1983-84 four tillage treatments were studied in three sites.

Tillage Treatments:

1.	Cultivator	= 7.5 cm deep alteration.
2.	Sub soil soiler	= 45 cm deep "
3.	Chisel plough	= 20 cm deep "
4.	Mold board plough	= 30 cm deep "

All plots were given the same secondary tillage using a cultivator just prior to planting. As a consequence of the results from the 1983-84 season only the moldboard plough and cultivator treatments were obtained in the 1984-85 season. The number of sites was increased to 20 in the rainfed environment and 8 and 5 in the irrigated environments of maize-wheat and rice-wheat cropping systems respectively. In the rice/ wheat area, which generally have heavier soils and a longer turn-around time (3-4 weeks) for seedbed preparation to remove the rice residues an third tillage treatment direct drilling (Zero tillage) was also added to find out if turn-around time can be reduced without a subsequent loss in yield (Byerlee et al.1986).

b) Variety:

Pak-81, Barani 83, S 19(Junco "S") and the variety commonly grown by farmers Lyallpur 73 were compared at each site in both years. At least one variety trial was conducted at each experimental site.

c) <u>Fertilizer:</u>

Nitrogen (N) and phosphorus (P) fertilizer trials were conducted in rainfed and irrigated environments with variable cropping systems. Because of the possibility of a tillage time/fertilizer interaction an incomplete factorial design that employed various N and P levels were super imposed on the tillage plots at all the sites in both years. Such an incomplete factorial provides information on the nitrogen response at recommend P and the phosphorus response at recommended N levels. In 1983-84 the nitrogen levels were 0, 50, 100 and 150 Kg/ha and the phosphorus levels 0, 70, and 120 Kg/ha. In 1984-85 N and P levels were 0, 50, 100 and 150 and 0, 40, 80 and 120 Kg/ha respectively.

d) <u>Weed Control:</u>

The following herbicide treatments were used at the 3-5 leaf stage of wheat using a MAT-OSU bicycle plot sprayer at 40PSI and application rates of about 250l water/ha using code Number 8002 flat fan type nozzles.

(i) Check plots- No herbicide applied.

(ii) DMA-6 (2,4D) at 1.7 litre product/ha (1 Kg ai 2,4D/ha).

(iii) Buctril M (Bromoxynil+MCPA) at 1.3 litre product/ha (40% ai).

(iv) Banvil-P (Mecoprop+Dicamba) at 4 litre product/ha (32.4+2.1% ai).

(v) Dicuran MA (Chlortoluron+MCPA) at 2.5 Kg product/ha (40+20% ai).

(vi) Tribunil (Methabenzthiazuron) at 2.0 Kg product/ha (70% ai).

(vii) Tolkan (Isoproturon) at 2.0 Kg product/ha (50% ai).

Herbicides were applied as strips across the widths of the fields in plots where weeds were present.

Data Collection and Design:

In both years a simple design was used in which treatments were not replicated within individual fields. Instead large strips were planted and four 2 meter square samples were taken at random from each strip to determine yield. In both years all samples were counted in each sample and then threshed; grains were sub sampled, counted and weighed to obtain the 1000 grain weight. Straw yields were determined by weight bundles and subtracting grain weight.

Data Analysis:

Statistical analysis employed the software packages ANOA 11, Agrostat and Regress. Agrostat was used for the economic and regression analysis and in the handling of the site parameter descriptions. From the regression analysis of the fertilizer data co-efficients were used to calculate the N and P recommended application levels at different marginal rates of return using the following equation.

$$\text{N or P recommended } MRR_1 = \frac{(MRR_1 + 1) \times fp/cp - b}{2c}$$

Where MRR_1 = Specific marginal rate of return, fp = fertilizer price, cp = crop price b = linear co-efficient, c = quadratic co-efficient.

A marginal rate of return was defined as the increase in net benefit which can be obtained by changing from one production alternative to another, divided by the increase in the variable costs for the same change.

RESULTS AND DISCUSSION

Climate:

The climatic conditions in the two wheat growing seasons were different with respect to rainfall and temperature. The rainfall during the two seasons was poorly distributed, resulting in moisture stress at several critical growth stages and thus below average wheat yields, 1983-84 had a severe drought from October to mid-February, sufficient moisture during booting and then further moisture stress and high temperatures were experienced during the grain filling period. In the 1984-85 season sufficient moisture was received early and late in the growing season, but moisture stress during the period of booting to early grain-filling was experienced. These environmental conditions affected the response of wheat to deep tillage.

<u>Tillage:</u>

Wheat yields were significantly influenced by different tillage treatments. The results from the 1983-84 and 1984-85 season showed significant responses to the use of moldboard plough. The mold board plough treatments gave an average 52% (1.3 t/ha) and 36% (0.76% t/ha) higher grain yields than the traditional cultivator treatment in the rainfed environments in the 1983-84 and 1984-85 respectively (Figure 1). All other tillage treatments did not differ significantly from the cultivator treatments. This compares with a 15% yield increase in 1982-83 season which was comparatively wet with no moisture stress (Hobbs et al. 1983). This suggest that where moisture stress is experienced improved yield can be obtained from good primary mold board tillage operations.

Wheat responses to tillage across different environments was varied, the response to mold board tillage as compared to cultivator tillage was higher (36%) in the rainfed environments and in the irrigated maize-wheat (10.6%) cropping systems in NWFP then in the other systems studied. There were no yield differences due to tillage treatments in the rice/wheat areas in Punjab, (Figure 2).

Straw yield was also increased on average 20% due to moldboard ploughing during 1984-85. This is an important product used for animal feed in the rainfed areas.

Tillers/m^2 and grain per spike were the two yield component responsible for the increase in yield in both years with the use of moldboard plough (table 1). This suggests that the benefit existed throughout the wheat growing season since tiller numbers are determined during the vegetative phase and grains per spike during the reproductive phase.

Soil moisture, rooting depth, dryland root rot, disease and weeds were the important factors reduced by tillage treatment. Soil moisture data taken in 1983-84 indicated that soil moisture difference between tillage treatments were small. However, in 1984-85 soil moisture data (table 2) showed increased moisture availability in the mold board treatments, particularly below 30 cm. These differences between years could be due to differences in rainfall in September and October for two years. The higher moisture contents in the mold boarded plots in 1984-85 indicated that water infiltration went deeper into the soil profile as a result of the loosening of the compacted layer in this tillage treatment (Khan et al.1985, Reddy et al.1983).

In 1983-84 the soil rooting profiles of all 4 treatments were examined. Figure 3 is a drawing made from the photographs of the root profiles of the cultivator and mold board plots. Apparently, there was a compact layer in the cultivator plots 10 cm below the soil surface and extending well into the soil profile. This compacted layer apparently restricted root growth in the cultivator tillage treatment. In the mold board plough treatment there was no compact layer and rooting was chisel plots were similar to the cultivator plots with regards to compaction and rooting.

Variety:

In over 50 experiments planted over the years 1983-85, Pak-81 provided an average increase in yield of more than 20% over the traditionally used variety Lyallpur 73. The results of the varietal trials in the rainfed areas of Pakistan from 1982-85 are summarized in table 3.

The best varieties from the trial conducted in the barani (rainfed) areas in the past three years were Pak-81, and S-19. Pak-81 was developed under irrigated conditions but has performed very well in the rainfed areas and is now almost a recommended variety for these areas. Pak-81 and S-19 yielded significantly higher (21% and 23% respectively) than the check variety Lyallpur 73. S-19 is a selection made at National Agriculture Research Centre but is yet to be released.

FERTILIZER

A) Rainfed:

The response to fertilizer of wheat from 13 barani experiments in 1983-84 rabi season are shown in figures 4 and 5 for N at constant P (70 P_2O_5 Kg/ha) and P at constant N(100 Kg N/ha) respectively. The response of N was quadratic in function whereas phosphorous only gave responses up to the first 70 Kg P_20_5/ha. In 1984-85 more data was collected at each site and included information on land type (Mera VS Lepara), and previous crop. Data from these 24 experiments were combined for multiple regression analysis with the following results.

Y	$= 1184 + 14.45\ N - 0.09N^2 + 11.47\ P - 0.077\ P^2$	
	*** ** ** ns	
	$= 858\ PC + 672\ LT + 449\ PL + 0.068\ NP - 6.04\ LTP$	
	*** ** *** 13.7% *	
R^2	= 35% * = 10%, ** = 5% and *** = 1/% significance	
PC	= Previous crop, 0 = fallow, 1 = maize	
LT	= landtype, 0 = mera, 1 = maize	
PL	= ploughing, 0 = shallow, 1 = moldboard	
NP	= N x P interaction	
LTP	= landtype x P interaction	

The average of data from 24 experiments for N and P response is shown in Figures 6 and 7, respectively. These curves also show the responses on mera and lepara land types and the average response over all land types. The only significant interaction was between land type and phosphorus application which means that the phosphorus recommendation should very with land type. 1983-84 was a very dry year especially during the vegetative stages and the response to N was therefore low whereas in 1984-85 the Moisture stress occurred during flowering and the N response was much higher (co-efficient 18.8). In 1984-85 nitrogen and phosphorous responses were positive although less phosphorus appears to be needed on lepara land. This may be as a result of the higher does of farm yard manure received by lepara land then by mera land.

B) <u>Irrigated:</u>

The results from 1984-85 showed that addition of nitrogen and phosphorus fertilizer significantly influenced wheat yields in irrigated environments. Figure 8 shows wheat responses to nitrogen after maize, sugar cane and rice.

Wheat responses to applied nitrogen fertilizer varied between cropping systems. The predicted economic optima from these response curves varied from 103 Kg/ha for wheat after maize, 137 Kg/ha for wheat after sugar cane to 155 Kg/ha for wheat after rice. These variable responses to fertilizer application between different crop rotations clearly shows that crop rotation should be an important determinant for farmers in estimating what rate of fertilizer to apply in each of the selected areas table (4). Researchers have traditionally provided one fertilizer recommendation for all irrigated wheat. Farmers' on the other hand have adjusted fertilizer rates to reflect different cropping patterns.

WEED CONTROL

The data in table 5 show that herbicides influenced wheat yields significantly in the irrigated Maize-Wheat cropping system in NWFP, where broad leaved weeds are one of the major problems experienced by farmers. There was 10 to 22% yield increase by using one of the various selective herbicides for weed control. Banvil-P, Buctril-M, Tolkan and Dicuran-MA were the most cost effective herbicides.

CONCLUSIONS

1. Tillage, moisture, variety, land type, cropping patterns, N:P fertilizer and weeds are the major important factors influencing wheat yields. These important agronomic factors responded differently to various environments suggest the need for site specific research for developing recommendation domains.

2. The excessive shallow ploughing with the traditional cultivator to help conserve soil moisture and control weeds is probably resulting in the formation of a compacted layer below the plough layer, that is restricting the root growth and reduces the rate of water infiltration deeper into the soil profile. This situation can be remedied by good primary tillage using a moldboard plough with resulting benefits of better rooting, less weeds, less dry land root rot disease and greater availability of moisture and nutrients.

3. The differential responses of wheat to N:P fertilizer application by different crop rotational system emphasizes the need to develop specific recommendations for farmers with regards to fertilizer use.

4. The results out lines in this paper has clearly shown that by adoption of the improved recommended production practices such as proper tillage, proper variety, balance N:P fertilizer application and proper weed control through appropriate selective herbicides, maximum/potential yields can be obtained.

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Table 1: Effect of two tillage treatments on the yield and yield components of wheat during 1983-84 and 1984-85

Parameters	1983-84		1984-85		Average	
	MB	CU	MB	CU	MB	CU
Grain yield (t/ha)	3.80*	2.50b	2.89a	2.13b	3.35	2.32
Tillers/m^2	273a	242b	210a	195b	242	219
1000 wt (g^ms)	39.2a	38.0a	39.9a	39.2a	39.6	38.6
Grains/Spike	35.6a	27.6b	30.2a	25.2b	32.9	26.4

MB - Moldboard, CU = Cultivator
"Figures followed by the same letter do not differ significantly from each other at the 95% confidence level using a Duncan Multiple Range Test.

Table 2: Soil moisture percentage by tillage treatment just before planting wheat in the 1983-84 and 1984-85 seasons under rainfed conditions.

Tillage Treatment	Depth cm			Average
	0 - 15	15 - 30	30 - 45	
1983-84				
Cultivator	12.8	13.7	16.5	14.3
Moldboard	13.8	13.7	16.1	14.5
Chisel	14.5	15.0	17.7	15.6
Subsoiler	12.8	15.7	18.2	15.6
1984-85				
Moldboard	12.02	14.58	16.70a	14.43a
Cultivator	11.74	11.22	10.36b	11.11b

*Figures followed by different letters are significantly different at 5% level using DMRT.

Table 3: AVERAGE YIELD (T/HA) OF 4 WHEAT VARIETIES AND % INCREASE OVER LYALLPUR-73 IN RAINFED AREAS OF THE NORTHERN PUNJAB.

VARIETIES	YIELD t/HA 1982-83	YIELD t/HA 1983-84	YIELD t/HA 1984-85	AVERAGE (82-85)	% INCREASE OVER LYALLPUR-73 (82-85)
NO OF EXPERIMENTS	7	8	13	28	
PAK 81	4.40ab	2.90a	3.63a*	3.64a	21.3
S 19	4.60a	2.92a	3.58a	3.70a	23.3
BARANI 83	4.20b	2.76a	3.25ab	3.40ab	13.3
LYALLPUR 73	3.65c	2.59a	2.93b	3.00b	
AVERAGE	4.21a	2.79b	3.35c	3.45	

*FIGURES FOLLOWED BY THE SAME LETTERS ARE NOT SIGNIFICANTLY DIFFERENT AT 5% LEVEL OF SIGNIFICANCE USING DMRT.

Table 4: FERTILIZER RECOMMENDATIONS FOR DIFFERENT CROPPING PATTERNS COMPARED TO LEVELS APPLIED BY FARMERS.

ROTATION	RECOMMENDATION CALCULATED FROM RESPONSE CURVE[a] (kg/ha) N	P	CURRENT RESEARCH RECOMMENDATION (Kg/ha) N	P	FERTILIZER USED BY FARMERS (Kg/ha) N	P
a) IRRIGATED						
MAIZE-WHEAT (NWFP)	103	82	136	57	91	27
SUGARCANE-WHEAT (NWFP)	137	82	136	57	112	37
RICE-WHEAT (PUNJAB)	155	49	136[b]	111[b]	77	44
b) RAINFED						
1. MERA LAND	71	88	84	57	41	34
2. LEPARA LAND	53	48				

a) BASED ON RESPONSE CURVES IN FIGURE 3 AND USING 1985 PRICES THE MINIMUM ACCEPTABLE MARGINAL RATE OF RETURN ON CAPITAL FOR FARMERS IS ASSUMED TO BE 0.5

b) SOURCE: BAJWA, 1985.

Table 5: ECONOMIC ANALYSIS OF SUPERIMPOSED HERBICIDE TREATMENT (AVERAGE OF 15 LOCATIONS) FROM IRRIGATED MAIZE-WHEAT CROPPING SYSTEM NWFP IN 1983-84

HERBICIDE	YIELD KG/HA ACTUAL	YIELD KG/HA INCREASE	BENEFIT P_p/HA	COST P_p/HA	COST/BENEFIT RATIO
CHECK	3390	-	-	-	-
DMA-6	3710	320	152	238	2.2
BANVIL-P	3800	410	656	210	3.1
BUCTRIL-M	3840	450	720	231	3.1
TRIBUNIL	3960	570	912	491	1.9
TOLKAN	4140	750	1200	450	2.7
DICURAN-MA	4140	750	1200	473	2.5
ENVOY	3930	540	864	NA	-

1. COST INCLUDES 75 RUPEES FOR APPICATION EQUIPMENT AND LABOUR.

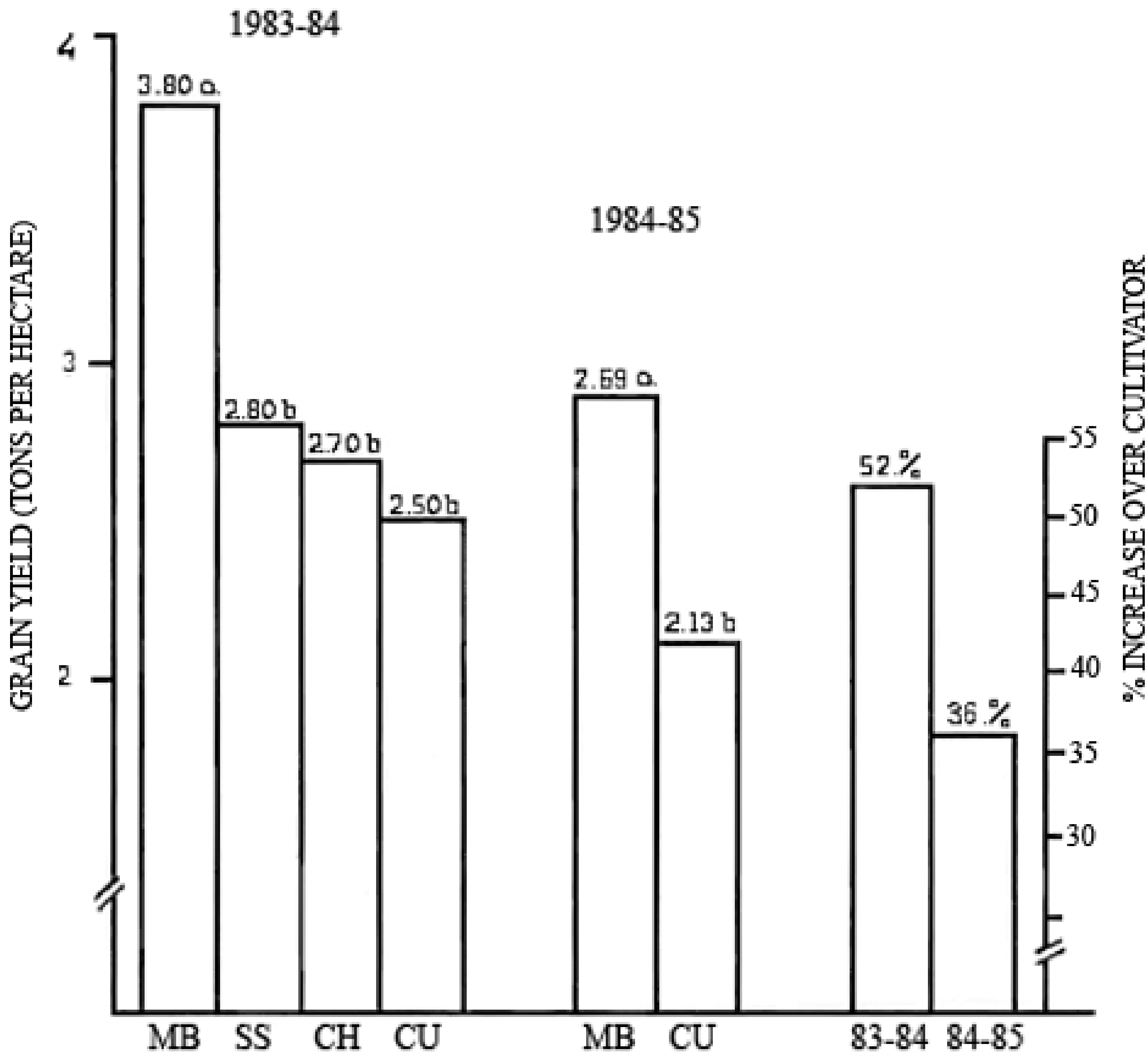
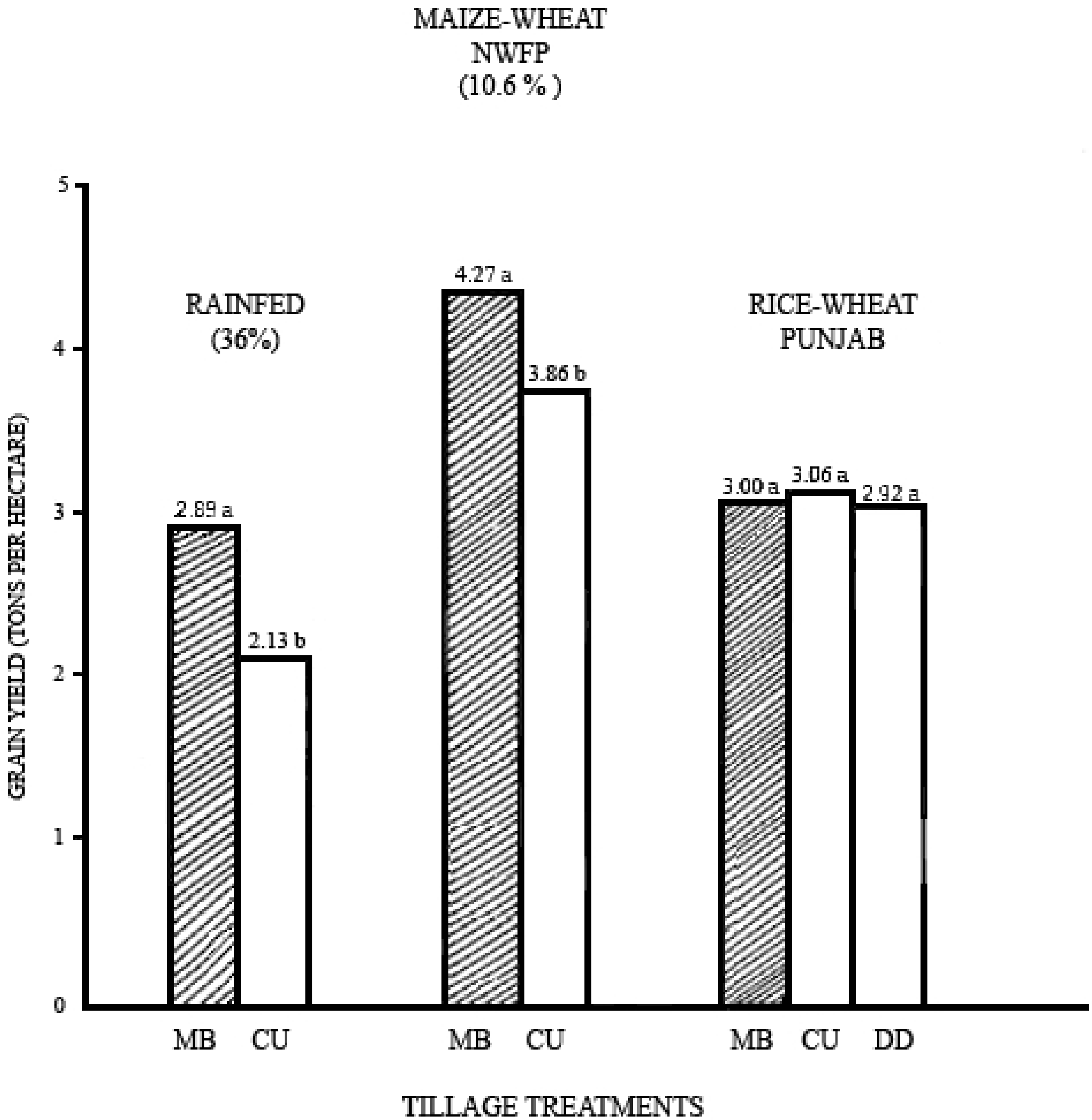


Fig 1: The effect of tillage treatments on the grain yield of wheat in Rawalpindi District in 1983-84 (average of 3 locations) and in Rawalpindi - Islamabad districts 1984 -85 (average of 16 locations) and the % increase of moldboard over cultivator in both years.



MB = MOLDBOARD, CU = CULTIVATOR, DD = DIRECT DRILLING

MB = Wheat Responses to Tillage in Rainfed and irrigated environments 1984 - 85

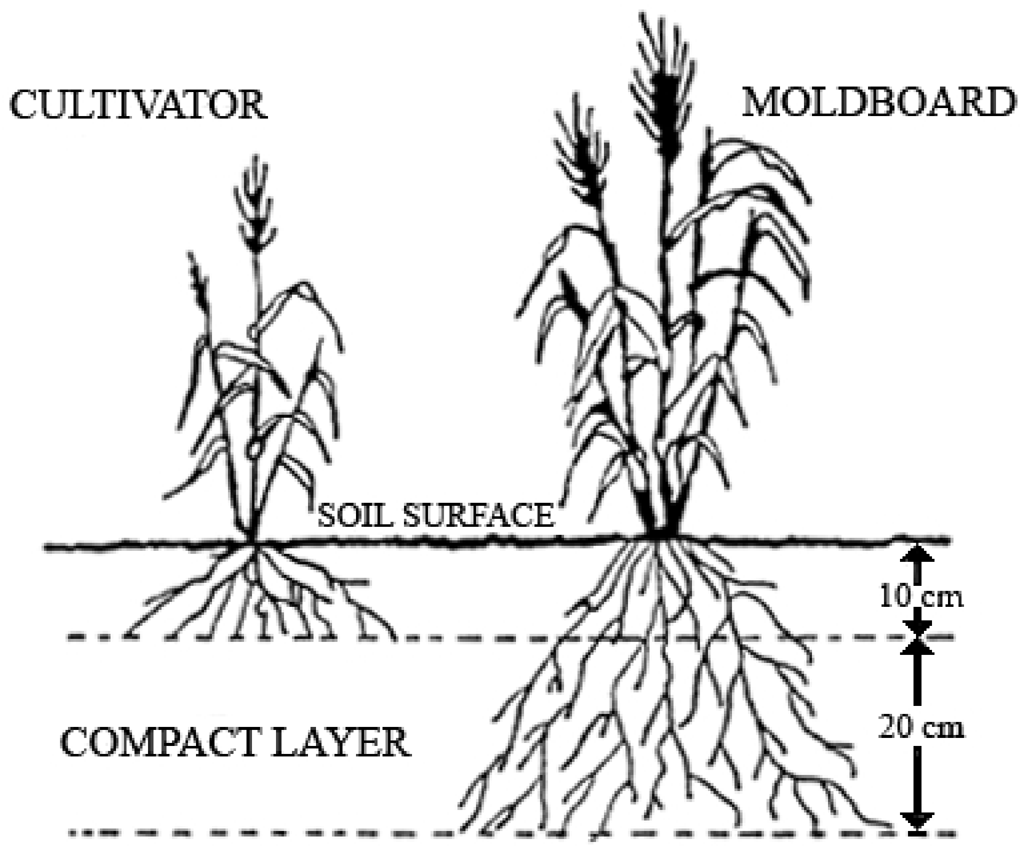


Fig 3. Wheat rooting profiles of the cltivator and moldboard ploughed treatments in February following drought in the 1983-84 Rabi season, Rawalpindi, District.

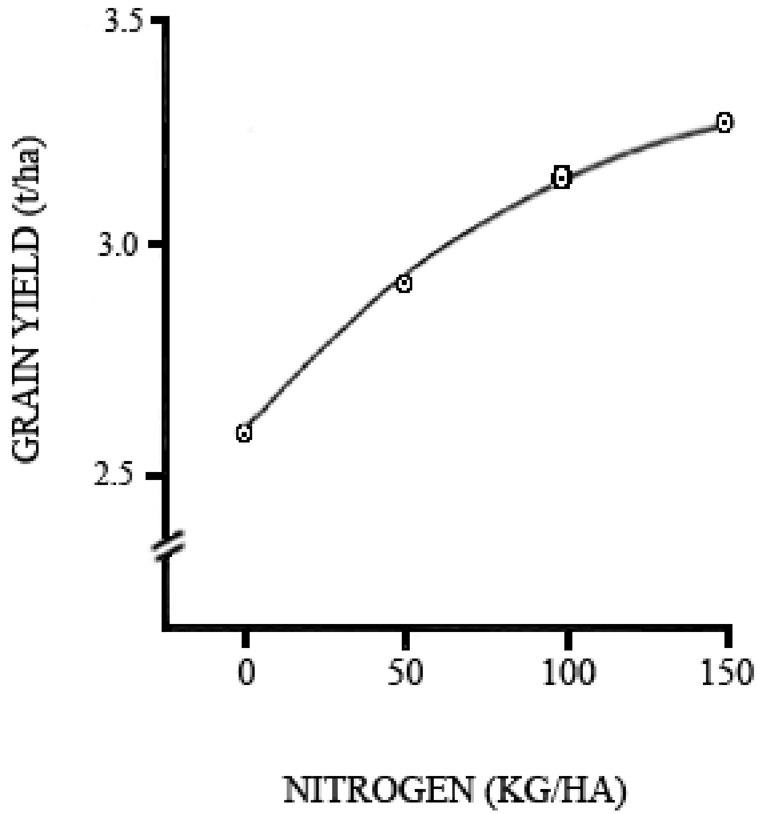


Fig 4: Nitrogen response curve of 13 barani sites during 1983-84.

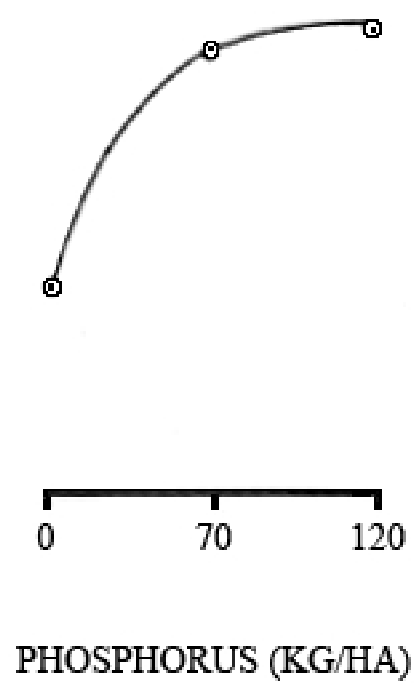


Fig 5: Phosphorus response curve of 13 barani sites during 1983-84.

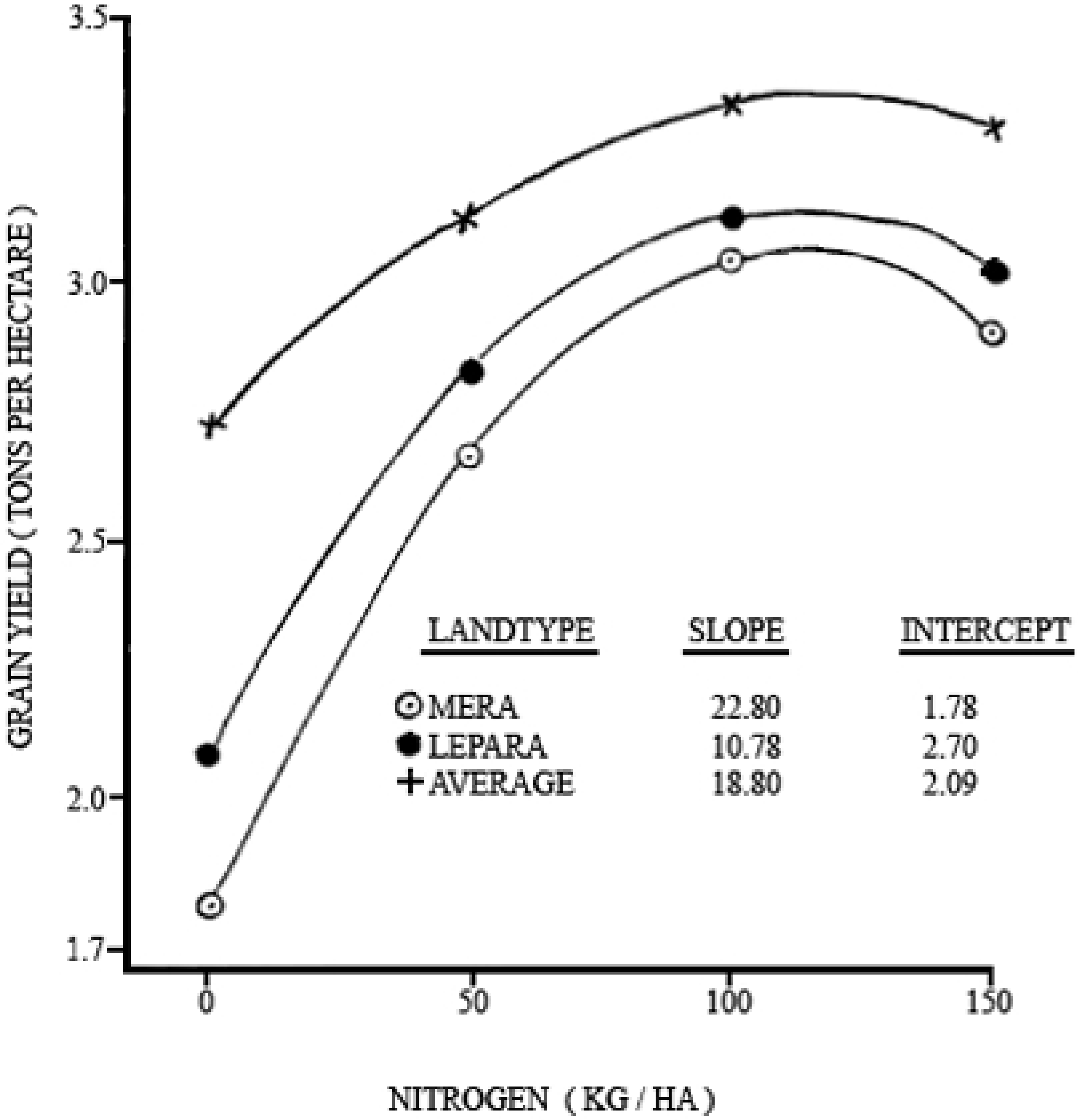


Fig 6 Nitrogen response curves for wheat at constant P (80 kg/ha) grown in barani area during 1984-85.

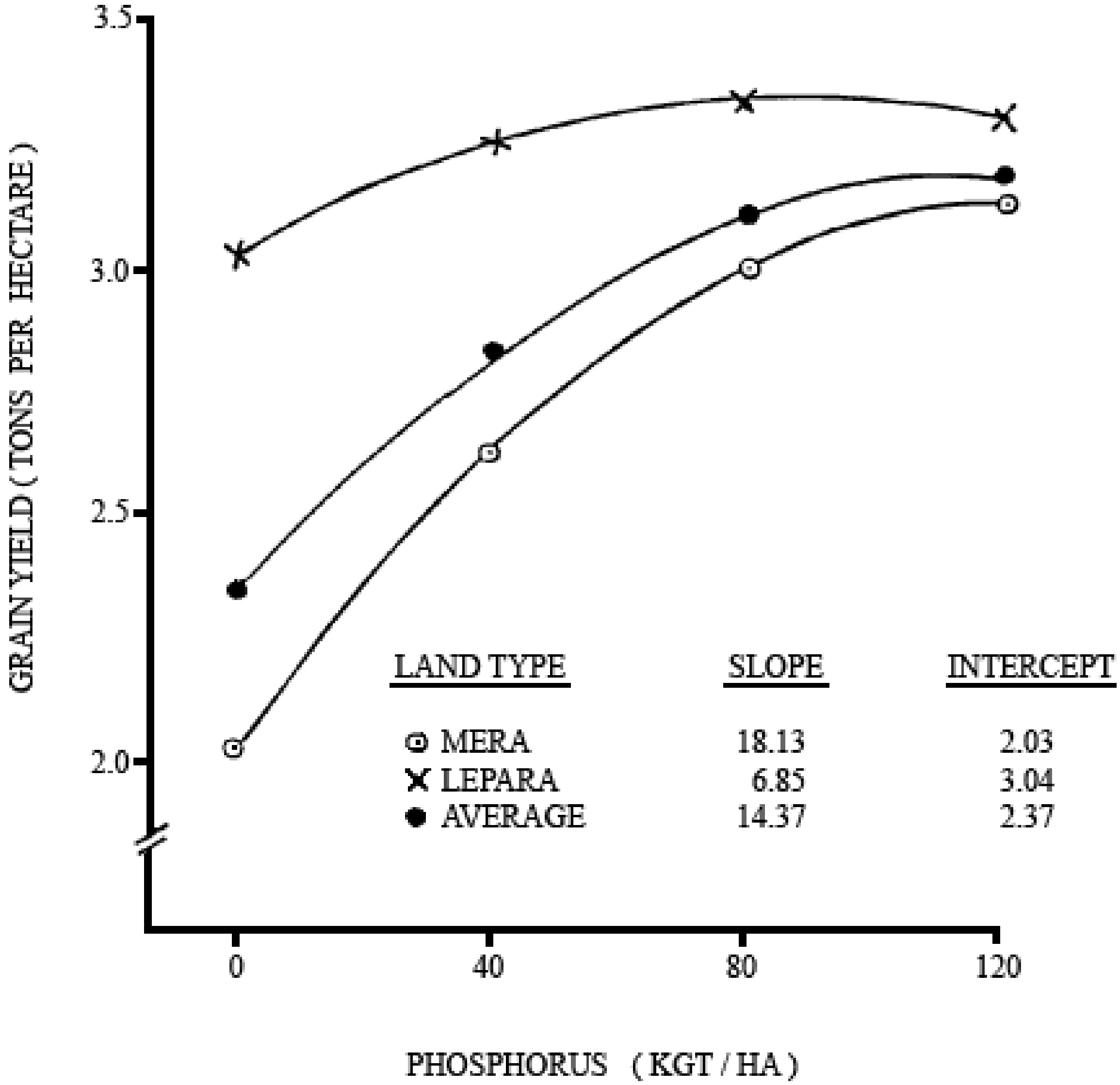


Fig 7: PHOSPHORUS RESPONSE CURVES AT CONSTANT N (100 KG / HA) FOR WHEAT GROWN IN BARANI AREA DURING 1984-85.

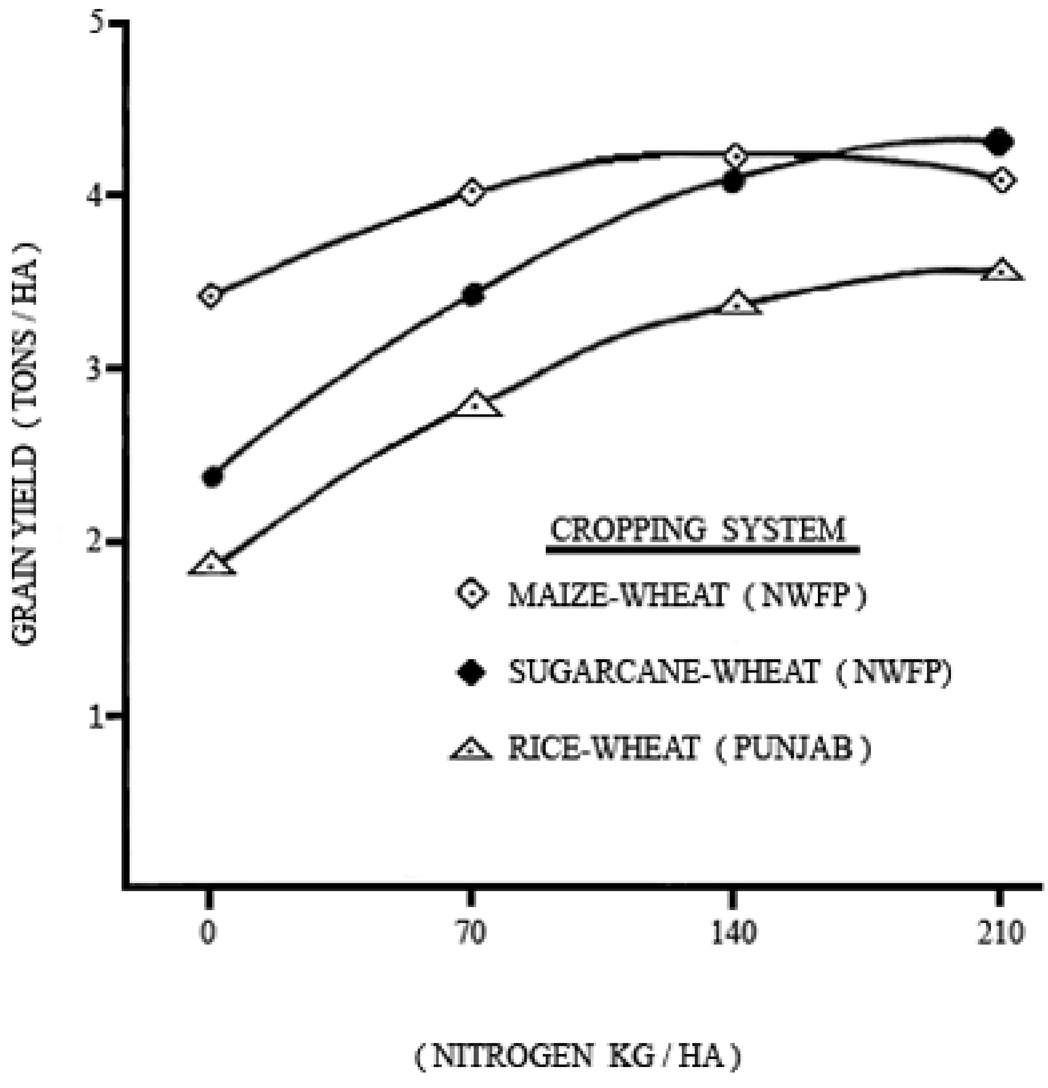


Figure 8: Wheat Response to Nitrogen Fertilizer by Cropping Pattern, 1984-85.

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