CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

1979 REPORT ON THE CONSULTATIVE GROUP AND THE INTERNATIONAL AGRICULTURAL RESEARCH SYSTEM

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An Integrative Report

September 14, 1979
CGIAR Secretariat

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I. INTRODUCTION

1. The concept of conducting agricultural research for the benefit of the developing countries at a number of individual international agricultural research centers is now almost 20 years old. The Consultative Group on International Agricultural Research subsequently founded to support such centers and link them in an integrated system now approaches its second decade.

2. One or two decades represent a very short time in biological research, long enough to define major problems and assemble and equip teams of trained manpower, but often too short to have a measurable impact on production in farmers' fields.

3. Because the technology developed for wheat and rice has had a spectacular impact on production, and since the CGIAR system as a whole has grown rapidly, it is sometimes inferred that the research conducted at the international agricultural research centers (the IARCs) will soon result in further dramatic advances in the production of other food crops. This is probably unduly optimistic. Future advances are likely to be gradual, though effective just the same. They will result from the combined effects of progress on many fronts.

4. The CGIAR Secretariat's 1977 and 1978 annual reports (the "Integrative Reports") analyzed the growth and achievements of the system and attempted to assess the impact of its research on production. The 1978 Report summarized the available information regarding the impact of the modern varieties on agricultural output and yields and discussed some of the major socio-economic consequences. Of necessity, it rested heavily on the results of the development of wheat and rice technology since improved varieties of crops in the other IARC research programs are not yet widely grown. The introduction of the new high-yielding varieties of rice and wheat had had remarkable and widespread favorable effects, but the impact of research on other crops and farming systems, while likely to be important, will probably be less dramatic and harder to achieve. Nevertheless, the research programs established subsequent to those for rice and wheat, while still young, are producing a stream of new knowledge and new technology. Some of this may be applied in farmers' fields in the near future, but some may not be taken up for years. While everyone would agree that the ultimate objective is increased production by farmers, it must be recognized that a research system as such must be judged by its output of new knowledge and new technology development (R&D) which can be modified as necessary and applied by developing country institutions. Modern agriculture could not function without advances in scientific knowledge; the transformation of this into inputs, farming techniques and farmer skills is the most important factor in increasing productivity. While

improved technology is only one element of development, the output of new knowledge, the development of new technology, the training of scientists and the improvement in the national agricultural R&D systems will undoubtedly form the most pervasive and long-lasting effect of international agricultural research.

5. Part II of this year's Report is, therefore, about the output of the system. It describes the breadth and scope of the scientific endeavor at the centers, the research strategies they pursue and some of the innovative features of the research programs. It does not attempt to speculate on when such technology might be applied nor on its potential impact at farm level. Neither does it attempt to assess the quality of the research work at the centers; this is covered by the quinquennial reviews of the Group's Technical Advisory Committee.

6. Because R&D is a long-term process, it needs assurance of steady long-term funding. Such funding has in fact been forthcoming from the donor members of the CGIAR, though the decrease in the last two years in the rate of increase in contributions is a matter of concern, particularly at a time of rapid inflation. This decrease has come just as the output of the centers is increasing significantly and the period of consolidation decided upon by the Group three years ago is coming to an end. The effect has been to open up in 1980 a sizeable gap between the requirements of the centers and the estimated supply of funds, and, accordingly, to heighten the Group's concern with priorities, the growth of the centers and cost-effectiveness.

7. At the same time, however, the need for increased agricultural productivity in the developing countries remains as urgent as ever. The recent United Nations Conference on Science and Technology for Development has again drawn attention to the imbalance of resources for research on the global level, to the grave disadvantage of most developing countries. The CGIAR is an international effort directed at redressing this imbalance in an area of prime concern to both developing and the developed countries.

8. Considering the present and potential output of the CGIAR system, and the intention of the richer countries, as expressed at the Tokyo Economic Summit, to place more emphasis on overcoming hunger and malnutrition and on increasing aid for agricultural research, it is opportune for the CGIAR to reaffirm its long-term commitment to the development and support of international agricultural research.

9. This year's Report concerns itself in particular with the output of the system and the need for longer-term planning by the Group. In Part II it starts with a survey of the output. Part III describes the needs of the international network in 1980, and includes proposals to close the gap between budget requests and estimated contributions. Part IV recommends the development of a longer-term financial plan for the CGIAR, with a proposal to double by 1984, in current terms, the resources made available to international agricultural research. Part V draws some conclusions.

II. CONTRIBUTION OF THE CENTERS TO TECHNOLOGY DEVELOPMENT

Introduction

10. Agricultural research contributes to both scientific principles and technology development. Basic scientific principles are universally applicable, but using them to generate new technology is much influenced by the physical, biological and socio-economic environments in which agriculture, the primary area of economic activity in the developing countries, takes place. In other words technology does not have the wide applicability of scientific principles. However, the international centers have concentrated mainly on technology development since it is through the application of new technology that increases in productivity are obtained. In addition, mission-oriented basic research (paragraph 86) is needed in many areas; some of the centers are now putting more of their resources into such research, though major efforts on shorter-term targeted research must, of course, continue.

11. Progress at the centers is covered in their annual reports, and in contributions to scientific journals and seminars. However, scientific and technology advances tend to be episodic in nature, at least in the short term, so the discussions of one year's progress or the advances in one particular aspect discussed in a research paper, cannot give an adequate picture of the overall contributions over time. A paper such as this cannot cover all the contributions that have been made by the centers; it must, of necessity, be selective. In being selective, most attention has been given to the plant breeding, farming systems and socio-economic research programs which produce the main R&D output of the system. The paper also gives some attention to ways in which the centers have contributed to the exploitation of existing scientific ideas by institutional innovation and to their influence on the kinds of goals that are set by national research organizations. Trained scientists are one of the most valuable products of a scientific organization and some aspects of the IARCs' contribution in this area are also discussed.

Plant Breeding Programs

12. More than 50% of the resources of the crop research programs of the centers is used in plant breeding and closely related projects. Plant breeding has been likened to a factory in which materials with wide genetic variation are passed through a series of processes in which the end product is improved varieties.1/ In the international centers, material may be taken off the "assembly line" at various stages, and passed on to national programs for finishing according to their particular needs, or finished varieties may be produced by the center.

1/ Arnold, M. H., Agricultural Research for Development. Cambridge University Press, 1976. pp. 353.

13. The goal of the early programs at both the International Rice Research Institute (IRRI) and the International Maize and Wheat Improvement Center (CIMMYT) was the production of plant types that would be highly responsive to fertilizers, insensitive to day-length and resistant to some of the major diseases; in other words, high productivity was the goal. This goal is still pursued in most programs, CIMMYT, for example, stating that the breeding of durum wheat varieties with high yields under optimum growing conditions is one of its primary aims. However, the impact of the new technology has shown that output would not increase significantly in many areas unless the new technology was suitable for the resource-poor farmer.

14. The recognition of this limitation has led to changes in breeding programs, to the recognition of the importance of studying existing farming systems and consequently to greater emphasis on yield stability and selection for low input, high risk conditions. This change in emphasis has also persuaded many national scientists to pay more attention to breeding for adverse conditions. Most scientists recognize, however, that it will be necessary for countries to follow both strategies for, just as individual countries vary in their requirements for high input technology, so do regions within countries. Variations in soils and climate influence greatly the distribution of crops. Bread wheats, for example, are grown in the better rainfall areas, while barley is the crop of poor farmers on poor land; sometimes cash crops, (cotton, for example) may occupy the better land, and food crops, like cassava, the poorer areas. No country can afford to neglect regions with high production potential, if only to produce cheaper food for the rapidly increasing urban populations, but the resource-poor farmers, often in areas of high risk, must also have access to better technology.

Conservation and Utilization of Genetic Resources

15. Man has made great use of the genetic variation over the past 10,000 years in the relatively few species which he uses for food, shelter and clothing. Although genetic diversity can be created by mutation breeding, by far the larges reservoir of such variation (gene pools) remains in the many cultivated varieties and closely related wild species. Hence the international centers have a major involvement in the collection and conservation of such material.

16. More than half a century ago it was recognized that from the beginning there were only a limited number of centers of diversity or origin of the important species. These are areas of great antiquity of cultivation and thus are of great interest to plant breeders, but unfortunately, they are now suffering genetic erosion due to the replacement of the wide range of local, primitively cultivated, varieties by the improved cultivars and to the extension of cultivation into the natural habitat of the closely related wild species. In addition, much tropical rain forest, the source of genetic diversity of valuable timber species and tropical fruits as well as some potentially valuable drugs, is being cleared for agriculture.

17. The threat to these irreplaceable resources has become increasingly recognized during the past two decades. FAO took a major initiative by convening a panel of experts which led to proposals for the collection and conservation of such materials. The outcome was the organization, in 1974, of the International Board for Plant Genetic Resources (IBPGR) as part of CGIAR.

18. The Board has been active in organizing collecting expeditions, especially aimed at threatened species, and in proposing plans for the evaluation and storage of material collected, in drawing up agreed lists of descriptors, in establishing suitable computerized information storage and retrieval systems and in training of scientists.

19. The innovative nature of the IBPGR's work lies not so much in its nature but in the scale on which it is taking place. Individual scientists and national programs have collected plant materials for generations and some very large national collections have been in existence for years. The international collaboration in collecting and distributing materials and disseminating information on them has been one of the contributions of the CGIAR system. These operations will have a long-term benefit for both the developed and developing countries since a number of the species being collected are important crops in developed countries, too.

20. Table 1 shows the size of the germplasm collection at the IARCs which, however, represent only a part of the materials held in collections around the world. (ICARDA, not shown in the Table, will have collections of wheat, barley, lentil and broad bean.)

21. These collections are not all new, many having been derived from existing collections. The CIMMYT maize collection, for example, contains much material from Mexican collections. Major collections have been made of many species, but some collections are not well documented and large areas of important centers of diversity may have been poorly collected; moreover some species, for example tropical fruits and tropical forest trees, have had very little collection. There are also major gaps in information and classification of collections of some species, even though large collections exist. The IBPGR has initiated projects to improve this situation in national programs, but since the management of germplasm storage and information is not always given the priority it deserves, this is a long-term task.

22. The international centers are also making a significant contribution to improving germplasm storage techniques. While true seed from the majority of crop plants can be stored under suitable conditions for many years, there are problems with a number of important species, particularly root and tuber crops which are usually propagated vegetatively. The combination of genes in the clones needs to be preserved and this requires some means of vegetative reproduction. Conservation by growing the crop annually is expensive in terms of land and labor and can lead to serious losses through diseases. Thus the international centers concerned with germplasm of potato, yam, sweet potato and cassava are trying to overcome this problem by the use of meristem or other forms of tissue culture. Meristem tissue culture methods have now been developed whereby cassava germplasm can be stored in clonal form for a relatively long period (2-3 years).

Table 1.

Center Germplasm Collections

Crop	Approximate Number of Accessions	Center*
Maize	13,000	CIMMYT
Pearl Millet	5,500	ICRISAT
Rice	37,000	IRRI
Rice	4,500	IITA
Sorghum	15,000	ICRISAT
Cassava	2,500	CIAT
Cassava	350	IITA
Potato	12,000	CIP
Cowpea	8,000	IITA
Chick-pea	11,300	ICRISAT
Lima Bean	1,200	IITA
Phaseoleus sp.	21,000	CIAT
Pigeon Pea	6,000	ICRISAT
Soybean	800	IITA
Groundnut	7,000	ICRISAT
Forages	3,500	CIAT.

*For names and locations of international agricultural research centers (IARCs) in the CGIAR system, see Annex I.

Plant Breeding Objectives

23. The ultimate objective in plant breeding is higher productivity. A national program may have very specific objectives, such as an answer to a distinctive disease or pest problem, a soil deficiency, a climatic characteristic or a consumer preference. Because of their mandates, the international centers have to produce materials that have the inherent ability to perform well under a very wide range of conditions. This has led to considerable emphasis on the concept of wide adaptability.

24. The centers are equally concerned that their materials will be stable in yield from year to year. Even for locale-specific materials, plant breeders aim at varieties that will give consistently superior yield each year and this requires testing for a number of years before release. By testing materials widely, e.g., on a continental scale, the pest and disease and climatic variations that might occur over several years at one or a few sites may be encountered in one year if many sites are used. It is not unlikely that materials with wide adaptability will show good year-to-year yield stability at a particular location. The question remains, however, as to how wide, wide adaptability should be in order fully to exploit a specific environment.

25. While irrigated rice and wheat have shown the adaptability needed to cope with a range of pest and disease problems, improved cultivars of rain-fed food crops have not yet been widely adopted on farmers' fields, so there is little information on how such environments affect crop growth through interaction with the genetic makeup of the plant. However, attention to the problem of local adaptability is ensured by the centers' cooperation with national programs and by the development of a series of gene pools for specific environments as is done, for example, in maize. It is recognized that cultivars for rainfed agriculture will require such locale-specific characteristics as early sowing, appropriate duration to harvest, and drought, pest and disease tolerance.

26. Another aspect of yield stability concerns the breeding of cultivars which will perform at least as well at low or nil inputs as the traditional varieties and yet perform more efficiently when inputs are available. This is a difficult objective and some modern varieties, while proving superior at medium or high inputs, have yielded less than traditional varieties at low or nil inputs. Disease and pest resistance must be as good in the new as in the old varieties.

27. Because of the increasing concern with the resource-poor farmer, there is now a concerted effort by the IARCs to design cultivars and farming techniques that will have low requirements for purchased inputs, as this will partially eliminate the need for a sophisticated infrastructure to make these inputs available. One aspect of this is the attention to plant population improvement and the production of open pollinated cultivars. Such cultivars allow the farmer to use his own seed rather than purchase seed each year. Hybrid seed, on the other hand, requires efficient production and distribution facilities that are lacking in most developing countries.

28. The broad objective of the IARCs breeding program is to provide farmers with varieties that will outperform the traditional varieties even in the existing conditions. Such improvements can be obtained through better pest and disease resistance and ability to withstand drought, but it should be emphasized that the opportunities for increasing yields in the absence of better farming practices and increased inputs are limited.

Plant Breeding Organization

29. Generally, the international centers use the same plant breeding techniques as those in national programs throughout the world, but they differ in capacity and in organization.

30. Plant breeding is basically a system of managing the direction and increasing the speed of the processes that occur in nature, and the number of progeny with the desired combination of useful characters can be increased by manipulating large numbers of parents. In this the centers have a distinct advantage in that they are able to handle large numbers of crosses and to distribute their materials widely for testing (Table 2). They have more genetic variation at their disposal by way of germplasm collections than most national programs; they have made their breeding programs interdisciplinary by involving other disciplines. In several crops they are able to double or treble the number of generations per year by techniques such as "shuttle" breeding, i.e., carrying out the crossing programs twice a year by operating in two different climatic regions, as used in wheat. They have developed techniques for seed production in crops that are normally vegetatively reproduced. Finally, they have been able to use the extensive international testing networks in which the centers and national programs exchange and test breeding material (Figure I).

31. The introduction of global testing is an example of a vast expansion in scale of an idea that began many years ago. In 1952 FAO started a regional nursery screening program in North Africa in collaboration with the U. S. Department of Agriculture and the European Cereal Rust Association. Now there are international testing networks for each of the crops of the centers working on plant improvement. These may cover as many as 80 or 90 countries with several sites in each country (Table 2). International collaboration on such an extensive scale has been one of the outstanding achievements of the international system during the past decade.

32. An advantage of a global testing network is that widespread screening for new diseases or pests is possible and disease "hot spots" can be used to test for resistance in new materials and thus help to keep one step ahead of races of diseases that are continuously evolving. Global cooperation on protection against serious pests and diseases is particularly important in an age when these can move rapidly, not only from one tropical country to another, but from the tropics to the temperate countries.

Table 2

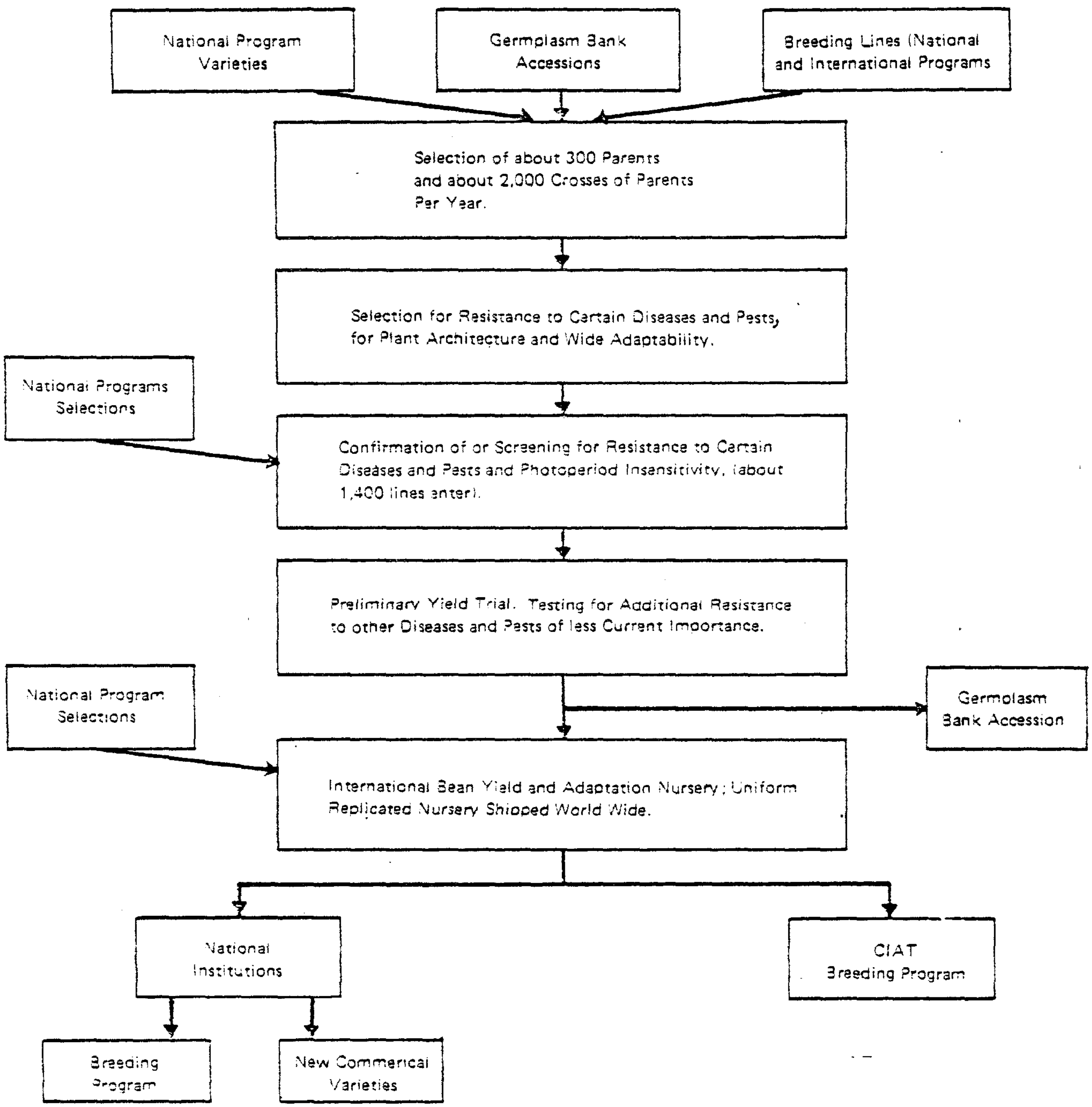
International Testing of some Major Crops by IARCs (1978)

Crop	Number of Crosses/ Pollinations	Nurseries/Lines Number Sent for Testing	Nurseries/Lines Number of Countries in which Tested
Rice	5,000	577	41
Bread Wheat	10,000	595	95*
Durum Wheat	5,000	352	56*
Triticale	4,000	400	77*
Maize	17,000**	3,470	80*
Barley	2,500	258	74*
Cassava (CIAT)	500	30	20
Chick-pea	1,200	327	28
Pigeon Pea	500	39	20
Cowpea	100,000**	39	20
Bean	1,500	250	30
Groundnut	50,000**		

* These include some nurseries in developed countries.

** Pollinations.

FIGURE 1
SELECTION, BREEDING AND PROGENY TESTING OF BEANS IN INTERNATIONAL AND NATIONAL PROGRAMS (CIAT)



Source: CIAT, The Bean Program

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Plant Quarantine

33. While global cooperation on testing for plant pests and diseases offers many advantages, a program which involves moving large quantities of plant material around the world also raises many problems of disease transmission and plant quarantine. Every country is naturally fearful about the introduction of new pests and diseases, but the standard of plant quarantine varies considerably. The IARCs have developed seed treatment techniques which are impressive in both their effectiveness and the scale on which they operate. As indicated in paragraph 22, centers dealing with clonal material (IITA, CIP and CIAT) have developed various tissue culture techniques that ensure freedom from viruses. Use of true seed rather than clonal material can also overcome some of the problems, though even this presents difficulties, e.g., spindle tuber virus in true seed of potatoes. Generally the recipient countries have a sound trust in the quality of the IARC materials, but there are still difficulties in moving plant materials in an efficient and timely manner. Since such movements are vital to the operation of plant improvement programs, this is obviously an area requiring continuing attention from the IARC system.

Plant Breeding Achievements

34. Through plant breeding research the achievements of the international centers have been significant in improving resistance to pests and diseases, tolerance to adverse climates and soils and nutritional quality.

35. Pest and Disease Resistance. The introduction of the dwarf genes in wheat and rice raised yield ceilings substantially and the new short season rice varieties made double or even treble cropping a practical proposition in many areas. This is an outstanding example of a successful plant breeding program, but success must be judged not only by large yield increases but also by other factors like pest and disease resistance. Since the achievements in the 60s, CIMMYT and IRRI have devoted substantial plant breeding resources to maintaining these gains. When the introduction of new genes for pest and disease resistance in rice also introduced weaker straw and greater susceptibility to lodging, further breeding to overcome these weaknesses was needed. Such genetic linkages have proved difficult to break,[2/] and much effort has been required to bring the yields of the newer varieties up to that of IR8 which was released in 1966.

36. While the research also on the other cereal crops is designed to raise yield ceilings by improving the ratio of grain to straw, pests and diseases limit yield increases. This is equally true of tuber crops and grain and forage legumes. So a great deal of research resources has to be devoted to improving pest and disease resistance.

2/ Chandler, R. F. Rice in the Tropics. A Guide to the Development of National Programs. Westview Press, 1979.

37. In the tropics and sub-tropics, the range and severity of diseases and pests are more extreme than in temperate zones and less is known about them. Moreover, the absence of a natural disease "break" caused in temperate climates by winter cold and the year-round presence of host plants in some areas, leads to greater persistence. This contributes to the rapid evolution of new biotypes of brown planthopper, for example, where host plant resistance can break down due to emergence of new races of pests or disease in as little as two years. Table 3 lists some of the major diseases and pests, which, of course, vary in importance from year to year and region to region. Furthermore, a once relatively minor pest or disease can assume importance very rapidly. Examples are the brown planthopper, a minor pest in the 1960s, but one of the most prevalent today, and tungro virus, which is now a very serious disease in rice, as is Septoria in wheat. These changes in plant-pest relationships cannot be predicted until substantial areas of new varieties are grown by farmers.

38. While many traditional cultivars have become obsolete because of disease susceptibility, the introduction of modern cultivars could result in greater potential damage due to the replacement of a large number of traditional cultivars by relatively few modern varieties. It has been estimated that 25% of the 130 million ha of the world's rice is in short-strawed, high tillering, photoperiod insensitive cultivars.[3/] Furthermore, it is calculated that this area of some 32 million ha is planted with only about 100 varieties which have replaced hundreds of the traditional cultivars. In Korea, for example, the variety Tongil, first released in 1972, covered nearly 40% of the total area by 1977. Large areas planted to one variety obviously present a threat of dramatic damage in the event of new pests and diseases. So far, the availability of a wide range of genetic materials has enabled the centers, in collaboration with national programs, to identify sources of resistance to the majority of these diseases and pests so that tolerant or resistant varieties have either been developed or are being tested.

39. A particularly striking example of the progressive development of resistance is given in Figure II which illustrates how rice varieties have been bred which are resistant to the major diseases and pests of the crop in the Philippines. CIMMYT has developed wheat varieties resistant to rusts and Septoria. IITA has a number of cassava lines resistant to both mosaic and bacterial blight, maize varieties resistant to streak virus and cowpeas with insect resistance. The CIAT bean program, although relatively new, has incorporated sources of resistance to important diseases such as common mosaic virus, rust, anthracnose, and angular leaf virus into lines with improved yield potential. CIP potato varieties with enhanced resistance to blight have been bred and further improvements are expected, as combined resistance to blight and other pathogens, e.g., bacterial wilt, a number of virus diseases and cyst nematode, is attained.

3/ Khush, G. S., 1977, Disease and Insect Resistance in Rice. Adv. Agron. 29, 265-341.

Table 3. SOME MAJOR DISEASES AND PESTS OF CENTER CROPS

Crop	Disease	Pest
Rice	Blast, Bacterial Blight, Tungro, Grassy Stunt, Ragged Stunt, Yellow Mottle Virus	Brown Planthopper, Green Leafhopper Gall Midge, Whorl Maggot, Leaf Folder, Stemborers
Wheat	Stripe Rust, Stem Rust, Leaf Rust, Root Rotting Fungi, Septoria, Head Scab	A number, but not as important as with maize, for example
Maize	Leaf Blight, Ear and Stalk rots, Streak Virus, Downy Mildew, Stunt	Army Worm, Stemborers, Leafhoppers. Earworm
Millet	Downy Mildew, Ergot, Smut, Rust, Blast	Of minor importance in India. In Africa there are a number of serious pests, e.g., Headworm
Sorghum	Striga, Downy Mildew, Grain Mold, Charcoal Rot	Shootfly, Stemborers, Midge
Barley	Leaf Rust, Stripe Rust, Scald, Powdery Mildew, Leaf Spot, Net Blotch, Virus Stripe	A number, but not as important as with maize
Chick-pea	Wilt, Stunt, Ascochyta Blight	Heliothis
Pigeon Pea	Fusarium Wilt, Sterility Mosaic, Phytophthora Blight	About 200, the most serious being Borers and Pod Fly
Field Beans	Common Mosaic Virus, Rust, Anthracnose, Angular Leaf Virus, Bacterial Blight, Golden Mosaic Virus	Leafhopper, Chrysomelid sp., Bruchid sp.
Cowpea	Leaf Spot, Anthracnose, Rust, Target Spot, Bacterial Blight, Bacterial Pustule, Yellow Mosaic, Aphid-borne Mosaic, Golden-Yellow Mosaic, Yellow Serere Mosaic, Cucumber Mosaic Virus	Leafhoppers, Thrips, Pod borers, Aphids, Bruchid sp.
Groundnut	Rust, Leafspots, Peanut Mottle, Rosette, Peanut Stunt, Tomato Spotted Wilt Viruses	Leaf Miners, Pod Borers, White Grubs, Aphids and Thrips
Cassava	Cassava Mosaic Disease (Africa), Bacterial Blight, Anthracnose, Super Elongation, Phoma Leaf Spot, Complex of Root Rots (Latin America and Caribbean)	Mealy Bug, Whitefly, Green and Red Spider Mites, Thrips, Scale Insects, Hornworm
Sweet Potato	S.P. Virus Complex	Weevil, Aphids, White Flies
Potato	Late Blight, Black Wart, Pink Rot, Phoma; Bacterial Wilt, Leaf Roll Virus, Virus X, Virus Y and numerous other identified and unidentified viruses	Potato Cyst Nematode, Root Knot Nematode, False Root Knot Nematode (at least 9 species)

FIGURE II

RESISTANCE RATINGS OF IRRI VARIETIES IN THE PHILIPPINES

Variety	Diseases				Insect			Soil Problems			
	Blast	Bacterial Blight	Grassy Stunt	Tungro	Green leaf-hopper	Brown Plant-hopper*	Stem Borer	Alkali Injury	Salt Injury	Zinc Defi-ciency	Phos-phorus Defi-ciency
IR8	MR	S	S	S	R	S	MS	S	MR	S	MR
IR5	S	S	S	S	R	S	S	S	MR	R	MR
IR20	MR	R	S	R	R	S	MR	S	MR	R	R
IR22	S	R	S	S	S	S	S	S	S	S	MR
IR24	S	S	S	MR	R	S	S	MR	MR	S	MR
IR26	MR	R	MS	R	R	R	MR	MR	MR	S	R
IR28	R	R	R	R	R	R	MR	MR	MR	R	R
IR29	R	R	R	R	R	R	MR	S	MS	R	R
IR30	MS	R	R	R	R	R	MR	MR	MR	R	MR
IR32	MR	R	R	R	R	R	MR	S	—	—	—
IR34	R	R	R	R	R	R	MR	S	S	R	R

R = resistant MR = moderately resistant MS = moderately susceptible S = susceptible
*Biotype 1

World Bank — 20255

Source: IRRI

40. The search for resistance to rice blast (*Pyricularia oryzae*) illustrates the enormous amount of work that has been needed to develop varietal stability to this highly variable organism. The disease now appears under some degree of control in lowland rice in Asia, but remains a major threat to upland rice, especially in Africa and Latin America. There are also pests and diseases to which resistant lines have not yet been developed or sources of resistance identified, for example ragged stunt in rice and insect pests in some crops.

41. Plant breeders have used several approaches to breeding for disease resistance. In some crops, rice for example, resistance has often involved a single major gene (vertical resistance). However, breakdown in resistance can occur rapidly and in some instances replacement varieties may be required about every three years or less. Breakdowns of this kind are not limited to developing countries, but few developing countries have the capacity to maintain the required intensive breeding program for resistance to new diseases or pests. Thus the IARCs have been able to play a major role when new races of pests or diseases emerge, for they have been able to draw on their extensive germplasm collection to identify sources of resistance.

42. A second approach to disease resistance which is being increasingly used is to breed multilines, i.e., genotypes with the same form and structure (phenotypes) but with differing sources of genetic resistance. This helps to ensure that if a new disease race appears, only a minority of plants will be susceptible. This prevents disease spreading from palnt to plant in epidemic proportions. CIMMYT has developed wheat multilines with differing sources of resistance to rust, and CIAT rice multilines with resistance to blast.

43. A third way of dealing with pests and diseases is to incorporate into varieties many minor genes that will provide a moderate level of resistance to the pest or disease (horizontal or field resistance). Such a technique is regarded as providing the best chances of long-term stability, but different methods of screening breeding materials will be needed. This approach is likely to be increasingly used in the future.

44. Breeding varieties with resistance to pests is one element of an integrated pest control program, others being biological and chemical control. Identifying natural predators, introducing sterile males to disrupt the mating cycle, the use of pheromones to confuse male insects and testing various pesticides are among the techniques being investigated and tested. Some of the IARCs are playing a leading role in developing components of integrated pest control, not only in monocropping but also in the mixed cropping systems which form a major part of tropical agriculture.

45. The foregoing account indicates that the IARCs have made very substantial progress in developing cultivars that show resistance to ever changing pest and disease syndromes. The results are spectacular only when the standard variety is ravaged by a new race of pest or disease to which the new variety is resistant. But breeding for pest and disease resistance is not a simple process;

in the natural spread of a disease the level of infection is often light or irregular which makes an accurate distinction between resistant and susceptible types difficult. IARC plant pathologists and entomologists have done much pioneering work in developing techniques whereby resistant or tolerant varieties can be identified.

46. Development of new resistant varieties will not of itself solve the disease and pest problems. Multiplication and wide distribution of high-quality clean seed of the new varieties is needed, and this is possible only through determined efforts by national governments.

47. Tolerance to Adverse Climate and Soil Conditions. Breeding for tolerance to heat, cold, drought, and infertile soils forms part of the crop improvement program at the IARCs. Breakthroughs in improving drought tolerance could have very substantial impacts on the production of rainfed annual crops. A good deal of work has been done on this subject in crops like wheat, maize and sorghum, but mainly in the developed countries. However, the term "drought" covers a whole spectrum of conditions, some of which are fairly specific to tropical areas. Whereas spring planting in the temperate areas usually starts with the soil profile at maximum moisture capacity following winter rains, seeding in tropical soils usually starts with the soil profile at a low moisture level following the dry season. Although rice is normally regarded as a semi-aquatic plant growing in water-logged conditions in areas of relatively high rainfall, many ricelands do, in fact, suffer quite severely from periodic drought due to rainfall variability. IRRI and IITA have been studying the rooting characteristics of various types of rice, screening the germplasm for drought resistance, including developing methods for mass screening techniques and criteria that can be used to define "drought tolerance". IITA has been screening other crops, e.g., maize, for drought stress and tolerance of high soil temperatures. Breeding for drought tolerance may not bring the spectacular results attained in irrigated agriculture, but even small improvements would be of great benefit. However, major advances in this field are likely to need considerably greater inputs from a number of scientific disciplines.

48. There has been relatively good progress in several aspects of breeding for adverse soil and climatic conditions. CIP, for example, has produced potato clones tolerant to temperatures as low as 4°C and these are now being tested; research has also demonstrated that the potato can successfully adapt to high temperatures. The CIAT forage breeding program is concentrating on varieties suited to the acid, aluminum saturated, nutrient deficient soils of the llanos and cerrado; several accessions in the germplasm collection have shown low requirements for available phosphorus, combined with tolerance of levels of aluminium considered toxic to most cultivated plants and with resistance to important diseases and pests. Cassava selections for low fertility soil show promise.

49. The wheat germplasm collection contains materials with a good degree of tolerance to aluminum toxicity. Some rice varieties have a promising level of tolerance for salinity and others for iron toxicity. Some of IITA's cowpea varieties have good tolerance for acid soils.

50. Nutritional Quality. Several programs deal with quality, particularly consumer preference, such as color in beans, cooking quality in rice, kernel color in maize and sorghum, cooking time in grain legumes and baking quality in wheat. Prolonged cooking time, especially in areas where fuel is in short supply, is a serious handicap for the potential consumer. Leaf quality and levels of hydrogen cyanide in cassava are also receiving attention at IITA.

51. Protein quality has received most attention from maize breeders at CIMMYT. Maize contains 9-11% protein, but since it is deficient in the amino-acids, lysine and tryptophan, it is of relatively low quality for human and monogastric farm animals which can utilize only about half the protein.

52. The opaque 2 mutant gene (the kernel is opaque) can improve this, but the original high lysine maize had lower grain yield, an unacceptable "chalky" kernel, greater vulnerability to disease and grain that dried more slowly. Starting in 1969, CIMMYT has produced tropical, sub-tropical and highland tropical selections that overcome most of these problems. Since this work started, there have been changes in the standards set for nutritional needs with more emphasis being put on calorie needs by the poorest consumers. Nevertheless, it is accepted that certain vulnerable groups, like pregnant women, young children and those suffering from diseases, would benefit from a better quality protein.

Farming Systems and Socio-Economic Research

53. The impact of the modern wheat and rice varieties resulted from their introduction into existing farming systems. Irrigated agriculture dominated many of these systems and the semi-dwarf varieties with the concomitant fertilizers led to substantial yield increase in these mainly monocrop systems.

54. The extension of the research programs of the newer international centers into other commodities and into rainfed farming systems led to a recognition of the need for a thorough knowledge of existing farming systems, which often have very complicated cropping patterns, and which in many parts of Africa and South America make extensive rather than intensive use of land. Intensifying the utilization of such land, improving the use of water in semi-arid areas, introducing more efficient crop combinations in these and in areas of land hunger, such as South and East Asia, and monitoring the impacts of new technology have become major activities in the center programs. Thus farming systems and socio-economic research look at the whole spectrum of improving farmer practices and extend well beyond the use of improved planting materials into such areas as crop rotations, soil and water management and inputs like mechanization.

Farming Systems

55. Research on farming systems is receiving a substantial proportion (14%) of the CGIAR budget and four centers (IITA, ICRISAT, IRRI and ICARDA) have major programs in this complex research subject. While the other centers do not have specific programs, their research is determined with the relevant farming systems in mind. In addition to these, a large part of ILCA's program is devoted to farming (livestock) systems research. Thus the term "farming systems research" covers a range of activities which vary from center to center. Five major areas of activity have been recognized:4/

(i) the collection and analysis of base data;

(ii) the study of existing farming systems;

(iii) the design of new farming systems;

(iv) farm systems experimentation; and

(v) the evaluation and monitoring of new farming systems.

56. Research on various parts of this overall range of activities has been done by many national programs, but the centers are performing a leading role in developing a holistic approach so that the various components can be integrated into their programs.

57. The work on collection and analyses of base data includes that on social and economic factors as well as on biological and environmental characteristics. Several of the centers (ICRISAT, IITA, IRRI, CIAT) have assembled and analyzed data on the climate and soil characteristics of their areas of operation and ILCA is collecting and analyzing data on livestock production in several countries. These and the study of existing farming systems have provided the research workers on the experiment stations with a firm background on which to base their experimental programs and have improved their understanding of the farmers' needs.

58. The third facet of the program, the design of new farming systems, is the most extensive within the center programs. This involves a variety of approaches across the different centers. ICRISAT is focusing on water management so as to maximize the use of rainfall in the semi-arid tropics. IITA's program involves considerable research into intensification of cultivation on the upland soils of the humid and sub-humid tropics which have been farmed traditionally under a system of bush or grass fallows, and into the utilization of hydromorphic soils. Work at CIAT aims at intensifying production mainly through the use of fodder grasses and legumes, on the poor soils of the llanos.

4/ Farming Systems Research at the International Agricultural Research Centers. CGIAR/TAC, September 1978.

Socio-Economic Research

59. Socio-economic research performs several roles. It is utilized in village level studies to examine existing farming systems and to reach understanding of why farmers behave as they do and thus indicate areas where changes might be induced. It is used to identify constraints to the adoption of new technology and to monitor the progress and consequences of the new technology. It is thus involved at both the beginning and the end of new technology. As a consequence, socio-economic researchers co-operate closely with the biological and physical scientists of the centers in defining research priority areas within the center mandates.

60. Economists and biological and physical scientists working together in multidisciplinary teams can ensure that the technology being developed is shaped to the farmers' needs; identifying the technical and institutional constraints impeding the adoption of improved technology can assist governments in developing policy interventions aimed at overcoming these constraints. The country studies undertaken by a number of the centers in collaboration with their colleagues at national level have produced a wide perspective of farmers' problems in varying agro-climatic and economic conditions.

Achievements in Farming Systems and Socio-Economic Research

61. Unlike the research output of plant breeding, which is new technology, the product of socio-economic and farming systems research is new knowledge. Thus the application of results from research of this kind will need a different approach from that, say, of plant breeding where the application of the output -- an improved plant type -- can be distributed to national programs or farmers. Use of better seeds or appropriate fertilizers is a relatively simple concept with a highly visible impact. An improved farming system, often with many social implications, is a complex concept that is likely to have many locale-specific characteristics. It is highly unlikely that an IARC could "invent" an improved farming system that could then be taken up by a national program and extended to its farmers. However, the centers have taken a leading role in developing the methodology in what is a relatively new area of research; few national programs have the ability to do this. Farming systems research requires multidisciplinary teams operating in an interdisciplinary fashion and it requires long-term commitments of funds. One of the major outputs of the centers work on farming systems will therefore be scientists trained in the methodology; another will be new principles that can be widely applied by national research organizations in developing new systems for specific locations. Yet another output will be "building blocks" that can be used by national programs and farmers, e.g., better methods of soil tillage and conservation, improved tools, better methods of water management, improved crop combinations and cultivars of crops like maize, beans, rice, cassava, that will perform well in combinations or that have the requisite growing period or plant shape to suit particular crop combinations. Some aspects of improved farming systems technology will be relatively easy for farmers to apply on individual farms (for example cropping patterns and zero tillage techniques) whereas others, like improved moisture control by land shaping are likely to be successful only if applied over a watershed by groups of farmers. Economists are examining ways in which a country program could work with farmers to achieve this objective.

62. In socio-economic research, the centers have pioneered the development of networks, such as the International Rice Agro-Economic network (IRAEN) and the CIMMYT regional network which are helping national programs to build their own capabilities. Center research has been devoted to both "constraints" and "consequences" of new technology. In "constraints" research, two problems have been examined:

-- why are so many farmers unable to achieve the potential high yields of the modern varieties;

-- why have some farmers still not adopted modern varieties.

IRRI has a research program on what constrains the adoption of new technology. Figure III illustrates its approach to this problem.

63. Figure IV[5/] illustrates the concept of the difference between actual farm yields and maximum experiment station yield. Although this concept was developed for rice, it has general application to the problems of technology transfer.

64. The first component, yield Gap I, exists mainly because of environmental differences between the experiment station and the average farm. Technology that gives high yields on experiment stations may not give as high yields in the less favorable environments that exist on many farms.

65. "Constraints" research has focused on yield Gap II, which is divided into two areas of investigation. The first identified which biological, physical inputs and culture practices account for the gap; these factors may vary widely from one region to another, but before any remedies can be taken (for example, recommending a package of improved practices) the biological nature of the gap must be understood. Experiments on farmers' fields are essential to obtain this information. IRRI has, for example, identified the major elements of the yield gap of approximately 6 tons/ha for rice between the experiment station and farmers' fields. The result of this study is set out in Table 4.

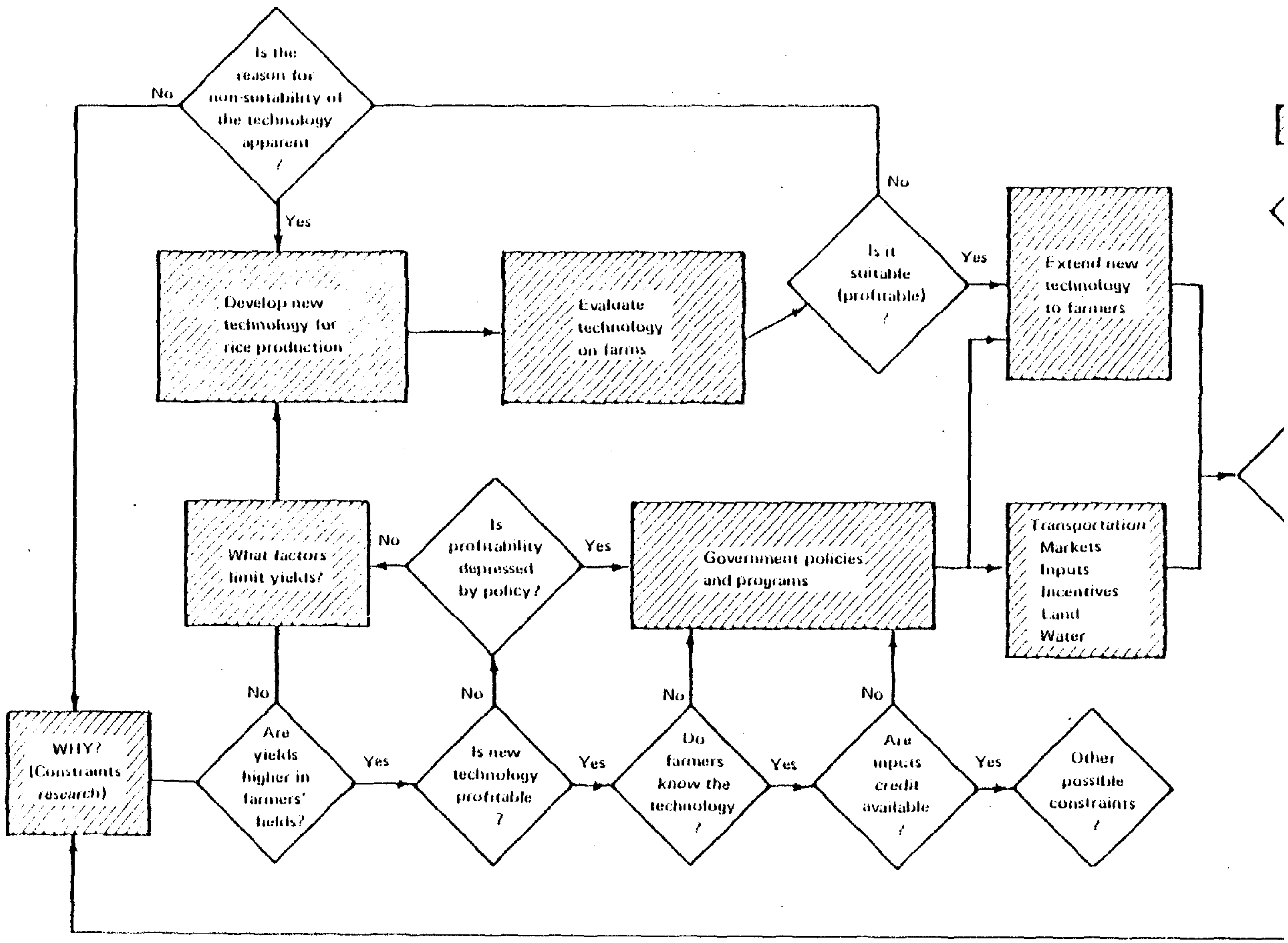
66. On the technical side, research to develop varieties with a higher degree of resistance to an unfavorable environment (drought, for example) should result in less year-to-year variability. However, the overriding need for further action by government in improving irrigation and drainage facilities and improving the supply of inputs, is obvious.

67. IRRI did a study on the adoption of modern rice varieties covering 2,344 farms in 36 villages in six countries in South and South East Asia. It found that the rate of adoption varied widely; in some villages over 90%

5/ A Handbook on the Methodology for an Integrated Experiment -- Survey on Rice Yield Constraints. S. K. De Dalta, K. A. Gomez, R. W. Herdt and R. Barker.

FIGURE III

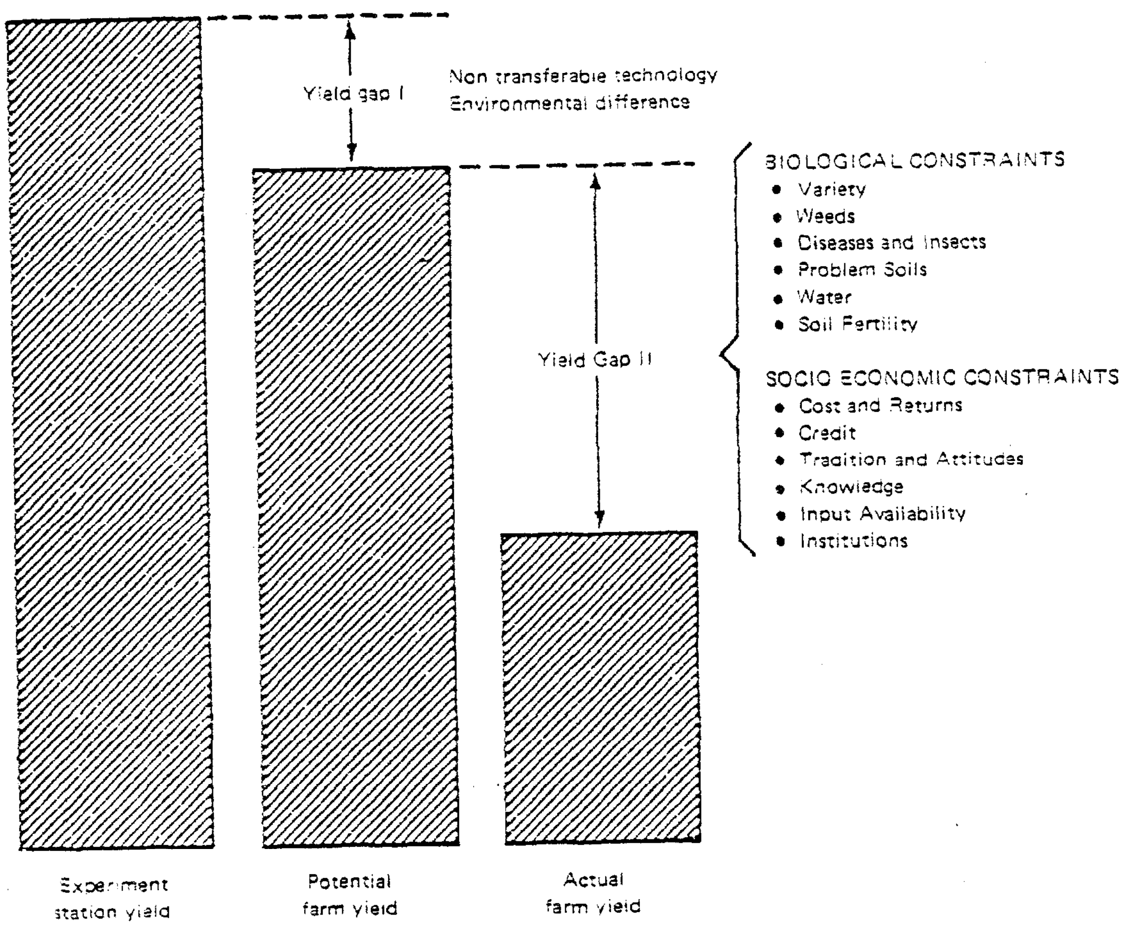
Constraints research in the development process.



Source: IRRI

FIGURE IV

The concept of yield gaps between and experiment station rice yield, the potential farm yield, and the actual farm yield (Gomez 1977).



Source: IRRI

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of the area was planted to modern varieties, while in others, less than 20% was sown to these varieties. The factors contributing to this variability were suitability of the varieties, the degree of water control and profitability. The wide acceptance of modern rice varieties in the Philippines also suggests that proximity to research centers, such as IRRI, is an important contributing factor in the transfer of technology. The study concluded that research for rice production in the national systems must be concentrated on the development of modern varieties suited to their particular agro-climatic conditions. Varieties are needed that perform well under different growing conditions such as salinity, flooding and deep water.

Table 4

Major Components of the Yield Gap

Yield Decrease Due To	Amount (tons/ha)	%
Lack of water control	1.4	23
Seasonal effects	1.2	19
Risk	1.0	17
Year to year variability	1.2	19
Residual effect due to non-availability of inputs and non-adoption of new technology	1.3	22.

68. ICRISAT's socio-economic program has concentrated on the analysis of traditional farming systems in India and the possibilities of introducing improved systems. Village level studies have indicated that there are practices that could significantly raise productivity. For example, the yield increase obtained from a combination of the three improved levels of technology -- improved varieties, use of fertilizer and better soil-water management -- were double the sum of the increases from the individual treatments, with the largest single increase obtained from fertilizer. CIAT has shown that bean yields on farmers' fields can be increased by 30-90% by simple changes in cultural practices.

69. The monitoring program at ILCA, designed to measure changes over time in the three components of the system -- the vegetation, the livestock and the people in livestock development projects -- should produce new methodology which will be within the resources of national programs to apply on a wide scale. In its Ethiopian Highlands program ILCA has a livestock package which increases income considerably.

70. An illustration of the value of negative results is the experience gained by IITA which has had a direct link to farmers through the Nigerian National Accelerated Food Production roject. The recommended practice was to intercrop a modern cassava variety with maize, in combination with improved plant protection and agronomic practices. This project has shown that the theoretically high profits were difficult to achieve in practice. Inputs were hard to get, the package was too costly and too complex compared to traditional practice and, even when markets were available, the farmers found that the extra income went largely towards repayment of loans obtained for the package. In addition, there was difficulty in disposing of the extra maize at prices attractive to farmers. This experience helped in formulating the agro-service center concept, now an integral part of the project.

71. Work by CIMMYT on uptake of high-yielding varieties of maize, has illustrated the importance of agro-climatic conditions. For example, the spread of hybrid maize in Kenya has been limited to the better rainfall areas and the spread of the high-yielding varieties of wheat in Turkey has been similarly limited by rainfall conditions. CIAT has found that cassava yields are affected by altitude as well as rainfall and soils.

72. A common finding of most of the IARC socio-economic research is the lack of infrastructure and the need to improve outmoded institutions in order to overcome the limiting factors of scarce inputs, credit, marketing and transportation. These are, however, issues which the centers do not have the competence or authority to deal with, given the many differing political and economic circumstances existing in their client countries. The centers' role has therefore tended to be limited to identifying rather than proposing solutions to such socio-economic constraints.

73. Research on the social and economic effects of the introduction of new technology is assuming increasing importance, but clearly much still needs to be done in view of the variations in the consequences of technical innovation, even in countries with comparable political and economic systems, due to different land tenure conditions, population pressures and institutional and environmental factors. The centers are thus playing a catalytic role in "consequences" research, but many of the problems are country specific and some touch on sensitive political issues which fall outside center research responsibilities or competence.

Mechanization

74. In many instances, improvements in farming systems will depend on the development of better farm equipment, either machine or animal powered. Three centers (ICRISAT, IITA and IRRI) have mechanization programs aimed at developing equipment which will improve productivity, prevent post-harvest losses and reduce drudgery on the farm. CIP also has a small program on storage and solar drying of potatoes and CIAT on storage and harvesting of cassava.

75. These mechanization programs aim to develop small machines that will intensify production and raise yields per unit area without displacing labor. This is possible because there are peaks in labor requirements resulting in a scarcity of labor, particularly in connection with multiple cropping. Small machines would also enhance the opportunities for introducing new operations which would have large labor requirements or would be too expensive to apply at existing wage rates.

76. The IITA program is focused on developing equipment for zero or minimum tillage farming practices suited to the situation of the resource-poor farmer. Also, in view of the fact that trypanosomiasis and other diseases largely prevent the use of draught animals for land preparation, seeding, weeding, harvesting and on-farm transport, a small two-wheeled tractor is being designed to help overcome this constraint.

77. ICRISAT's program is aimed at providing animal-drawn machines for different levels of crop management. Lack of power is often a major constraint to agricultural production in the semi-arid tropics; the size of the area cropped each year in these regions is determined by the available human power for certain critical operations, such as seeding, fertilizer application, land preparation, etc. The animal-drawn equipment being developed or adapted by ICRISAT is designed to increase the efficiency of these operations.

78. A common element of center mechanization research is that the equipment is designed for manufacture at the farm and village level and much of it can be made by small manufacturers. Indeed, production of much of the equipment is highly labor intensive.

Achievements in Mechanization

79. In mechanization IITA has developed "minimum" tillage techniques that reduce the energy input needed to conserve the topsoil, improve moisture storage and sustain high yields (with suitable inputs) for 5 years or more. ICRISAT has developed tools and cultivation techniques that allow intensified cropping of the heavy black soils during the wet season and prevent damage by run off. IRRI's cropping systems programs has taken multiple cropping systems that are a feature of intensive agriculture in East Asia, modified them and tried them widely in several countries in Asia. Some of these are now being adopted by farmers in areas where multiple cropping has not been traditional.

80. The kind of machinery development in which the centers are involved is summarized in Table 5. During 1976 about 3,800 power tillers and 770 threshers (1,900 in 1977) of the IRRI design were manufactured and sold. About 70% of the tillers and threshers were built in the Philippines, most of the remainder of the tillers in Thailand and the threshers in Thailand and India. About 25,000 power weeders of IRRI design were built in Japan.[6/]

6/ Industrial Extension of Small-Scale Agricultural Equipment Developed at IRRI, 1976.

Table 5

Some Equipment in Use or Being Developed at the International Centers

Center	Equipment	Use
CIP	Potato storage	Improved storage facilities
	Black box solar dryers	To retain nutritional qualities and reduce losses
ICRISAT	Wheeled tool carrier	Making beds and furrows Inter-row cultivation Supplemental irrigation
	Mechanical seeder	Precision planting of two or more intercrops
IITA	Controlled droplet applicator	More efficient use of fertilizer and herbicides
	Jab planter	Seeding in zero or minimum tillage conditions
	Rolling injection planter	" " "
	Fertilizer applicator	Fertilizer application in zero or minimum tillage conditions
	Rotary tiller	Establishing rice in poorly drained soils
	5.h.p. Tractor	Plowing, tilling and puddling Transport of on-farm equipment
IRRI	Thresher	To reduce losses in threshing and reduce time between planting of 1st and 2nd crops
	Dryer	To reduce spoilage
	Rotary tiller	To improve crop management
	Power weeder	" " " "
	Plow sole granular chemical applicator	" " " "
	Multicrop seeder	" " " "
	Windmill and pump	Energy source and irrigation
	Energy generation from agricultural residues	Alternative energy resource.
CIAT	Cassava harvester	To speed up harvesting
	Cassava solar dryer	To conserve crop

Training

81. All research institutions invest a considerable proportion of their resources in training. In the case of the IARCs this involves training both of the centers' own staff and of the students at various levels who come for specific training purposes. Since this paper deals mainly with outputs of research knowledge and new technology and since the training programs of the centers were discussed at a seminar during 1977 Centers Week, the subject is not treated in detail here, though it should be noted that approximately 10% of the CGIAR budget goes to training activities; some additional activities are funded through special projects.

82. Details of the number of trainees produced by the system are not available. Neither is the system of training at all centers exactly the same, while the same nomenclature may be used for different types of training. However, four distinct types of training have been recognized;7/ research education for research fellows (as part of an M.S. or Ph.D course), research training in various disciplines, production training, which usually includes a complete production cycle of the crop, and post-doctoral fellowships which have the dual purpose of providing the centers with well-trained young scientists and of training such scientists in tropical agriculture.

83. In the research education and research training programs, about 100-150 scientists are trained each year. In production training, the throughput is considerably higher and is probably of the order of 300-400 per year. Post-doctoral fellows number about 50-100 annually.

84. In addition, many of the centers run short courses lasting a few weeks, some of which take place away from the headquarters. Finally, the IARCs host a large number of seminars and workshops which bring together scientists from many national programs who have a common interest in a commodity or a program.

85. It is, of course, impossible to make any qualitative assessment of the contribution of the IARCs training programs to the progress of agriculture in the developing countries. Several centers have had follow-up programs which have indicated that national programs rate the IARC training projects as having very high priority. While the centers sometimes have problems in locating trainees with the requisite basic qualifications, the demand for training generally exceeds the centers' capacities. Such capacity is limited by both space and facilities and perhaps most importantly by the need to avoid overloading the research scientists with too many trainees.

Basic Research and the Generation of Scientific Knowledge

86. The term "basic research" tends to convey the idea of isolation from the problems of the everyday world. However, since research endeavor covers the whole spectrum from the most fundamental to the most applied, any boundaries

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7/ Burton E. Swanson. Research and Production Training at International Agricultural Research Centers: View from the Outside. CGIAR Seminar, 1977.

must be artificial. This paper uses the term "basic research" in the context of mission-oriented or strategic research -- the work that is needed to develop the scientific ideas on which future progress in agricultural technology must depend. The time horizon is considerably longer than that in technology generation, with the prospective payoff needing 10-15 years. Successful basic research thus requires informed judgments on the kinds of agricultural technology that the developing countries may need a decade or two hence and the security of long-term financial and scientific resources to sustain such an effort.

87. While IARC research has been generally devoted to exploiting ideas which have emanated mainly from work in the developed countries, there are some areas where new knowledge is needed if the centers are to continue to serve their purpose. They have to ask the question as to where the next advances in productivity are to come from and what strategies should be followed to develop the scientific ideas on which these will be based. Established and proven technologies are available for some irrigated crops, good progress is being made in some of the rainfed crops, but on the other hand, rather little progress is likely in some areas with the technologies that can now be foreseen.

88. The need for basic research has not been ignored by the centers and indeed there has been a spin-off of new scientific knowledge from their technology development work. Some of the centers already have plans to shift more of their resources towards basic research and have developed contracts with scientific institutes in the developed and developing countries, for example, ICIPE. ILRAD is, of course, a center which is very largely devoted to basic research. Second generation technical problems that have arisen in rice, such as some of the pests and diseases, have led to more attention to basic research. The fact that parents with resistance to diseases like sheath blight or ragged stunt have not yet been identified, makes this kind of research all the more urgent. While studies in the genetics of resistance to *Pyricularia oryzae* have been under way for many years, particularly in Japan, there is little comparable work on the genetics of resistance to the rice viruses which have become increasingly important in the last decade.

89. As noted in the opening paragraph, there are no hard and fast boundaries between the various kinds of research and the sections that follow are simply to illustrate some aspects of the kinds of mission-oriented basic research in which IARCs are involved.

Wide Crosses

90. Breeding programs of wide crosses between distantly related species or genera are being used to introduce disease or pest resistance into the domesticated species or, as in the work on triticale, to make a new kind of plant. Most of the centers are using some inter-specific or inter-generic crossing to introduce desirable characteristics. ICRISAT is using wide crosses of the groundnut *Arachis hypogaea* with its wild relatives, *A. chacoense* and

A. cardenasii to introduce resistance to Cercospora leaf spot. In cassava, the basis of resistance to the mosaic disease is derived from crosses of the edible cassava, Manihot esculenta with M. glaziovii. In potatoes diploid species, e.g., Solanum phureja, are being used to introduce resistance to bacterial wilt and root knot nematode.

91. While wide crosses have been used extensively to introduce desirable characteristics from wild into domestic species and this kind of research will continue to be significant, the object in triticale research has been to develop a man-made plant containing some of the most useful characteristics of both wheat and rye. This particular cross, known for more than a century, was first grown as a commercial crop in Hungary in 1968 and about 200,000 ha are now grown in Europe, North America and China. CIMMYT started collaborative work with the University of Manitoba in 1964. The differences in location permitted research on photoperiod response and search for resistance to virulent strains of rust. While the early selections gave about half the yields of the bread wheats in comparable trials, CIMMYT's discovery of the Armadillo strains which had good fertility, better filled grain and shorter straw, hastened progress. In 10 years, yields on the experimental station have reached those of the bread wheats. Problems such as disease susceptibility, lack of dormancy and thus sprouting during wet weather before harvest, remain. At the moment the crop is grown commercially in 11, mainly developed countries, but it is expected to fill a niche by displacing wheat in cool high altitude areas and acid soils, such as parts of Mexico, Northern India and Ethiopia. Triticale research is an example of a successful collaborative research effort between CIMMYT and developed country scientists. In the developing countries, lack of resources to improve the crop and to learn how to use it, are likely to make its uptake and spread a slow and lengthy process.

Nitrogen Fixation

92. Biologically fixed nitrogen is the only source of nitrogen for many crops in the tropics. The nitrogen-fixing capacity of legumes has long been known but little exploited; more recently some capacity has been discovered in the grasses, e.g., sorghum and sugar cane. Work at ICRISAT on sorghum is designed to discover whether nitrogen fixing bacteria in the rhizosphere can reduce the amount of nitrogen required by the plant from fertilizer, the conditions under which this could operate most effectively and those sorghum lines which have enhanced nitrogen-fixing capacity. At IRRI, the role of free-living nitrogen-fixing bacteria in flooded rice soils is being investigated (in collaboration with institutes in the U. S.). Recent results indicate that, in the greenhouse, 10-20 kg of nitrogen per hectare can be fixed during the growing season. Other nitrogen-fixing organisms, including the Azolla-blue-green algae associations, have long been known to fix nitrogen in flooded rice soils and the totals involved may be of the order of 60 kg per hectare per growing season.

93. Nitrogen fixation by legumes is also being studied at all of the centers concerned with these crops. Work at IITA has shown that a poor selection of legumes can deplete the soil of nitrogen just as do cereals,

and research is thus aimed at selecting varieties that make particularly efficient use of symbiosis between the legume host and rhizobia. The Asian-type soybean with good seed viability and an ability to nodulate with local rhizobia, is being used in breeding programs. Work at CIAT on Phaseolus bean, and at ICRISAT on groundnut, has similar aims. Breeding for pest and disease resistance in these species will also lead to improvements in nitrogen fixation since healthy plants have a much greater capacity to fix nitrogen.

Soil Research

94. IITA's research on the physico-chemical properties of tropical soils is a good example of the role of mission-oriented basic research in providing a better basis for applied research. A knowledge of the mineralogy and the surface chemistry of such soils is of importance in understanding their erodibility and the behaviour of added nutrients.

"True Seed"

95. The traditional "seed" used for planting such crops as potatoes and yams consists of tubers which are expensive to store and transport and carry several diseases, particularly viruses. IITA (yams) and CIP (potatoes) have been involved in developing methods which might be used by farmers to substitute botanical seed for the traditional planting materials. In potatoes, for example, the substitution of botanical seed for tubers could give substantial savings to the farmer since it is estimated that certified "tuber" seed may be as much as 60% of the cost of production, compared with, say, 5% using true seed. The problems to be overcome are genetic variability, the production of varieties that will readily produce seeds and agronomic techniques that can be used by small farmers to germinate, grow and transplant the seedlings.

Animal Diseases

96. It is estimated that the annual mortality of cattle from the four parasitic diseases -- Trypanosomiasis, Anaplasmosis, East Coast Fever and Babesiosis -- exceeds 5 million head, of which about 3 million die of trypanosomiasis.8/ ILRAD is one of a number of research organizations involved in studying ways of improving the host's natural and acquired immunity to the parasites. These parasites, and others like malaria, have mechanisms that enable them to evade the body's immune reactions due to their ability to develop antigenic variations and to suppress the immune responses of host animals.

97. The outer surface of a trypanosome consists largely of a glycoprotein antigen, which in the descendants of a single trypanosome can show that, while

8/ Barry R. Bloom, Games Parasites Play: How Parasites Evade Immune Surveillance. Nature, 279, 21-26.

the protein part of the molecule varies, the carbohydrate part remains unchanged. Attempts are being made to elicit immune responses against the carbohydrate groups in the hope that these will provide protection against a wide range of trypanosome variants. ILRAD investigators have also been able, for the first time, to cultivate African trypanosomes *in vitro* through the whole of their life cycle. This allows analysis of factors controlling antigenic variation, susceptibility of different stages to drugs, and other basic scientific problems relevant to control of the disease. The center is also studying genetically controlled resistance to trypanosomiasis in laboratory and domestic animals, including N'Dama cattle. Such work links closely with that of ILCA, which is studying the performance of N'Dama and other relatively resistant breeds of cattle under different management regimes.

98. Theileriosis (East Coast Fever) is a disease caused by protozoan parasites of the genus *Theileria* (*T. parva*, *T. lawrencei* and *T. mutans*). It causes a high mortality in cattle in East and Central Africa. A related important disease is produced by *T. annulata* which has a widespread distribution in North Africa and Asia.

99. *Theileria* is transmitted by ticks, and the established method of control is to destroy the vector, by dipping or other treatment with acaricides. These methods are costly and difficult for small farmers to apply, and resistance of ticks to all known acaricides develops. There is an urgent need for development of alternative methods of control, such as vaccination.

100. Cells containing *Theileria* parasites can now be cultivated *in vitro*, and a detailed study of immune responses to the parasites is being undertaken at ILRAD. It has been recognized for many years that animals which have recovered from theileriosis are resistant to infection by parasites from the same geographical area; however, it does appear that there are different antigenic types in different locations and research at ILRAD is aimed at differentiating these various types and attempting to find one or a small number of strains of the parasite that can be used for vaccination.

101. It is recognized that the basic research needed to develop immunological approaches to the control of these diseases presents difficult problems. Nevertheless, techniques have recently been developed that can facilitate the study of the mechanisms that cause resistance to infection. It is likely to take a considerable time for a payoff to this mission-oriented basic research, but such payoff, when it comes, is likely to have an application far beyond these particular diseases.

Basic Research in the Future

102. Only a relatively small proportion of the CGIAR's total resources are committed to mission-oriented basic research. It may be necessary to

increase this in future, but neither the centers nor the CGIAR have formulated any guidelines along which this might be done. If such research is expanded, it should be possible to contract with scientific institutes (mainly in the developed countries) which already have the resources to do such work. However, there are some aspects, pest and disease ecology, for example, which can be done only in the tropics. Similarly, parasitic diseases of animals can be most satisfactorily studied in their natural environments in the developing countries. It might also be argued that it is necessary to build up the capacity of scientific institutes in the tropics to generate new knowledge as well as new technology.

Concluding Observations

103. This part of this year's report has set out to review some of the contributions of the centers to research and technology development. The review is intended to convey an impression of the breadth and scope of the scientific endeavor rather than to raise issues or critically evaluate the research. This is not to suggest that substantial scientific issues do not exist, as they do in any healthy research organization.

104. In research terms the system is very young and it continues to explore new ways of improving the relevance and strengthening the quality of its research. There is increasing recognition that the impact of such research is very dependent on collaboration with national programs and that such programs can make major contributions to the advance of tropical agricultural research. The value of close collaboration with centers of advanced research in developed and developing countries is increasingly recognized, and the future is likely to see an increasing involvement of the scientific community of both developing and developed countries in the system.

105. The youthfulness of the system has both advantages and disadvantages. A young research system has a great degree of flexibility, it has opportunities to pick and choose research programs according to the best judgments of its scientists and it can offer its scientists an unrivaled array of challenging problems. On the other hand it faces a bewildering array of interesting and possibly profitable lines of research, many of which it must ignore. The review indicates that the centers have made hard choices, and while it cannot be expected that each choice will be equally fruitful, there is evidence that many of the activities are beginning to provide useful results.

106. Many millions of farmers and consumers have benefitted already from the technology developed by the system; many more will benefit in the next decade, but not all farmers have benefitted equally and never will. This is not due to any lack of recognition of their needs but to the limits to what biological research can now do. It has to be recognized that there are areas where the foreseeable technology will have little impact. Perhaps new kinds of research may open up opportunities that cannot now be predicted but even the most optimistic forecasts would put such benefits at one or two decades hence.

107. The present programs of the centers can provide technologies that will make farming inputs more productive but they cannot provide technologies that will substitute for all such inputs, as the review of socio-economic research shows. Thus research can be applied successfully only where there is the political will and the infrastructure to make these inputs available.

108. The center system is bound to change its character over time. Some of the programs may shift to more basic research as the national programs develop their capacity for technology development, particularly their defensive research to protect present gains. Such shifts will depend on how each center views its evolving role and on the views of the members of the CGIAR about the future roles of international research.

109. Finally it seems worth emphasizing once again that agricultural science knows no political or even ecological boundaries. The fuller exploitation of the world's relatively few food species will eventually benefit farmers and consumers everywhere and the CGIAR system can take credit for bringing the research systems of developed and developing countries closer together.

III. THE NEEDS FOR 1980

Introduction

110. In keeping with the vitality and flexibility of the research effort described above, the Consultative Group and the network which it supports will continue to grow and diversify in 1980. At least two donor members are joining the CGIAR and several developing countries are considering joining as donors. The addition of two new activities -- ISNAR and IFPRI -- will bring to 13 the number of centers and programs supported by the Group. The 11 current activities plan continued development, particularly in rice and livestock-related research.

111. Even with this expansion, the levelling-off in the rate of growth of individual centers begun this year will continue in 1980. The proposed increase in financial requirements between 1979 and 1980 will be the second lowest in the nine-year history of the CGIAR.

112. Despite the moderation in center growth rates, it has appeared for some time that the likely level of contributions in 1980 will not keep pace with expressed needs. This is due to several factors: the addition of new activities, unprecedented rates of inflation, particularly in the countries where the centers are located, and the economic problems of several major donor countries. Consequently, at its meeting in May 1979, the Consultative Group adopted or reaffirmed principles which would help to bridge the projected gap between budget requests and contributions in 1980. It also asked the TAC, Center Directors and the two Secretariats to work together to bring the deficit within manageable proportions. Failing this, the Group agreed to convene a Standby Committee to devise a solution.

113. Once a year, TAC and the Center Directors meet together to review programs. This year the meeting took place at ICRISAT in Hyderabad, India, in early July. During this meeting TAC and the two Secretariats identified potential savings of about $8 million in the collective 1980 budget requests of the centers amounting to $126 million. These reductions are described below. In most cases they will require substantial and difficult adjustments to proposed programs. The effect of these budget cuts would be to bring the 1980 net budget requirement to within about $2 million of the projected level of contributions, which is an acceptable deficit at this stage of the budget cycle. In the past, due mainly to marginal underexpenditure, a deficit of this magnitude has largely disappeared without further intervention.

114. While a solution may have been worked out for next year (assuming the estimate of donor contributions proves reasonably accurate), the ad hoc deferrals and budget adjustments are, for the most part, temporary expedients to manage a difficult situation. They are not a lasting solution. The continued effectiveness of the research effort requires a more stable, rational and systematic approach to ensure a balance between requirements

and resources. Centers need reasonable assurance of the resources likely to be available over the next several years if they are to plan and carry out research programs on a cost-effective basis. Part IV of this Report puts forward a suggestion for a longer-term financial plan for the CGIAR.

1980 Budget Requests

115. The core budget requests for operations and capital of the 13 centers and programs supported by the Group in 1980 are as follows:

Table 6

1980 Core Budget Requests

Center	Core Operating	Capital	Total Gross	Total Net	Increase Over 1979 Revised Total Net Requirements
	($ millions, rounded)[1]				%
Established Centers					
CIAT	14.8	0.9	15.7	15.3	17
CIMMYT	17.2	1.0	18.2	17.3	27
CIP	7.8	0.4	8.2	7.5	18
IITA	14.4	1.5	15.9	15.3	6
IRRI	16.0	0.8	16.8	16.5	22
IBPGR	3.1	-	3.1	3.1	22
WARDA	2.7	0.7	3.4	3.1	32
Subtotal	76.0	5.3	81.3	78.1	18
Developing Centers					
ICRISAT	10.7	2.9	13.6	11.8	40
ILCA	8.5	1.3	9.8	9.7	41
ILRAD	9.2	2.5	11.7	11.5	37
IFPRI	2.5	0.1	2.6	2.6	-
Subtotal	30.9	6.8	37.7	35.6	50
Newer Centers					
ICARDA	8.8	3.5	12.3	11.9	22
ISNAR	1.2	-	1.2	1.2	-
Subtotal	10.0	3.5	13.5	13.1	34
TOTAL	117.0	15.4	132.4	126.8	26

1/ Columns do not always add up to the totals due to rounding to the nearest hundred thousand dollars.

116. The total budget request shown above of $132 million, and the net request (after deducting earned income and funds brought forward from 1979) of $126.8 million, are the amounts approved by the Boards of Trustees of the centers and contained in each center's Program and Budget Paper. They do not reflect the proposed adjustments recommended by TAC and the Secretariat.

117. On the basis of the requests of the centers, the system would grow, in financial terms in current dollars, by 26 percent over 1979. About 10 percent of the growth over 1979 would be due to inflation, and 4 percent to the addition of ISNAR and IFPRI. The balance of about 12 percent represents real growth due primarily to the continued development of ICARDA, ILCA and ICRISAT to planned full development levels, and to some real expansion in virtually every other center.

118. The principal new activities proposed for 1980 by the centers are as follows:

CIAT - upland rice program, cassava utilization, regional services program;

CIMMYT - expansion of regional programs and wide crossing program, germ plasm storage facility;

CIP - modest real growth of operational budget but no new programs;

ICARDA - continued development of research program and initiation of construction of principal research station in Aleppo;

ICRISAT - development of West African program, consulting services team, Phase II headquarters construction;

IITA - additional working capital;

ILCA - continued development of humid/subhumid and highlands programs;

ILRAD - acquisition of cattle-rearing facility, staff housing;

IRRI - biological nitrogen fixation program, expansion of cooperation with national programs, particularly with the People's Republic of China;

WARDA - research station in Liberia, core budget support for portion of four regional research programs;

IBPGR - no major new activities;

IFPRI - continued development of core program; and

ISNAR - initiating operations.

These and other proposed new activities are described in each center's program and budget submission and in the Secretariat commentaries.

119. Senior staff would grow by 45, which is in line with previous years. At 9 percent, the growth is consistent with the real financial growth of the system.

Table 7

Senior Staff Positions, 1978-1980

Center	1978 Actual	1979 Revised	1980 Budget
CIAT	61	61	65
CIMMYT	69	77	88
CIP	29	29	30
ICARDA	22	28	33
ICRISAT	44	57	66
IITA	94	95	95
ILCA	48*	52*	61*
ILRAD	31	46	51
IRRI	57	58	59
IFPRI	24*	25	25
Total	479	528	573

* Manyears

120. By the end of 1980, about 7,000 persons would be employed in the CGIAR network.

121. Expenditures on research would remain at about 61 percent of total operating expenses, and the proportion devoted to other activities would also be the same in 1980 as in 1979 -- training and conferences (8 percent), library and documentation (5 percent), general administration (11 percent), general operations (13 percent) and miscellaneous (2 percent). In absolute terms, the distribution would be as follows:

Table 8

Object of Expenditure

($ millions)

	1978 Actual	1979 Revised	1980 Budget	1981 Forecast
Research	44.3	56.6	65.1	70.5
Training and Conferences	5.4	7.6	8.5	8.7
Library and Documentation	4.3	5.0	5.7	6.4
General Administration	9.3	10.5	12.0	13.0
General Operations	10.8	12.6	14.1	15.8
Other and Contingencies	1.1	2.0	2.2	2.2
Subtotal	75.2	94.3	107.6	116.6
Price Increases	-	-	9.2	20.4
Subtotal, Core Operations	75.2	94.3	116.8	137.0
Core Capital	21.8	14.9	15.6	14.4
Subtotal, Core	97.0	109.2	132.4	151.4
Special Projects	10.7	16.8	12.8	11.3
TOTAL EXPENDITURES	107.7	126.0	145.1	162.7

122. With the addition of ISNAR and IFPRI, the proportion of activity in the CGIAR not related to particular commodities would increase to 22 percent of total expenditures by 1981. The distribution within commodity research would be roughly the same in 1980 as in the past, with some relative decrease particularly in rice and other cereals research, beginning in 1981.

Table 9

Distribution of Expenditure by Commodity or Program

(percentage)

	1978 Actual	1979 Revised	1980 Budget	1981 Forecast
Cereals	37	35	36	32
Root Crops	11	11	10	9
Legumes	8	8	7	8
Livestock	20	21	21	21
Farming Systems	9	9	9	8
Other 1/	15	16	17	22
TOTAL	100	100	100	100

1/ IFPRI, ISNAR, IBPGR and research support which cannot be allocated to specific commodities.

123. Capital expenditures for 1980 would be $14.7 million, the lowest in five years due to the scheduled completion in 1979 of ICRISAT Phase I construction and ILCA's headquarters complex. Major capital expenditures in 1980 would be for ICARDA and the ICRISAT Phase II headquarters and West African capital programs.

Proposed Budget Reductions

124. As indicated above, the net request for 1980 (of $126.8 million) is about $9-10 million greater than estimated contributions. At the Hyderabad meeting in July 1979, steps were taken to reduce this projected gap by about $8 million. Proposed budget reductions of six types were worked out:

i) deferral or deletion of certain new program activities as recommended by TAC and described more fully below (savings of $1.0 million);

ii) limitation of the real growth of established centers as recommended by TAC in the light of the policy on limiting growth adopted by the CG at its May 1979 meeting ($1.5 million);

iii) adherence to the Group's policy that a center in the middle of a budget biennium should not increase its budget for the second year above what had been approved initially ($1.1 million);

iv) across-the-board reduction of 25 percent in each center's budget for new equipment in 1980 ($1.3 million);

v) deferral of all new staff housing construction ($0.7 million); and

vi) technical budgetary adjustments (revised estimates of fill rates, contingency reserves, price increases, and revised estimates of funds brought forward and earned income) - ($2.3 million).

125. The proposed adjustments worked out in Hyderabad consist of specific program reductions resulting from the TAC review of each center's program and budget together with standard budget adjustments applicable to all centers based on analyses by the CG Secretariat.

126. The principal recommendations on programs are that:

i) the proposed increase in upland rice research at CIAT and WARDA be deferred until TAC and the four centers involved in rice research (the two above plus IITA and IRRI) have met to seek to rationalize CGIAR support to rice research;

ii) the proposed transfer of certain CIAT off-campus special projects to the core program be deferred until the current TAC stripe analysis of off-campus activities within the CGIAR has been completed;

iii) ILCA should consolidate its research effort before any significant expansion takes place;

iv) the proposals by ICRISAT and CIMMYT for real program increases in the second year of their biennium should not be accepted in the light of the principles adopted by the Group on biennial budgetting. (TAC also felt that logically no program reductions should be recommended for the five centers in mid-biennium -- CIMMYT, CIP, ICRISAT, IITA and the IBPGR -- whose 1980 programs had already been approved by the Group); and that

v) established centers, principally IRRI and CIAT, should limit their real growth in the light of the decision taken by the Group in May 1979 to limit the expansion of the developed centers.

127. These program reductions recommended by TAC would save about $3.8 million and together with the technical budgetary adjustments and reductions in expenditure on equipment and housing would result in total savings of about $8 million. The effect of these proposals for each center is shown in Annex IV. The average reduction in the 1980 budget request of the centers is about 6 percent, ranging from no reduction (ISNAR) to 16 percent (WARDA). The principles on which the standard budget adjustments are based are also described in Annex IV.

Recommended 1980 Budgets

128. Taking into account these reductions, which in each case have been worked out in consultation with the center concerned, the recommended 1980 core budgets for operations and capital are as follows:

Table 10

Recommended 1980 Core Budgets [1/]

	Operations	Capital	Total Gross	Total Net	Increase Over 1979 Revised Net Budget Requirements	Real Growth in Operations 1979/80
	($ millions, rounded)				%	%
Established Centers						
CIAT	14.4	0.6	15.0	14.6	12	4
CIMMYT	16.8	0.3	17.1	16.2	19	3
CIP	7.7	0.3	8.0	7.3	16	2
IITA	14.3	0.8	15.1	14.6	1	-
IRRI	15.5	0.4	15.9	15.6	15	3
IBPGR	3.1	-	3.1	3.1	22	3
WARDA	2.5	0.2	2.7	2.6	8	8
Subtotal	74.3	2.6	76.9	74.0		
Developing Centers						
ICRISAT	10.2	2.2	12.4	10.5	25	5
ILCA	7.8	1.2	9.0	9.0	29	3
ILRAD	8.8	1.6	10.4	10.3	22	11
IFPRI	2.4	-	2.4	2.4	-	-
Subtotal	29.2	5.0	34.2	32.2	35	
Newer Centers						
ICARDA	8.7	3.1	11.8	11.4	17	15
ISNAR	1.2	-	1.2	1.2	-	-
Subtotal	9.9	3.1	13.0	12.6	29	
TOTAL	113.4	10.8	124.2	118.8	20	9

1/ See Annex V for complete presentation in $'000.

129. As indicated in the table above, the recommended budget would permit some growth for virtually every center. Apart from the technical budgetary adjustments and across-the-board equipment reductions, the 1980 programs and budgets of the five centers in mid-biennium (CIMMYT, CIP, ICRISAT, IITA and IBPGR) already approved by the Group last autumn would not be reduced. The 1980 budget requests of the three centers entering a new biennium (CIAT, ILRAD and IRRI) would be cut back (to 3-4 percent real growth for CIAT and IRRI and 11 percent for ILRAD) in accordance with TAC's recommendations and, for CIAT and IRRI, the policy on growth enunciated by the Group at its May 1979 meeting.

Proposed 1980 Funding

130. If these recommended budgets are agreed by the Group, proposed funding for 1980 would be as follows:

	1980 ($ millions)
Core Operations	113.4
Capital	10.8
Total Core	124.2
Less: Earned Income and Funds Brought Forward	5.4
Net Requirement from CGIAR	118.8

1981 Requests and Forecast

131. Three centers — CIAT, ILRAD and IRRI -- have prepared biennial budgets for the period 1980-81. In keeping with the spirit and principles of biennial budgetting, TAC reviewed the 1981 budgets of these three centers and has recommended their acceptance by the Group subject, in the case of CIAT, to certain action by the Board of Trustees and, for all three centers, to the availability of funds in 1981. TAC also recognized that actions required by these centers in 1980 to reduce their programs and budgets may have implications for the 1981 budget, and the mid-term budget request would be reviewed with this circumstance in mind.

132. On the basis of their requests set out in their Program and Budget Papers for the 1980/81 biennium and adjusted in accordance with the recommendations set out above, the total net requirements of these three centers in 1981 are indicated below. Analyses of the real growth in 1981 are provided in the Secretariat commentaries on each of the three centers.

	Recommended Funding 1980	1981	Change 81/80 Current	Real
	($ millions)		%	
CIAT	14.6	17.3	18	8
ILRAD	10.3	11.8	15	1
IRRI	15.6	19.0	22	7

133. The remaining ten centers and programs will not be submitting budget requests for 1981 until next year. As is customary, however, each has made a forecast of 1981 needs. The sum of the three firm requests and the ten estimates is about $152 million. Assuming the normal amount of earnings and funds carried forward, this forecast suggests that the total net request for 1981 may be not less than $146 million, excluding any new centers or programs which might be added to the network. Almost three-quarters of this amount relates to the centers which have yet to work up their 1981 budgets. In the light of a policy limiting growth, it may well be excessive. It is slightly more than is suggested in Part IV of this Report.

IV. LONGER-TERM FINANCIAL PLANNING

Introduction

134. Technology development is a long-term process, and therefore dependent on stabile and continuing financial support. While temporary difficulties such as the CGIAR faces in 1980 can be managed through ad hoc and short-term adjustments, the longer-term effectiveness of the centers will require a reasonable degree of assurance that adequate resources will be forthcoming, and not subject to annual fluctuations and uncertainties.

135. For some time now, the Consultative Group has been moving toward a longer-term perspective on its growth and evolution. In 1976, the CGIAR Review Committee urged that each center develop a longer-term indicative plan which would include analyses of its direction, balance among activities, priorities and appropriate size. Several centers have undertaken such a review. The TAC Priorities Paper, considered by the Group at its May meeting, has also identified several new high priority activities which could warrant the Group's support over the next few years.

136. The Group will be able to make rational choices regarding possible new or expanded activities, and the centers will be able to devise realistic and practical forward plans (and future program and budget requests), only if there is a longer-term financial plan for the system as a whole to guide these efforts. If the Group wishes to plan for its systematic development, offer guidelines to the centers on their future development and avoid the kind of situation which was handled ad hoc for 1980, it should seriously consider the development of a longer-term financial plan for the CGIAR itself.

137. The time for developing a forward financial plan is propitious on other grounds as well. After several years of relatively abundant agricultural production, grain reserves are again diminishing. The pessimistic forecasts of grain output in 1979/80 are focussing attention once again on the inadequacies of food production in many developing countries. At the economic summit meeting in Tokyo in June 1979, the leaders of Canada, France, Germany, Italy, Japan, the U.K. and the U.S. focussed on the food problem and the steps needed to increase agricultural output. They stressed the particular importance of agricultural research. Their final communique said, in part:

> "We will place more emphasis on cooperation with developing countries in overcoming hunger and malnutrition. We will urge multilateral organizations to help these countries to develop effective food sector strategies and to build up the storage capacity needed for strong national food reserves. Increased bilateral and multilateral aid for agricultural research will be particularly important. In these and other ways we will step up our efforts to help these countries develop their human resources, through technical cooperation adapted to local conditions."

138. The recent United Nations Conference on Science and Technology for Development reinforced the need for greater attention to the technology requirements of the developing world. It has been estimated that about $150 billion is spent globally each year on research and development. About a quarter is spent

on defense, 15 percent on basic research, and 8 percent each on non-military space activities and energy. Only 3 percent is spent on agriculture worldwide. Furthermore, most R and D takes place in developed countries. Only about 5 percent of total research and development expenditure in all sectors is spent by developing countries. The $100 million spent by the CGIAR in 1979 is almost insignificant compared to the amounts spent elsewhere on R and D, the importance of agriculture in developing countries, and the historically high pay-off from investment in agricultural research, as indicated in last year's Integrative Report.

Five-Year Plan

139. To begin to meet the needs of these countries more adequately, the Consultative Group should consider increasing the flow of resources to international agricultural research over the next five years. A realistic target would be to double (in current dollar terms) the funds available for international agricultural research over the next five years (by 1984), to about $250 million.

140. Even with relatively conservative assumptions regarding inflation, $250 million is the level of activity which would be achieved if the Group were only to maintain the same, or even a somewhat lower, rate of development as will have been achieved between 1975 and 1980. It is consistent with the growth path suggested by the CGIAR Review Committee in 1976 (which suggested a 1980 budget level of $116.4 million, very close to the expenditure planned today).

141. If a target of doubling the financial resources of the CGIAR by 1984 is consistent with the historical development of the Group, it is also fully in line with the priorities and principles of growth established by the CG The TAC Priorities Paper identified five research areas which it believes warrant first priority attention by the Group: tropical vegetables, water and soil management, aquaculture, pest and disease management, and food policy. IFPRI will join the CGIAR in 1980. TAC is preparing a proposal for a vegetable research center, and has recently considered reports on water and soil management and aquaculture. The work of the International Center for Insect Physiology and Ecology (ICIPE) is related to pest and disease management, and ICIPE has applied to become part of the CG system. At least one serious, carefully prepared proposal in an area of high priority could be brought before the Group each year for the next several years.

142. A doubling of resources is also compatible with the recent decision of the Group to limit the growth of the existing centers. Several larger centers, including ICARDA, ICRISAT, ILCA and ILRAD, are some years from "full development." Real growth rates of 10-20 percent (depending on the stage of development) can be assumed through 1982 (1984 for ICARDA). For the established centers, TAC and the Secretariat suggest that some modest growth over time could be accommodated within a limits-to-growth policy to provide flexibility to respond to new problems and requirements and to important and promising discoveries. The projections below provide real growth of up to 3 percent per year for the established centers (and for newer centers after reaching their planned full development). This assumed modest growth in the established centers affects the total growth only marginally.

If they had no real growth at all, the requirement in 1984 would be reduced by only $18 million, a sum which might alternatively be needed for new activities or to meet higher inflation than assumed. If, as a matter of CG policy, existing activities, after reaching full development, were to be permitted no growth at all and if also no new activities were added to the CGIAR, the level of expenditure by 1984 in current terms would still approach $200 million. Judging by its past history, however, when important gaps in agricultural research are found, the Consultative Group will wish to consider filling them, and as time goes on may wish to become involved in areas not yet considered, such as basic research, research on crops other than food crops, or closely related activities like agroforestry.

143. If the existing centers grow within the modest limits indicated above, four new activities are added between 1981 and 1984 and the Group begins to be involved in new areas of interest toward the end of the five-year period, the development of the CGIAR would be as follows, in real terms:

Five-Year Financial Plan (Gross Requirements)
(Constant $ millions)

	1980	1981	1982	1983	1984
Thirteen Existing Activities	124	134	143	147	151
Four of New Activities Already Identified	-	2	5	14	23
New Areas of Interest	-	-	2	5	9
TOTAL	124	136	150	166	184

144. The projected growth patterns for each center and program under this plan are indicated in Annex VI.

145. Assuming an average inflation rate of 9 percent between 1980 and 1984 (which is the weighted average of the rates of inflation assumed by the centers for 1979 and 1980), the growth in current dollar terms would be as follows:

	1980	1981	1982	1983	1984
Constant (1980) $ millions	124	136	150	166	184
Current $ millions	124	149	180	216	259

146. This pattern represents a 20 percent annual growth rate in current dollars, and 10 percent in real terms, for the period 1980-84 (which is somewhat lower than the historical growth of the CGIAR) and would represent a net requirement of about $250 million in current dollars by 1984.

147. It follows from the foregoing that a doubling of CGIAR resources by 1984 is a reasonable and, indeed, a modest target, consistent with the historical development, priorities, principles and current processes of the Group. It can be achieved if current donors are able to maintain their rate of increase in contributions ach-

ieved between 1975 and 1980 and if some new donors can continue to be attracted to the Group.

148. Even though most donors cannot make binding commitments five years ahead, agreement in principle to a doubling of resources over the next five years would be a valuable expression of the intention of the international community to increase substantially the resources devoted to agricultural research for the benefit of the developing countries.

149. There are also practical benefits. Such a "statement of intent" can serve as a guideline to TAC and the Group for the formulation and consideration of new program proposals. The size and the timing of potential new activities can be molded within this growth objective. On the basis of express principles of growth, it can also provide more explicit guidance to the centers regarding their longer-term development.

150. Agreement on this order of magnitude would also help resolve the problem of resource allocation within the system. It could serve as the basis for developing guidelines to be agreed by the Group and provided to the centers each year as the basis for budget preparation. It would permit more effective involvement of the Group in determining the size and the balance of the overall research effort.

<u>Future Governance and Management</u>

151. A system the number of whose units increases by about 30 percent in five years and whose total program expands by 48 percent in real terms will be more complicated to manage than the present one. The unique characteristics of the Group -- informality, decentralization, and relative lack of bureacracy -- may be hard to sustain. The existing relationships among donors, Center Boards and management, TAC and the Secretariats may need further rationalization. Most importantly, the allocation of responsibility and accountability for the scientific quality, management efficiency and financial integrity of the enterprise will need to become more explicit.

152. By sheer size, and in the face of competing demands among centers for funds, the governance and management of the system are likely to become the major issues facing the Group over the next few years. The challenge will be to maintain the unique characteristics and strengths of the CGIAR as it becomes a larger, more complex institution. There is no doubt that it can be accomplished if the Consultative Group continues to enjoy the good will of donors, and if they are prepared to accord to international agricultural research the high priority which its record shows it deserves.

153. One of the recommendations of the 1976 Review Committee was that the system ought to be reviewed every three to five years. It suggested an <u>ad hoc</u> committee of the Group be appointed "to conduct a review of the substantive program of the CGIAR as well as review those policies, procedures and management mechanisms which require attention" (Recommendation No. 14). Centers Week 1979 marks the third anniversary of consideration of the Report by the Group. It is appropriate to begin thinking about the next review -- its objectives, coverage and timing. At the latest, the next review should take place in 1981 so as to set the course for a new period

beginning in 1982. The Group may wish the Secretariat to prepare terms of reference and a work plan for the second major review of the appropriate scope, scale and character of the international research effort supported by the CGIAR, paying particular attention to questions of organization and management as the system grows to embrace as many as 17 separate entities with a total gross budget of about $260 million. The Secretariat could prepare a proposal for discussion at the next meeting of the Group.

V. CONCLUSIONS

154. The international centers and programs supported by the CGIAR are engaged in the most pervasive effort in biological research in the developing world. The new knowledge gained, the scientists trained and the intellectual communication generated by this activity represent a significant achievement. While the kind of rapid and spectacular impact of the research effort on wheat and rice production during the past decade is unlikely in the future, new knowledge and new technology -- particularly for rainfed agriculture -- can be generated by the international centers which will result in significant increases in production. The mechanisms are already in place.

155. What is needed is imaginative, long-term, patient research which, in turn, requires a long-term commitment from the international community to maintain and extend its financial support.

156. With only 3 percent of the world's research and development budget being devoted to agriculture, the scope -- and the necessity -- for increasing such support is considerable. In suggesting a doubling of resources contributed to international agricultural research over five years in nominal terms, it is proposed only that the international community maintain its support for the continued development of this unique enterprise at rates which it has found possible to support in the past. At 10 percent per year in real terms this target is realistic, and should enable the international network to bring the unique resources of the CGIAR to bear on a growing number of difficult problems in increasing and stabilizing food production in the developing world.

157. Growth even on this modest scale implies substantial sums of money and a system of such size to warrant serious attention to questions of governance, management, cost-effectiveness and accountability. The time is approaching for the Group to address itself to the scope, size and character of its support of agricultural research. This suggests that planning should now take place for a second review of the CGIAR and its system in preparation for its second decade.

International Research Centers
and Programs Supported by the CGIAR

CIAT	-	International Center for Tropical Agriculture Cali, Colombia
CIMMYT	-	International Maize and Wheat Improvement Center El Batán, Mexico
CIP	-	International Potato Center Lima, Peru
IBPGR	-	International Board for Plant Genetic Resources Rome, Italy
ICARDA	-	International Center for Agricultural Research in the Dry Areas, with a principal station in Aleppo, Syria and head office in Beirut, Lebanon
ICRISAT	-	International Crops Research Institute for the Semi-Arid Tropics Hyderabad, India
IFPRI	-	International Food Policy Research Institute Washington, D.C., U.S.A.
ILCA	-	International Livestock Center for Africa Addis Ababa, Ethiopia
ILRAD	-	International Laboratory for Research on Animal Diseases Nairobi, Kenya
IITA	-	International Institute of Tropical Agriculture Ibadan, Nigeria
IRRI	-	International Rice Research Institute Los Baños, Philippines
ISNAR	-	International Service for National Agricultural Research Location under consideration
WARDA	-	West Africa Rice Development Association Monrovia, Liberia

Membership of the Consultative Group on International Agricultural Research

September 1, 1979

A. Continuing Members

Countries

Australia	Germany	New Zealand	Switzerland
Belgium	Iran	Nigeria	United Kingdom
Canada	Italy	Norway	United States
Denmark	Japan	Saudi Arabia	
France	Netherlands	Sweden	

International Organizations

African Development Bank
Arab Fund for Social and Economic Development
Asian Development Bank
Commission of the European Communities
Food and Agriculture Organization
Inter-American Development Bank
International Bank for Reconstruction and Development
International Fund for Agricultural Development
OPEC Special Fund
United Nations Development Programme
United Nations Environment Programme

Foundations

Ford Foundation
International Development Research Centre
Kellogg Foundation
Leverhulme Trust Fund
Rockefeller Foundation

B. *Fixed-Term Members Representing Developing Countries, 1979-80

Asia: India, Philippines

Africa: Kenya, Senegal

Latin America: Costa Rica, Peru

Southern and Eastern Europe: Greece, Romania

Near East: Egypt, Syria

*The countries of the five major developing regions of the world participate in the Consultative Group through representatives elected for a two-year term by the FAO members in each region. Two countries are elected from each region, one serving as member and the other as alternate, as they may decide, in the Group's deliberations.

ANNEX III

CGIAR Contributions 1972-1979

($ millions)

	Actual							Estimated	Total
	1972	1973	1974	1975	1976	1977	1978	1979	
African Dev. Bank							.025	.030	0.55
Arab Fund						.310	.310	.300	.920
Asian Dev. Bank				.300		.500	-	.300	1.100
Australia		.005	1.015	1.215	1.745	1.790	2.590	2.560	11.065
Belgium	.140	.600	.380	.620	1.740	2.250	2.655	3.000	11.310
Canada	1.160	1.780	4.675	4.340	5.390	6.300	7.380	6.750	38.055
Denmark	.250	.225	.370	.400	.455	.615	.765	1.050	4.180
EEC						2.300	2.240	3.780	3.900
Ford Foundation	5.315	3.675	3.000	2.300	2.000	1.590	1.000	1.000	20.380
France			.130	.410	.510	.415	.300	.740	2.605
Germany		1.805	3.040	3.935	4.475	5.350	6.800	9.150	34.630
IDB			2.030	4.120	5.000	5.700	6.185	6.200	29.250
IDRC	.175	.345	.545	.990	1.780	1.305	1.085	.385	6.930
IFAD								1.300	1.300
Iran					1.975	2.000		-	3.975
Italy					.100	.030	.100	.100	.360
Japan	.105	.220	.265	.675	1.200	2.500	3.500	5.000	13.475
Kellogg Foundation	.155	.290	.230	.290	.300	.310	.320	.300	2.245
Netherlands	.375	.430	.555	1.235	1.500	1.720	1.960	2.400	9.315
New Zealand					.105	.025	.025	.025	.180
Nigeria				.545	.645	.620	.630	.615	3.140
Norway	.075	.185	.445	.310	1.120	1.510	1.865	1.355	3.030
Rockefeller Foundation	3.390	4.545	3.500	2.385	2.165	1.595	1.250	1.200	21.130
Saudi Arabia					1.000	1.000	-	-	2.000
Sweden	1.000	.150	1.490	2.290	2.255	2.240	2.725	2.970	15.235
Switzerland		.410	.140	.460	.355	1.205	1.350	1.900	6.240
United Kingdom	.690	1.110	1.920	2.410	2.390	3.515	4.800	6.000	23.475
UNDP	.350	1.300	1.465	2.165	1.930	3.300	4.400	4.098	18.998
UNEP				.600	.340	.340	.260	.410	2.180
United States	3.770	5.390	6.805	10.755	14.870	18.140	21.400	26.300	105.930
World Bank	1.250	2.780	2.375	3.195	5.325	7.350	8.675	10.200	42.360
Others									
Kresge	.750								.750
TOTAL	20.060	26.355	34.525	47.545	62.370	77.225	84.575	99.113	451.198

Source: Centers' Program and Budget Papers and accounts, 1974-1980.

September 11, 1979

Proposed 1980 Budget Reductions

1. As described in the section of the Integrative Report on proposed budget reductions, TAC and the Secretariat are recommending budget reductions of several kinds. One is a group of standard (mainly technical) budget reductions, another is deferral of new housing construction, a third is limits to the rate of real growth of some centers, and the fourth comprises selected specific reductions in program.

2. Standard reductions apply equally to all centers and are as described below. Only two centers were proposing new housing construction in 1980, and deferral was recommended in both cases. Limits to the rate of real growth were recommended where TAC did not wish to single out particular program elements for reduction and felt it should be left to the center to decide what to cut. Select specific cuts in program were recommended where TAC, after reviewing a center's program as a whole, identified activities TAC believed should, for the reasons given, be cut, particularly given the constrained financial position of the CGIAR system in 1980.

3. The standard reductions (or limits) recommended to be applied to all centers, and worked out with them at the Hyderabad meeting, are as follows:

(a) Fill Rates for International Staff Positions

For each center, without distinction between those in mid-biennium and other centers, its historical fill rate has been applied to its 1980 budget request. For centers in mid-biennium, the historical fill rate has been applied to the number of CGIAR-approved positions. For other centers the rate has been applied to the number of requested positions. The cost of a manyear has been conservatively estimated at $80,000.

(b) Mid-biennium Increases

The CGIAR on early occasions decided that requests for additional funds from centers at mid-biennium should not be entertained except for reasons beyond a center's control, such as increased inflation. ICRISAT is the only center whose request for additional funds would meet this criterion and a modest increase is recommended for increased inflationary costs in this case alone.

(c) Contingency Reserve

The contingency reserves of all centers except ICRISAT have been adjusted to 1 percent of the operational budget, after adjustments for fill rates and deletion of mid-biennium increases. A 2 percent contingency reserve has been recommended for ICRISAT in view of the uncertainties of the West African programs. It has been assumed that in times of financial stringency, instead of relying on a relatively large contingency reserve, centers should attempt to meet financial shortfalls in individual programs through savings in other ways, for example by restricting travel.

(d) Price Increases

Budget reductions through the application of historical fill rates, mid-biennium decreases and reductions in the contingency reserve will, in turn, decrease requirements for price increases due to inflation. The centers' own forecast inflation rates have been used in making these adjustments.

(e) Working Capital

Working capital requirements have been limited to 30 days operating expenses, i.e. to 30/365 of the operational budget after adjustments (a), (b), (c) and (d) above. Where centers have requested increases less than the amount calculated by this formula, no adjustment has been made.

The effect of these adjustments is to reduce the total requested from the CGIAR by $4,733,000.

4. IRRI and ILRAD included in their budget requests items for housing. In each case, the recommendation is that these be deleted from 1980 budgets. The total reduction amounts to $720,000.

5. Specific reductions in program as recommended by TAC are as follows:

Center	Proposed Action	Reduction ($'000)
CIAT	Defer upland rice program	277
	limit to growth (4%)	80
	capital deferral	80
	no core regional services	-
CIMMYT	At its option, CIMMYT to initiate building of germ plasm facility provided cost spread over 1980 and 1981 and absorbed in approved 1980 budget	-
CIP	No adjustments	-
ICARDA	Defer some capital	100
ICRISAT	No adjustments after disapproval of mid-term increase	-
IITA	No adjustments	-
ILCA	Limit to real growth (4-5%)	608
ILRAD	Limit to real growth (10%)	369
IRRI	Limit to real growth	230
	deferral motor pool capital proposal	80
IBPGR	No change	-
IFPRI	Limit to real growth (not discussed by TAC but already agreed by center)	194
WARDA	Defer Liberian station	382
	defer two posts	115
ISNAR	Review in autumn	-
	TOTAL	2,515

6. A summary of the effect of the foregoing adjustments on each center's budget request and the resultant recommended funding is in the table attached to this Annex.

Summary of 1980 Budget Requests,
Recommended Adjustments and Recommended Funding

	Net Request	Recommended Adjustments TAC1/	Recommended Adjustments Technical2/	Recommended Funding
		($ millions, rounded)		
Established Centers				
CIAT	15.3	0.4	0.3	14.6
CIMMYT	17.3	0.9	0.2	16.2
CIP	7.5	-	0.2	7.3
IITA	15.3	-	0.7	14.6
IRRI	16.5	0.5	0.4	15.6
IBPGR	3.1	-	-	3.1
WARDA	3.1	0.1	0.4	2.6
Subtotal	78.1	1.9	2.2	74.0
Developing Centers				
ICRISAT	11.8	0.1	1.2	10.5
ILCA	9.7	0.6	0.1	9.0
ILRAD	11.5	0.9	0.3	10.3
IFPRI	2.6	0.2	-	2.4
Subtotal	35.6	1.8	1.6	32.2
Newer Centers				
ICARDA	11.9	0.1	0.4	11.4
ISNAR	1.2	-	-	1.2
Subtotal	13.1	0.1	0.4	12.6
TOTAL	126.8	3.8	4.2	118.8

1/ Includes deferral of housing, program adjustments and limits to mid-term increases.

2/ Includes limits to fill rates, price increases, contingency allowances, and working capital, and a 25% reduction in equipment budgets. Also includes revisions of earnings and funds brought forward.

ANNEX V

Recommended Center Budgets for 1980

($'000)

Center	Operations	Capital	Total	Net Requirement
CIAT	14,364	634	14,998	14,598
CIMMYT	16,768	267	17,035	16,161
CIP	7,687	361	8,048	7,311
ICARDA	8,725	3,100	11,825	11,443
ICRISAT	10,133	2,229	12,362	10,497
IITA	14,326	780	15,106	14,606
ILCA	7,843	1,143	8,986	8,974
ILRAD	8,797	1,646	10,443	10,323
IRRI	15,503	374	15,877	15,577
WARDA	2,526	242	2,768	2,608
IBPGR	3,124	0	3,124	3,114
IFPRI	2,400	0	2,400	2,388
ISNAR	1,199	0	1,199	1,199
TOTAL	113,395	10,776	124,171	118,799

Illustrative Possible Growth
of the CGIAR System 1980-84

Gross Core Operating and Capital Requirements
(For assumptions, see page 2)

	1980	1981	1982	1983	1984
		(Constant $ millions)			
Established Centers					
CIAT	15.0	15.3	15.8	16.2	16.7
CIMMYT	16.8	17.5	18.0	18.5	19.1
CIP	8.0	8.4	8.7	8.9	9.2
IITA	15.1	15.2	15.7	16.1	16.6
IRRI	15.9	16.5	16.9	17.4	18.0
IBPGR	3.1	3.2	3.3	3.4	3.5
WARDA	2.7	2.9	3.2	3.4	3.7
Developing Centers					
ICRISAT	12.4	13.8	16.1	15.8	15.8
ILCA	9.0	10.4	11.4	12.5	12.5
ILRAD	10.4	12.0	13.2	13.8	13.2
IFPRI	2.4	2.9	3.4	4.0	4.1
Newer Centers					
ICARDA	11.8	14.4	13.6	13.7	15.4
ISNAR	1.2	2.2	3.5	3.5	3.5
Subtotal	124.0	134.7	142.8	147.2	151.3
New Activities					
Newly Created Entity	-	1.5	3.0	5.5	7.0
Newly Created Entity	-	-	2.0	3.0	4.0
Adoption of Existing Center	-	-	-	6.0	6.2
Adoption of Existing Center	-	-	-	-	6.0
Subtotal	-	1.5	5.0	14.5	23.2
Others[1/]	-	-	2.0	5.0	9.0
Total	124.0	136.2	149.8	166.7	183.5
Provision for Price Increases	-	12.3	28.2	49.2	75.3
TOTAL (Current $ millions)	124.0	148.5	180.0	215.9	259.0

1/ See assumptions page 2.

Assumptions

1. Assumptions on growth of centers in the CGIAR system in 1980 are as follows:

> Three percent real growth each year for established centers. Newer and developing centers would also grow at three percent after reaching full development. ILRAD and ICRISAT would reach full development in 1982 and ILCA, ICARDA and IFPRI in 1984. ISNAR would reach its full operating cost in 1983. Estimated operational expenditures in the year of reaching full development would be $14.4 million for ICRISAT and ICARDA; $12.0 million for ILRAD and ILCA; $3.5 million for ISNAR: $4.0 million for IFPRI. For the larger of these centers, the estimates are in line with the present size of centers such as IITA and CIAT.

2. It is assumed that research into such areas as water management, aquaculture, vegetables, pest and disease management, and plant nutrition would be added to the CGIAR at a rate of one activity each year beginning in 1981.

3. A notional amount of $9 million is provided in 1984 for other activities which the Group might by then wish to take on. While these are not now identified, they might include such things as support for fundamental research, research on crops other than food crops, research on related activities such as agro-forestry.

4. An average inflation rate of nine percent for the period 1980-84 is assumed.

Program Budget Analysis
Summary Table for All CGIAR Centers
for Period 1974 through 1981

CGIAR SECRETARIAT
DATE: 09/13/79

Table 1 - Statement of Expenditures and Funding

	ACT74	ACT75	ACT76	ACT77	REV78	ACT78	BUD79	REV79	PRO80	REQ80	REC80	PRO81	TOTAL
A-CORE OPERATING BUDGET SUMMARY (US$000)													
RICE	2,341	3,339	4,222	5,276	6,423	5,836	8,113	8,121	7,757	9,657	-	8,944	49,297
BEANS	374	517	698	931	1,072	1,102	1,007	1,380	1,126	1,419	-	1,509	8,192
BEEF	741	1,306	2,423	3,629	5,081	4,987	6,592	6,506	6,402	7,046	-	7,334	34,633
CASSAVA	399	413	573	743	959	939	887	1,205	1,167	1,308	-	1,377	7,287
MAIZE	1,189	1,528	1,413	1,995	2,352	2,330	2,313	2,893	2,714	3,082	-	3,357	19,466
SWINE	230	211	150	144	196	179	171	233	176	-	-	-	1,349
BARLEY	67	83	111	97	124	120	115	129	124	129	-	129	911
TRITICLE	174	295	265	302	310	249	230	277	286	277	-	277	2,364
SORGHUM	534	580	637	788	924	951	1,038	1,371	1,529	1,592	-	1,700	8,471
CEREAL IMPR	281	501	901	1,019	1,297	1,357	1,441	1,624	2,058	1,843	-	1,158	8,907
GRAIN IMPR	432	564	892	1,054	1,515	1,508	1,674	1,838	2,322	2,045	-	2,322	11,027
RISTER IMPR	283	412	506	641	764	803	816	958	1,064	1,064	-	1,064	5,944
TRYPSMS	-	217	1,076	968	2,016	1,740	2,410	2,339	2,974	2,716	-	3,117	12,173
E COT FV	-	109	252	562	1,416	1,117	1,607	1,719	2,131	1,996	-	2,292	8,047
CF STUDY	-	-	-	62	98	-	-	-	114	-	-	-	62
CHICKPEAS	216	416	541	700	799	833	904	946	921	962	-	1,056	5,674
GROUNDNUTS	-	14	189	238	392	393	508	506	531	559	-	922	2,821
WHEAT	983	1,261	1,362	1,805	2,476	2,440	2,197	2,857	2,638	3,093	-	3,479	17,996
FORAGE	-	-	191	105	262	180	428	400	507	500	-	507	1,883
CROP SYS	259	495	988	1,169	1,361	1,283	1,627	1,606	1,400	1,594	-	1,585	9,087
FARM SYS	1,145	1,512	1,830	2,126	2,846	2,688	2,720	3,586	4,590	4,106	-	4,802	22,623
PLANT SCI	-	125	253	548	1,071	965	1,566	1,466	1,725	1,680		1,805	6,842
BIOCHEM	105	169	235	298	423	406	428	472	410	538	-	552	2,815
GENETICS	-	-	-	165	281	264	240	607	488	499	-	514	2,049
RES SUPT	560	432	711	1,065	1,957	1,234	2,202	1,621	1,864	2,123	-	1,952	9,927
POTATOES	877	1,031	1,616	2,055	2,903	2,650	2,811	3,417	3,278	3,384	-	3,488	19,160
FARM SUC	293	375	471	341	545	641	587	494	657	511	-	513	3,811
REGNL PR	-	-	-	167	405	340	518	505	450	618	-	618	2,248
IMMUNOLOGY	-	-	-	-	-	-	-	325	-	377	-	433	1,135
FOOD POL RES	-	-	-	-	-	-	-	-	-	1,320	-	-	1,320
COMM LAB	192	271	568	638	910	1,253	1,166	1,514	1,261	1,790	-	1,778	8,191
STAT OPS	1,166	1,470	2,203	2,559	3,493	3,262	3,169	3,999	4,304	4,849	-	5,396	25,657
EQUIP REPL	1	10	16	28	82	88	145	118	160	154	-	155	570
STATISTICS	74	232	236	247	431	325	529	387	627	417	-	673	2,646
ECONOMICS	216	323	427	502	770	793	762	1,071	1,183	1,228	-	1,278	5,975
TOTAL RES	13,132	18,231	25,956	32,967	45,954	43,456	50,921	56,490	58,938	64,476		66,086	330,560
TRG & CONF	2,225	2,714	3,222	4,275	6,521	5,291	7,014	7,608	7,785	8,525		8,635	44,011
LIB & DOC	1,200	2,122	3,043	3,725	4,212	4,069	5,055	4,973	5,085	5,732		6,021	31,680
GEN ADMIN	3,465	4,319	5,733	7,331	8,990	9,104	8,560	10,576	10,470	12,595	-	11,663	67,376
GEN OPER.	4,253	5,718	6,872	9,677	10,925	10,712	10,699	12,564	13,075	14,041		15,043	82,043
OTHR+CONT	661	577	167	596	1,115	902	1,145	1,395	1,548	2,055		2,247	8,879
INFLATION	6	-	-	-	76	-	8,571	693	16,747	9,270	-	20,365	30,334
TOT OPNS	24,942	33,681	44,993	58,571	77,793	73,534	91,965	94,299	113,648	116,694	113,264	130,060	594,883
B-CAPITAL EXPENDITURE BUDGET (US$000)													
CONSTRN	4,115	8,455	9,171	14,119	17,157	17,826	7,594	9,683	8,976	8,814		9,497	68,019
EQUIPMT	2,479	1,904	2,409	4,138	5,873	2,334	3,186	4,201	3,501	3,991		3,697	26,378
AD TO WK	820	951	2,897	749	1,638	1,078	916	1,129	1,659	2,781	-	1,258	11,869
TOT CAP	7,414	11,310	14,477	19,006	24,668	21,238	11,696	15,013	14,136	15,586	10,907	14,452	126,264
TOTAL CORE	32,356	44,991	59,470	77,577	102,461	94,772	103,661	109,312	127,784	132,280	124,171	144,512	721,149
C-SPEC PROJ	4,483	5,835	8,020	9,702	15,997	10,750	8,561	16,767	13,342	12,728	12,728	11,343	83,149
CENTER TOT	36,839	50,826	67,490	87,279	118,458	105,522	112,222	126,079	141,126	145,008	136,899	155,855	804,298
CENTER FUNDING													
EARN INC	2,256	1,971	1,868	2,591	2,125	3,043	1,746	2,331	2,028	2,556	2,437	2,165	19,833
FDS B/F	4,904	3,040	4,377	319	(13,717)	(11,776)	(1,964)	(7,533)	(3,217)	(3,077)	(2,935)	(1,051)	(10,236)
REQ OF CG	35,004	46,060	61,979	75,305	86,619	79,953	99,951	99,448	122,539	126,647	118,799	141,296	691,030
BUDGET SUMMARY IN CONSTANT 1979 DOLLARS													
DEFLATOR	1.467	1.304	1.262	1.161	1.075	1.075	1.000	1.000	0.935	0.935	0.935	0.874	-
CORE OPTG	36,590	43,920	56,781	68,001	83,627	79,049	91,965	94,299	106,261	109,109	105,902	113,672	630,631
CAPITAL	10,876	14,748	18,270	22,066	26,518	22,831	11,696	15,013	13,217	14,573	10,198	12,631	143,541
TOTAL CORE	47,466	58,668	75,051	90,067	110,145	101,880	103,661	109,312	119,478	123,682	116,100	126,303	774,172
SPEC PROJ	6,577	7,609	10,121	11,264	17,197	11,556	8,561	16,767	12,475	11,901	11,901	9,914	91,388
CENTER TOT	54,043	66,277	85,172	101,331	127,342	113,436	112,222	126,079	131,953	135,583	128,001	134,217	865,560

1/ ACT = Actual; BUD = Approved Budget; REV = Revised Budget; PRO = Projected Budget; REQ = Budget Request; REC = Recommended Budget

2/ "Total" includes all actual budgets since the beginning of CGIAR plus REV1979, REQ1980 and PRO1981. However, an amount for WARDA is not included in ACT1978. Data was not available.

Table 2 - Core Operating Budget by Major Expense Categories

	ACT74	ACT75	ACT76	ACT77	REV78	ACT78	BUD79	REV79	PRO80	REQ80	REC80	PRO81	TOTAL
PERS SERV	12,095	17,736	25,068	32,776	46,218	33,214	51,369	43,223	60,358	52,023	-	10,873	296,601
SUP & MTC	4,463	6,842	9,414	12,649	16,169	13,409	16,400	16,179	20,098	18,464		20,925	105,76[illegible]
EQUIPMT	2,127	1,662	2,406	3,067	2,746	1,895	2,650	2,346	3,700	2,444	-	3,157	20,[illegible]
TRAVEL	1,527	2,239	3,487	4,922	5,876	3,857	6,331	4,856	6,850	5,484	-	5,89[illegible]	33,310
OTH/CONT	1,681	3,375	6,462	7,580	8,283	5,529	16,717	7,155	23,292	10,622		15,708	[illegible]9,352

1/ Figures for REV1979 and REQ1980 do not include CIMMYT and ICARDA. Data was not available.

Table 3 - Center Staff Summary

	ACT74	ACT75	ACT76	ACT77	REV78	ACT78	BUD79	REV79	PRO80	REQ80	REC80	PRO81	TOTAL
IN POSIT	250	300	324	404	520	385	508	499	562	565		517	-
IN MYRS	207	252	281	369	448	349	505	439	526	506	-	537	-
SC POSIT	474	587	613	834	990	756	398	830	1,113	880	-	1,044	-
SC MYRS	375	450	490	725	971	708	705	831	799	888	-	1,045	-
TH POSIT	2,291	2,941	3,577	4,707	5,553	4,419	5,932	5,120	6,368	5,351	-	5,685	-
TH MYRS	2,119	2,693	3,200	4,493	5,401	4,204	6,067	5,261	6,216	5,579	-	5,882	-
IT POSIT	3,015	3,829	4,514	5,945	7,063	5,560	7,338	6,448	8,043	6,796	-	7,246	-
IT MYRS	2,701	3,395	3,971	5,587	6,720	5,261	7,477	6,531	7,740	6,973	-	7,464	-

/ Due to missing data, the staff summary does not accurately reflect the current status for 1979 and 1980.

Table 4 - Budget Analysis by Selected Indicators

	ACT74	ACT75	ACT76	ACT77	REV78	ACT78	BUD79	REV79	PRO80	REQ80	REC80	PRO81	TOTAL
MAJOR EXPENSES CATEGORY AS PERCENTAGE OF CORE OPTG EXP													
RESEARCH	53	54	58	56	59	59	55	60	52	55	-	51	55
TRG& CON	9	8	7	7	8	7	8	8	7	7	-	7	7
LIB & DOC	5	6	7	6	5	6	5	5	4	5	-	5	5
GEN ADM	14	13	13	13	12	12	9	11	9	11	-	9	11
GEN OPN	17	17	15	17	14	15	12	13	12	12	-	12	14
OTHER	3	2	-	1	1	1	1	1	1	2	-	2	1
INFLN	-	-	-	-	-	-	9	1	15	8	-	16	6
MAJOR CAPITAL ITEMS AS PERCENTAGE OF TOTAL CAPITAL													
CONSTRN.	56	75	63	74	70	84	65	64	63	57		66	68
EQUIP	33	17	17	22	24	11	27	28	25	26		26	23
ADD TO WC	11	8	20	4	7	5	8	9	12	18		9	9
BUDGET SPLIT BY MAJOR CATEGORY													
CORE OP	77	75	76	76	76	78	89	86	89	88	91	90	82
CAP TL	23	25	24	24	24	22	11	14	11	12	9	10	18
MAJOR EXPENSE CATEGORIES AS PERCENTAGES													
PRS SV	48	53	56	56	59	45	56	46	53	45	-	47	49
SUP&MTC	18	20	21	22	21	18	18	17	18	16	-	16	18
EQUIPMT	9	5	5	5	4	3	3	2	3	2	-	3	4
TRAVEL	6	7	8	8	8	5	7	5	6	5	-	5	6
OTH/CONT	7	10	14	13	11	8	18	8	20	9	-	12	11
FILL RATES EXPRESSED AS PERCENTAGES													
SENIOR S	83	84	87	91	86	91	99	88	94	90	-	104	-
ASSOC ST	79	77	80	87	88	94	101	100	90	101	-	100	-
OTHER ST	92	92	89	95	97	95	102	103	98	104	-	103	-
TOTAL ST	90	89	88	94	95	95	102	101	96	103	-	103	-
COSTS PER SENIOR STAFF MANYEAR ($000)													
TOT C-OP	120	134	160	159	174	211	182	215	216	231	-	242	-
TOT RSCH	63	72	92	89	103	125	101	129	112	127	-	123	-
TRAVEL	7	9	12	13	13	11	13	11	13	11	-	11	-
PERSONNEL COSTS PER TOTAL STAFF MANYEAR													
PER T/STF	4	5	6	6	7	6	7	7	8	7	-	8	-