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The Sudan Agricultural Research Corporation: Organization, Practices, and Policy Recommendations

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by

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EXECUTIVE SUMMARY

This report addresses the internal dynamics of the Agricultural Research Corporation (ARC) as well as the social, economic, and political context in which it is embedded. An understanding of this larger context is particularly important. For example, despite institutionalized agricultural research in the Sudan which dates back to the turn of the century, as a result of rapid population growth and other factors agricultural and food production per capita have declined precipitously in recent decades.

As the rate of development of science, technology, and social institutions is determined in large part by human resources (e.g., scientists and staff) an examination of the backgrounds, professional training and capability of ARC scientists was conducted. Sudan's agricultural scientific community, while increasing from 52 scientist years in 1967 to 212 scientist years in 1980 and from $2.8 million expenditures in 1966 to $9.6 million expenditures in 1980, is about average in terms of growth among developing countries. The scientists themselves are predominantly male (97%), and average 39 years of age. Only 33% come from farm backgrounds. The ARC scientific community is well trained, with 65% having received Ph.D.'s, a figure which far exceeds the World Bank target of 20%. This relatively large well-trained scientific community is insufficient in and of itself to conduct research. Other issues that need to be addressed are distribution of scientists within the country, management capability, diffusion of information to client groups, operating budgets, and congruence of training and national needs.

The research conducted by ARC scientists is generally of an applied nature. While ARC scientists considered financial support and operating supplies and materials as the most important resources for their work, these same resources were also generally regarded either as the least adequate or often as inadequate. It is to the credit of the individuals within the system that they have been able to adapt to these poor conditions and to continue their research. However, many scientists indicated that if salaries and support levels within the ARC did not improve, they would seek professional opportunities elsewhere.

As production of scientific knowledge is intimately bound to the ability to communicate and exchange information, an assessment of scientific communication was made. With respect to formal communications, the major vehicle by which the ARC scientists keep abreast of current literature is regular scanning of journals. Travel and scanning of publications other than journals were considered to be of little importance. Unfortunately, relatively few scientific journals are available to the ARC scientists due to budgetary constraints and restrictions on access to foreign currency. Likewise, travel, which is considered by other groups of agricultural scientists to be a major source of information, is not a major vehicle for ARC scientists due to insufficient funds for travel both within and outside the Sudan. To compensate for this relatively weak formal communication network ARC scientists have developed a strong informal communication network. Forty-five percent of ARC scientists report that they converse daily with scientists in their respective departments. This compares quite favorably to scientists in other countries.

ARC scientists were asked to rank goals for agricultural research. The primary goal of the ARC scientists is to increase agricultural productivity with development of new knowledge a close second priority. The major beneficiaries of the ARC research are identified by scientists as farmers (approximately 50%), industry (approximately 25%), and extension/government (16.1%). This differs considerably from those beneficiaries reported by scientists in other countries. Paradoxically, while farmers are defined to be the primary audience, the principal methods of diffusion are inappropriate or marginally adequate. They include: publication, diffusion through extension (where activity has been severely curtailed due to economic conditions), and meetings and walk-ins, in areas where there are great distances to be traversed by the farmers.

Recommendations include: (1) the need for a coherent national agricultural research policy, (2) reorganization to incorporate Farming Systems Research (FSR) approaches to research, (3) better integration of Western Sudan Agricultural Research Project (WSARP) and other sections into the ARC, (4) movement of ARC headquarters to Khartoum, (5) development of improved communications with outlying stations, (6) additional on-farm experimentation, (7) greater congruence between organizational goals and reward systems, and (8) greater sharing of scientific equipment.

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CHAPTER 1

INTRODUCTION

This report consists largely of data gleaned during a five-week visit to the Sudan during February and March 1982 by William B. Lacy and Lawrence Busch of the Department of Sociology, College of Agriculture, University of Kentucky as well as a review of relevant reports, and official documents. The visit of Dr. Lacy and Dr. Busch was supported by the International Grain Sorghum/Pearl Millet Collaborative Research Support Program (INTSORMIL CRSP). As a joint team had made a detailed report on Sudan Agricultural Research Capabilities just a few years earlier (Joint Team, 1977), this study focused largely upon the organization and structure of the Agricultural Research Corporation (ARC). Those wishing information on the general agricultural situation and other research agencies are referred to the Joint Team report.

A second source of data was a mail questionnaire sent to Sudanese students enrolled in graduate agricultural programs in the United States in 1982-1983. The details of the procedures used to analyze the data are reported in the Methodological Appendix.

A Conceptual Overview

Traditionally, agricultural research organizations have been examined from one of two perspectives. The first and older of these perspectives examined only the products produced by research organizations and how those products were or were not adopted by farmers. This led to the voluminous literature on the diffusion of agricultural innovations (see, for example, Rogers with Shoemaker, 1971). Social scientists employing this model focused not upon the research organization but upon the transfer of the

products to the farmer through the extension system. Feedback, to the extent that it existed, consisted of the farmer, either directly or through the extension service, informing researchers as to what practices were or were not adopted. In short, although the communication was in both directions, it assumed the relevance and appropriateness of the practices and products developed by the research community. Nonadoption was considered to be the result of the farmers' stubbornness or ignorance (cf., Busch, 1978).

More recently, attention has focused upon the internal dynamics of research organizations as evidenced by a wide variety of reviews of both national programs and the international centers (e.g., Joint Review Team, 1977; Ruttan, 1982). Most of these studies however, have limited themselves to the manpower requirements of research systems, and the monetary support necessary to effectively operate. They have tended to ignore the larger social, economic, and political context within which research systems are embedded as well as the internal dynamics of the research system itself. As a result, although the information provided by such studies is accurate, it is incomplete in very significant ways. This incompleteness becomes apparent if one examines the difference between scientific and everyday rationality.

Scientific or means-ends rationality is generally employed by scientists in the process of doing science. For example, among agricultural researchers, the scientist views higher productivity as the end and uses a variety of possible means (e.g., breed more productive plants, control pests, increase soil nutrients, modify cultural practices) depending on his or her disciplinary background in order to affect that end. The end itself

is tacitly assumed to be a given while the means are approaches that may be manipulated in order to further progress towards that end. For example, a scientist may focus upon improving cotton production on the Gezira Scheme and will look towards various means for increasing that productivity. The end of improving the productivity of the Scheme itself will not be called into question during the research process.

This kind of rationality is fundamentally instrumental (Idhe, 1979). First, it involves the utilization of instruments (e.g., microscopes, scales) in order to achieve the desired experimental results. Second, it is instrumental in the sense that it is concerned largely with the choice of means rather than the choice of ends. Scientists may employ analogical, symbolic, or even literary reasoning in their daily endeavors (Knorr-Cetina, 1981), but this takes place within an instrumentally constructed context.

Everyday rationality, however, is quite different. Here the ends as well as the means may be varied and complex. For example, a Sudanese small land-holder may perceive a variety of ends for the farm. These include making a profit, demonstrating success to one's neighbors, minimizing heavy labor, spreading work evenly over the year, minimizing soil erosion, and, most importantly, guaranteeing the minimum harvest necessary for subsistence every year. Importantly, these ends are not necessarily compatible. For example, profits may be foregone in order to reduce risk. Moreover, a Sudanese farmer will employ a variety of means in order to achieve these ends. A farmer might grow high productivity crops, maximize production, minimize the cost of purchased inputs, increase farm size, and/or grow varieties that are highly drought tolerant. The degree to which a farmer employs these means will be directly related to the relative weight given to

the various ends and his resource base. For example, a wealthier farmer may be more willing than a poorer farmer to adopt high input varieties that promise a high payoff. This is so simply because the wealthier farmer can afford to take the higher risk associated with the higher use of inputs.

We should also note that by virtue of the complexity of the interrelations between the ends and the pressure of time, the farmer will not be able to rationally calculate an optimal solution to a particular problem but will be forced to employ the solution that appears appropriate. In short, while scientific rationality tends to focus on one or a small group of ends that can be addressed through research, everyday rationality involves a variety of ends, many of which cannot be addressed by a single researcher or even an entire research system. This model of everyday rationality has implications for the way in which the flow of information and political support must occur in research and extension systems.

An alternative perspective on research and extension expands the number of participants in the model to include farmers, agribusiness people, urban consumers, legislatures, government officials, disciplines, production scheme officials, and bilateral and multilateral aid agencies. These various clients for agricultural research impinge upon the overall organization of the research system as well as the specific choice of problems that a given researcher addresses (Busch and Lacy, 1983). They may do this through funding mechanisms, by lobbying the funding organizations, by direct pressure on the research organization, or by administrative decree. The problems finally selected for research arise out of negotiations with these clients (Busch, 1980). This in turn limits the range of research products that are provided to extension agents or directly

to clients. If the researcher has done his or her homework, then the products produced are those that were demanded by clients in the first place and the diffusion process largely involves making known those products and how to use them to the clients that requested them.

Of course, all clients are not alike. Farmers may be wealthy or poor, may grow different crops, may or may not hire labor, and may have very different interests. In the case of Sudan, farmers can be clearly divided into three gross categories: those on irrigated production schemes, those on mechanized farming schemes, and those involved in rain-fed agriculture. Even within these three large groups, farmers may not have the same needs or interests. Similarly, legislators or government officials may be as interested in maintaining low food costs for urban consumers as they are in increasing farmers' incomes. Scheme managers are likely to be interested in the overall production of the scheme rather than in the income that accrues to a particular farmer. This is particularly apparent in Faki's (1982) study of the Gezira Scheme. He found that while scheme managers wish to promote cotton production, from the standpoint of the tenant, cotton compares unfavorably with other crops. Scientific disciplines also may develop their own agendas which may not be fully congruent with the needs of other clients. And, scientists' training in the United States and the United Kingdom may inadverently orient them towards problems considered important in those countries rather than problems considered important in Sudan.

Moreover, these various clients will have differential access to the researchers depending on wealth, power, status, class, education, and even their degree of articulation in making their research demands known. In

short, this alternative perspective and the report that follows add three dimensions previously neglected. First, the researcher is seen producing research in response to the demands of (some group of) clients. Second, it is recognized that some clients are likely to have more access to the research system than others. And, third, extension is seen largely as giving certain clients what they initially requested.

Brief History

Unlike the situation in many other states of sub-saharan Africa, agricultural research in Sudan dates back to the turn of the century. Research was begun in 1902 to meet the demands of the Lancashire cotton industry. As a spokesman for the cotton interests put it in 1913:

> Experiments have abundantly proved that the Sudan is not only the finest cotton growing country in the whole of the British Empire, but, what is more important, that it can grow that sort of cotton that Lancashire requires (quoted in Barnett, 1977:5).

At the beginning the focus of research was almost exclusively on cotton and particularly upon the proposed irrigated area between the two Niles that would eventually become known as the Gezira scheme. Arthur Gaitskell described the early research work:

> In 1918 a Gezira Research Farm had been started near Wad Medani, the capital of the Blue Nile Province, to study soil and water management, crop varieties, rotations, cultivation practices, fertilizer response and, of course, diseases and pests. With the setting up of this scientific station in the heart of the

> Gezira there began a close association between the back-room boys of the Research Farm and the field staff of the [Cotton Growing] Syndicate, not at all times easy but always stimulating and destined to play a vital part in the survival of the Scheme (1959:138).

Indeed, there is little question that without the research back-up provided, the Gezira would never have recovered from the serious cotton disease problems encountered in the 1930s.

The emphasis on a single cash crop for export was typical of most research organizations during the colonial period (Busch and Sachs, 1981). In most British colonies, single commodity research organizations were established to encourage highly capitalized export agriculture. As a result, the economy of the Sudan became increasingly dependent upon the annual cotton harvest.

After World War II, concern for nutritional deficiences forced attention toward food crops. Experimental work on mechanized grain production in Sudan began in 1945 (Holt and Daly, 1979). Research on food crops started in 1952 (Riley, 1981). Unlike most previous research, this research focused on rain-fed agriculture.

In 1967 the status of agricultural research within the Ministry of Agriculture was upgraded by the creation of a semi-autonomous Agricultural Research Corporation (ARC). In 1977 already existing research functions in the areas of food processing, forestry, fisheries, range management, and wildlife were incorporated into the ARC. More recently, with the

establishment of the Western Sudan Agricultural Research Project[1], a major stride has been taken toward the eventual improvement of rain-fed agriculture and livestock production in the west and the integration of social and economic scientists into the organization. Today, the ARC conducts research in all areas of agriculture broadly defined, with the exception of livestock research. That function is served by the Animal Production Research Administration and is beyond the scope of this report.

The Agricultural Situation

Sub-saharan Africa is one area of the world in which food production has not kept pace with population growth over the last decade. Sudan is no exception to this rule. Total agricultural production has remained constant over the last decade while total food production has increased slightly. However, due to population increases, per capita agricultural and food production have both declined considerably over the decade (Table 1.1). This is of particular concern when one examines the very significant increase in irrigated land during that period. Moreover, cotton production, the mainstay of Sudanese agriculture, has declined significantly in recent years due in part to increased insect resistence to insecticides.

Concomitantly, the Sudanese economy has fallen into serious difficulties largely as a result of increased oil prices. Given the enormous size of Sudan and the great distances between ports of entry and

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[1] WSARP is a large recently established project. It is financed by USAID and the World Bank. It will result in the creation of a number of experiment stations in the previously underserved western Sudan. It is administered separately by an assistant director who is directly responsible to the Director-General of the ARC.

TABLE 1.1
Selected Indexes of Agricultural Production, Sudan and Africa, 1971-1980

Index		YEAR 1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Index of Total agricultural production (1969-71=100)	Sudan	105	100	99	98	104	89	101	113	91	96
	Africa[a]	102	104	101	106	107	108	106	109	109	111
Index of Total food production (1969-71=100)	Sudan	106	100	98	99	108	104	115	124	105	110
	Africa[a]	103	103	101	106	107	109	107	110	110	112
Index of per capita agr. production (1969-71=100)	Sudan	102	94	91	87	90	74	82	89	70	71
Index of per capita food production (1969-71=100)	Sudan	103	94	90	88	93	87	93	97	81	82

Source: U.S. Department of Agriculture, 1981.

Notes: [a] excludes Egypt and South Africa

producing areas, transport costs have risen enormously over the last decade. In addition, balance of payments problems have led to deferred maintenance of the railroads and endemic oil fuel shortages.

The Agricultural Research Corporation has itself suffered significantly as a result of the general economic situation. Fuel for ARC vehicles is often unavailable, making travel to outlying fields difficult if not impossible. Foreign exchange for journal subscriptions, scientific equipment, and spare parts for existing equipment is often unavailable. Even money budgeted for capital expenditures is often withdrawn due to serious fiscal problems. At the same time significant numbers of newly trained scientists have been returning from overseas putting more pressure on an already over-extended research system. Finally, salaries have not kept pace with inflation. These circumstances have weakened the effectiveness of the ARC and led many researchers to consider professional opportunities outside the Sudan.

CHAPTER 2

SCIENTISTS: THE HUMAN RESOURCE

It has been posited that "human resources are the basic determinants of the rate of development of science, technology and social institutions" (Harmon, 1965:iii). These human resources, in the form of scientists, technicians, and research associates, provide the expertise and knowledge for scientific development. An understanding of the research enterprise in the Sudan Agricultural Research Corporation (ARC), its operations, capacities and needs and its ability to respond effectively to new challenges requires an examination of the scientists themselves. This section presents a review of the growth of the Sudan agricultural research community as well as a demographic overview of the contemporary population of agricultural scientists in the ARC.

Agricultural Scientists Worldwide

The agricultural scientific enterprise has grown dramatically during the twentieth century. This rapid growth has paralleled the great increase in scientists around the world. Indeed, it has been estimated that 90% of all scientists who ever lived are alive today. The 1981 Statistical Yearbook edited by UNESCO (1981) reported about 3.7 million scientists in 85 countries in research and experimental development.

The growth in agricultural scientists has been particularly dramatic in the developed countries. In the U.S. for example there were only 136 doctorates awarded in the agricultural sciences between 1920-1929. In the 1950's the number of doctorates being awarded yearly was over 300 and during

the 1970's, over 1,000 doctorates in the agricultural sciences were awarded yearly. By 1974 a total of over 16,000 doctorates had been awarded in the agricultural sciences (Harmon, 1978). Recent figures on U.S. agricultural research indicated there were 11,551 scientist-years devoted to public sector research in 1981 (USDA, Science and Education Administration, 1982).

This growth in the training of agricultural scientists in the developed countries has had an impact on agricultural science in Third World countries. An increasing number of third world agricultural scientists are among those scientists receiving doctorates in the U.S. and Western Europe. For example, in the U.S. 18% of the total doctorates awarded between 1965 and 1968 were to foreign citizens. In the agricultural sciences, however, foreign scientists received 37% (632) of the doctorates (National Academy of Sciences, 1971). Furthermore, most of the foreign students in the agricultural sciences were from Third World countries. Recent figures suggest that this trend in training of foreign agricultural scientists has continued to the present and may have increased.

Concomitant with the increase in the number of trained agricultural scientists has been the growth in the agricultural research systems of Third World countries. During the 1970's substantial real growth occurred in many national agricultural research systems with a number of countries maintaining annual growth rates exceeding 10 percent in number of scientists and/or research expenditures. In 1980 the number of agricultural scientists in 76 third world countries was 36,000, a rise of 38% in five years. Total research expenditures for these countries was U.S. $890 million, a rise of 71% during the same period. However, the growth has been uneven. Forty-six percent of the scientists and 62% of the research expenditures among the 51

developing market economy countries for which data were available (including Sudan) were concentrated in only five countries: Brazil, Argentina, India, Nigeria, and Mexico. Eighty-six percent of the scientists and 88% of the expenditures were in 15 countries which include the African nations of Nigeria and Kenya (Oram and Bindlish, 1981). According to a recent report by Oram and Bindlish (1981), Africa, especially the semi-arid sub-Saharan tropics, and the Central American-Caribbean region are the least well-equipped in numbers of scientists both in relation to population as well as in absolute terms. However, there are a considerable number of countries outside the top 15 with a scientific community in excess of 100 including Senegal, Sudan, Ghana, Tanzania, and Zambia.

Sudan's Agricultural Scientists and Support Staff

The growth in the Sudan's agricultural research system has been substantial since its modest beginning in 1902. Early research stations and laboratories such as the Welcome Laboratories (1903), Shambat Unit (1904), and the Gezira Research Station (1918) were staffed initially by British scientists and were devoted almost exclusively to export crops. After World War II there were widespread development efforts by the British which included the building of research and extension programs in former colonies and other parts of the developing world. By 1950 Sudan's agricultural research system included fifty-five scientist-years (Evenson and Kislev, 1971). The number of scientists showed little or no change for the next decade and a half. By 1967 there were still only 52 scientist-years committed to agricultural research in Sudan (Cooper, 1970). However, within the next three years the number of scientist years had more than doubled to 121, distributed as follows (UNESCO, 1970):

Agricultural Research Corporation	80
Ministry of Animal Resources,	
Veterinary Research Division	17
University of Khartoum	24

This number continued to increase during the 1970's, reaching 175 by 1975 and 212 by 1980 (Oram and Bindlish, 1981).

The Agricultural Research Corporation accounts for approximately two thirds of Sudan's agricultural research scientist-years. This is likely to increase if the ARC retains most of the scientists currently working in the system and incorporates most of the ARC assistant scientists and scientists currently being trained abroad. The ARC's List of Research Scientists and Senior Administrators (1980) revealed that in October 1979, 123 scientists and 38 assistant scientists were working at ARC research facilities in the Sudan. In addition, there were 33 scientists and 82 assistant scientists pursuing graduate training abroad. Finally there were thirteen ARC scientists on secondment to other organizations such as the Food and Agricultural Organization of the United Nations (FAO), International Center for Agricultural Research in Dry Areas (ICARDA), the University of Gezira, and International Development Research Centre (IDRC).

A recent report of the ARC entitled The Rehabilitation of the Agricultural Research Corporation of the Democratic Republic of Sudan (ARC, 1981) estimated that the scientific staff consisted of 164 scientists and 139 assistant scientists (including the 85 abroad for training). In addition there were 625 technical assistants, 400 clerical and support staff and nearly 4,000 laborers.

The annual growth rate of Sudan's agricultural scientific staff for the period 1970 to 1980 was 5.5% while the average for 41 third world countries with available data was 6.1%. Sudan ranked 22nd among these 41 nations. Comparisons with other African and Middle Eastern nations are reported in Table 2.1.

TABLE 2.1
Annual Growth Rate of Agricultural Scientific Staff in African and Middle Eastern Nations, 1970-1980

Country	Annual Growth Rate
Togo	20.7%
Nigeria	17.3%
Tanzania	11.3%
Syria	9.7%
Senegal	8.2%
Kenya	6.5%
Sudan	**5.5%**
Jordan	4.9%
Zaire	4.9%
Burundi	4.5%
Zambia	3.4%
Madagascar	-.6%

Source: Oram and Bindlish, 1981

With respect to scientific support staff, the situation in Sudan appears to be better than that of most developing countries. Although while less than half (47%) of the 64 developing countries with available data have at least one research technician per scientist, Sudan has a technician to scientist ratio of more than 2:1 (Oram and Bindlish, 1981, 2.6:1). This ranked Sudan 5th among these 64 countries, with only Nigeria (7.4:1), Ghana (2.7:1), Swaziland (2.7:1) and Malaysia (3.6:1) having higher ratios. However, when contrasted with developed countries like the U.S. where the ratio is 5.1:1[2], it is clear that nearly all developing countries need to increase scientific support staff.

In our 1982 sample of Sudan researchers, scientists reported an average of 2.3 technicians, 7.8 laborers, and 1.1 other persons working under their direction. While these figures appear quite satisfactory, many scientists pointed out that both technicians and field staff were often shared by large groups of scientists. In addition, declining budgets and demands of production schemes have made it extraordinarily difficult for the ARC to compete for farm labor during the peak planting and harvesting times. As a result, many scientists reported that experimental plots were not harvested on time or at all. This is clearly a waste of both money and trained scientific personnel.

Growth in Sudan's expenditures for agricultural research has also been substantial over this period. By 1961, expenditures in U.S. dollars for the ARC were $1.2 million (S £ 384,000). Boyce and Evenson (1975) estimate that the ARC accounted for about 70% of Sudan's agricultural research expenditures. Five years later the ARC annual expenditures had more than

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[2] 5.1 includes 2.6 graduate students, 0.2 postdoctorates, 1.5 technicians, and 0.8 other staff (Busch and Lacy, 1983).

doubled to U.S. $2.8 million (S £ 897,000). By 1971, expenditures had increased another 60% to U.S. $4.5 million (S £ 1,422,000). More recent research expenditures figures for Sudan as a whole, illustrate similar trends. From $4.5 million in 1970 (calculated in constant 1975 U.S. dollars) expenditures rose gradually to approximately $6.3 million by 1975 and increased another 50% to $9.6 million in 1980 (Oram and Bindlish, 1981:79). Oram and Bindlish note that in recent years expenditures seem to have increased more slowly in sub-Saharan Africa than in 76 other Third World countries which experienced a 94% rise in expenditures between 1975 and 1980. Sudan's growth rate of expenditures between 1970-1980 was 8.0% per annum. Among 41 developing countries for which data was available, Sudan was 18th in growth of expenditures. If one examines the 12 low income developing countries grouped by per capita GNP level, Sudan was still 5th in growth of expenditures behind Bangladesh, 37.0%; Burundi, 18.9%, Kenya, 27.4%; and Togo, 8.8%. Finally, Sudan's research expenditures as a percent of agricultural gross domestic product over this period was .57, 16th among the 41 developing countries, while its growth rate of agricultural gross domestic product was 2.7%, 19th among these countries. From these figures it is clear that the Sudan agricultural research system is about average in terms of growth among the developing countries.

Despite the growth in agricultural research staff and expenditures in Sudan and other developing countries, Oram and Bindlish (1981:9) note "even to approach parity with the scientifically advanced countries would require 1980 expenditures to be increased 2 1/2 times overall, and scientists numbers more than threefold." They observe that in many countries there is little understanding of the level of resources that may be required for

effective agricultural research programs. They point out that even the better equipped research systems have serious gaps in staff, support services, and management. Results cannot be expected instantaneously and successful research requires both time and stability. Oram and Bindlish conclude that increases are needed in support of agricultural research and the training of scientists and that cutbacks would be self-defeating.

The Joint Team report (1977) reiterated these needs for future scientific manpower in the Sudan. Their recommendations suggested priority attention for substantial increases in the number of scientists to about 700 within the next 12 to 15 years (about 1990). They also recommended the number of technicans be increased to about 1500. Finally, a recent ARC report (1981) emphasized that the initial investment in human resources and equipment will be wasted unless there is continued investment in scientific training and a complete rehabilitation of the agricultural research system. The rehabilitation costs are estimated at S £ 28.5 million entailing about a 60% increase in the total annual budget. This report concludes that there are no shortcuts to building a viable and efficient research system and to raising agricultural productivity.

Demographic Characteristics

Given the growth in the number of agricultural scientists, as well as the recommendations for continued growth, it is surprising that so little attention has been directed to exploring who these scientists are, what they do and what they think. The remainder of this chapter will be devoted to examining the demographic characteristics, family background, education, and nature of the work of agricultural researchers in Sudan's Agricultural Research Corporation. The data reported here are based primarily on

interviews with 71 Sudanese scientists conducted in Sudan during February and March 1982 and a mail survey of Sudanese students studying agricultural science in the United States during fall 1982 and spring 1983 (see Methodological Appendix).

Sex. An examination of the demographic characteristics of Sudanese agricultural scientists reveals that generally women remain underrepresented in these jobs. In the ARC's list of research scientists on October 1979 (1980) there were four women scientists among 123 (3.3%) and two women assistant scientists among 38 (5.2%). Five of these six women scientists were in research stations recently transferred to the ARC (Food Research Center, Forestry, and Wildlife). Women were a slightly larger percentage of the scientists and assistant scientists on study courses. Here 11 of the 82 (13.4%) assistant scientists and 1 of the 33 (3.3%) scientists were women. Again there was a strong tendency for the women scientists to be in areas such as Food Research where six women were involved in courses. Additionally, women were more likely to be engaged in study courses at the University of Khartoum (approximately 50%), while less than 5% of the males were receiving training in Sudan. In our survey, five of the interviewed scientists were women, a slightly higher percentage than the earlier figures (7.4%). Once again the women were in the Food Research Center, the Fisheries Center, and the Forestry Research Center. In addition, there were no women in the sample of Sudanese agricultural scientists studying in the United States.

The sex distribution among Sudanese scientists is similar to patterns we reported among U.S. agricultural scientists. In our sample of U.S. public sector agricultural scientists in 1979, a little more than 4% were

female. Similarly, the women were concentrated in nutrition (41%), social sciences (19%) and food science (10%) (Busch and Lacy, 1983).

Age. The average age of scientists in our Sudan sample was 39 years with an age range of 29 to 52. Since we oversampled scientists in Wad Medani and Khartoum where older scientists tend to be stationed, the actual mean age may be less than 39. Not surprisingly, the average age of our sample of Sudanese scientists studying in the U.S. was about 5 years younger than the scientists on site (34.4). Consequently, the average will likely decrease slightly with the influx of these new scientists.

An unanswered question concerns possible consequences of age for the scientific enterprise. Do younger scientists accept new scientific ideas with greater alacrity than older scientists, as some research has suggested (Hull et al., 1978)? If so, how can Sudan fully utilize its relatively youthful and recently educated scientific community? Can the younger scientists be challenged and exposed to new ideas and scientific developments if travel money, communication, and access to literature are limited, particularly for scientists at remote stations? These and other possible consequences of demographic characteristics of scientists on the products and processes of science need to be addressed.

Family Background

Another important question to address is the family origins of agricultural scientists. The occupation of fathers of scientists was utilized as an indicator of family origin. The family background of our sample reflects very diverse family experiences (Table 2.2). While approximately a quarter of the scientists came from a farmer-owner family background, a fifth of the scientists had fathers who were businessmen or

merchants and another sixth of the scientists had fathers who were government employees. In addition, about a fifth of the scientists came from a labor background. Given the large percentage of the population of Sudan that remains on the farm and the nature of the research in the ARC, it is perhaps surprising that such a small percentage of scientists come from a farm background.

TABLE 2.2
Father's Occupation when Scientist was 16 years old:

Father's Occupation	Scientists' Responses Frequency	Percent
Farmer-owner	19	26.7
Business-merchant	14	19.7
Government	12	16.9
Skilled Labor	9	12.7
Laborer	5	7.0
Farmer-Tenant	5	7.0
Education	3	4.2
Other	3	4.2
Religious Leader	1	1.4
	71	100

The family background pattern of Sudan scientists is in contrast to U.S. scientists particularly those in agronomy, animal science, agricultural engineering and agricultural economics. In these disciplines over half of the scientists came from a farm background despite a U.S. farm population of less than 4% of total population. This farm family background was significantly associated with scientists' greater concern with the utility

of their research, with client needs and demands, and with feedback from extension staff. Those scientists with other family backgrounds were more likely to be committed to scientific ideals and the potential contribution of their research to scientific theory (Busch and Lacy, 1983).

These associations between family background and research orientation raise some unanswered questions for Sudanese agricultural science. Do scientists from a farm background consciously integrate their research with their earlier farm experience? Are these scientists more aware of the needs and experiences of the farm sector and, therefore, more likely to consider these factors important in their research?

Education

The extent of education of agricultural scientists has increased worldwide with each generation. In the U.S. the percent of all agricultural scientists in 1976 in both the public and private sectors with bachelor's, master's and doctoral degrees as the highest degree earned were 54, 20 and 25.8%, respectively. In a more selective sample of currently active public sector agricultural researchers, more than 92% had received the doctoral degree. Among the thirteen agricultural disciplines, only two, forestry (81%) and agricultural engineering (63%), had fewer than 90% with doctorates (Busch and Lacy, 1983).

Information on levels of agricultural scientific education among third world countries was available for only 32 countries (including five African nations). These countries encompassed a scientific staff of around 20,000. Among those countries just under 9% of the scientists had a Ph.D. as their highest degree earned with 27% at the masters of science and about 64% at

the bachelor of science or equivalent level (Oram and Bindlish, 1981). The 36% at a post graduate level represents an improvement from the past but the Ph.D. component is well below the target of 20% suggested in the World Bank sector policy paper. Despite upward trends in the extent of scientific education among scientists, in several Third World countries, about 40% of the countries for which data was available had 5% or fewer of their scientists with Ph.D. degrees. Many countries still rely heavily on bachelor level staff as the heart and foundation of their agricultural research system.

The four African countries for which data were available on levels of scientific training (Kenya, Nigeria, Madagascar, and Sudan) have on average a much higher proportion of post-graduate staff than Asian or Latin American countries. These four nations reported 27% of their scientists with a Ph.D. as their highest degree and 37% at the masters of science level. As noted earlier, Kenya, Nigeria, and Sudan also have relatively large scientific staffs, whereas in most other African countries, there is a severe shortage of trained local persons. According to Oram and Bindlish (1981) Sudan's 1980 distribution of scientists engaged in agricultural research by qualifications (includes ARC, Agricultural Economics, and Livestock) is as follows: 65 Ph.D. (23.8%), 123 M.Sc. (44.7%) and 84 B.Sc. or equivalent (31.5%). The percentage of Ph.D. staff in Sudan is only slightly lower than Kenya's (30.8%) and Nigeria's (30.7%).

Within the ARC, an examination of the formal training of scientists and assistant scientists currently working in the system as of October 1979 (ARC, 1980) reveals a much higher proportion of Ph.D.s on the staff. Of the total 161 scientific staff, 81 had received a Ph.D. This percentage is even

higher (65%) if one excludes the assistant scientists. In addition, twelve of the thirteen ARC scientists on secondment at that time also had received their Ph.D. degrees.

Not surprisingly, a majority of the education at the masters level and nearly all at the Ph.D. level was received at universities in Great Britian and the United States. Indeed, 96% of the Ph.D. degrees awarded to Sudanese scientists were received at institutions in those two countries. The training is equally divided between the two nations with 39 scientists receiving their Ph.D. degrees in the U.S. and 38 in Great Britain. This important role of Great Britain and the U.S. in Ph.D. training is also reflected in our 1982 survey of 71 ARC scientists, forty-six (65%) of whom had received their Ph.D. degrees. Within this latter group fifty percent had obtained their doctorate from Great Britain and forty percent had been trained in the U.S.

Advanced training in some disciplines, however, is more likely to take place in a specific country. For example, Ph.D. degrees in entomology and in food science generally have been obtained in Great Britain. The placement of assistant scientists in these disciplines in study courses, primarily in Great Britain, indicates this will continue in the near future. In contrast, Ph.D. training in horticulture is primarily limited to the U.S. institutions.

In addition, there appears to be a slight shift in terms of the location of Ph.D. training from Great Britain to the United States. The figures on scientists and assistant scientists on study courses in October 1979 indicated that 52 were in the U.S. while there were 34 in Great Britain

and 29 in other institutions, primarily the University of Khartoum. This shift is also suggested in the distribution of scientists on site. Eighteen of the forty scientists at Wad Medani (ARC Headquarters and Gezira Research Station) had received Ph.D. degrees from Great Britain while ten scientists located there had Ph.D. degrees from the U.S. The reverse pattern was the case for the other research stations. Since the senior scientists are more likely to have received their degrees earlier in time and to be located at Wad Medani, this pattern of British Ph.D.s at Wad Medani probably reflects the earlier heavier reliance on Great Britain for Ph.D. training.

Conclusion

This discussion of the human resources in agricultural research worldwide and in the Sudan suggests that one of the strongest dimensions of the ARC is its community of well-trained scientists. In addition, there appears to be a positive ratio of technicians to scientists relative to other Third World countries. However, a number of additional issues should be addressed regarding human resources for agricultural research in the Sudan.

An important issue is the distribution of scientists within the country. In several developing countries national research is highly fragmented among many ministries and organizations. This fragmentation, as opposed to planned dispersion, makes effective planning and resource allocation, as well as the avoidance of unnecessary duplication, difficult if not impossible. Sudan has taken the first steps to address this by bringing together within the Agricultural Research Corporation, the Food Research Center, Fisheries Research Center, Forestry Research Center, and Wildlife Research Section. These efforts need to be continued.

An equally important issue regarding the distribution of scientists involves the dispersion of resources in an attempt to meet local socio-economic situations, special environments, or particular commodity needs. The organization of the Sudan ARC, with its 1) ten regional stations serving defined ecological zones; 2) commodity stations such as the Guneid Sugar Cane Research Station and Gum Arabic Research Station; 3) various sections and specialized centers such as the Food Research Center, Forestry Research Center, and Fisheries Research Center; and 4) a number of testing sites, suggests that a number of stations may lack funding and a critical mass of staff necessary for the effective conduct of research. Oram and Bindlish (1981:49) note that "the problem of trying to be all things to all people is probably most severe in countries with a wide environmental range, including some such as India, Thailand, China, Ghana, Nigeria, Turkey, Sudan, Mexico and Brazil, which cut across ecological zones due to size...." These problems arising from dispersion of scientists are not easy to overcome. However, Sudan needs to review their establishment regularly to determine whether and where to consolidate human resources most effectively.

As noted, the size of Sudan's agricultural scientific manpower, although not optimal, has certainly reached a critical mass in numbers of staff. As levels of training of staff improve, management will become a main determinant of their effectiveness. The agricultural research community must compete for funds in the overall budget. Therefore, some scientific personnel should receive training in research management. These managers must be able to demonstrate to policy makers, where appropriate, that agricultural research funds will be effective in achieving national objectives and priorities. Agricultural research managers have to convince

planners of the worth of their research programs, as well as communicate regularly with those in government who give direction to the national economy, direct related activities, and manage the budgets. In addition, they must maintain effective contact with their own scientists and staff.

The relationship between scientists and other staff components in the broader agricultural system must also be examined. When scientsts are not properly complemented in their activities by support staff, either internal to the research system such as necessary labor for field research, or external to the research system such as adequate personnel in national seed distribution or extension services, they may not be as effective. Furthermore, their efforts and activities may be diverted from research to other tangential duties. Finally, their results are not likely to reach their intended audiences.

The issue of recurrent funding needs and its relationship to scientific staff is another important theme throughout this report. Most recurrent expenditures appear to be for salaries for current staff. With inflation and increasing numbers of scientists returning from training, a continual erosion of operating budgets appears likely. Consequently, although Sudan has reached a critical mass of scientists, little remains for operations. This not only leads to a high degree of inefficiency in the use of this valued resource of trained scientists; it also contributes to high levels of frustration among the scientists themselves. To some extent, foreign donors contribute to this plight since a number are hesitant to finance recurrent expenditures or even impose an absolute sanction on such support. Ironically, gains from capital investment depend on the effective

utilization and retention of trained human resources. As Pineiro and Trigo (1981) observe in their study of Latin American agricultural research, "professional staff in general are not being used effectively and one important reason is the lack of budgetary support for operational costs. There is a limit to the number of investigations that can be properly supported, and new ones should not be added unless there is a firm commitment to provide the budget needed to support them." In short, training and staff development should be matched to the provision of recurrent funds and capital investment.

Finally, the training of scientists and technicians should be congruent with the overall needs and priorities of Sudan. The relative balance and share of human resources devoted to export and/or cash crops as opposed to food crops for national consumption is one example of an area requiring further analysis. The nature and balance among various disciplines is another area that needs reassessment regularly to determine particular weaknesses. The Western Sudan Agricultural Research Project, for example, appears to be filling gaps in the relatively weak areas of pasture management, animal husbandry, social sciences, and economics. However, no one project is sufficient. The process of training scientists and other human resources requires a constant review of the strengths and weaknesses of the research system and the relevance of this system to national priorities.

CHAPTER 3

THE CURRENT SITUATION

The description of the current situation in the Agricultural Research Corporation (ARC) is based primarily on the responses and perceptions of our 1982 sample of scientists in the system. Where appropriate these responses are contrasted with those of Sudanese students currently enrolled in graduate agricultural programs in the U.S. in 1982-1983 and with those of U.S. agricultural scientists.

Research Orientation

Scientists in the ARC are strongly oriented towards applied research. When asked how they would categorize their research over the last five years in terms of basic science, applied science, and development, their strong applied orientation became apparent. ARC scientists classify 83% of their research as being applied while U.S. scientists classify only 55% in that category. Conversely, while ARC scientists see 12.7% of their research as basic, U.S. scientists see 30% as basic research. Development plays a minor role in ARC research, due in part to the relatively small number of engineers employed there. Given the kinds of resources available to ARC scientists and the research needs of Sudan, this appears to be an appropriate division of effort.

Research Sites

Researchers were also asked where their research took place. On average, scientists reported that 55.9% of their research took place in experiment station fields, while 32.9% of their research took place in the

laboratory. Only 3.2% of research was conducted in farmers' fields. This strong emphasis upon field work reflects the applied orientation of the ARC scientists. However, the low percentage of research taking place in farmers' fields should not been seen as an indication of an unwillingness on the part of scientists to conduct research there; rather, many scientists expressed frustration over the lack of adequate transportation and the relatively weak institutional ties that would permit on-farm experiments. In addition, scientists whose research required greenhouse work strongly voiced their frustration over the lack of such facilities.

Resources: Adequacy and Importance

Various resources are necessary to the research process. These range from transportation to opportunities for advancement. Using a series of items adopted from Hargrove (1978), scientists rated the adequacy of resources available to them at the ARC on a scale from 1 (very adequate) to 5 (very inadequate). Then, they rated each item regarding its importance for the success of their work (Table 3.1).

The availability of experimental land was seen as the most adequate resource followed by personal freedom to determine research problems. On the other hand, equipment and tools to use in research, and financial support were seen as the most inadequate research resources. Transportation, availability and quality of trained technical help, and opportunities for advanced education were also seen as inadequate.

TABLE 3.1
Sudanese Agricultural Scientists' Ratings of Adequacy and Importance of Resource Facilities

Resource	Adequacy of Resources[a]	Importance of Resources[b]	Difference Between Importance and Adequacy
Operating Supplies and Materials	3.6	1.2	-2.4
Availability of Experimental Land	1.7	1.5	-.2
Equipment and Tools to Use in Research	4.0	1.3	-2.7
Transportation	3.8	1.3	-2.5
Availability and Quality of Labor	3.3	1.4	-1.9
Financial Support	4.1	1.1	-3.0
Scientific Literature	3.0	1.3	-1.7
Availability and Quality of Trained Technical Help	3.7	1.4	-2.3
Personal Freedom to Incorporate New Materials and Techniques into your Research	2.1	1.6	-.5
Personal Freedom to Determine Research Problems	1.9	1.6	-.3
Contact with Other Scientists	2.7	1.4	-1.3
Opportunities for Your Advanced Education	3.7	1.5	-2.2
Opportunities to Gain Scientific Recognition	3.2	1.4	-1.8
Opportunities for Professional Advancement	3.2	1.5	-1.7
Opportunities for Training for People who work Under You	3.7	1.5	-2.2
Average Mean Score	3.3	1.4	-1.9

[a] Mean score of 71 scientists--1 very adequate; 5 very inadequate

[b] Mean score of 71 scientists--1 very important; 5 very unimportant

While the perceived adequacy of resources differed significantly, scientists viewed most of those resources as very important to their work. Scientists saw financial support and operating supplies and materials as the two most important resources in their work but ranked all resources as important. Furthermore, the discrepancy between adequacy and importance is quite large for many of the resources.

Mean scores concealed considerable age differences on several items. The median age of our sample was 42 years. Scientists over 42 years of age found transportation less adequate and scientific literature and trained technical help more adequate than did their younger colleagues (Table 3.2).

TABLE 3.2
Adequacy and Importance of Selected Items by Age Group[a]

	Mean Scores by Age Group	
	Less than 42	Greater than or equal to 42
Adequacy		
Transportation	3.4	4.2*
Scientific Literature	3.4	2.6*
Availability and quality of trained technical help	4.0	3.3*
Importance		
Scientific Literature	1.1	1.6*
Opportunities for your advanced education	1.3	1.7*

[a] 1 very adequate; very important -- 5 very inadequate; very unimportant.
* Differences significant $p < .05$.

This suggests that 1) transport problems are felt more acutely by older scientists, 2) the locally available literature base is probably geared toward those subject and disciplinary areas that are well-established, and 3) older scientists have somewhat greater access to trained technical help.

With regard to the importance of various resources, age differences were observed on only two items: "scientific literature" and "opportunities for your advanced education." In both cases, younger scientists saw these items as more important than their older colleagues.

Perceptions of Sudanese Students in the United States

Sudanese students presently enrolled in Ph.D. programs in the United States also rated the various resources available to them at their host institutions in terms of adequacy and importance for their work (Table 3.3). Scientific literature, personal freedom to incorporate new materials and techniques, personal freedom to determine research problems, and transportation were the most adequate resources. While these four resources received the highest adequacy ratings, there was virtually no difference between this group of variables and the remaining resources. The range was from 1.4 to 2.2 and thus all were considered to be adequate to very adequate. The only exception to the high adequacy ratings was availability and quality of labor resources.

With regard to the importance of various resources, scientific literature, equipment and tools, opportunities for advanced education, and personal freedom to incorporate materials and techniques into research were considered to be the most important resources. While these resources were rated slightly higher than the remaining resources, all resources were considered to be very important.

TABLE 3.3
Ratings of Adequacy and Importance of Resource Facilities by Sudanese Students in the United States

Resource	Adequacy of Resources[a]	Importance of Resoures[b]	Difference Between Importance and Adequacy
Operating Supplies and Materials	2.1	1.9	-.2
Availability of Experimental Land	2.2	2.6	+.4
Equipment and Tools to Use in Research	1.8	1.7	-.1
Transportation	1.6	2.4	+.8
Availability and Quality of Labor	3.1	2.3	-.8
Financial Support	2.2	1.8	-.4
Scientific Literature	1.4	1.6	+.2
Availability and Quality of Trained Technical Help	2.2	1.9	-.3
Personal Freedom to Incorporate New Materials and Techniques into your Research	1.5	1.7	+.2
Personal Freedom to Determine Research Problems	1.6	1.9	+.3
Contact with Other Scientists	2.0	1.8	-.2
Opportunities for Your Advanced Education	1.9	1.7	-.2
Opportunities to Gain Scientific Recognition	2.1	1.8	-.3
Opportunities for Professional Advancement	1.8	1.9	+.1
Opportunities for Training for People who Work Under Your Direction	2.2	2.3	+.1
Average Mean Score	2.0	1.9	

[a] Mean score of 25 students--1 very adequate; 5 very inadequate

[b] Mean score of 25 students--1 very important; 5 very unimportant

In comparing the mean scores of students' ratings on adequacy and importance of the various resources, there is relatively no difference. None of the resource ratings differed by more than 1 point. All the resources were considered both adequate and important with the exception of availability and quality of trained help.

Not surprisingly, the Sudanese students, all of whom are enrolled in major land-grant and agricultural schools in the United States, considered their institutional resources to be significantly more adequate than did the ARC scientists on site in the Sudan. The students rated every resource, with the exception of availability of experimental land, more adequate than did the Sudanese scientists.

These findings are generally consistent with those found among Asian rice breeders (Hargrove, 1978), U.S. scientists (Busch and Lacy; 1983), and sorghum scientists (Marcotte, Busch, and Lacy; 1983). Sudanese scientists and scientists from other less developed countries agree with scientists from the U.S. and from other developed countries as to what is important with respect to resources, but are laboring under considerably less adequate conditions in the conduct of research.

Extramural Support and Collaboration

It is to the credit of scientists at the ARC that they have not utilized the current fiscal problems as an excuse for abandoning a meaningful research program. Our study reveals that 50% of researchers have received financial support from organizations other than their employer during the last five years. Organizations supplying that financial support included the Food and Agriculture Organization of the United Nations, various national foreign aid agencies, and the Sudan National Council for

Research. Support has ranged from the provision of small pieces of equipment or subscriptions to scientific journals to the provision of entire laboratories and research stations. Despite the large numbers of highly trained scientists employed by the ARC, however, many aid agencies continue to see financial support largely in terms of providing training for additional scientists or supplying expatriate scientists. Sudanese scientists and administrators rightly resent this and feel that aid could be better spent to provide adequate equipment and resources for the existing system. If the support does not improve, about a third of the Sudanese scientists expressed their intent to seek work in other countries where more adequate resources, support and salaries are provided.

Most research efforts within the ARC are conducted by groups of scientists rather than by single individuals. In fact, 73.8% of ARC scientists report working with other professionals in their research. While many of these individuals are other scientists within the system, ARC scientists report working with university faculty as well as scientists in other branches of the government. In many developing countries such interministerial relationships are virtually impossible to maintain. The ARC should be commended for encouraging scientists to cross boundaries to enhance effective research programs.

Career Advancement

A central feature of all organizations is a reward system that 1) provides a career ladder (or internal labor market) for employees, 2) provides monetary and/or non-monetary incentives to employees, and 3) encourages employees to support the goals of the organization. In most manufacturing organizations such reward systems are geared toward the

increased production of a standardized, homogeneous, concrete product. As such, incentive systems are relatively simple and are focused upon productivity-increasing behavior. In addition, career ladders tend to be quite short, with few positions that demand complex skills. Only a small number of persons are likely to be involved in management of the organization.

Research institutions also are engaged in a production process. However, the products of research may be either abstract (e.g., farm management practices) or concrete (e.g., improved seeds). In addition, unlike manufactured goods, research products may take years to produce. Most importantly, the products of research are both heterogeneous and somewhat unpredictable. Occasionally research projects may fail to come to fruition through no fault of the scientist.

This poses difficult problems for the research administrator. A reward system must take into account the enormous diversity of research products as well as the differing frequency of production across disciplines. In addition, it must take into account the relevance of research products to the various clients of the research system. Finally, it must include some way of avoiding measures of scientific productivity and/or effectiveness that can be manipulated by the scientist. This has gradually become problematic in U.S. agricultural research where scientists have been rewarded for publishing articles in scientific journals. As a result, over the last two decades U.S. agricultural scientists have tripled their output of journal articles. Clearly, a corresponding increase in agricultural productivity did not occur.

Scientists in the ARC were asked what criteria they felt were important for advancement within their organization (Table 3.4). Publications were seen as the single most important criterion for advancement. Scientists further qualified this to mean largely the writing of annual reports. Years of service was seen as the second most important criterion while actual evaluation of research projects ranked third. Only one out of six scientists identified problem solving or meaningful research as a criterion for promotion.

TABLE 3.4
Criteria For Advancement

Criteria	Scientists' Responses	
	Number	Percent[a]
Publications	42	59.2
Years of Service	19	26.7
Evaluation of Research/Projects	16	22.5
Problem Solving	12	16.9
Meaningful Reserach	11	15.5
Education	7	9.9
Administrative Work	6	8.5
Fieldwork	3	4.2
Projects	3	4.2
Reputation	2	2.8
Willingness to go to Distant Stations	1	1.4
Personal ties	1	1.4

[a] Does not equal 100% because the scientists were requested to give up to three criteria.

These perceptions indicate serious discontinuity between the goals of the ARC and the system used to reward scientists. As with U.S. scientists,

there is little guarantee that publications will have an effect on client groups. Clearly, years of service with ARC is likely to be unrelated to any client needs. On the other hand, few scientists saw field work, or problem solving as important in career advancement. Thus, it appears that while the ARC does use objective criteria for advancement of scientists, these criteria do not have the effect of encouraging scientists to produce results that are useful to potential client groups. With relatively little effort and no additional expenditure, it might be possible to change the reward system in order to better direct research toward the needs of farmers and other clients.

Scientists' Future Career Plans

As noted above, the Sudan's proximity to the various oil producing countries of the Middle East as well as the common language it shares with those countries puts the Sudan in a particularly difficult situation with regard to maintaining an adequate supply of trained scientists. Salaries for doctoral scientists in Saudi Arabia and other Arab countries often surpass those of ARC scientists by a factor of 5 to 10. Clearly, no salary adjustments are likely to be possible in the foreseeable future that would eliminate this differential. This makes some assessment of the future career plans of scientific staff essential for predicting the staffing problems which the ARC may encounter over the next decade.

When asked what type of work they would like to be doing in 10 years, 82% of ARC scientists saw research as their first choice. An additional 11% saw teaching as their choice, while 5% wished to enter administrative positions in agriculture and 2% wished to enter an extension role. These

data reflect the strong commitment to research that we encountered in the interview process.

Scientists were also asked in what type of organization they would prefer to be working in 10 years. Here, we found that 35% desired to work for a government research organization such as the ARC while 40% preferred to work for a non-profit international research organization. In addition, 6% preferred to work at an agricultural college, 5% for a private corporation and 2% for the extension service. At first glance these data suggest that the ARC might be in danger of losing more than half its scientific staff. However, this is rather unlikely. Specifically, it should be noted that job openings in non-profit, international organizations would be unlikely to accommodate more than a few scientists. Few scientists expressed a strong interest in moving to other types of organizations.

Conclusion

In conclusion the current situation in the ARC combines potential and opportunity with frustration and inadequacies. The current scientific staff is well trained and generally highly committed to do applied research in agriculture. They will soon be augmented by additional colleagues being trained overseas. However, the facilities, supplies and other research resources are sorely inadequate even for the present staff. Without infusion of adequate financial support these human resources will be underutilized and potentially lost from the system entirely by a large scale exodus.

CHAPTER 4

SCIENTIFIC COMMUNICATION

Unlike other production processes, the production of scientific knowledge is intimately bound-up with the continuous exchange of scientific information. In fact, "without communication there would be no science" (Abelson, 1980). The centrality of communications to science becomes apparent when one considers the many ways in which the scientific enterprise can go astray. Scientists who are isolated from other members of the scientific community may work on problems that have already been solved or may employ approaches already shown to be inadequate. Scientists isolated from clients may produce results that are scientifically valid yet useless to clients. Scientists isolated from their disciplinary communities may employ out-dated methods and reach erroneous conclusions. In short, without frequent, prolonged social interaction, the scientific enterprise rapidly begins to crumble.

This raises particularly difficult problems for agricultural scientists in developing countries. Indeed, one aspect of underdevelopment is the lack of a communications infrastructure. In addition, an enormous diversity of agroclimatic zones often necessitates that scientists be located in remote areas lacking modern communications. This can result in the establishment of one-person experiment stations scattered around the country.

Fortunately, one-person stations are not the case in Sudan. However, several stations may lack a critical mass of scientists and staff. Consequently some scientist at remote stations may lack adequate

communication facilities to contact colleagues at other stations and adequate access to formal channels of scientific communication such as journals due to minimal library facilities and journal subscriptions. Additionally, the size of the Sudan coupled with transportation limitations have placed real and sometimes severe limitations upon scientists' abilities to meet and communicate with each other.

Scientific communication may be formal or informal. Formal communication includes various written sources, such as journal articles, books and book chapters, technical reports and bulletins, abstracts, and preprints. It may also include the reading and exchange of papers at professional meetings. Informal channels are usually oral and include face to face conversations, telephone exchanges, visits to colleagues' laboratories, and personal correspondence. These types of communications differ in some important ways. Formal communication is public, with large potential audiences, permanently stored and retrievable, primarily user selected, moderately redundant, relatively dated even when first published, and likely to provide little direct feedback to the author or originator. In contrast, informal communication is usually private, with a restricted audience, typically neither permanently stored nor retrievable, relatively timely, current, and likely to afford considerable feedback to the originator (Lacy and Busch, 1983). These two forms of communication should be considered as interdependent and complementary sources of information.

How, then, do scientists in the ARC receive scientific information and keep abreast of current scientific developments? Not surprisingly, regular scanning of journals in their field and personal contact with colleagues were seen as the two most important ways of keeping current in their field.

In contrast, travel and scanning of publications other than journals were of little importance to ARC scientists (Table 4.1).

Although ARC scientists did not utilize travel as a major means of keeping abreast of scientific information, some Third World scientists do make frequent trips for scientific purposes. For example, Hargrove (1978)

TABLE 4.1
Scientists' Means of Remaining Informed of Current Scientific Developments

Means	Percent of Scientists
Regular scanning of journals	56
within discipline	46
outside discipline	20
foreign journals	50
Regular scanning of other publications	5
Attendence at scientific meetings	36
Personal contact with colleagues	45
in the department	35
in other institutes	37
in other countries	29
Regular scanning of indexes or abstracts	19
Sudan science abstracts	8
other	14
Requesting reprints	29
Preprints	14
Travel	11

in his study of Asian rice breeders noted that seventy-five percent of the breeders involved in the study averaged 2.8 trips in the 5 years immediately prior to the study. These trips were utilized mainly to attend non-degree training courses. These scientists averaged 1.7 courses attended (Hargrove, 1978).

Informal Communication

Informal communication plays a particularly important role in the life of ARC scientists. Forty-five percent of ARC scientists report conversing with their colleagues daily over scientific issues. This compares favorably with U.S. agricultural scientists who report communicating about their research with scientists in their own departments somewhat less than weekly. However, this high level of informal communication may be an attempt to compensate for the relatively limited opportunities to meet with colleagues at other stations or in other nations as well as the weak formal communication ties.

TABLE 4.2
Scientists' Frequency of Communication with Colleagues Regarding Scientific Issues

Communication Frequency	Scientific Responses	
	Number	Percent
Daily	24	45.3
Weekly	11	20.8
Monthly	11	20.8
Less than once a month	3	5.7
Other	4	7.5
TOTAL	53	100.0

Only 19 of the scientists interviewed reported that they usually attended scientific meetings. Tight budgets have forced the ARC to restrict domestic scientific travel while the lack of foreign exchange has made overseas travel nearly impossible. This lack of travel opportunities may be

particularly problematic in science. Studies have demonstrated that about 1/3 of the useful information gained from someone other than ones immediate circle of colleagues was volunteered in conversation even before the scientist was aware of the need for it. Without travel this type of exchange is unlikely to occur.

Formal Communication

Scientists were also asked whether they subscribed to any scientific journals. On the average, Sudan scientists subscribed to approximately 0.7 journals. Moreover, there were very few duplications in the list of journals. Subscriptions tended to be specific to discipline and personal interests. One reason for the low level of subscriptions to scientific journals was the difficulties described by many scientists in obtaining the necessary foreign exchange to subscribe to such journals. Many felt the required bureaucratic approvals did not warrant the effort.

Despite the limited number of journal subscriptions, over 50 scientists did report that they read other journals regularly. Among the journals most commonly read were the Agronomy Journal, Experimental Agriculture, Crop Science and Food Science and Technology. Fifty-six scientists said they read at least one journal regularly while 14 said they read as many as 5 journals on a regular basis. On average, each scientist read approximately 2 1/2 journals regularly.

The other side of the scientific communication process is the publication activities of individual scientists. The most common type of publication of scientific results among ARC scientists is the report. This supports the importance attached to annual reports in promotion decisions (Chapter 3). In addition, ARC scientists published an average of just

slightly above 1/2 a journal article over the last 3 years. Other types of scientific publications were relatively rare among ARC scientists (Table 4.3).

While publication activity is considered to be the primary criterion for advancement, and thus an important activity for the ARC scientists, the actual productivity is relatively low compared to U.S. scientists

TABLE 4.3
Types and Rates of Publications for Sudan and U.S. Scientists

Publications	Average Per Scientist[a] Sudan	U.S.
Domestic scientific journal articles	.54	6.70
Books	.01	.12
Book chapters	.04	.63
Abstracts	.10	3.76
Bulletins	.03	1.17
Reports	1.31	3.98

[a] Average per scientist for last 3 years.

publication patterns (Busch and Lacy, 1983) (Table 4.3). Even the publication averages for reports were considerably higher among the U.S. scientists. The ARC scientists' publication rates also were lower than the 38 Asian rice breeders, who averaged 4.8 articles per year (Hargrove, 1979). Additionally, while 76% of the ARC scientists did not publish journal articles, only 24% of the Asian rice breeders failed to publish journal articles.

When asked in what journals they had published, Experimental Agriculture and the Sudan Journal of Food Science and Technology were the two most frequently mentioned journals. However, when asked in what journals they would prefer to publish if assured of publication, all the respondents gave the names of American or British journals. Consequently the disciplinary orientation of the temperate zone appears to be the standard towards which scientists in the ARC aspire.

Conclusion

In sum, scientific communication in the ARC is restricted in several important ways. Scientists' access to journals is limited by their minimal financial resources and difficulty in obtaining foreign currency to purchase subscriptions. They are also often limited in access to journals due to small library holdings or lack of transportation to reach libraries. Despite this, ARC scientists read approximately 2 1/2 journals regularly. Access to fellow colleagues at other stations, institutions, or nations is also limited due to restricted travel opportunities and minimal telephone services. Effective agricultural research policy must address the importance of the scientific communication system, its integral relationship with the goals and products of agriculture and agricultural research, and the potential conflicts in the present system.

CHAPTER 5

GOALS AND BENEFICIARIES OF AGRICULTURAL RESEARCH

Research Goals

Agricultural research is, by definition, a goal oriented activity. This is implicit in its strong mission orientation. However, the particular goals utilized in a research program may differ markedly from program to program, discipline to discipline, and scientist to scientist. In addition, scientists' perceptions of research goals may differ significantly from those of administrators. In order to assess the relative importance of various research goals for scientists in the ARC, a list of 10 common research goals was utilized. These range from increasing agricultural productivity to improving the level of rural living. Scientists were asked to rank each of these 10 goals on a scale from 1 (of no importance) to 5 (of highest importance) in terms of their own research. Mean scores range from a high of 4.5 for increasing agricultural productivity to a low of 2.6 for improving of marketing efficiency. Importantly only one goal ranked below the mid-point of 3 on the 5 point scale (Table 5.1). This suggests that, unlike their counterparts in the United States, ARC scientists take a broad view of research goals in their own work. In fact, these scores may understate the differences, given the narrower range of disciplines present in the ARC.

Differences within ARC

In order to determine whether there were any differences in the ranking of research goals by groups of scientists within the ARC, the scientists

TABLE 5.1
Goals of Agricultural Research: Sudanese Agricultural Scientists and Students

Goals	Sudanese Scientists[a] Total (n=71)	1 (n=30)	2 (n=16)	3 (n=25)	Sudanese Students (n=25)
Increase Agricultural Productivity	4.5	4.6	5.0	3.9	4.7
Develop New Knowledge or Improved Methodology	4.3	4.2	4.1	4.6	4.6
Decrease Production Costs of Farm Products	3.9	4.0	4.1	3.7	3.8
Improve Level of Rural Living	3.6	3.3	3.1	4.2	4.6
Protection from Insects, Disease and other Hazards	3.6	3.4	3.7	3.8	4.3
Protect Consumer Health and Improve Nutrition	3.6	3.2	2.9	4.7	4.2
Promote Community Improvement	3.4	3.2	2.5	4.2	4.2
Expand Demand by Developing New Products or Enhancing Product Quality	3.4	3.0	2.9	4.3	3.9
Expand Export Markets	3.2	3.1	2.9	3.6	3.5
Improve Marketing Efficiency	2.6	2.4	2.2	3.2	3.5

[a] Group 1 agricultural scientists at Gezira and Shambat, Group 2 scientists at remote regional stations (Hudeiba, Kadugli, Kenaana, New Halfa, Rahad, Sennar and Yambio), Group 3 scientists at the commodity stations and specialized centers (Food Research Center, Forestry Research Center, Gum Arabic Research Station, Fisheries Research Center and Wildlife Research Section).

[b] Scale 1 to 5; 1 of no importance through 5 of highest importance.

were divided into 3 groups. The first group was composed of scientists at the Gezira and Shambat stations; the second group represented the other regional stations while the third group represented the commodity stations and specialized centers.

There is a considerable substantive difference in the ranking of research goals for these 3 groups. The production-oriented regional stations (groups 1 and 2) identified increasing agricultural production as their primary goal. All sixteen scientists working at the outlying regional stations (group 2) listed this goal as 5.0 on the importance scale. The scientists from group 3, the commodity stations and specialized centers, on the other hand, viewed consumer health and improved nutrition, development of new knowledge, new products, community improvement, and improvement of rural living, respectively, as being more important than increasing agricultural production. This is a direct reflection of the commodity and specialization orientation of the group 3 stations (Table 5.1).

Sudanese Scientists Compared to Sudanese Students

The Sudanese students presently enrolled in United States colleges and universities ranked these goals on the same scale as the scientists. The Sudanese scientists and Sudanese students are basically in agreement in terms of priority. To increase agricultural productivity is the primary goal of both groups with development of new knowledge a close second. Expanding demand, exports, and marketing efficiency are the goals of least importance. Generally, while in agreement, the student responses averaged higher mean scores than scientists on all goals with the exception of decreasing production costs of farm products. The goal of decreasing costs

was not considered by the students as being as important as most of the other goals (Table 5.1).

The Sudanese students, however, do rank improving the level of rural living at the top of their list of goals and substantially higher than all three groups of Sudanese scientists (Table 5.1). Several of these students are sponsored by WSARP and these students may be reflecting this project's emphasis on subsistence agriculture in rainfed areas. This also suggests that this new thrust of the ARC in the western Sudan will bring a greater diversity in the perceived primary goals for agricultural research.

Sudanese Scientists and Students Compared to U.S. Scientists and International Sorghum Scientists

Both the Sudanese scientists and students have generally the same goal prioritization as U.S. scientists (Table 5.2). This is consistent with our previous findings which compared an international group of sorghum scientists to U.S. scientists (Marcotte, Busch, and Lacy, 1982) (Table 5.2). These results confirm that there is relative agreement between developed country and less developed country scientists on many of the goals of agricultural research. Both groups of scientists viewed increased agricultural productivity and the development of new knowledge as the primary goals of research. While this commonality of interest in the establishment of research goals is a function of a number of factors, a likely predominant factor is that the majority of the Sudanese scientists received their graduate training in Western institutions. Given this similarity of educational backgrounds and this similarity of research systems within which they work and publish, it is not surprising that scientists in diverse settings would have similar goals for their research.

TABLE 5.2
Goals of Agricultural Research[a]

Goals	Sorghum Scientists[b] Total (n=103)	Developed Countries (n=39)	Developing Countries (n=64)	U.S. Scientists[c] (n=1431)	Sudanese Scientists (n=71)	Sudanese Students (n=25)
Increase Agricultural Productivity	4.6	4.5	4.7	3.9	4.5	4.7
Improve Level of Rural Living	4.2	4.2	4.2	3.2	3.6	4.6
Protection from Insects, Disease, and Other Hazards	4.1	4.1	4.2	3.5	3.6	4.3
Develop New Knowledge or Improved Methodology	4.1	4.1	4.1	4.4	4.3	4.6
Decrease Production Costs of Farm Products	3.6	3.2	3.8	3.6	3.9	3.8
Protect Consumer Health and Improve Nutrition	3.6	3.6	3.6	3.2	3.6	4.2
Promote Community Improvement	3.4	2.8	3.8	2.5	3.4	4.2
Improve Marketing Efficiency	3.3	3.0	3.5	2.4	2.6	3.5
Expand Demand by Developing New Products or Enhancing Product Quality	2.9	3.0	2.9	3.1	3.4	3.9
Expand Export Markets	2.4	2.4	2.4	2.3	3.2	3.5

[a] Scale 1 to 5, 1 = no importance through 5 = highest importance.

[b] Marcotte, Busch, and Lacy, 1983. International Sorghum Scientists in attendance at the Sorghum in the 80s Conference, Hyderabad, India.

[c] Busch and Lacy, 1983.

Despite this general agreement on goals, however, there are a number of interesting differences among these groups of scientists. First, Sudanese scientists, and sorghum scientists and particularly Sudanese students rate most goals higher than the U.S. scientists and view a broader range of goals as important in their research. For example, the sorghum scientists in both the developed and developing countries as well as the Sudanese students perceive improved level of rural living as one of the most important goals for research. This is in sharp contrast to the considerably lower rating given this goal by U.S. scientists and Sudanese scientists. In addition, expanding demand and export markets were considered more important by the Sudanese scientists than the other groups. This is primarily due to high ratings of these goals by group 3 scientists. Finally, the broad goal of promoting community improvement was considered a substantially more important goal among developing country scientists than among the developed country scientists. This was true for the sorghum scientists as well as for comparisons between the U.S. and Sudan.

Goals by Father's Occupation

The goals of agricultural scientists may be influenced by family origins. This was examined by comparing the ratings of those scientists who at 16 years of age lived in households where the father's occupation was a farmer to those from other backgrounds. Only 34% of the scientists had fathers who were farm owners, farm tenants, or farm laborers, despite a population which is predominantly agricultural. The remaining scientists' fathers were in education, business, government, religion, skilled labor, and unskilled labor. Interestingly there was not a major variation in perceived goals for agricultural research between those with a farm

background and those without this background. The most important goals for both groups were to increase agricultural productivity and to develop new knowledge or improved methodology (Table 5.3). The least important goal for both groups was to improve marketing efficiency. However, those scientists with farm backgrounds did see the goal of improving the level of rural living as considerably more important than their nonfarm colleagues. Those scientists of farm background also consistently rated all goals higher than those scientists from other backgrounds. The occupational pattern of fathers of the Sudanese students in the United States is generally similar to that of the ARC scientists. However, there is a greater percentage with farm background (44%). The slight influx of scientists with this family background may tend to broaden the range of goals seen as important for agricultural research.

Beneficiaries

As previously stated, agricultural research is a goal oriented activity, the principal goal of which, as defined by the ARC scientists, is to increase agricultural productivity. It seems apparent that in order to pursue this mission, it is incumbent upon the scientists to understand clients' circumstances. Moreover, one of the most important and difficult roles for the scientist, acting as change agent, is that of diagnosing clients' needs (Rogers and Shoemaker, 1971).

Given this requisite for understanding and diagnosing client needs by the scientists, researchers were asked who they perceived as the main audience for their research. The largest group of perceived beneficiaries of agricultural research was farmers. Nearly 50% of the scientists listed farmers as the audience for their research followed by industry (24.2%), and extension/government (16.1%) (Table 5.4). This identification of farmers as the principal audience appears consistent with the scientists' goal of

TABLE 5.3
Goals for Agricultural Research by Father's Occupation[a]

Goals	Father's Occupation		
	Farm Background[b] (n=24)	Other[c] (n=47)	Total (n=71)
Increase Agricultural Productivity	4.8[d]	4.4	4.5
Develop New Knowledge or Improved Methodology	4.5	4.2	4.3
Decrease Production Cost of Farm Products	4.0	3.9	3.9
Improve Level of Rural Living	4.2	3.3	3.6
Protect Consumer Health and Improve Nutrition	3.9	3.5	3.6
Protection from Insects, Diseases and Other Hazards	3.6	3.6	3.6
Promote Community Improvement	3.6	3.2	3.4
Expand Demand by Developing New Products or Enhancing Product Quality	3.6	3.3	3.4
Expand Export Markets	3.7	3.0	3.2
Improve Marketing Efficiency	3.0	2.5	2.6

[a] Father's occupation when scientist was 16 years old.

[b] Farm background included farm owner, farm tenants, farm laborers.

[c] Other includes the following occupations: education; business/merchant; government; religious, skilled labor; unskilled labor; other

[d] Mean scores, 1 of no importance to 5 of highest importance.

increasing agricultural productivity. However, it does deviate somewhat from previous studies on agricultural scientists. For example, the most important perceived actual beneficiaries for United States agricultural scientists were large farmers and the general public, followed by other scientific disciplines, small farmers and agribusiness. Additionally, in that study there was minimal differentiation among beneficiaries (Busch and Lacy, 1983:167-68).

TABLE 5.4
Agricultural Scientists' Perceived Beneficiaries of Agricultural Research

Beneficiaries	Scientists Responses Number	Percent
Farmers	29	46.8
Industry	15	24.2
Extension/Government	10	16.1
General Public	4	6.5
Students/Universities	3	4.8
Projects	1	1.6
	62	100.0

Information Diffusion

To determine the method by which the scientific information was diffused to the audience, we asked the scientists how their audience received the information. There were five major methods of diffusion (Table 5.5). The most popular method by which information was disseminated was

that of reports and publications. Ironically, the World Bank reports that adult literacy in the Sudan in 1975 was only 20% (World Bank, 1980). Consequently in most instances these reports could not be utilized by farmers even if that was the intended use of these publications. The second most popular choice was diffusion through extension. Given the serious difficulties that have befallen the Sudanese economy and the resultant scarcity of staff and fuel for extension vehicles, this method of information diffusion must be highly problematic. With regard to meetings, distribution of information at schemes, and walk-in farmers, it is difficult to assess the efficiency or magnitude of information that may be distributed by these methods. However, given the diverse ecological conditions and the great distances that many farmers would have to travel to research stations, it is highly unlikely that a large amount of information is diffused in these ways.

TABLE 5.5
Method by Which Beneficiaries Received Information

Information Method	Scientists Responses	
	Number	Percent
Reports/Publications	12	19.0
Extension	11	17.5
Meetings	11	17.5
Schemes	8	12.7
Walk-in	8	12.7
Seminars	2	3.2
Administrative Sections	2	3.2
Other	9	14.3
	63	100.1[a]

[a] Does not equal 100.0 due to rounding.

The problem of adequately and effectively reaching the perceived client groups is recognized by many scientists in the ARC. This awareness is reflected in their responses to the question: How can the diffusion of information be improved? The scientists' recommendations focus on improved linkage between the ARC and extension as well as improved extension services and increased personal contact (Table 5.6). The primary suggestion for improvement was to formalize the linkage of ARC and extension. Given the mission of extension which is to disseminate research information, this recommendation is consistent with the goals of the scientists. From this

TABLE 5.6
Scientist's Suggestions to Improve Effectiveness of ARC Information Diffusion to Farmers

Method of Improvement	Scientists Responses	
	Number	Percent
Formalize Linkage of ARC and Extension	20	36.4
Improve Extension	8	14.5
Meetings/Personal Contact	8	14.5
Demonstration Farms	7	12.7
Demonstrate on Farmers Fields	7	12.7
Training for Farmers	5	9.1
	55	100.[a]

[a] Does not equal 100.0% due to rounding.

analysis of theperceived goals, beneficiaries and methods of information diffusion, we concur in the scientists assessment of the need for improvement. There is a need for a formalization of linkages between ARC and extension, an improvement of extension services and an increase in personal contact with farmers, either through meetings or demonstration farms. The Farming Systems Research approach appears to be one of the potential means for enhancing this communication. These improvements would likely be beneficial to both the client groups and the scientific community.

Conclusion

The data reported on perceived research goals and beneficiaries suggest some potential and fundamental anomalies in the role of agricultural research in the Sudan. The first potential problem concerns the perceived beneficiaries. Scientists see farmers as the audience for their research, yet have limited or nonexistent communication links with these potential clients of their research.

The second issue centers on research goals. Scientists view certain goals as significantly more important than others in the conduct of their research. Although in general, Sudanese scientists view a wider range of goals as important, various subgroups differ in their perceptions of the most important goals. This would be relatively unproblematic if there were no link between maximization of particular research goals and the flow of benefits of research to certain groups. However, this simply is not true. For example, successful research efforts focused on increasing agricultural productivity are likely to benefit (1) literate farmers near experiment stations, (2) processing and marketing firms that are able to purchase

agricultural commodities at lower prices, and (3) perhaps consumers. However, in the event that food quality and nutritional goals are generally neglected, little or no benefit may accrue to consumers. Similarly, emphasis on research to expand export markets may benefit certain export crop farmers at the same time as it may raise prices for food crops among local consumers. The promotion of community improvement may also cost some groups and benefit others. For example, crop and livestock protection may be effectively accomplished through the use of chemical sprays but such chemicals may also increase health hazards to farm workers, rural residents, and ultimately the general public.

In conclusion, the pursuit of every goal involves costs and benefits. It may appear that the solution is to develop a system that maximizes the benefits and minimizes the costs. However, this approach only addresses the issue of the outcomes and ignores the issue of beneficiaries and those likely to incur costs. No simple economic cost/benefit analysis can resolve this fundamental problem. These complex issues highlight the need for a more informed, comprehensive agricultural research policy.

CHAPTER 6

RECOMMENDATIONS

The following recomendations emerged from the study. Some are based upon specific observations and comments received from scientists and/or administrators. Others emerged as we conducted our interviews and analyzed the data. While we stand behind our recommendations, the reader should be aware that they were developed following relatively short visit to Sudan and should be tempered by the knowledge and opinions of those with greater experience within the Agricultural Research Corporation.

For the sake of clarity we have arranged our recommendations in several sections.

A. National Organization and Coordination

1. Many scientists identified the need for a coherent national agricultural research policy. They often felt unsure about the appropriate directions for applied research. The appointment of national coordinators, and the creation of a policy committee composed of national coordinators and station directors, chaired by the deputy director for programs, begins to address this issue. We suggest that this committee could be assisted by an advisory council representing various parties interested in agricultural research (e.g., the regional ministries of agriculture, production schemes, farmer organizations, other relevant ministries, etc.). Such an advisory council should be broad in scope, covering all of the affected

constituencies and ensuring that divergent views on research policy are heard at the national level.

It is also important that a national agricultural research policy contain general guidance for various research projects, some notion as to the priority geographical areas, food crops, export crops, livestock, and farming systems, and some general guidelines for funds disbursement within these various areas. Such a policy should also be cognizant of the demographic structure of the scientist population as it relates to these priorities and the training needs of future scientists.

In contrast, a national policy should not attempt to dictate the terms of specific research projects to particular scientists, nor should it ignore the limitations imposed upon any changes in direction by the very training received by current scientific staff. Finally, a national agricultural research policy should be implemented gradually and changed gradually so as to ensure that ongoing projects are brought to successful completion before new ones are attempted. Only in this manner can the cumulative character of scientific programs be ensured.

2. The recent development of regional ministries of agriculture provides a decentralized administration focusing on regional issues in agriculture. Currently, several of the regional administrators have had broad research experience and appreciate the value and needs of the research community. Opportunities for collaborative activities and research support between ARC stations located in these regions and the respective ministries should be actively pursued. In addition, in some regions it may be possible to create regional advisory councils to ensure the relevance of research to

regional needs. Regional representatives should sit on national policy committees.

3. There are three fundamental ways in which agricultural research systems may be organized: by discipline, by commodity, and by farming system. Historically, the first two of these orientations have been developed during the last century. In some countries experiment stations were organized around commodities (chiefly export crops such as cotton, rubber, coffee, etc.), while in other countries research was organized along disciplinary lines (e.g., plant pathology, horticulture, agronomy, rural sociology). More recently, attention has been directed toward the farming systems approach in which research is organized around farming systems found in particular ecological zones. This orientation permits the incorporation of the everyday rationality of farmers (Chapter 1) into the research process. In order to maximize the effectiveness of an agricultural research program all three of these approaches must be considered. For example, neglect of the disciplinary dimension may lead to weakened relations with organizations such as the Soil Survey, and may inhibit scientists' abilities to keep up with the (largely disciplinary) scientific literature. In contrast, neglect of the commodity dimension may lead to disciplinary fragmentation such that, for example, pest control recommendations produced by entomologists are incompatible with cultivation practices recommended by agronomists. Finally, neglect of the farming systems dimension may lead to an inappropriate mix of commodities, planting times, and labor requirements such that the labor needs are magnified, opportunities for multiple cropping are passed over, etc. In short, an

effective agricultural research program must include some aspects of all three orientations.

4. The Western Sudan Agricultural Research Project (WSARP) needs to be better integrated into the ARC. As is well known, this project was specifically designed to provide a farming systems approach that would be particularly effective in reaching low income farmers utilizing traditional practices in unirrigated agriculture. Although scientists joining the WSARP team have themselves been educated in a particular discipline, still a difference in approach is reflected in the scientists' perceived research goals. WSARP scientists and those at other outlying stations view a wider range of goals as important to their research than do the scientists at Shambat and Wad Medani. By virtue of the distance of the WSARP experiment station sites from those in the East, as well as the newness of the venture, relatively little attention has been paid to the important problem of integrating research in Western Sudan research into the larger mission of the ARC.

As the Western Sudan experiment stations become fully active, the need for integration will be magnified. If handled properly, this may be an opportunity for major improvement of the entire Research Corporation. WSARP should be able to effectively draw upon the strong, well-established disciplinary and commodity programs already in existence. In turn, scientists at the more established stations should be able to utilize the farming systems expertise developing in WSARP in order to improve their effectiveness. It should be recognized that the various irrigated and mechanized schemes are themselves farming systems though of a type quite different from those found in the Western Sudan. Limiting the farming

systems approach to the Western Sudan and the commodity and disciplinary approaches to the Eastern Sudan is likely to lead to sharp divisions in the ARC and to hamper progress towards the creation of a fully integrated organization. We believe that it is important that this issue be tackled now rather than several years later. The inherent difficulties involved in joining the two parts of the system need to be resolved while organizational forms are relatively new and unentrenched. Leaving the issue for future resolution is likely to make the problem far more intractable.

5. While the need for research on experiment stations should not be ignored, the ARC should give serious consideration to the use of the Farming Systems Research (FSR) approach at all stations. This might actually help to alleviate the current strains on station budgets by moving some portion of the research off the station (where hired labor is necessary) to farmers' fields. This would also permit scientists to gain a greater appreciation for the problems farmers face and ensure that research conducted on the station is consonant with farmers' needs. Finally, it would provide the interface between research and extension that is currently lacking.

If such a move were contemplated, it would involve some retraining of existing scientific staff in the FSR approach. This might be accomplished by having such a training program carried out at one of the WSARP sites. This would have the additional advantage of helping to integrate WSARP with the rest of the ARC. This kind of project would be particularly suited to funding through foreign assistance.

6. Currently the sections recently added to the ARC (i.e., fisheries, food research, forestry, wildlife) do not have national coordinators. Many scientists in these sections already feel isolated from scientists in the

older sections. In addition, these stations are somewhat different in their organizational structure, mission, and perceived goals for research than the other parts of the ARC. Consideration should be given to the appointment of national coordinators in each of these areas in order to more effectively integrate them into the ARC. Such coordinators would not only speak for their respective sections at national meetings, but would also help to utilize the services of these sections in support of other stations' projects. For example, agronomic research on millet might be better coordinated with food research on the same crop through national coordinators in both areas.

7. The roles and responsibilities of national coordinators need to be more carefully delineated, especially with regard to station and section heads. The current situation invites potential organizational problems. First, coordinators lack a separate budget and must depend upon station directors or section heads for support. Second, while coordinators make recommendations for national budgets, they depend upon section heads for their own research programs. By more clearly delineating the roles and responsibilities of these national coordinators, potential conflicts over budgets and research priorities may be avoided.

8. The ARC headquarters should be relocated from Wad Medani to Khartoum as already suggested in the report of the International Agricultural Development Service (Joint Team Report, 1977). This would facilitate access to other divisions of the Ministry of Agriculture, Food, and Natural Resources, as well as other government ministries and offices, such as the National Research Council. Location in the capital would enable greater contact with private organizations and international agencies which

would lead to more collaborative efforts and increased awareness of potential sources of funds. Other advantages would include increased overall visibility of the ARC and greater ease in reaching the headquarters for most members of the ARC and other visitors. Finally, such a move would eliminate the perceived bias towards the Gezira station and reduce confusion over the lines of authority. Resistance to the move has been voiced and the reasons need to be carefully explored. For example, one concern among some scientists and research administrators at Wad Medani is access to comparable and affordable housing in Khartoum.

9. In the 1977 Joint Team Report it was recommended that "an agricultural research scientist with demonstrated capability and experience in the organization and management of agricultural research of broad geographical scope and interdisciplinary complexity should be recruited as a consultant to assist the Director General with the overall organization and management of the ARC." The ARC was fortunate to recruit Dr. James Riley for that position. Utilization of his expertise in agricultural research administration could be expanded even further than is currently the case. For example, his knowledge and experience would be an effective addition to agricultural policy meetings.

B. Manpower Training

10. One of the strongest dimensions of the ARC is its community of well-trained scientists. However, since Sudan is a large country with multiple ecological zones, agricultural scientists in the ARC have been widely dispersed to meet local socio-economic situations, special environments, or particular commodity needs. The ARC itself has been organized into regional stations, commodity stations, specialized centers

and testing sites. As a consequence a number of stations lack a critical mass of staff, as well as funding necessary for the effective conduct of research. The ARC needs to review the overall organization regularly to determine whether and where to consolidate human resources most effectively.

11. A second manpower issue is the congruence between the training and experience of the scientists and the overall needs and priorities of Sudan. For example, shifts in national emphasis from export and/or cash crops to food crops for national consumption and vice versa require continuous reexamination of available human resources and their allocations, capabilities, and limitations. The nature and balance among various disciplines also entails regular reassessment. Clearly, the process of training scientists and other research staff requires a constant review of the strengths and weaknesses of the research capabilities and the relevance of these capabilities to national priorities.

12. While the size of Sudan's agricultural scientific manpower is not optimal, it has reached a critical mass in numbers of scientists. As this research program grows management will become a main determinant of its effectiveness. Therefore, some scientific personnel should receive training in research management. As suggested earlier, these managers should be able to demonstrate to policy makers, where appropriate, that agricultural research funds will be effective in achieving national objectives and priorities. Furthermore, they need to communicate regularly with those in government who give direction to the national economy, manage the research budgets, and maintain effective contact with their own scientists and staff.

13. Although the ARC has a relatively large and varied scientific staff, it has a serious shortage of well trained technicians. This shortage

has at least two components: First, it is difficult to attract technicians graduating from technical schools or to retain them due to limited career opportunities within the ARC. Second, since technicians graduate from three year post-secondary programs, they feel nearly as well qualified as assistant scientists who have bachelor's degrees. These factors coupled with relatively low salaries encourage a high turnover among technicians. The recommendation of one scientist to establish a technical secondary school to train agricultural technicians for the ARC appears to be a promising complement to the current on-the-job training. In addition, a career ladder and opportunities for further training for technicians should be established.

14. As noted earlier in the report, most ARC scientists have received graduate education in either the United States or the United Kingdom. Given the significant differences in the ecology and agricultural needs of these countries as compared to Sudan, careful attention should be paid to the relevance of this education. For ARC scientists graduate education at the masters or doctoral level should be relevant to the interdisciplinary applied research conducted by the ARC. The ARC already encourages this through its current practice of requiring assistant scientists to spend two years within the ARC before going abroad for advanced studies. This could be further encouraged by selecting universities involved in applied research in similar climatic zones and by encouraging students to pursue Ph.D. training in conjunction with the international centers (e.g., International Crops Research Institute for the Semi-Arid Tropics, International Center for Agricultural Research in Dry Areas). In particular, the ARC should strongly

encourage scientists to write master's theses and doctoral dissertations on subjects of direct concern to the ARC and Sudan.

C. Research Funding and Organization

15. Foreign governments and private organizations occasionally make funds available for agricultural research on both a programmatic and individual project basis. The ARC should consider the best means to identify such sources on a regular basis, to inform appropriate administrators and scientists, and to assist in the procurement of these funds.

16. Consideration should be given to the formation of a small research fund within the ARC that would be allocated competitively. These monies complement the station formula funding and those funds available from the National Council for Research and could be used to either support important immediate national objectives or promising but underfunded long term needs.

17. Generally, research funds are administerd by a section leader or department chairman based on the current needs of the section. Therefore, funds may be available at the beginning of a funding period but unavailable to scientists whose needs occur later in the fiscal year. Several scientists have suggested the need for section leaders to allocate a portion of the yearly budget to each scientist. They believe this would enable them to better plan the year's experiments within the parameters of their available budget and to make critical choices in advance.

18. The ARC should be permitted to sell the produce derived from experimental plots and to use the proceeds to supplement the general operating budget. At the same time, the ARC is urged not to convert

experimental plots into production units for this would undermine the central mission of the ARC.

19. The large irrigated production schemes rely on the ARC for a continuous infusion of new research results and often place heavy demands on the researchers. These schemes should be encouraged to lobby on behalf of the ARC among the government agencies responsible for research funding. Further, we concur with scientists who believe that all the schemes should provide a direct though unrestricted contribution to the research program.

20. Currently each scientist conducts separate discipline-oriented field experiments. This often results in several experimental plots planted in the same crop at the same research station. The possibility and viability of doing interdisciplinary field research on these experimental plots should be explored. This could be a means for a) reducing overall costs of the field research, b) lessening problems of labor shortages at key periods in the research (e.g., during weeding and harvesting time), c) promoting interdisciplinary research, and d) contributing to research results which are applicable across interdisciplinary lines.

D. Communications

Administration-Scientist

21. Due to inadequate infrastructure, communication between the stations is extremely poor. Scientists and research administrators must spend hours, days, and sometimes weeks traveling to Wad Medani and other stations to ensure that their messages reach the appropriate people. A radio communication system linking the research stations would be a relatively inexpensive, yet effective way to dramatically improve communication.

22. Communication between scientists and administrators needs to be improved. Currently, many scientists are unaware of the efforts of administrators to secure funds and improve the position of the ARC. As a consequence, they are highly critical of that effort. In addition, many scientists believe that their problems and their research efforts are not fully appreciated. In part, this appears to stem from one or more of three sources: physical distance from ARC headquarters, being in a subject field newly added to the ARC, and being a young or new member of the staff and therefore lacking informal contacts. These problems may be ameliorated by more frequent visits to remote stations by senior administrators, and by a "state of the ARC" address and question and answer session for scientists at the annual meeting.

Among Scientists

23. Communications among the scientists in different research fields is currently limited. A newsletter or similar type communication could provide scientists with summary information of recent scientific developments in the ARC, new products, methods, meeting announcements, etc.

24. The annual research meeting at Wad Medani is more a demonstration for other agencies than a scientific meeting. Previously this meeting was also used as an opportunity for scientists to discuss their research problems. Serious consideration should be given to reinstituting an annual agricultural scientific meeting.

25. Research results are often buried in annual reports. These reports are less detailed than journal articles or bulletins and only a few copies are produced. Hence, what research is completed is often unavailable

even to colleagues, let alone farmers. The revival of the Sudan Journal of Agricultural Research should be a high priority.

26. Delays in the publication of annual reports make it difficult for scientists to follow the work of co-workers, particularly outside their discipline. To expedite publication of annual reports it is recommended that a literature graduate from the University of Khartoum be hired to replace the current expatriate editor.

27. Scientists identified journals as one of the two most important ways of keeping abreast of scientific developments. The various libraries of the ARC appear minimally to meet these needs. A relatively inexpensive way to expand the information available to scientists is to provide access to agricultural data bases, such as the Commonwealth Agricultural Bureau and the Current Agricultural Information Network. This activity might be supported by foreign aid.

28. Scientists report few contacts with other African researchers based in similar ecological zones in part due to language differences. Foreign aid agencies could help facilitate such interaction by translating key publications from francophone Africa into English or Arabic and promoting cross-national contact within Africa.

With Farmers

29. The effectiveness of the ARC in reaching farmers needs to be improved. a) A first step might be to strengthen the link between the ARC and the extension service, perhaps through assignment of an extension staff member to every ARC station (or section). This person's responsibility would be to facilitate communications between ARC staff and extension agents through planning and executing FSR and on-farm adaptive research.

b) Alternatively, the ARC might create positions for "agricultural development specialists" or "Farming Systems Research specialists." The role of these specialists would be to ascertain the needs of farmers and translate them into researchable topics. c) Another strategy would be to conduct more research on farmers' fields. Many researchers expressed a willingness to do this but transport constraints limit the feasibilty of this approach.

E. Promotions

30. Some scientists are currently being penalized for pursuing a Ph.D. immediately following a masters degree. Promotion policy requires a masters degree and four years of in-country service after being promoted to "scientist" as conditions of promotion to "senior scientist." Those scientists who choose to obtain the Ph.D. immediately following the masters degree must wait four additional years after their return to be promoted to senior scientist. Consideration should be given to reducing the 4-year rule for those scientists who obtain the Ph.D. directly after the masters degree.

31. In many instances an apparent discrepancy exists between a) the organizational goals of the ARC which stress applied research and problem-solving and the development of useful methods and products, and b) the criteria for scientist's promotion which stress written annual reports and academically-oriented journal articles. Greater attention needs to be given to the evaluation of new products and technologies and their contribution to organizational and national agricultural goals. Annual awards to scientists whose on-farm research directly contributes to farm production might be instituted, with these awards taken into consideration for promotion. Additionally, scientists might be encouraged, in both new

projects and annual reports, to demonstrate the relevance of their work to organizational and national goals.

F. Equipment

32. The equipment and tools needed for research were seen by scientists as the most inadequate research resources in the ARC. Obviously, more funding is needed for equipment. In addition, in some instances better utilization of the existing equipment could improve the situation. Some stations are run as aggregates of projects with little equipment sharing. Station programs need to be better integrated with equipment seen as station property rather than the property of a single researcher.

33. In addition to specialized research equipment, there is a need for three types of general use equipment: a small computer to handle statistical needs, copying machines for the libraries at Wad Medani and the Food Research Centre, and a radio communication system..

G. Conclusion

34. The current situation in the ARC combines opportunity with the frustration of inadequate resources. The staff, soon to be augmented by additional colleagues, is generally well trained and highly committed to applied research in agriculture. However, the facilities, supplies, and other research resources are inadequate, even for the present staff. Without adequate funding, the potential offered by the available human resources will be underutilized and potentially lost to the system. If all efforts fail to improve the fiscal situation of the ARC, serious consideration should be given to reducing the scientific staff through attrition and closing of selected facilities. This last resort would make it possible for the ARC to provide minimum levels of support to the

remaining scientists and would enable those scientists to conduct a limited small scale program.

The above recommendation is neither an optimal nor even an acceptable stategy under most circumstances. Therefore, our final recommendation is to the Sudanese government and to other potential funding agencies. It is not enough to provide funds for training of new scientists and technicians. Budgetary support for operational costs other than salaries is essential but often neglected. Training and staff development should be matched to the provision of recurrent funds and capital investment. Consequently, infusion of adequate funding and resources for current operations, as well as for institutional development in the ARC, should be a high priority of the Sudanese government and other agencies interested in agricultural development in the Sudan.

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METHODOLOGICAL APPENDIX

Data Collection

The research conducted for this Report on the Sudan Agricultural Research Corporation involved a variety of sources of information. The sources included reviews of historical materials, reports and government documents, a series of on site interviews of about two hours each with 62 ARC scientists, 9 questionnaires returned from ARC scientists whose worksites were not visited, and approximately 20 interviews with research administrators and government officials.

The statistical results reported about Sudanese scientists were based on responses to those interviews and questionnaires. The number of respondents (n = 71) represents approximately 55% of the ARC scientific staff on site in the Sudan.

Additionally, questionnaires were sent to approximately 50 Sudanese students enrolled in universities in the United States between September 1982 and May 1983. Of those 50 students, 25 were being supported by the ARC, with the remainder being supported by other government or private organizations. The response rate was approximately 50% (n = 25).

For a number of sections of the report, this information was compared to information previously collected on 1431 agricultural scientists in United States public agricultural research institutions (see Busch and Lacy, 1983), and 103 agricultural scientists from developed and developing countries in attendance at the "Sorghum in the 80's" conference held in Hyderabad, India in 1981.

Data Analysis

Conventional statistical procedures were utilized to analyze quantitative data. In addition, a rich body of qualitative information was gleaned from the lengthy interviews. While some might argue that the non-random nature of our sample makes statistical inferences problematic, we would counter that its large size--55% of the total staff--and its geographical representativeness make it highly likely that it does accurately portray the entire population of scientists. As such we have treated the sample as if it were randomly chosen.

Details on the design and implementation of the interviews and questionnaires and other aspects of the study are available from the authors.