the consultative group on international agricultural research
technical advisory committee

report of the tac quinquennial review mission to the international crops research institute for the semi-arid tropics (icrisat)

tac secretariat
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

AGD/TAC:IAR/79/4
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CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH
TECHNICAL ADVISORY COMMITTEE

REPORT OF THE TAC QUINQUENNIAL REVIEW MISSION TO THE INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS (ICRISAT)

TAC Secretariat
March 1979

NOTE BY THE TAC SECRETARIAT

A summary of TAC comments and recommendations is appended at the end of the report. For more details on TAC's views regarding this report, reference is invited to the minutes of the 71st TAC meeting (AGD/TAC:IAR/79/12, pages 17-21, paras 97-122).

REPORT OF THE TAC QUINQUENNIAL REVIEW MISSION TO THE INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS (ICRISAT)

Panel: L.T. Evans (Chairman)

Messrs: M.H. Arnold
L. Brader
A. Burhan
F.G.A. Fournier
J.R. Harlan
J.B. Kendrick
Raj Krishna
A.J. Hayman (Secretary)
J.K. Coulter (Observer
B.N. Webster (Observer)

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DIVISION OF PLANT INDUSTRY

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December 15, 1978

Dr. Ralph W. Cummings
812 Rosemont Avenue
Raleigh, North Carolina 27607

Dear Dr. Cummings:

I wrote to you in October 1978 immediately after the Quinquennial Review of ICRISAT, to advise you of the recommendations in our draft report concerning two specific matters under consideration by the meeting of the CGIAR in November 1978. Since then our draft report has been edited and transmitted to the chairman of the Governing Board of ICRISAT for his comments.

We hope that our report will be found useful and constructive by TAC and the CGIAR, as well as by the Governing Board and staff of ICRISAT. Intense effort, under considerable pressure, was required of the whole panel to ensure its preparation before the end of the review mission. Advanced drafts of all chapters were made available to the Director of ICRISAT, and all his corrections and comments were considered by the panel before the draft sent to you in October was compiled. Consequently, we trust that all errors of fact have been eliminated, but a number of differences of opinion between ourselves and the Director and Governing Board of ICRISAT remain. On only one recommendation did the review team not reach complete agreement, and I should record here that Professor J. R. Harlan wishes to dissociate himself from our recommendation concerning the future of the pigeonpea breeding programme (paragraph 130).

The ICRISAT review was one of the first to be undertaken under the revised guidelines for quinquennial reviews, which influenced several aspects of our procedures and our report. The panel met the Governing Board in Paris immediately before we began our review mission, and profited greatly from the opportunity to discuss their aspirations for ICRISAT. As requested in the new guidelines, we have devoted rather more attention to the centre's mandate than has been customary in preceding reviews. In our final chapter we have tried to address directly the terms of reference for our review, even when this required recapitulation of our earlier conclusions. Finally, in response to the donors' request for more critical reviews, we have not hesitated to make criticisms where we felt they should be expressed, but have done so against a background of confidence in the ability and strength of purpose with which ICRISAT is tackling the difficult goals before it.

/...

From amongst our many impressions, two might be mentioned at this stage. One which surfaces at many places in our report is the urgent need for a stronger programme in Africa, to be achieved both by shifting resources from India and by the provision of additional resources. There is also a need for the continuation of many lines of work in India, but it was our impression that an effective division of labour between the strong Indian national research system and the centre is emerging, which should progressively free some of ICRISAT's resources for work in other regions of the semi-arid tropics.

Our major regret is that we did not have time for follow-up discussions of their work with individual scientists to the extent we would have liked, and were therefore unable to contribute much detailed comment on their programmes. One procedure which we followed and recommend to subsequent reviews was the full discussion each evening of the programmes presented to us each day, so that we reached agreement on our main conclusions before the first drafts of the report were written, which undoubtedly saved a lot of time in later discussions. Although all members of the panel participated in the subsequent editing of every draft, the text still bears the strong imprint of our varied styles and approaches. I have not tried to homogenize these because the realities of quinquennial review procedures are such that individual panel members have differing impacts on the various sections of the report.

Every member of the panel has developed an active interest in ICRISAT's goals and work as a result of this review, and we hope that all members of the panel will be kept informed by the TAC Secretariat of the reactions of TAC, the CGIAR and the centre to our report.

Finally, we wish to record our thanks to the Governing Board and to the Director and staff of ICRISAT for their generous help and unstinting cooperation throughout the review. On behalf of all members of the team I should also like to thank our Secretary, Mr. Andrew Hayman, for his expert organization of our activities, and John Coulter, our very hardworking "observer" whose broad knowledge of the other centres and the CGIAR system as a whole was invaluable to us, as was that also of Brian Webster.

Yours sincerely,

CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

TECHNICAL ADVISORY COMMITTEE

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16 March 1979

Mr Warren Baum
Chairman, Consultative Group on
International Agricultural Research
World Bank, 1818 H Street, NW
Washington, DC

Dear Mr Baum:

I am pleased to forward herewith the report of the Quinquennial Review of the International Crops Research Institute for the Semi-Arid Tropics, which was conducted under the chairmanship of Dr Lloyd T. Evans during the period 23 September through 14 October 1978. Other members of the review panel were: Dr M.H. Arnold, Plant Breeding Institute, Cambridge; Dr L. Brader, Chief, Plant Protection Service, FAO; Dr Ahmed Burhan, Director-General, Agricultural Research Corporation, Sudan; Dr F. Fournier, Inspector General, ORSTOM, Paris; Dr J.R. Harlan, the University of Illinois, USA; Prof. J.B. Kendrick, Jr., Vice President for Agricultural and University Services, the University of California; Dr Raj Krishna, Member, Planning Commission, Government of India; Dr John Coulter, Scientific Adviser, CGIAR; and Mr A.J. Hayman, Program Officer, CGIAR (Secretary). Mr B.N. Webster, Deputy Secretary of TAC, joined the team for the last period at the Hyderabad headquarters.

This was the first quinquennial review of an international agricultural research centre to be carried out under the revised terms of reference and guidelines developed in 1978. The team found the task very demanding and the time available to cover all aspects of the terms of reference and donors' questions, shorter than they would have liked. The team is to be commended for its excellent organization and conduct of the review and for having addressed all aspects in a thoroughly competent and professional manner. The panel gave a highly commendatory report of the centre, its progress to date, the staff quality and morale, and the way in which the centre is defining and addressing its mandate. At the same time, the panel did not hesitate to make a number of suggestions on specific aspects of the Institute's programme and on its approach, especially with respect to its involvement in West Africa and the need for a restudy of the management structure.

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The panel's report was discussed by TAC at its 21st meeting held in Washington 13-20 February 1979. The Institute's Director-General, Associate Director, and Board Chairman participated in this discussion. TAC generally endorsed the report and requested that it be forwarded to the CGIAR for consideration at its meeting in May 1979. TAC's comments are attached hereto. The ICRISAT Governing Board had not had an opportunity to discuss the review report at the time of the last TAC meeting. Board consideration is anticipated during March and their views will probably be available before the date of the discussions at the CGIAR meeting.

Respectfully submitted,

Ralph W. Cummings

Ralph W. Cummings
Chairman, TAC

ICRISAT QUINQUENNIAL REVIEW

I N D E X

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

The following points are given in the order in which they appear in the report, not in their order of priority.

II. THE MANDATE

(Para 21). We recommend that the agroclimatological work should continue to redefine the semi-arid tropical (SAT) areas of the world on a more adequate basis.

(Para 26). We agree that some of the minor millets deserve a share of ICRISAT's attention.

(Para 31). We agree that a higher priority should be given to the improvement of yield rather than of protein content and quality.

(Para 34). We agree that any crop relevant to SAT conditions may be used in Farming Systems research, but breeding should be confined to the mandate crops.

(Para 40). We consider that it is not necessary to limit ICRISAT's research to zero or low input conditions, but it is necessary to ensure that yield and stability under the poorest farmers' field conditions are not adversely affected.

III. CEREALS

(Para 45). We recommend that comparisons of both sorghum and millet breeding materials should, from an early stage, be undertaken at both low and high levels of farming.

(Para 48). We recommend that urgent attention be given to filling the post of statistician/biometrician.

(Para 49). We recommend that a specialist consultant in population genetics be retained from time to time to review the breeding program.

(Para 50). We recommend that attention be given to the epidemiology of pests and diseases, and endorse the addition of pathology staff proposed in the 1979 budget.

(Para 53). We recommend that discussions be initiated between ICRISAT staff and the CILSS Secretariat concerning pest management for cereal crops in Africa.

(Para 55). We suggest that the possibilities for closer coordination and common control of the sorghum and millet programs should be re-examined.

PEARL MILLET

(Para 61). We recommend that ICRISAT continue the collection of pearl millet genetic resources until a reasonably good sampling of African and Indian material has been obtained.

(Para 68). We support the initiation of long-term nitrogen balance studies on soils under millet crops.

(Para 73). We recommend that ICRISAT take appropriate action to impress on African governments the need for efficient seed multiplication and distribution.

SORGHUM

(Para 83). We recommend that the sorghum program in West Africa should be strengthened and expanded with some core funding according to a long-range plan.

(Para 85). We stress the urgency of further collecting of sorghum genetic resources from Africa and Asia.

(Para 95). We note several areas of sorghum entomology that are in need of greater attention, but do not consider that the addition of senior staff is necessary.

IV. PULSES: CHICKPEA

(Para 100). We recommend that ICRISAT continue work on chickpea as a mandate crop, but suggest that a long-term objective of the program should be to assist the Government of India to develop a national program which satisfies Indian needs.

(Para 113). We consider that the currently planned resources for chickpea research are sufficient and that no further real increases should be needed.

PIGEONPEA

(Para 124). We suggest that progress in the breeding for resistance to Heliothis be monitored with a view to shifting resources to other areas of research in due course.

(Paras 125 and 129). We recommend that further physiological research on pigeonpeas should be concentrated on intercropping regimes in collaboration with the farming systems program, as indeed should other research on the crop. In this way the entomological, pathological and physiological work on intercrops and farming systems could be strengthened without the need for additional resources.

(Para 130). We recommend that consultations be initiated with ICAR and the All-India Coordinated Pulse Improvement Program on the feasibility of integrating the breeding program with the national program over the next five years.

V. GROUNDNUTS

(Para 137). We recommend that attempts should be made to find a suitable place in eastern or central Africa from which the regional groundnut program could be coordinated.

(Para 147). We recommend that a principal staff position for a senior entomologist in the groundnut program should be created as a matter of urgency.

(Para 148). We support the inclusion of a crop physiologist in the 1979-80 budget proposals.

VI. FARMING SYSTEMS RESEARCH (FSR)

(Para 166). We recommend that continuation of research on broad bed cultivation systems be limited to a few well-defined objectives, and suggest that in extending this work to Africa note should be taken of previous research with draft animals.

(Para 174). We suggest that research on fertilizer responses in India be reviewed after a period of three years with a view to greater emphasis on SAT African problems.

(Para 177). We recommend close cooperation between ICRISAT and IITA in their research on soil problems in Africa.

(Para 182). We recommend that ICRISAT should include cash crops and animals in its farming systems research where considered appropriate.

(Para 187). We recommend an additional senior national staff position in the entomology of intercropping.

(Para 198). We recommend that extension of FSR to Africa should be preceded by a survey of the national research capabilities of the various countries to determine where the program activities could be most appropriately placed.

VII. ECONOMICS

(Para 236). We recommend several (7) fields of research for priority attention by ICRISAT's economists.

(Para 238). We support the continuation of the village-level studies (VLS) with some modifications. We endorse the decision to include villages in the main groundnut and pearl millet/chickpea areas in India.

(Para 239). We recommend that data collection for the expanded VLS program be contracted out as far as possible to national institutions.

(Para 240). We recommend that methods be found to put VLS data in more accessible form.

(Para 252). We suggest that in selecting economic research projects in the future, the division of work between ICRISAT's own staff and national researchers be determined according to the criteria of policy relevance for SAT, innovation/replication, and the strengthening of national research capability.

(Para 256). We recommend that priority be given to topics in the field of marketing for economic research by ICRISAT in Africa, and the early establishment of a Rural Community Studies Program.

(Paras 262 and 263). We suggest that the social anthropology work of ICRISAT should be focussed on Africa rather than on India, and included in the core budget.

(Para 267). We recommend that most of the marketing economists' time should be devoted to Africa, that only one core project economist and one marketing economist should be based in Africa, and that of the two new production economists one should have a strong background in systems analysis

VIII. SUPPORTING PROGRAMS

(Para 274). We recommend that every effort be made to inform governments of recipient countries of ICRISAT's phytosanitary precautions.

(Para 276). We recommend that the Biochemistry Unit remain as a service rather than becoming a research group, and suggest that its name be changed to identify its functions.

(Para 279). We urge the Biochemistry Unit to provide analytical services to support programs in Africa.

(Para 285). We recommend more formal publication of papers in a continuing ICRISAT research publications series.

(Para 288). We recommend that only one annual report be produced each year.

(Para 290). We recommend that internal courses should be organized on the presentation of information in the written and spoken forms.

(Para 295). We recommend that ICRISAT expand its contacts with other institutions collecting library material, particularly in relation to agriculture in francophone West Africa.

IX. TRAINING

(Para 312). We recommend the introduction of an audio-tutorial system of instruction for trainees.

(Para 313). We recommend that ICRISAT collaborate with IITA and ILCA in the development of joint training courses appropriate to African conditions.

X. COOPERATIVE PROGRAMS AND TECHNOLOGY TRANSFER

(Para 322). We endorse the current arrangements for the extension of ICRISAT's research in India.

(Para 343). We recommend that if IITA is unable to provide core funding for the breeding of cowpeas adapted to SAT conditions, then ICRISAT should be encouraged to do so.

(Para 346). We agree that a substantial amount of core funding for the African program is justified.

(Para 360). We commend the concept of a mobile network rather than of subcenters for the African core funded program.

(Paras 362 and 364). We recommend the formulation of a long-term plan for ICRISAT's African activities, and believe this should be a precondition to approval by the CGIAR of the full proposal as presented in the 1979/80 budget.

XI. MANAGEMENT

(Para 374). We suggest that ICRISAT should consider a more open means of recruitment of senior research staff.

(Para 378). We recommend that ICRISAT give serious and continuing attention to questions of career development for the national scientific staff.

(Para 384). We believe that the projected staff levels justify the proposed capital expansion in ICRISAT's 1979/80 budget.

(Para 385). We recommend that no firm commitments be made to the building program in West Africa prior to the Board's reconsideration of the structure of the African core program.

(Para 388). We urge ICRISAT not to delay consideration of obtaining more experimental farm land in the vicinity of Patancheru.

(Para 392). We recommend that ICRISAT should work with ICAR and its four cooperating agricultural universities to obtain long-term financial support for the management of its out-stations on university farms.

XII. CONCLUDING OBSERVATIONS

(Para 424). We recommend that a scientific management consultant be engaged to examine the management structure of ICRISAT.

(Para 430). We recommend that ICRISAT's proposal to establish a team of three consulting scientists should not be implemented at this stage.

(Para 433). We recommend that the interval between successive in-house reviews be extended to a minimum of two years.

I. INTRODUCTION

1. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) was established in 1972, with the objective of improving the nutrition and welfare of the poorest population groups dependent on rainfed agriculture in the semi-arid tropics (SAT), through improved crop varieties, and farming systems. With its headquarters established near Hyderabad in India, and recognized by the Government of India as an international organisation, ICRISAT's responsibilities are world wide, within the limits of its mandate. Its core funding (expected to amount to some $9 million in 1979 for operations) is provided by the Consultative Group on International Agricultural Research (CGIAR).

2. The members of the CGIAR together are expected to contribute $103 million in 1979 to support international agricultural research. Such large amounts of grant money, mostly from public sources, require vigilant stewardship. An essential part of this is the regular, independent assessment of the scientific quality, effectiveness, and relevance of the activities supported, by detailed reviews of every aspect of the work, done every five years by a Panel of outside specialists. This report gives our findings as members of such a "Quinquennial Review" Panel for ICRISAT.

3. The CGIAR is guided on scientific matters by its Technical Advisory Committee (TAC), which is responsible for selecting the Panel, and providing Terms of Reference and administrative support for the review. TAC itself considers the Report, and may or may not agree with its conclusions. It remains our work alone.

4. Quinquennial Review Panels are charged with the general responsibility:

> "On behalf of the Consultative Group, to assess the quality and value of the scientific programs of the Centers in order to assure the Consultative Group members that the operations being funded are being carried out in line with declared policies and to the full international standard expected."
>
> "It is hoped that the review will inter alia assist the International Centers themselves in planning their programs and ensuring the validity of the research priorities recognized by the Boards of the Centers."

5. Such reviews of IRRI, CIMMYT, CIP, CIAT, IITA, WARDA have already been done. After consultation with TAC and the Director General of ICRISAT, our Terms of Reference were agreed as follows:-

"Terms of Reference of the Quinquennial Review of ICRISAT

6. In pursuance of the main objectives, defined above, the Mission is requested to give particular attention to the following aspects:

(i) The mandate of the Institute, its appropriateness and the interpretation thereof with respect to:

(a) the immediate and long-term needs for improved food supply and human welfare in developing countries;

(b) present and possible future areas of work.

(ii) The relevance, scope and objectives of the present program of work and budget of the Institute and of its forward plans for the next five years in relation to:

(a) its mandate and the criteria for the allocation of resources as defined by TAC;

(b) the ongoing activities of other international institutes and organizations and of relevant national institutes in cooperating countries and in others where the work of the institutes has bearing;

(c) the policy, strategy and procedures adoped by the Institute in carrying out its mandate, and the mechanisms for their formulation;

(d) the Institute's rationale for its present allocation of resources, its present and future overall size, and the composition and balance of the program in the fields of research, training, documentation information exchange and related cooperative activities.

(iii) The content and quality of the scientific and related work of the Institute with particular reference to:

(a) the results of past research;

(b) the current and planned research and the role of the scientific disciplines therein;

(c) the information exchange and training programs, their methodologies and the participation of the research staff therein;

(d) the adequacy of the research support and other facilities;

(e) the management of the scientific and financial resources of the Center and the coordination of its activities.

(iv) The impact and usefulness of the Institute activities in relation to:

(a) the present and potential impact of the research conducted by the Institute;

(b) its information exchange and training programs;

(c) cooperation with national research and development programs;

(d) cooperation with other international institutes and organizations.

(v) Constraints on the Institute's activities which may be hindering the achievement of its objectives and the implementation of its programs, and possible means of reducing or eliminating such constraints.

(vi) Any specific questions which concerned members of the CGIAR, cooperating institutions, the Institute's Director or its Board of Trustees, may request TAC to examine.

On the basis of its review, the Mission will report to the Chairman of TAC its views on the need for any changes in the basic objectives or orientation of the program elements, and on means of improving the efficiency of operations, and will make proposals for overcoming any constraints identified under item (v).

7. While the Mission should feel free to make any observations or recommendations it wishes, it must clearly understood that the Mission cannot commit the sponsoring organization, viz. the CGIAR/TAC."

8. The following list of specific questions were approved by TAC for our consideration:

"(i) the geographical scope and limits of ICRISAT's mandate, as related to the definitions of semi-arid, arid and sub-humid tropics and to the mandate of other Centers, in particular in Africa and Latin America (possible gaps and overlaps). Cooperative agreements with other IARCs, national program and international institutions, and determination of areas of responsibility. 1/

(ii) Differences in food production problems of the SAT in Asia, Latin America and Africa. Extent to which ICRISAT program address these different problems. Rationale for the present focus on rainfed farming. ICRISAT's role in the context of other land uses in the semi-arid tropics (irrigated farming, livestock production, forestry).

1/ In particular IITA, CIMMYT, IRRI, ICARDA, ILCA, CIAT, SAFGRAD, CILSS, ICAR, IARI, All-India coordinated programs, Arid Zones Research Institutes, UNDP, UNEP, FAO, UNESCO (MAB), IDRC, USAID, ODM, CSIRO, IRAT, IRHO, ORSTOM, etc.

(iii) Relative importance of main food commodities in calorie and protein supply of the population in SAT and future trends (pulses, in particular pigeonpea, oilseeds and cereals). Implications for future research priorities.

(iv) Scope and role of socio-economic studies in the formulation of the research program's priorities and objectives. Relationships between socio-economic research, crop research and farming systems research. Rationale for the emphasis placed on the problems of the small farmer and on scale-negative practices, as related to overall development needs and the overall interests of consumers and producers. Alternatives and possible conflicts in improving productivity and human welfare in SAT. Implications for ICRISAT priorities and programs.

(vi) Optimum size anticipated for ICRISAT program and budget. Balance between program areas and research disciplines. Balance between production and post-harvest research. Resource allocation for yield maintenance versus yield increase. Forward planning and program changes. Consultations with other institutions and national systems in the process of planning and programming research, training and information activities at the Centre.

(vii) Adequacy of sites, facilities and resources in relation to program objectives and to the problems addressed.

(viii) Organization of multi-disciplinary teamwork.

(ix) Cooperation with IBPGR in germplasm collection (including exploration) and storage, and data processing and retrieval, especially for "non-mandate" crops.

(x) Staff recruitment and management policies.

(xi) Cooperative programs, their present scope, impact and future plans; relations with the host country, ICAR and other national programs; regional representation and impact on extension activities in Asia and Africa. Personnel and infrastructure requirements for ICRISAT programs in Africa and Latin America; criteria and priorities set among request for cooperative programs and special projects. Rationale for the two core-funded sub-centres proposed in West Africa. Relationships with UNDP-funded and other ICRISAT activities in Africa.

(xii) Place and role of basic research at ICRISAT. Cooperation with advanced research institutions.

(xiii) Training: needs, levels and effectiveness; relative importance of training in production agronomy as compared with training of research workers.

(xiv) Quarantine problems and needs.

(xv) Organizational structure, programming and interaction of Farming Systems Research (FSR) activities.

(xvi) Balance between the watershed and farm foci of the FSR programme.

(xvii) Extension of FSR program outside India; plans, methodology and logistics. Balance of cooperative programs in FSR in India and outside.

(xviii) Place and role of ICRISAT's 'non-mandate' crops in FSR.

(xix) Evaluation of farming systems research work under farmer conditions. Adequacy of present arrangements. Future needs for operational research in this field. Interaction with national programs."

9. The preparations for the Quinquennial Review were made in close cooperation with the Director of ICRISAT who participated in the selection of the Team and contributed to the list of major questions to be addressed by the Review.

10. Prior to the review of the ICRISAT headquarters activities the panel met with the Chairman and some members of the Governing Board, and a survey was undertaken of part of ICRISAT's cooperative program in W. Africa. Details of our itinerary are given in Annex I.

11. After our visit to West Africa, we began our review at ICRISAT headquarters near Hyderabad on 30 September 1978 and it was concluded on 14 October 1978 with the presentation by the Panel's Chairman of the main recommendations to the Director, Program Leaders and other senior staff. During this two week period we visited experimental fields, laboratories and other facilities of the ICRISAT campus and one farming area where ICRISAT conducts Village Level Studies. Opportunities were provided during this period for adequate discussion with the Director and staff and for specific examination in depth of certain critical issues. The Director's written comments on the complete draft of our report were taken into account and where we thought it appropriate, we changed parts of our report to reflect them.

12. We record our appreciation of the complete cooperation, and unstinted assistance provided by ICRISAT's Board, Director, and staff throughout the preparation and progress of the Review.

II. THE MANDATE

13. In October 1971, a group of consultants presented their 'Proposal for an International Crops Research Institute for the Semi-Arid Tropics' to the Technical Advisory Committee of the Consultative Group on International Agricultural Research. The primary goal of the proposed Institute was to assist the nations within the semi-arid tropical zones to increase their production of rainfed crops. A Memorandum of Agreement with the Government of India was signed in March 1972 and the constitution of ICRISAT, based on that recommended by the study team, was confirmed by the Governing Board in July 1972.

14. The purposes and activities of ICRISAT as defined in the Constitution are as follows:

"1. The Institute will serve as (a) a world center for the improvement of sorghum, millet, pigeonpeas, and chickpeas; (b) a center to promote the development and demonstration of improved cropping patterns and systems of farming which optimize the use of human and natural resources in the low rainfall, unirrigated, seasonally dry and semi-arid tropics; and (c) a center which may undertake such other programs or extensions of these programs as its Governing Board shall determine.

2. The Institute will engage in any and/or all of the following types of activities:

(a) Research on practical and theoretical problems including plant breeding related to the production of sorghums, millets, chickpeas, and pigeonpeas, and on the cropping and farming systems in which these crops are major components.

(b) Collection, evaluation, maintenance, manipulation, and distribution of basic germplasm and of improved plant materials for use in breeding, improvement and production programs of national and regional programs.

(c) Publications and dissemination of research results.

(d) Organization of periodic conferences, forums, and seminars on problems related to the Institute's objectives.

(e) Training of scientists who will be involved in research, educational and action programs in the various countries in which the Institute's programs will be applicable.

(f) Assistance in the development of appropriate educational, research, and extension institutional arrangements in the cooperating countries to facilitate use and application of the work of the Institute.

(g) Establishment and operation of an information center and library which will provide a collection of the world's literature on the major and relatied subjects of concern to the Institute.

(h) such other activities as the Institute may find necessary in furtherance of the purposes of the Institute."

15. This official constitution statement of the mandate of ICRISAT was later condensed by the Governing Board into the following four objectives, as stated in the Annual Report for 1973-74.

"1. To serve as a world center to improve the genetic potential for grain yield and nutritional quality of sorghum, pearl millet, pigeonpea and chickpea. Groundnuts will be added as a fifth crop next year.

2. To develop farming systems which will help to increase and stabilize agricultural production through better use of natural and human resources in the seasonally dry semi-arid tropics.

3. To identify socio-economic and other constraints to agricultural development in the semi-arid tropics and to evaluate alternative means of alleviating them through technological and institutional changes.

4. To assist national and regional research programs through cooperation and support and contributing further by sponsoring conferences, operating international training programs and assisting extension activities."

16. The study team had recognized the importance of groundnuts in the semi-arid tropics (SAT) and stated that they could be included among the mandate crops if resources were available. Following the recommendation of an expert committee in 1974, groundnuts were added to the mandate, and the program was initiated in 1976.

17. The collection and maintenance of the genetic resources of mandate crops was recognized from the outset as a responsibility of the institute. Following a request from IBPGR, the Governing Board agreed that ICRISAT should become a long term repository for genetic resources of three of the minor millet species, namely finger millet (Eleusine coracana), foxtail millet (Setaria italica) and proso millet (Panicum miliaceum), and it is examining the possibility of taking responsibility for several other species of the minor millets.

18. The Governing Board has also decided that ICRISAT 'will aim its research at a particularly disadvantaged target group, the small farmer of limited means farming his land with few inputs and without the benefit of regular, regional irrigation'.

The Geographical Mandate

19. In defining the geographical mandate of ICRISAT, the study group used the definition and delineation of Troll (see Annex V). These were based on areas with a mean annual temperature of more than 18 C, with either 2-4.5 wet months for the dry SAT, or 4.5-7 wet months for the wet-dry SAT. Wet months are those in which precipitation exceeds evapotranspiration.

20. As discussed below, Troll's demarcation leads to some conflicts between the geographic and the crop mandates of ICRISAT, setting boundaries which do not coincide with those of the main crops.

21. Troll's approach was global in extent, and therefore demarcated the SAT in broad terms, on a slender data base. More thorough investigation by ICRISAT's agroclimatology unit is leading to boundaries substantially different from those of Troll. In Niger, for example, the dry SAT sea is reduced from 34% to 10%, whereas in India the dry SAT area is increased from 26% to 64% of the country. While this may not change the basis of ICRISAT's research, it will change its area of concern in ways which may affect the balance of its programs and cooperative activities. We therefore recommend that the agroclimatological work should continue to redefine the SAT areas of the world on a more adequate basis. When this is done, it may be necessary for the Governing Board to consider whether ICRISAT should redefine its geographical mandate, possibly with greater emphasis on or even restriction to the dry SAT.

22. In the meantime, Troll's demarcation of the SAT is being used. On this basis, the area of ICRISAT's geographic mandate includes 49 countries (many of them among the poorest in the world), 19.6 million km^2, and more than 600 million people. The broad distribution of this mandate area and population, and of the mandate crops, is shown in the following table:

Percentage distribution within the SAT in:

		India	W. Africa	E.Africa	S.Africa	N.C.& S. America
Geographical area		10	24	22	20	19
Population		56	13	5	8	10
Production of:	Sorghum	34	15	11	2	32
	Millet	52	36	6	3	1
	Chickpea	78	-	5	-	5
	Pigeonpea	97	-	1	1	-
	Groundnut	50	19	9	7	9

23. In terms of Troll's classification, India has by far the largest proportion of the total SAT population, and this is likely to be considerably higher when the revised demarcation of SAT areas is completed. Also, in terms of population per km^2 of semi-arid lands, India has by far the highest figures. The location of ICRISAT within India and its orientation towards Indian problems could be justified on the basis of these criteria, but many other criteria, such as national research capacity, must also be taken into account in determining the geographical distribution of ICRISAT's work.

The Crop Mandate

24. The crop improvement component of the mandate is in the classic mould of the early IARCs, with strong emphasis on plant improvement through breeding. Sorghum and pearl millet are among the most important staple foods of the world in terms of calorie and protein production.

25. Over half of the world's sorghum is produced by the developing countries, but to do so requires four times as much land as in the developed countries. Within the developing world, 30% of the sorghum is produced outside the SAT zone, thereby broadening ICRISAT's geographic relevance.

26. Millet production, by contrast, is mostly (94%) in developing countries, with about 55% in the SAT. However, many species of millet are included in the FAO figures for production, and only about 40% is due to pearl millet. Of the other millets, foxtail millet comprises 24% of total production, Proso millet 16% and finger millet 11%. The Constitution of ICRISAT refers simply to millet, but in reformulating the objectives of the Institute, the Board referred only to pearl millet. The figures given above indicate that the other millets are also important crops, several of them in the SAT countries, and we therefore agree with the Board's decision to accept responsibility at least for the genetic resources of the minor millets. There has been relatively little research on any of the millets, and considering their importance to the developing world some of the minor species may deserve more of ICRISAT's attention. India is the major producer of millet within the SAT, but the main areas of production of pearl millet are well to the north of Hyderabad, Andhra Pradesh producing only a very small proportion of the total Indian output.

27. The two pulse crops are, in terms of total SAT production, much less important than the two cereals. The trend production in 1974 was 5.9 million tonnes (mt) for chickpea and 1.7 mt for pigeonpea, compared with 19.4 mt for sorghum and 16.0 mt for millets. But unlike the cereals, the average SAT yields are falling in both pulses, partly because of displacement to poorer land by the higher yielding cereals. In India, where they are important components of the diet, the pulses are in short supply and prices have risen rapidly in recent years.

28. Chickpea is grown widely in the Middle East and Mediterranean regions, being a crop of temperate origin. However, 90% of the crop is produced by SAT countries, the great bulk of it in India, although it is also grown to some extent in parts of E.Africa and the Americas. Within India, most of the crop is grown at higher latitutdes than Hyderabad, which is at the margin of its range even for the desi types.

29. The production of pigeonpea is about one tenth that of the millets within the SAT region, and separate figures for its production are no longer published by FAO. It is overwhelmingly an Indian crop, but is grown to some extent in many tropical countries. This was the only justification offered for its attention by ICRISAT in the report of the Study Group for its foundation and one might well query whether pigeonpea is of sufficient international importance to justify a specific mandate. However, it is a significant crop throughout India, where a majority of the SAT people live, both for its nutritional value and for its role in the stability of cropping systems. The potential importance of the crop elsewhere is difficult to assess, but it could become increasingly important in several parts of the Americas and in Africa.

30. Groundnuts are unquestionably an important crop throughout the SAT, which produces 12 mt, 67% of the world crop. India is the greatest producer, but for many other SAT countries the groundnut is a very important food and export crop.

31. ICRISAT was conceived at a time of widespread concern that the protein component of diets in developing countries was limiting and this, together with their particular significance in India, probably influenced the inclusion of chickpea and pigeonpea in the mandate. With the revision of protein and dietary standards by WHO/FAO since that time, greater emphasis is now placed on calorie supply as the major limiting factor. In the light of this change, the Governing Board agreed in 1975 that a higher priority should be given to yield improvement than to protein content and quality. We agree with this appraisal.

32. As noted above, there is some lack of congruence between the two major elements of the mandate, as defined geographically or by crop. The revised demarcations of SAT areas by ICRISAT's agroclimatology unit do not resolve these problems. In the case of India, the revised boundaries now include the main pigeonpea areas, but exclude much of the millet and chickpea areas into the arid zone. They similarly exclude sites such as Hissar and Sholapur which are of importance in ICRISAT's research, but include areas which are not thought of as semi-arid in the agricultural areas. In

relation to crop distribution within India, the best fit between crop distribution and climatic zones is obtained by using the boundaries between 0/1 and 3/4 wet months. However, under the different climatic and soil conditions of Africa and South America these boundaries would not be appropriate, up to 7 wet months being the most appropriate in some areas. There is a need, therefore, for further clarification of the relation between the geographic and the crop mandates, and for an examination of whether other indices for the description of the SAT would be more useful, such as those considered in the preparatory work done by WMO, FAO and UNESCO for the UN Conference on Desertification.

Farming Systems

33. ICRISAT was among the earliest of the IARCs to give formal recognition in its mandate of the need to supplement research on individual crops with research on their integration into productive and stable farming systems. The Board decided that only unirrigated systems should be considered, while recognizing that irrigation will be needed on the experiment station at times in order to preserve germplasm or speed up the progress in breeding programs. However, the use of supplementary irrigation from small catchment tanks is not excluded, and indeed a watershed approach is central to much of the farming systems research.

34. Another question raised by the inclusion of farming systems in the mandate is the policy for research on non-mandate crops, of which there are many of importance in the farming systems of the SAT. The Program Committee recommended in 1973 that any crop relevant to SAT conditions may be used in farming systems research, including the many oilseeds, cotton, other pulses and cereals (such as maize), forage plants, pastures and even fruit trees, but that breeding work on these crops was not to be undertaken. We agree with this conclusion on the grounds that we can see no other way in which realistic research in farming systems can be conducted.

35. The farming systems mandate also refers to the optimum use of human resources, presumably in recognition of the over-abundance of labor in rural India and the need for labor-intensive rather than labor-displacing technologies, whereas in Africa it may be necessary to evolve labor-saving technologies.

The Socio-Economic Mandate

36. The revised mandate also recognizes the need for greater understanding of the socio-economic constraints to agricultural development. For ICRISAT this is a particularly complex task requiring research in a variety of social science themes in areas with diverse socio-economic and cultural traditions.

37. The national research systems within the developing countries of the world, and all the IARCs, are attempting to deal with the agricultural problems of resource-poor farmers. Many of the farmers outside the SAT have as few resources, and often far less land, than those of the SAT. It would be

unfortunate, therefore, if ICRISAT's emphasis on the farmer of limited means was taken to imply that other centers and research systems are not equally concerned with his probl

38. The SAT farmer is exposed to great seasonal and annual variability. Consequently, stability of production is emphasized in the mandate. This is an objective which is also shared by most SAT agricultural scientists.

39. Although the small farmer emphasis is basic, it should be recognized that many agronomic technologies are scale-neutral, and may benefit medium and large as well as small farmers. The benefits of greater yield stability apd more effective plant protection should also accrue equally to all classes of farmers.

40. Given the focus by ICRISAT on the small farmer of limited means, there is a need to ensure that genetic materials and practices developed by the Institute should not only be superior at the field station, but also under the conditions of the small farmer's field. This is not to say that the farmer of small means will not use inputs such as fertilizers when it is profitable to do so. The wheat and rice farmers of India have used high yielding varieties and fertilizers to an extent which is surprisingly little affected by farm size. This is also true of sorghum grown in the kharif season. Thus, we consider that it is not necessary to limit ICRISAT's research, e.g. in breeding programs or farming systems, to zero or low input conditions. Indeed, were ICRISAT to do so it could be criticized for perpetuating agricultural under-development. But it is necessary to be sure that yield and stability under the poorest farmers' field conditions are not adversely affected.

Assistance to National and Regional Programs

41. The ICRISAT mandate is more explicit than those of many other IARCs in emphasizing its role of assistance to national systems, although all IARCs accept that this is one of their important functions. A problem is generated by the wide range in socio-economic conditions among the countries within their mandate. Consider, for example, the range of conditions, cultures, languages, traditions, research experience and strength, educational opportunities and availability of trained support staff found in India, Upper Volta, Senegal, Brazil and Thailand. Consequently the cooperative activities and support appropriate for one country may not be so for another. To reduce these activities to the lowest common denominator would result in insufficient help to the least developed nations, whereas to match the appropriate support for these latter in the help given to India (e.g. in training or varietal testing) would be wasteful and unwanted. This part of the mandate therefore poses a problem as to how, and on what grounds, to differentiate the kinds of support given to the various SAT nations.

42. It is already clear that crop dominance in different areas should not be the sole criterion for allocating resources for location specific work. Numbers of people and of poor farmers, nutritional needs, future crop potentials and the relative national research capabilities should also be taken

into account. Proportionately more resources will be required wherever and for as long as national systems are deficient.

43. The mandate of ICRISAT was carefully formulated, is still relevant, and needs no major change or extension. It is an important mandate, and although its several elements are not entirely congruent, it provides a workable guide for the research and policies of the Institute.

III. CEREALS

44. The two cereal crops included in the ICRISAT mandate, namely sorghum and pearl millet, are undoubtedly the two most important food crops of the SAT. The cereal improvement program is designed to help the poor farmer who has very limited resources. Nevertheless the farmer's ability to achieve substantially heavier yields will be primarily dependent on the extent to which he can improve his farming practices. Genetic improvements can help to stabilize yields at low levels of productivity, by alleviating the effects of damage caused by pests and diseases and by adapting the crop more closely to environments characterized by erratic rainfall, but they do not necessarily increase the potential for raising yield levels. Heavier yields are achieved mainly through farming systems that make more water and nutrients available to a crop variety that has the capacity to produce more grain.

Breeding

45. In crop improvement programs these two aims, of stability and of increased yield potential, can be in conflict, in that a variety bred for its response to improved farming conditions may perform worse than an unimproved variety in the absence of other inputs such as fertilizers. Although plant breeding cannot be done under the field conditions of the poor farmer, the performance of representative populations of the breeding material should be monitored under minimal farming practices from an early stage in the program. We were pleased that leaders of the cereal programs are aware of these principles but it was clear that opinions differ on their importance. We therefore support the multi-disciplinary work designed to examine the performance of improved genotypes under a range of farming conditions, both in India and Africa, and we recommend that these should include some comparisons at low and high levels of farming for both millet and sorghum material. In this connection we commend ICRISAT for setting aside permanent insecticide-free and low fertility areas.

Statistics and Field Experimentation

46. Reference was made in several contexts to the difficulties of evaluating breeding material under heterogeneous soil conditions. The large coefficients of variation obtained for yield and its components were commented upon, particularly by the cereal breeders in Africa. At ICRISAT center, serious difficulties have been avoided to some extent by the creation of accurately graded areas for field experiments. Nevertheless in all breeding programs, the desire for low coefficients of variation can lead to an undesirably heavy use of fertilizers and insecticides, and also causes reluctance to evaluate material at lower levels of inputs. In this connection we noted that statistical designs other than randomized complete, or incomplete blocks are being used, and suggest that designs which make use of the correlations among groups of neighboring plots should also be considered.

47. On a world-wide basis, statistical methodology for examining genotype-environment interactions is evolving rapidly. The use of appropriate techniques for analyzing the complex problems encountered is fundamental to breeding for yield stability and, in this respect, we commend work in the millet program undertaken in collaboration with the University of Queensland.

48. Owing to the overall importance of statistical procedures in the programs we recommend that urgent attention should be given to filling the post of statistician/biometrician to give closer support to these aspects of the work.

Population Genetics

49. We noted and approved the use of the biometrical analyses introduced into the programs. Many of these types of analysis are useful, but have limitations both with respect to the assumptions on which they are based and to the detailed interpretations that can be made. For these reasons we recommend that aspects of the programs specifically involving biometrical analysis should be reviewed from time to time by a consultant who is internationally recognized for expertise in population genetics and its application to plant breeding programs.

Crop Protection

50. In pathology and entomology we fully support the great effort being devoted to programs in resistance breeding and commend the teams for the rapid progress made. Nevertheless in view of the heavy workload which the screening procedures impose, we fear that other aspects of crop protection may not receive the attention they deserve. We therefore endorse the addition of pathology staff proposed in the 1979 budget and we recommend that attention should be given to the epidemiology of pests and diseases. These studies should examine environmental factors that enhance or hinder pest and disease development, such as weather conditions, cultural practices, cropping sequence, sowing dates and fertility level. Such information will be essential for future programs designed to develop integrated procedures for pest and disease management.

51. We also believe that monitoring the occurrence of pests and diseases in the SAT on the mandate crops, and on their wild and weedy relatives, would provide early warning of potentially serious outbreaks of pests and diseases, particularly after resistant varieties become generally used in a given locality. Possible breakdowns in resistance might then be predicted and avoided.

52. In relation to the need for additional information concerning the development and destructiveness of the pests and diseases of millets, sorghum and the pulses we believe much valuable information could be obtained by working more closely with the farming systems program than is apparent at present. We believe that this cooperation would not only be of benefit to the

crop protection program, but also to the overall strategies of farming systems which, in our judgment, must take into account not only what such systems do for increasing yield, but also what they may do for enhancing or hindering disease and pest problems on the crops in the system.

53. In the forthcoming five-year period substantial attention will have to be given to problems specific to Africa. In this respect the establishment of a large CILSS program on integrated pest management in basic food crops should be taken into account. This program will concentrate on strengthening national research capabilities, developing a pest surveillance and forecasting network, setting up demonstration and study areas and elaborating pest management strategies for the Sahelian countries. ICRISAT could make a significant contribution to this program through its research on various elements of the overall approach. For example, in the CILSS program no provision is made for the development of resistant varieties because of ICRISAT's expertise in this area. At present, it is not possible to judge the amount of additional work that will be needed for effective collaboration, but we recommend that discussions should be initiated between staff of ICRISAT and those of the CILSS Secretariat.

General Considerations

54. Although our thoughts in the above sections have been formulated primarily in relation to the programs in cereal improvement, they apply in large measure to the crop improvement programs in pulses and groundnuts, and also to the work on intercropping.

Future Structure

55. We noted and support the greater resources proposed for sorghum and millet in the 1978-79 budget. These increases allow for the division of the work into two separate programs. We agree that the scale of the breeding and research in these two crops has now reached the stage where some division of responsibilities is desirable. Nevertheless, having regard to the many common factors in these two programs and the heavy demands they make on the full range of support services, we suggest that the proposals for future operations be reexamined to ascertain the desirability of maintaining close coordination and some measure of common control over the two programs. We make this suggestion against a background of our impressions of an excellent team spirit among staff at all levels, and the need to maintain the rapid progress that is so clearly evident.

PEARL MILLET

56. The aims of the pearl millet improvement program have been clearly defined to draw upon a wide range of germplasm in order to provide different populations of segregating material, from which improved varieties may be

bred for a range of local conditions. At ICRISAT, the work is linked to that in intercropping and is closely integrated with work in pathology, entomology, physiology, microbiology and nutrition. A good start has been made with cooperative programs in Africa.

Breeding

57. In pearl millet, as in other outbreeding crops, the key to varietal improvement lies in fixing favorable recombinations and maximizing heterosis. Although hybrids offer the most effective way of exploiting these principles, production of hybrid seed is relatively costly and it should not be grown for a second generation. Consequently there are many areas in the SAT where the introduction of hybrids is not yet feasible. The ICRISAT program takes full account of this limitation and from the outset has given emphasis to the importance of population improvement and the synthesis of experimental varieties. At the same time full attention is given to improving the components of hybrid systems for use in areas where now, or in the future, hybrids may be used.

58. Evaluation procedures take into account the overriding needs of resistance to diseases, tolerance to drought, and improved performance at different levels of soil fertility. Recombination is effected only among plants that have themselves been exposed to disease attack in special infection nurseries at ICRISAT centre, and the selection criteria incorporate information provided by a wider coverage of disease nurseries including those in Africa. Important and representative material is subjected to water stress by sowing in January and varying the amount of water applied during growth in the dry season. Yield is evaluated during the normal rainfall season at two levels of soil fertility achieved by applying fertilizer mixtures at rates of 20 N:20 P_2O_5 and 120 N:60 P_2O_5 kg per hectare. Furthermore, appropriate groups of material are evaluated at different trial centers in both India and Africa. Assimilation of data on all the measured traits over all trials in time for November sowing in the disease nurseries places a heavy burden on the breeding team, and we were impressed by the scale of the program and the dedication of the staff in meeting these requirements.

59. Work on the comparison of methods of recurrent selection affords a good example of the type of investigation that can adequately be undertaken only with the resources of an international center. The project is long-term but has been well planned to provide information on the two main aspects of these comparisons; those related to the rate of genetic advance and those related to the resources required for a given rate of advance. The second of these is of overriding importance in the developing countries and the work should make an important contribution to the methodology of millet breeding, particularly for the national programs of countries in Africa.

60. In resistance breeding, rapid progress has been made jointly with the pathologists in identifying sources of resistance to downy mildew and incorporating these into the breeding material. Because of the differences in disease expression in Africa and India further progress will be dependent on use of a wider range of genetic resources in the breeding program.

Genetic Resources

61. Some of the gaps in the world collection of pearl millet have been filled-in recently by collections made by ORSTOM on contract for UNDP and the IBPGR. Central African Empire, Niger, Nigeria, Senegal, and part of Mali were covered by competent collecting teams. ICRISAT has sent its own teams to collect in various parts of India. The situation now is much better than it was three years ago and the amount of variability available for plant breeding has increased sharply. We recommend that ICRISAT continue the work until a reasonably good sampling of African and Indian material has been obtained.

Pathology

62. By far the most important and widespread disease of pearl millet is downy mildew. Ergot and smut are also important, while rust and blast occur in certain areas.

63. The techniques developed for screening the germplasm collection for resistance to downy mildew through the creation of international disease nurseries have facilitated rapid progress in breeding for resistance. Marked differences in disease expression under African and Indian conditions, however, have shown the urgent need to examine variability in the pathogen. In this respect we commend the collaborative program which has been initiated with the Commonwealth Mycological Institute at Kew. We also endorse the proposals for a joint study with the plant breeders on the genetics of host-plant resistance.

64. Of the other work on downy mildew, an important achievement has been the demonstration that internal seed-borne transmission probably does not occur. This conclusion is of importance in relation to the strict quarantine requirements imposed on the movement of pearl millet seed in and out of India, which have been based partly on reports that the disease can be internally transmitted in the seed.

65. Work on the control of ergot has been successful in showing the effects of pollen on the disruption of infection, and this project forms another example of effective collaborative work with the plant breeding team.

Entomology

66. Observations at ICRISAT center have shown insect pests to be of minor importance in pearl millet. Until recently the same situation occurred in most of the SAT areas. However, in recent years a number of pests notably a headworm, has caused considerable damage in Africa. Appropriate attention should be paid to the possible development of new pest problems.

Crop Physiology

67. Relatively little is known of the physiology of pearl millet and many aspects require urgent examination. The physiology team has initiated several important lines of investigation but is concentrating its attention on two questions of central importance to the performance of millet crops. These are:

- among a range of genotypes, is relative performance under low input conditions directly related to that under higher input conditions?

- what yield components and growth processes contribute to stability of grain yield?

These questions are of crucial importance in relation to the plant breeding program and we commend the program for its approach. It would be valuable to extend the range of conditions used in the experimental program to zero input conditions at least on the experiment station, and also to traditional farmers' fields.

Microbiology

68. Active nitrogen fixation under pearl millet plants has been demonstrated under conditions in which it is unlikely to have been caused by artefacts. In view of the great significance under low input conditions of variations among genotypes in nitrogen fixing capacity, this program deserves every encouragement. We were impressed by its comprehensiveness and by the range of techniques employed, and we support the initiation of long-term nitrogen balance studies on soils under millet crops.

Cooperative Programs in Africa

69. We reviewed the programs in pearl millet improvement in Senegal and in Upper Volta, where we also heard presentations of the work in Niger, Mali and Nigeria. We did not review work in the Sudan.

70. Breeding programs are rightly based on population improvement, but the local collections of material lack adequate genetic variability for rapid advances to be made in all the required characters. ICRISAT material affords a wider range of genetic diversity but lacks adequate resistance to downy mildew, particularly in Upper Volta. Some of the material has valuable characteristics, however, and is particularly well adapted to conditions in Senegal.

71. We accept the overriding importance of the need for ICRISAT material to be tested for wide adaptability at an early stage in the breeding program, but we suggest that methods should be sought (such as by reducing plot sizes or numbers of replications) to make most effective use of available manpower. We recognize that this problem has arisen partly owing to pressures on ICRISAT center to be seen to be assisting the programs in Africa, but these comments serve to exemplify the general need to strengthen core support for cooperative programs in Africa. Furthermore there are problems in millet improvement, such as the incorporation of resistance to Striga, which cannot be tackled at ICRISAT center.

72. Stronger programs in millet breeding in African countries would have, through exchange of material and experience, reciprocal advantages for the program at ICRISAT center which, in turn, would be in a stronger position to help the programs in India and other SAT regions.

Seed Multiplication and Distribution

73. In contrast to India, the African countries have virtually no organized systems for the multiplication, distribution and maintenance of outbreeding crops. Work on millet improvement can have little hope of success in Africa until adequate seed development organizations have been created. Moreover the work implies active extension in order to train farmers in the importance of saving seed for sowing from the centers of their fields and, for greater efficiency, the simultaneous introduction of new seed to groups of farms or villages. We recommend that, as the program develops, ICRISAT should take appropriate action to urge these needs on the governments of SAT countries in Africa.

74. Although the material has not yet reached the stage where it is of great benefit to national programs, impressive progress has been made. The program has benefited from its well conceived strategies and the competence and dedication of all the staff involved.

SORGHUM

Breeding

75. Externally supported sorghum breeding programs began in India some 20 years ago with the Rockefeller Foundation Indian project. A world collection of sorghum was assembled. The accessions were given IS numbers (Indian sorghum) and formed the base of the present world collection accepted by sorghum breeders around the world as the standard. The base collection included a reasonably systematic coverage of India and, later, Ethiopia. Other materials came in on a less systematic basis. With the establishment of ICRISAT, the IS collection was acquired and populations developed at Serere (Uganda), Samaru (Nigeria) and in the USA were added. The combination of elite Indian material with elite African material appears to give excellent performance in both India and East Africa.

76. The hybrid CSH-6, for example, developed by the All India Coordinated Sorghum Project, Rajendranagar, is used as a standard at ICRISAT and as a check in most of the international trials. It is basically an Indian guinea - kafir on the female side and an African zera-zera (caudatum) on the male side. Other excellent combinations are being sought among the populations now available.

77. The sorghum breeding program now at ICRISAT is a continuation of a 20-year old project, although there was a five year hiatus from 1968 to 1973, partly covered by the All-India program. The stability and maturity of the project is evident. The strategy is largely based on population improvement which takes a long time to develop but which is appropriate for an

institute like ICRISAT. Because there has been time and continuity in the Indian, Ugandan and U.S.A. programs several elite populations are now available with the prospect that they will generally improve with time.

78. Populations are generated by insertion of genetic male sterile genes into selected lines and backcrossing at least twice. This is followed by three cycles of random mating before selection cycles can begin. In all this may require some 10 years. The selection cycles are based on multi-locational testing of S_2 lines. The best performers are recombined by intercrossing. Each cycle takes two years and, perhaps, several cycles are required before the populations begin to take on elite characteristics. Once the populations have been generated, however, improvement can be expected more or less indefinitely depending on how they are manipulated.

79. The general objectives of the program are to generate elite populations with superior performance over a range of maturities and with broad geographic adaptation. Other populations are generated containing specific selected traits such as resistance to Striga, charcoal rot, downy mildew, grain mold and so on. These resistances and other special traits can be introduced into elite populations by intercrossing the populations. The genetic base of populations can also be broadened by introgression with selected exotic accessions from the world collection. These improved elite populations may then be supplied to national programs where local breeders can select out lines, parents for hybrids, or for compositing synthetics. The population development strategy is appropriate for this purpose.

80. On the other hand, interest in hybrids is apparently increasing, a good deal of testing is underway, and an increase in diversity of maintainer lines is being sought. Selected hybrids can be entered into the Indian national testing network and good ones can be used. In West Africa the use of hybrids would appear to be a long way off.

81. In addition to the general goals of developing elite populations or hybrids with disease and pest resistance and appropriate maturities, the program includes some more specific targets such as adaptation to high elevations, to areas of long rainy seasons, equatorial latitudes, and the rabi season of India. For some of these objectives, there may be no appropriate materials in the collection. Tolerance to low, but not freezing, temperature has been found in the sorghums of the Ethiopian plateau and is available. This is the source used for high elevation breeding in Mexico. Presumably, the target area is small and the attention given would be minor. Sorghum is an important crop of the Indian rabi and better types could no doubt be developed. We are concerned, however, about the heavy bias toward the Indian region at the expense of work urgently needed in Africa. A better balance is required.

82. Populations suitable for West Africa have not yet been generated. Interest in food products and use is, at present, mainly confined to chapati quality. The preferences and usages of Africans are not considered. Since the

populations are cycled in India and largely based on Indian tests, the bias is expected, but it is hoped that populations suitable for West Africa can soon be generated and cycled, based on West African multilocational tests. If ICRISAT is to succeed in its mandate, a redress of the bias is necessary.

83. Sorghum breeding in West Africa has been strengthened by ICRISAT Cooperative programs. Earlier work carried on by IRAT consisted primarily of selecting lines from within local populations. This has provided some useful base materials, and selection is continuing in the direction of shorter, earlier, less photosensitive materials. The present goal is a compromise between local populations and typical modern grain sorghums with respect to height, maturity and compactness of head. Grain mold is one of the serious problems, as it is in India. Striga, zonate leaf disease, charcoal rot on certain soil types, shoot fly, midge and stem borers are all serious and resistance are being sought in African materials. Sources from Hyderabad have not been very helpful to date. Some attention is being given to grain quality in the Upper Volta cooperative program. The ICRISAT programs in West Africa are relatively new and we recommend that they should be strengthened and expanded with some core funding, according to a long range plan.

Genetic Resources

84. The performance of ICRISAT with respect to the assembly of sorghum genetic resources has left much to be desired. The IS base collection provided a very fragmented coverage of Africa and Asia and contributed essentially nothing in the way of wild materials. Several known races of cultivated sorghums were completely missing. The most serious deficiencies were noted by a committee established by the Rockefeller Foundation whose report was published in 1971. The same deficiencies were again noted by the Sorghum and Millets Committee of the International Board for Plant Genetic Resources in its meetings at Hyderabad in both 1976 and 1978. The priorities for collection presented at this review are almost identical with those published in 1971. Since its establishment ICRISAT has had difficulty in appointing a principal scientist to take charge of sorghum genetic resources, and has consequently played a minor role in attempts to augment the world collection. ICRISAT materials are not doing well in West Africa and this may be in part associated with the skimpy collections there. Sources of insect and disease resistance have probably been overlooked for lack of wild materials to screen.

85. Rounding out the world collection is not just an academic exercise. The materials are needed now for the breeding program, and they are disappearing in Africa. It may already be too late to salvage some of the races. The maintenance, management and analysis of a large world collection is a full time job for a specialist. The burden should not be assigned to the plant breeder who has all he can do to keep up with his improvement program. Some of the materials are difficult and require special attention. More than one location will probably be needed since adaptation of some accessions is very limited. Yet, these very adaptations may be needed for the breeding program. Therefore we stress the urgency of further collecting of sorghum genetic resources from Africa and Asia.

Pathology

86. The main diseases are grain molds, charcoal rot and downy mildew. Some leaf diseases also cause significant losses locally. Reasonably good sources of resistance have been identified which are inherited on a multi-factorial basis. It is probable that these resistances can be enhanced by strong selection pressures. The identification of sources of resistance has involved extensive screening of the world collections and the close cooperation of cereal pathologists and plant breeders. The team is to be commended for the rapid progress made.

87. The rapid development of resistance to grain molds in a number of breeding lines of sorghum is a considerable achievement, considering the high degree of susceptibility in the parental material initially screened. Careful selection of individuals in the susceptible population and subsequent genetic manipulation have yielded some outstandingly resistant lines with desirable agronomic qualities.

88. Striga is one of the most serious pests of sorghum in the tropics. There are species in Africa not present in India and the proposal to increase screening efforts in Africa is viewed with approval. An enlarged African collection might improve chances of success. The problem is urgent and a solution should be pursued vigorously.

Entomology

89. The most outstanding feature of the sorghum entomology program is the well planned development of an integrated pest management system, that will provide optimal results with minimal costs to the SAT farmers. It is considered that in the foreseeable future pesticide use in the SAT will be minimal, mainly for economic reasons. The research results at ICRISAT show that excellent opportunities for alternative means of control are available.

90. The program activities determined by this approach are:

- survey and evaluation of major pest species, as well as their parasites;
- identification of species that justify detailed research at ICRISAT on the basis of their overall importance to the SAT;
- study of the population dynamics of these species;
- development of screening techniques for varietal resistance to major pest species;
- identification of insect resistance traits in germplasm.

91. The most important pest species are shootfly, stemborers and midge and excellent research results have already been obtained. They include

among others, development of field screening techniques for shootfly and stemborer resistance, identification of resistant germplasm for all three species, analysis of the shootfly species complex, identification of alternative host plants and identification of various parasites.

92. For research on basic aspects linkages have been developed with other research institutions. Such research includes:

- identification of the stemborer sex pheromone by the Tropical Products Institute, London;

- a study of the chemical basis of insect resistance and shootfly attractants by the Max Planck Institute for Biochemistry, Munich;

- biology and larval dispersal studies of the stemborer, Chilo partellus, by the Centre for Overseas Pest Research, London; and

- shootfly ecology, antibiosis and non-preference factors by ICIPE, Nairobi.

93. Since 1976 pest nurseries, which include entries found to have desirable characteristics for resistance to shootfly, Chilo stemborer and midge, have been organized.

94. We were impressed by the excellent results achieved in the program and commend the research team for its thorough and comprehensive approach to the sorghum insect problems. The results of the varietal resistance screening program are already extensively used. Complemented by studies on the population dynamics of the major pest species and on the role of parasites, these results have already led to the formulation of practical recommendations for effective control.

95. We note that certain research areas are insufficiently covered. These include:

- the extent of the losses caused, their economic importance and the development of guidelines for the establishment of economic damage thresholds;

- the possible use of Trichogramma parasites for the control of stemborers; and

- the study of the significance of predators in the regulation of the major pest species. This research should be done jointly with the intercropping program.

We consider that research on the above elements does not require the appointment of additional senior staff.

Physiology

96. The program in cereal physiology includes a range of studies dealing with growth, adaptation, components of yield, stability, nutrient uptake, and seedling drought resistance. Much of the research is focussed on the question of whether performance at the relatively high levels of soil fertility under which selection is carried out in the breeding programs bears a direct relation to performance under low input conditions. This question has yet to be answered satisfactorily, although it is central to plant breeding strategies for low input conditions. We, therefore, commend this project and the related research in sorghum physiology as well as the joint research with other projects.

Microbiology

97. The comprehensive microbiological program concerned with nitrogen fixation in association with sorghum should continue to be vigorously pursued on all fronts, in view of its likely significance for plant breeding programs focussed on the needs of farmers with small resources.

IV. PULSES

CHICKPEAS

98. Nowhere does the incongruity between the climatic-geographic mandate and the crops mandate of ICRISAT show more clearly than in the choice of the chickpea. Chickpea is not a tropical crop and is very poorly adapted to the Hyderabad area. It cannot be grown at all in kharif and is so sensitive to high temperatures that delayed planting in rabi is required. It may also suffer from high temperatures in spring towards maturity. It is true that India leads the world in chickpea production, but that production is primarily in subtropical rather than tropical India. Chickpea is important on the Ethiopian plateau and is grown on a small scale on the plateau of eastern Africa and the highlands of Mexico and the Andes where the climates are relatively cool. It is not grown in West Africa and is only a minor SAT crop outside of India.

99. A primary breeding program cannot be conducted at Hyderabad alone and facilities are required further north where the crop is important in India. The Hissar location appears to be well within the desi chickpea belt of adaptation. Hissar, however, would permit only a rabi crop. A site in Kashmir is being used to grow an off-season generation. An ICRISAT plant breeder has been posted to ICARDA at Aleppo, Syria.

100. Despite the above incongruity, we recommend that ICRISAT continue work on the crop, based on the arguments that:

- chickpea is an important pulse on the world scene and has an excellent nutritional profile that contributes substantially to the diets of the poor;
- like most other pulses it is a neglected crop and deserves investigation by teams with adequate facilities, resources and expertise;
- it is impractical for ICARDA to operate effectively in India because of quarantine restrictions; and
- introgression between desi and kabuli types is better done in India.

As much of the research must be conducted away from the Hyderabad base and will primarily serve India, a long-term objective should be to assist the Government of India in strengthening the research capability on chickpea so that the national program can satisfy Indian needs. ICARDA is in a better position to serve the more temperate regions.

Breeding

101. The breeding program was lacking a senior plant breeder at the time of our mission. Crossing work goes on and this has been one of the chief functions of ICRISAT. Materials are distributed to cooperators in the International Chickpea Screening Nursery. Selections are underway on breeding methodology, inheritance of quantitative characteristics as well as genetic markers, and the development of disease resistant and pest tolerant strains. Crosses with wild species of Cicer are being made with the objective of transferring disease and insect resistance.

102. At first, large numbers of crosses were made annually with selection among populations at the F_1 and F_2 level, followed by pedigree selection starting with individual plants in F_2. More recently, the program has been modified so that material can be advanced to F_5 before the main selection is done. We noted these changes, but did not discuss the genetic evidence for their basis with respect to chickpea breeding in the SAT context. Considering the short time that the breeding program has been in effect and the difficulties in working with the crop from Hyderabad, good progress has been made. It is hoped that more continuity in leadership can be developed in future and that rapid progress will continue.

Genetic Resources

103. The world collection of chickpea seems to have fairly good coverage. The 150 accessions from Ethiopia probably do not sample the variability in that country very adequately, especially if many of them are market samples. There are no collections from Kenya, Uganda, Tanzania or Malawi, and none from the Andean region. France, Italy, Yugoslavia, and Greece may not be adequately sampled. Some of the types from the USSR have been of exceptional interest and perhaps more wild species and especially a wider sampling of Cicer reticulatum would be highly desirable. By and large, the chickpea collection represents a better sampling than many of the other world pulse collections. The gaps should be filled in as soon as possible.

Pathology

104. The diseases of primary concern are wilt complex, stunt, and Ascochyta blight. Attempts to unravel the pathology of the 'wilt complex' have revealed a number of fungi, many of which are capable of causing significant disease reactions on their own. Recognition of alfalfa mosaic virus as a causal agent, and the tentative identification of pea leaf roll virus as a causative agent of stunt should aid the resistance screening program. Ascochyta blight screening has revealed partial resistance in a few promising germplasm accessions.

105. Elucidation of the wilt complex will permit a proper assessment of the relative importance of the various pathogens associated with this disease. While establishment of a wilt-sick screening plot at ICRISAT will permit the identification of potentially useful parent material, the large number of pathogens apparently involved in the complex may mask the specific resistance reactions and may lead to failures when breeding material is tested in multiple locations and in international nurseries. We suggest that initial screening should be conducted against specific pathogens that are most prevalent and most destructive, as soon as the relative importance of the fungi in the complex can be assessed.

106. Ascochyta blight is a disease associated with the rainy season. The disease does not occur naturally at Hyderabad, so progress in selecting Ascochyta blight-resistant plants in field trials will require nurseries in areas favorable for the disease. To meet this requirement screening will be done in field plantings at Aleppo, Syria and international chickpea Ascochyta blight nurseries are being planned for 1978-79.

107. We note that the assessment of the possible role of nematodes in chickpea pathology is not being overlooked, and that the virus work appears to be proceeding satisfactorily.

Entomology

108. The pulse entomology program is effectively oriented to the development of an integrated pest management system. In this, emphasis is placed on a combination of biological control, cultural control and the introduction of more resistant varieties. ICRISAT provides excellent opportunities and facilities for the development of such a program, as in the large pesticide free area maintained at the experimental station.

109. The pulse entomology program became fully operational only in 1977. Its objectives are:

- to provide service to the other disciplines in the pulse program;
- collaboration with pulse entomologists elsewhere and participation in training activities;
- development of a data bank of information relevant to pest management in pulses; and
- research on the development at practical pest management.

110. Chickpea has fewer problems with insects than does pigeonpea, Heliothis being by far the most damaging pest. Notwithstanding the recent establishment of the program some preliminary results have already been obtained, indicating differences in tolerance to Heliothis attack among in different chickpea lines. ICRISAT scientists are collaborating with the Max Planck Institute, Munich in an investigation of a malic acid exudate which may

be an insect protectant. Such collaboration with other institutes is to be commended.

Physiology

111. The physiological analysis of growth and development in chickpeas has provided several valuable insights, and work on genetic variation in the capacity for compensatory growth following injury may need extension. The lack of response to P fertilizer is of great interest and should be investigated in more detail. Growth analysis at Hyderabad, however, may have little relevance to the crop in its area of adaptation. Such work would be more appropriately carried out at Hissar.

Microbiology

112. Defective nodulation of chickpea crops appears to be common in vertisols even when chickpea rhizobia are abundant. An active program has been developed and its emphasis on surveying the relative effectiveness of both rhizobial and chickpea genotypes should eventually be of considerable significance to the breeding program.

113. On the whole, the chickpea work has been effective despite difficulties in working with a crop outside its primary range of adaptation. No doubt the work would be even more effective if more of it could be conducted where chickpea is more at home. We consider that the resources planned for chickpea in the 1979-80 budget are sufficient for an effective program on the crop, and that no further real increases should be needed over the next few years.

PIGEONPEAS

114. In pigeonpea, the congruity between the crop mandate and the SAT mandate is excellent. Pigeonpea is a crop of the semi-arid tropics. The problem with this crop is that the total world production is small compared with that of the major food crops, and well over 90% of the total is produced in India.

115. We recognize that pigeonpea is grown in most of the tropical countries of the world and that it is usually a poor man's crop. We also recognize that improvement of plant type, earliness, and high yield may result in a future expansion of production, but the present small production outside of India suggests that pigeonpea production is primarily an Indian problem to be solved by Indian resources as far as possible.

116. Rapid progress in pigeonpea improvement has been made at ICRISAT. A hybrid seed production capability has been developed that promises a substantial increase in yield. Early types have been developed that yield as well

as or better than long-season cultivars. Sources of resistance to sterility mosaic and Phytophthora blight have been identified and their genetic bases established. In view of these successes a sound basis for pigeonpea breeding in the SAT has now been laid. It would therefore appear that pigeonpea breeding could be progressively integrated with the national program over the next few years, and consultations should, therefore, be initiated with ICAR and the All-India Coordinated Pulse Improvement Project on the feasibility of such an approach.

117. Pigeonpea is needed for farming systems research in India, just as cowpea is essential for farming systems research in West Africa. There will be a continuing need for research on the pathology, entomology, physiology and microbiology of pigeonpea in relation to its use in intercropping systems, as indeed there will be for new genotypes from the All-India program. The germplasm collection should be maintained by ICRISAT and the center may wish to cooperate with the All-India Project in continuing international screening nurseries.

Breeding

118. Most of the highlights of the breeding program have been mentioned above. Large numbers of crosses are produced in the program with selection being made in early generations. Advanced generation materials are being made available to national breeding programs. Selections under intercrop and under sole crop conditions are being compared. Crosses with Atylosia species are being made to increase genetic variability and with the hope of transferring high protein and resistance to Heliothis armigera. The cultivated pigeonpea (Cajanus cajan) was apparently derived from a wild Atylosia and a revision of these genera is underway. While the taxonomic work on the group is important, no increase in this work is necessary.

119. The breeding program has yielded significant results in a short period of time and is to be commended.

Genetic Resources

120. It is difficult at this stage to assess the present sampling of pigeonpea variability. A careful assessment should be made to identify geographic and ecological gaps to be filled. More wild Atylosia accessions would probably be required to provide adequate supplies for the wide cross program.

Pathology

121. The major diseases have been identified as fusarium wilt caused by Fusarium oxysporum f. sp. udum, sterility mosaic, and phytophthora blight. Effective screening techniques have been established to permit the identification of potentially resistant cultivars to each of these diseases, as well as multiple screening plots to examine plant material for potential resistance or tolerance to a combination of them. While resistant or tolerant cultivars have been identified for each of the diseases and some have shown multiple resistance to two of the three diseases none has yet shown simultaneous resistance to all three of them.

122. The pathology work is being conducted in a satisfactory way, giving primary attention to the identification of resistant and tolerant breeding lines. There is evidence of good collaborative research with the pulse breeders and with pathologists and mycologists in other institutions where supplemental information is required to understand fully the nature of the causal organisms involved.

Entomology

123. Insects cause very serious damage to pigeonpea. Some 200 species have been recorded on the crop, but the most serious are the borer, Heliothis armigera, and the pod fly, Melanagrom yza obtusa. Extensive surveys in farmers' fields in India carried out during the past four years indicate that on average 30-40% of pigeonpea pods are damaged by these pests. An integrated pest management approach has been taken and some preliminary results have already been obtained although the program is only about one year old.

124. Future activities of the pulse entomology program will concentrate upon:

- host plant resistance;
- natural enemy encouragement and augmentation;
- study of the impact of sowing dates and cultural practices on pest development; and
- support to the intercropping entomology program.

We endorse this program and are convinced that the current research team is fully capable of carrying it out effectively. We recognise the strong technical and administrative support that has been given to the program, and trust that it will continue in the future. Our judgment is that resistance to Heliothis will be of only limited usefulness, and suggest that progress on this be carefully monitored to see whether some of the research capacity should in due course be shifted to the other areas of research.

Physiology

125. The experiments to date have clarified several important aspects of the physiology of pigeonpea, and the screening program for resistance to factors such as waterlogging and salinity have made some progress. The lack of response to soil-applied P fertilizers requires further elucidation. Since pigeonpea is mainly grown as an intercrop, we recommend that further physiological work should be concentrated on intercropping regimes, in collaboration with the farming systems program.

Microbiology

126. The behavior of the N-fixing Rhizobia on pigeonpea has been little studied in the past. Many pigeonpea crops are poorly nodulated, and there is an urgent need for an active program on nitrogen fixation by this crop. Work at ICRISAT in this area is welcomed by the All-India Pulse Coordinator, and we were pleased to see the vigor with which this program is being pursued. The attack on the problem is broad but effective, and we hope that it will continue to include work on competition and after-effects of pigeonpea crops in view of its importance as an intercrop in farming systems.

127. We support the development of a modest project on mycorrhizae particularly in view of the lack of response to P fertilizers by this crop.

Conclusions

128. The research teams working with pigeonpea are doing a competent, professional and effective job. They are to be commended. We are concerned, however, by the question of the appropriateness of the crop for an international institute. We believe that the future role of pigeonpea will be mainly in intercropping with sorghum, millet and maize, to provide additional grain production in the post-rainy season, as well as some stability of production in low input systems. As for its geographical importance, we expect that India will remain by far the dominant producer. We do not envisage much increase in SAT Africa, but there may be increases in pigeonpea production in Central and South America, the Caribbean countries and S.E. Asia.

129. We therefore recommend that ICRISAT's work on pigeonpea should increasingly concentrate on the intercrop situation in relation to the work on farming systems. In this way, the entomological pathological and physiological work on intercrops and farming systems could be strengthened, as we consider desirable, without the need for additional resources.

130. We also recommend that consultations take place with ICAR and the All India Coordinated Pulse Improvement Project on the feasibility of integrating the breeding program with the national program over the next five years. 1/

1/ Dr. J. R. Harlan dissociates himself from this recommendation.

GROUNDNUTS

131. Groundnuts are grown in most tropical and sub-tropical countries of the world. The kernels contain up to 50 percent non-drying oil and about 25 percent protein. The haulms are used for fodder. World production is estimated to be about 18 mt annually, of which about two thirds are grown in the SAT. India alone produces more than 5 mt. The need for work on this crop can be exemplified by the losses caused by the two leaf spotting diseases which alone are estimated to amount to 3 mt. annually. Consequently we have no reservations about the inclusion of work on groundnuts in the ICRISAT mandate.

132. The program leader was appointed in 1976 and, owing to the fact that work on groundnuts was not included in the original mandate, facilities available for the program have been somewhat limited. Nevertheless a comprehensive program is now in progress, covering breeding, cytogenetics, genetic resources, pathology, microbiology and a small project in entomology. Much of this work involves collaboration with other research institutes.

Breeding

133. A major problem in groundnut breeding is the need to increase genetic variability. Lack of variability in groundnuts is associated with the predominantly autogamous reproductive system, as well as isolation and lack of introgression from wild types. The case for intensive investigations on inter-specific crossing is therefore stronger for groundnuts than for the other crops included in the ICRISAT mandate, and we commend the strong team approach involving breeding, cytogenetics, pathology and microbiology.

134. Valuable sources of resistance have already been identified in the wild species and some interesting new types of plant have been discovered. For example, one inter-specific cross yielded a type with exceptional reproductive capacity, while in an F_2 population of an infra-specific cross a non-nodulating form was discovered. This could give rise to a very useful experimental tool in assessing the benefits of nitrogen fixation.

135. Natural outcrossing in groundnuts is believed to be less than one percent, but in Georgia and Indonesia, where solitary forms of bee are numerous, outcrossing can rise to as much as 10 percent. We consider that the project designed to measure outcrossing at the ICRISAT center is entirely appropriate and we particularly commend the spectacular progress made in techniques for artificial cross-pollination. By careful attention to detail, the success rates for hand pollinations have increased, over a short period of time, from less than 3 percent to more than 60 percent under screenhouse conditions, and from less than one percent to more than 50 percent in the field.

136. The most urgent need in groundnut improvement for countries of the SAT is to incorporate resistance to the various diseases. We agree with the priority accorded to this aspect of the work and support the inference that many of the problems of poor crop husbandry in groundnuts are associated with the small farmers' disenchantment with growing disease-ridden cultivars. Breeding methods aimed at achieving multiple resistances in a single cultivar are appropriate for the present stage of the work, but will undoubtedly become more complex as the program evolves.

137. The breeding program has not yet been extended to cover the SAT countries of Africa. Owing to the strong support given to work on groundnuts in the countries of West Africa by the IRHO, we do not consider that ICRISAT's regional program on groundnuts should be centered in that area. We therefore recommend that, in spite of the known difficulties, attempts should be made to find a suitable place in eastern or central Africa from which the regional program could be coordinated. Such a solution would have the added advantage of widening the regional network of ICRISAT's core-funded activities in Africa.

Cytogenetics

138. While closely linked with other disciplines in the evaluation of wild species and their derivatives, work in cytogenetics is more specifically aimed at investigating and overcoming barriers to hybridization. Introgression from diploid wild species to tetraploid cultivars is being achieved in various ways, and cytological evidence as well as the observed segregation in hexaploid lines, suggest that worthwhile recombination between chromosomes of different genomes does occur. Very good progress has been made in this work, stemming from the strong support it has received from Reading University.

Genetic Resources and Quarantine Arrangements

139. As a designated world center for groundnut germplasm, ICRISAT has already acquired a wide range of material covering both the cultivated and wild species. In this work, close contact is maintained with other research institutes, particularly in the USA.

140. A workable system for importing of groundnut germplasm has been developed with the Indian authorities and a regular supply of new material is now being received. We do not, therefore, consider that it is necessary, at this stage to proceed with the proposal to develop routines for quarantine on an off-shore island.

Pathology

141. The principal diseases of groundnuts are rust caused by Puccinia arachidis, leaf spots caused by Cercospora arachidicola and Cercosporidium personatum, and four virus diseases: peanut mottle, peanut stunt, rosette and tomato spotted wilt (bud necrosis). Screening for rust resistance has identified several new sources of resistance both in wild and cultivated forms. Virology studies have shown that bud necrosis is caused by tomato spotted wilt

virus and revealed a newly identified vector, Scirtothrips dorsalis. Rapid progress is being made using the latest techniques in virus identification and purification.

142. Plans to expand studies of the epidemiology of rust and on variation in the pathogen were outlined. These aspects of the disease are important because of their implications for the breeding program. The search for resistance to Aspergillus flavus has been hampered by the lack of suitable laboratory facilities but, owing to the importance of this organism in relation to aflatoxin, we support a modest investment in work on screening for resistance at the post-harvest stage. Nonetheless, owing to the fact that this problem can be controlled by appropriate attention to harvest and post-harvest management, we consider that greater inputs into extension services are likely to achieve more rapid progress than breeding programs at the national level.

143. We believe the virology program is making good progress. We encourage the relationships established with scientists in India, England, Japan and the USA, and with those in other research organizations such as ORSTOM and IITA, who have cooperated in the virology work, and we were impressed by the progress achieved in spite of deficient facilities at ICRISAT Center. We support the development of adequate laboratory accommodation and the provision of appropriate equipment, including an electron microscope, for virus identification and characterization.

Entomology

144. In the proposal for research on groundnuts by ICRISAT it is noted "that ICRISAT should be fully informed about the insect pests of peanuts, but since most of these are locale-specific no special program is proposed other than observation and control on the Institute's fields... It will, however, be essential to search for resistance to insect pests in both wild and cultivated materials in the genetic collections, some resistances have already been recorded".

145. As a consequence of this statement, ICRISAT's research program on entomology has been limited to one project to identify harmful and beneficial arthropods of groundnuts and to study the role of disease vectors. Through surveys it has already been demonstrated that a significant number of insect pests can cause substantial damage. They include leaf miners, pod borers, white grubs, aphids and thrips. Aphids and thrips are the vectors of important virus diseases, such as groundnut rosette virus and bud necrosis virus.

146. Consequently we consider that the arguments for a limited entomology program are not valid. Some of the above pests are of universal importance. Selection for resistance can be done successfully only when effective screening techniques have been developed and sufficient biological knowledge about the insects has been collected. Moreover, breeding for resistance to virus diseases has much greater chances of success if efforts are made to introduce resistance to their vectors simultaneously.

147. We therefore recommend that a principal staff position for a senior entomologist should be created as a matter of urgency. The position should be filled by an entomologist with experience in disease transmission.

Physiology

148. The aims of breeding to increase yield potential in the absence of disease attack are less well defined and it is in this region that support from a crop physiologist is required. Little is known about the plant characteristics required for adapting groundnuts to varying and erratic patterns of rainfall distribution, and nothing is known of these characteristics under conditions of intercropping. We therefore support the inclusion of a crop physiologist in the 1979-80 budget proposals.

149. Groundnut crops in India are often very poorly nodulated, yet potentially the groundnut could be one of the most effective nitrogen-fixing crops, because of its vigorous nodulation - even up the stem beyond the crown - and the high activity per unit nodule weight. There is considerable variation among groundnut genotypes in these respects, and therefore considerable scope for improvement in a breeding program. Such work at ICRISAT was welcomed by the All-India Coordinator for Oilseed Crops. The greatest need, however, is to extend the program to SAT Africa, which may require the provision of additional staff. There is also a need to investigate the extent of nodulation under different systems of intercropping.

Collaboration with Other Research Institutes

150. A particularly strong feature of the groundnut program is the excellent collaborative work which has been built up with other research institutes on a world-wide basis, notably with the University of North Carolina, Reading University, and research institutes in Japan and Australia. We endorse this mode of operation, which affords valuable opportunities for fundamental work in the developed countries to contribute to the work of international centers, as well as providing interactive stimulus to the research workers involved.

VI. FARMING SYSTEMS

Introduction

151. Farming systems research (FSR) is an holistic approach to the problems and needs of the farmer, aimed at the more efficient use of resources in agricultural production.

152. FSR has an important role in the developing countries where knowledge of the aspirations and management practices of small farmers is still scanty, and where new technology must be adapted to local conditions; there is a pressing need for better use of the resources available to agriculture in the SAT. Furthermore, developing countries often lack effective means of communication between the small farmer and research organizations and FSR can thus play a very important role in the transfer of technology while at the same time offering a feedback mechanism to research workers on vital problems affecting the farming systems.

153. These characteristics of FSR make it highly relevant to the mandate and objectives of ICRISAT. The institute emphasizes that traditional agricultural systems in the SAT have developed through long experience against a background of very limited resources and highly variable rainfall. Such systems, while relatively stable in the past, are no longer adequate for the increasing population and the need for more modern agriculture.

154. Such considerations led to the inclusion of ICRISAT among the centers whose programs were examined in some detail by the FSR Stripe Review panel established by the CGIAR. Their perceptive report was available to us and, in view of our broad agreement with their conclusions in respect to ICRISAT's FSR work, the following observations are mainly supplementary to those in the Stripe Review.

155. Several difficulties are associated with FSR. It is a relatively new discipline so methodologies still need to be developed, and work by a multi-disciplinary team is required. Considerable resources are needed over long periods and the research generates voluminous and diverse data which need special skills for interpretation and use.

156. FSR comprises three major inter-related facets, namely base data analysis, research station studies, and on-farm studies. The FSR program at ICRISAT covers these three basic activities, and has done research in cooperation with the All-India Dryland Project under ICAR, and in association with the Village-Level Studies (VLS), and other activities of the Economics program (q.v. Chapter VII). VLS provide an understanding of the existing situation, its analysis in terms of constraints and risks in adopting new technology, and opportunities for the evaluation of new systems.

157. Research station studies into components of FSR are conducted by sub-programs on agroclimatology, soil physics, soil fertility and chemistry,

cropping systems; farm power and equipment; land and water management; agronomy and weed science; and cropping entomology. The small watershed is taken as the basis of management in these studies.

158. On-farm studies on the application of ICRISAT's FSR technology are at a very early stage of development as they started only in 1978 and are based in 3 villages representative of three different agroclimatic, soil and management conditions.

Data Collection and Analysis

159. Crop production and crop suitability at any specific location are determined primarily by the interaction of moisture, temperature, radiation, soil fertility and disease and pest pressures. As far as the SAT region is concerned, undependable rainfall is the primary cause of unstable production. Thus climatic data are essential not only for research on farming systems but also as a basis for the transfer of agricultural technology and thus agricultural development.

160. ICRISAT has collected, analyzed and interpreted a large amount of climatic data and has refined the accuracy of delineations of the climatic zones of the SAT regions. The determination of water availability for plant growth based on water holding capacity of soils, rainfall probability and evapotranspiration has provided an excellent basis for work on cropping patterns in India.

161. We consider that ICRISAT has developed an important role in climatology studies in the SAT countries and we support their continued development, particularly in the African region, although we recognize that climatic data in parts of the region are often scarce and sometimes unreliable. We also consider that more data on soils in the SAT regions need to be assembled, and that work on moisture characteristics of the different soils needs intensification.

Watershed Management

162. Because water has long been acknowledged as the primary factor limiting production in the SAT region, ICRISAT developed a land and water management program aimed at optimizing the use of these resources, soon after its creation.

163. Its efforts have been directed at the establishment of cultivation methods which will reduce runoff and erosion by increasing infiltration, safely dispose of and if possible store excess water, avoid waterlogging and improve and extend the timing of cultivation, particularly on the vertisols (black soils).

164. Water balance studies using measurements of rainfall, evapotranspiration, runoff and erosion complement this work, as do the determination of moisture extraction patterns in the root zone and micro-climatic studies.

165. After trials on many systems of cultivation ICRISAT found that broad beds (150 cm) with a gentle slope (0.4%-0.8%) which could be built by draft animals or small tractors, offered the best solution, particularly for the vertisols.

166. We recommend that continuation of this research on ICRISAT station should be limited to a few well defined objectives. We consider that the extension of such research into other areas and land types and on to farmers' fields is the next step. We recognize that land management practices of the bed and furrow type have had a considerable amount of research in the SAT countries. This has had a mixed success but we suggest that ICRISAT, in the course of extending this work, particularly to the African region, make an analysis of this past experience, including the use of draft animals.

167. We consider that the work on agroclimatology and soil physics provides a sound basis for understanding moisture behavior in these soils and we support its continuation both as a basis for extrapolation to other regions and as a source of information on year to year variation. The work on crusting and soil structure needs greater emphasis.

Mechanization

168. Mechanization, including the use of animal-drawn implements, can increase production greatly. In some SAT countries neither mechanical nor animal power makes a significant contribution, while in others animal power is an important part of agricultural production. Power systems must, therefore, be designed for different levels of improved land management.

169. To develop better cropping systems ICRISAT has studied the power needs of small farmers in India. They have focussed on improving the efficiency of the existing power source i.e. animals rather than on substituting a mechanical source. Consequently the main attention has been given to the development of more efficient implements. The program has successfully adapted a French designed wheeled tool carrier to conditions in India. However, because of cost ICRISAT is now designing a less expensive implement.

170. We were impressed by the efficiency of the implements and support the continuation of this work, particularly the exploration of ways of making the equipment available to the small farmer. However, we recognize that Indian farmers are a long way ahead of those in many parts of the African SAT in the use of animal power and that in consequence a good deal of adaptive research will be necessary in Africa and that the application of results may be slow.

Soil Fertility

171. ICRISAT has not had a major program in soil fertility although it is recognized that research on efficient use of fertilizer and on the conservation and recycling of soil nutrients is of great importance. A principal scientist will take over this program in the near future.

172. Early trials at ICRISAT established the responses of cereals to N, P and Zn on both alfisols (red soils) and vertisols. P responses were small or non-existent in chickpeas and pigeonpeas. Boron toxicity on pigeonpeas and S deficiency on sorghum have been observed. Soil physical problems, especially crusting, were found to occur on the alfisols.

173. ICRISAT proposes to concentrate its research on inefficiencies in the use of applied N on vertisols (possibly due to denitrification), the relationships between soil nutrients and N fixation, and appropriate fertilizer programs for intercropping. The lack of P response in pigeonpea seems to be worth further investigation.

174. We consider that even though much work has been done on fertilizer responses in India the other topics deserve attention. However, in view of the great need in much of SAT Africa for the development of a strategy on fertilizer use we suggest that this work be reviewed after a period of 3 years with a view to shifting more of the emphasis to that region.

175. In many parts of the SAT areas of Africa soil fertility differs from that in India. In the former the soils are of lower natural fertility and indeed their natural fertility levels could not carry nearly as large a population density as those in similiar rainfall areas of India. Past research has shown that fertility has to be built up over a period of time using a combination of fertilizer and cultural practices. Farming systems in the African SAT are perhaps even more diverse than those in India, ranging from various types of shifting cultivation to continuous cropping and sometimes total soil degradation.

176. Furthermore past research has also shown that there is often a rapid deterioration of the soil structure when the land is cultivated mechanically and that surface crusting becomes a serious problem.

177. Soil moisture behavior in these soils is not well understood, and this is an area needing additional research. We consider that the problems of soil management under intensified agriculture in West Africa will present a major challenge to ICRISAT and that some of the problems are more closely akin to these being studied by IITA than to those in India and we recommend close cooperation between the two programs.

Cropping Systems

178. We were impressed by the well-designed and fruitful program on representative cropping systems (relay, sequential, ratoon and intercropping), as the basis for developing improved methodologies for cropping systems research, in which intercropping receives the most attention. Combinations of sorghum-pigeonpea and pearl millet-groundnut have been compared with sole cropping and have clearly demonstrated the advantage and better use of resources which result from intercropping a slowly establishing pigeonpea with a rapid, early, upright, non-ratooning cereal. The advantage, using the criterion of the Land Equivalent Ratio, was shown to increase with plant populations higher than the optimum for each crop when grown alone.

179. Pigeonpea is an important component of cropping systems in India, but of minor importance in SAT Africa. As a sole crop its slow initial growth provides little soil protection, but its ability to thrive on soils of low fertility is an obvious advantage. Consequently we consider that it is important to include it in cropping systems research both in India and in Africa.

180. We consider that this program is making a worthwhile contribution to the development of methodologies for cropping systems research. This is an important area of research where the services of a consultant biometrician will continue to be needed.

181. One of the problems in cropping systems research is that of selecting appropriate crops, considering the wide range and diversity of crops usually grown by farmers. ICRISAT is examining the role of forage, fodder and fuel crops in farming systems but we consider that the role of cash crops outside the commodity mandate of the center cannot be ignored. Furthermore animals are often important, and their role in many African farming systems is complicated by the transhumant nature of the population.

182. We therefore recommend that ICRISAT should include cash crops and animals in its farming systems research where considered appropriate. We are not suggesting improvement programs for the commodities not specifically mentioned in the center's mandate; this means in effect that the program will use the best local materials.

Intercropping Entomology

183. The activities carried out in the entomology program are:

- study of pest buildup and losses caused by major pest species;
- pest monitoring through light trapping;
- survey and evaluation of biocontrol agents.

184. Contrary to what might have been expected percentage yield loss due to Heliothis armigera was found to be higher on intercropped pigeonpea than on a sole crop in typical low fertility conditions. Moreover, in many cases parasites did not move with the pest species from one interplanted crop to the other. This leads to the situation that each crop has its typical parasite complex. The use of viruses as a control measure for H. armigera is given special attention and links have been developed with the Boyce Thompson Institute for the study of the various characterization and safety aspects.

185. A close relationship should be maintained between the entomological work on intercropping and that on sorghum and millet, as also in the pathology work. As the same researchers are at present involved effective coordination and interchange is currently ensured.

186. Through intercropping, optimal use is made of the available natural resources, providing the farmer with the improved likelihood of stable production. However, it also leads to several major changes in the cropping ecosystem, such as prolongation of the growing season. This will entail changes in the pest complexes, as is already evident. Detailed studies are therefore needed to avoid the propagation of cropping patterns with an unacceptably high level of pest risk.

187. ICRISAT's work on intercropping entomology might be described as a pioneering exercise and will produce results of great significance for agricultural entomology in general. We commend the scientists for their well balanced approach. In the coming 5 years, leadership for this work should be provided by the principal entomologists of the cereals and pulses program, as has been done in the past. It is to be expected that the amount of research will expand beyond its current scope. So far most of it has been carried out at the research station and observations under farmers' conditions are urgently needed. In addition the study of the role of biocontrol agents should be expanded to include predators. We recommend that one more senior national staff position be established to cope with the additional work.

Weed Research

188. The total program of weed research at ICRISAT is carried out as part of the farming systems program, and its objectives are the development of effective, economically feasible weed management systems for the major SAT crops and cropping systems.

189. It has been clearly demonstrated that weeds constitute a significant production constraint, not only due to direct competition for light, water, space and nutrients, but also indirectly as a limiting factor on the area that can be effectively managed by one farm family. The latter aspect is particularly relevant to the African situation.

190. ICRISAT's activities carried out in weed research are: weed surveys in India and Africa, weed management field research, herbicide screening and weed ecology studies. Some of the main findings are that:

- the African weed flora resembles the Indian alfisol flora
- certain intercrops, like cowpea, prove to be very effective weed suppressors, whereas groundnuts favor weeds
- significant varietal differences exist in herbicide tolerance.

191. The weed research program is very well adapted to the needs of the SAT. It follows a realistic approach and provides an essential contribution to the farming systems program. It will continue to develop the best adapted weed control technologies, leaving the final choice for their application to

the various national programs. The use of herbicides on rainfed crops on the vertisols is technically promising but may not be economic in many circumstances.

On-farm Research

192. ICRISAT wishes to put the technology from its FSR into operation in the farmers' fields. This is needed to test the technology in the real world of the farmer and to get information which will determine the next steps in the research program. ICRISAT has done preliminary experiments on its station on "Steps in Transfer of Technology". These have measured separately, and in combination, the effects on yields of improved varieties, fertilizers and improved soil management. This investigation has shown the strong synergistic effects of these components, leading to very large yield increases. Although there is evidence that use of modern varieties or fertilizers alone may be profitable in some areas, their combination with improved soil and water management could hasten extension.

193. Such results offer a strong incentive to ICRISAT to use a 'complete technology package' approach when working on farmers fields, though it is well recognized that the land and water management aspect may call for some group action on a watershed basis. At the moment however this is being tried on a single field basis. Unlike the use of improved varieties, there is no well charted path from the international center experiment station to the farmer's field for farming systems technology. We commend ICRISAT for working so closely with the All-India Coordinated Research Project for Dryland Agriculture in off-campus activities and emphasize the need for continuing close association with this and other Government of India agencies at each step in this program. We consider that ICRISAT will need to set up a network of collaborative experiments in the country, with the All-India programs.

Relations with Indian Projects

194. If and when profitable farming systems for various input levels are experimentally developed, and recommended to the national system, it will be essential to recommend, at the same time, suitable changes in extension methods. The systems will have many elements: new varieties, crop-sequencing, new kinds of land preparation (beds, slope-changes, realignment of waterflows), and the storage and use of run-off. Some of these components, particularly soil and water management devices, will require new skills which extension personnel traditionally do not have. New, intensive, practical training in these skills will have to be organized. The variations as between systems recommended for different areas and farm-sizes will be significant; therefore training will have to be correspondingly location-specific.

Relation to the African Program

195. ICRISAT's work on FSR is all done in India, although it is considered that the methodologies and principles developed are adaptable to other situations and that models can be developed for wider application. Plans for extending the FSR program to Africa have been delayed by such constraints as lack of trained scientists, facilities, and funds.

196. Several important factors have to be taken into account when designing an African program. These include the work that has been done already, (particularly by French and British scientists), the major differences in socio-economic conditions (especially land tenure), natural resources (particularly the impoverished soils), and the role of cattle and other livestock.

197. Thus while we support the early extension of FSR to Africa we recognize that some of the approaches developed at ICRISAT will need considerable modification. Because of the nature of land holdings and the physiography of the area, the watershed as used at ICRISAT may not be the appropriate unit and the work will have to be based on bigger water catchments. The broad goals of the program in Africa are the same as those in India, but the time frame for their achievement may be considerably longer.

198. We recommend that the extension of the work into Africa should be preceded by a survey of the national research capabilities of the various African countries in an attempt to determine areas of strength and weakness and to decide where activities of the program would be most appropriately placed. FSR can develop programs of practical value only through the collaboration and participation of national research systems. Such a survey will also ensure that past work will be adequately assessed and that the objectives of the program will be clearly defined in the light of the above constraints.

199. Of the three aspects of FSR it would appear that research station work is receiving the greatest attention in many national systems in Africa and this aspect is perhaps the least difficult component at present. Most of the national organizations in Africa lack the methodology and adequately trained personnel to participate in base data analyses and on-farm research. It therefore appears that the main areas of activity where ICRISAT Center can give support to an African program are:

- base data analysis of soils, agroclimatic zones, socio-economic factors, and other factors relevant to selection of benchmark locations and representative systems. Secondary data seem to be available from various sources but the methodology of analysis to serve FSR needs to be developed;

- development of methods of data collection, techniques and methodology for village level studies and FSR adapted to African conditions; and

- training of scientists, technical assistants and economic investigators. To ensure that trained personnel return to work in FSR it will be necessary to start a cooperative program to provide the necessary links with ICRISAT headquarters, to identify candidates for training and to serve as a base for further training and demonstration.

200. The above central activities should aim at giving support to a wide range of countries and to the regional FSR cooperative program located in Africa which, due to the complexity of FSR, may involve both station and on-farm research in a few selected countries.

201. In considering the size of a team we think that a minimum need at a site would be 2 agronomists, one concerned with productivity and the other a land and water management specialist. Inputs from the social scientists would be an additional need.

Future Development of FSR

202. The impressive increases in production which have been obtained in this research project, in a zone long regarded as having low potential, has excited considerable interest in the use of the techniques in agricultural development programs.

203. However, even in India there is still a considerable amount of research to be done before this technology can be confidently introduced on a large scale. ICRISAT's work on developing methodology, on studying the underlying principles and on developing models is an excellent example of the important role of an international center.

204. Its next step, that of testing the technology at 3 village sites will provide some of the feedback that is necessary to guide ICRISAT's on-station research program. Nevertheless much wider testing will be necessary, in areas where social and economic factors will play differing but equally important roles. As these factors vary so will the importance of the various inputs in the technology package. While the national program may find it easy to test some elements of the package, e.g. new varieties and fertilizers, it will also have to provide the necessary equipment for testing the land and water management techniques.

205. Since the technical components of the packages appear sound, there may be some scope for encouraging the Government of India to undertake pilot projects under intensive management. While such projects might not be easily replicable on a large scale because of the cost to the Government they might provide a more rapid approach to the extension of the technology to the farmer.

206. While ICRISAT has some useful FSR technology to offer in India it is not in a position to offer advice on development projects in the African SAT. It seems to us that it is premature for ICRISAT to become involved in designing farming systems for development projects there before it it has designed and carried out research projects under the conditions of the African SAT.

VII. ECONOMICS

207. In reviewing ICRISAT Economics Research we applied the criteria of (1) relevance to the ICRISAT mandate, (2) methodological rigor and innovativeness and (3) the need to supplement and strengthen national economic research in areas of ICRISAT interest.

208. The following major themes have been pursued under the ICRISAT Economics Program (IEP) in India:

Traditional Farming Systems	Consumer Preferences
New (Farming Systems) Technologies	Marketing Syst
Rural Labor Markets	Demand and Supply Elasticities
Water Management	Regional Specialization & Equilibrium
Farm Mechanization	Allocation of Research Resources
Nutrition	SAT Crop Trends
Risk & Uncertainty	

Credit, storage and sociocultural aspects of economic development are additional themes on which projects are proposed to be initiated in the next 5 years.

209. The coverage of the current and prospective Economics Program is very comprehensive, and adequate to support and evaluate the other research of ICRISAT on mandate crops and farming systems. It also comprises the study of most of the major socio-economic constraints in which technological and institutional changes would be called for to alleviate the poverty of small farmers and landless workers.

210. A few important themes are missing in the ICRISAT Economics agenda, such as land relations, input supply systems, extension and price policy. Deficiencies in these dimensions of the agricultural scene can seriously constrain SAT farm growth even after highly productive farming systems have been discovered. But it is not necessary that ICRISAT itself should use its core resources on these omitted themes. It would suffice for it to stimulate national economic research institutions to develop SAT-specific knowledge in these fields.

211. In order to form an overall judgment on the performance of the ICRISAT Economics Program (IEP) in India it is necessary to review briefly the findings of important individual studies for their relevance to ICRISAT objectives, and other research, and their methodological quality. Program priorities for the coming years can then be derived.

212. There are at least 4 fields in which IEP research is evaluating, influencing or actively interacting with other research in ICRISAT, namely the allocation of research resources, old and new farming systems, nutrition, and consumer preferences. There is at ICRISAT a rather rare degree of inter-disciplinary receptivity and cooperation oriented to problem-solving.

Research Resources

213. An interesting attempt has been made to evaluate objectively the allocation of research resources by ICRISAT between crops and regions. Calculations of the Boyce-Evenson indices of regional congruence (between research allocations and crop values) on the basis of ICRISAT budget data suggest the need for larger allocations for groundnut research, and for work on farming systems and economics, particularly in SAT regions other than India. They also indicate that in most program areas more resources need to be deployed not only in West Africa but also in East and South Africa and the SAT regions in America. There are obvious limitations of the methodology yielding these results. Future inter-regional shifts in output are ignored. The specific needs of existing research systems are not considered. And resources generating internationally transferable knowledge cannot be properly chalked up against the region in which this knowledge first emerges. Therefore a refinement of the methodology will be necessary. But a review of the allocation of research resources, at least once in 5 years, will have a good pay-off. Work done so far has already suggested several desirable adjustments in budgeting required over the next few years.

Nutrition

214. IEP research on nutrition has produced findings which point to changes needed in the objectives of the plant breeding programs to give due attention to energy, vitamins and minerals as well as to the protein content of the new cultivars.

Village-Level Studies

215. The study of traditional farming systems by means of a highly innovative Village Level Studies program (VLS) has produced valuable insights for scientific as well as economic researchers and identified the key issues requiring ameliorative research. Studies of the traditional farming systems with VLS data brought out the dominance of rainy season fallow on vertisols, intercropping with as many as 10 to 60 different combinations, low wages and earnings, and chronic, massive unemployment. These and other data about tilling, weeding, water regimes, fertilization, labor demand, pest and diseases, risk behavior, etc. assisted in identifying the key components of ICRISAT research in breeding, farming systems and economics.

Farming Systems

216. Research on new farming systems is a natural sequel to the work induced by the knowledge of the pathology of traditional systems. Again, the

IEP continues to contribute significantly to research on new farming systems by concurrently monitoring the marginal costs and returns 1/ of all separate and composite treatments. The results on experimental farms suggest that net income from a completely improved farming system can be at least 3 times the income from a traditional system. The marginal benefit from better fertilization is greater than that from a better variety or better management alone. And the synergistic effect is very large: the combination of any two or more improved inputs yields more income than the sum of the marginal incomes attributable to them.

217. The economics of new technologies and farming systems is, and must remain, the most important single preoccupation of ICRISAT economic research. For the ultimate payoff of the ICRISAT investment itself will be the delivery to millions of farmers of improved farming systems for each SAT region which will maximize incomes, subject to the irreducible constraints under which farmers operate at any given time.

218. The next logical step in research on the economics of farming systems is to select systems which are optimal in this sense. Since a large number of experimental and field observations pertaining to various treatments is already available, the time is ripe for the use of activity analysis (programming) models to derive optimal solutions which satisfy the additional, real constraints relevant to small farmers.

219. After new systems have spread in some regions, it will be necessary to develop methods of monitoring the employment and equity effects as well as the income effects of these systems at regional levels.

Risk

220. IEP research on risk and uncertainty focuses on four basic tasks:

- the measurement of various types of instability which generate risk, and the decomposition of the variance of gross returns into yield, price and cropping pattern components;
- the measurement of the subjective risk aversion of different classes of farmers in various situations,
- the study of the actual behavior and experience of farmers in drought seasons; and
- the ranking of possible public policies to help farmers.

221. The decomposition of return variance confirmed the dominance of yield variance. Measured risk has been shown to grow with the value of input (investment).

1/ The terms "costs" and "returns" in this Chapter refer to financial costs and returns at the farm level.

222. An innovative experiment to measure subjective risk aversion revealed that when the size of the payoff or loss is substantial, small as well as large farmers have the same 'moderate to intermediate' risk aversion. Risk aversion seems to increase with the size of the payoff/loss. In further work on risk behavior, it will be necessary to distinguish between attitudes to different types of risk. And the attitude towards alternative loss options may not be the same as towards profit possibilities requiring new investment.

223. A study of the actual experience of drought episodes with the available empirical material has shown that farmers, particularly small farmers, suffer serious consumption and asset losses; and income from government relief works provides the largest share of sustenance in drought periods.

224. We attach special importance to more research on the actual experience of drought and the economics of more efficient relief systems including insurance and consumption lending by public agencies.

Water Management

225. Under the IEP many useful studies have examined the economics of alternative water regimes. One of the key economic problems of small-scale watershed management is to determine the optimum production between field retention and the runoff of available rainwater in different kinds of soils, with different slopes, land preparation practices, and techniques of recycling the runoff. A preliminary model has been designed to estimate this proportion. The model needs to be developed further and estimated for a variety of situations. A runoff equation has been estimated but many additional equations will have to be estimated to get all the needed parameters. And the measurable costs and returns of the operations involved in watershed management will have to be computed. We support the continuation of modeling work on small-scale watershed management in India. In Africa the units of modelling may have to be different and much larger than in India.

226. A study of the density of traditional tanks in different regions of India has identified some of the major physical variables which explain this density. But more work is needed to explain why the estimated benefit-cost ratio for tank irrigation is low and yet tank irrigation persists on a large scale. Perhaps tank irrigation should be studied as a part of the total traditional farming system to reach a true judgment on its benefit. In any case, tank irrigation is so widespread and important in India that its technology and economics should be the subject of continuous study by ICRISAT and other institutions.

227. There is some interest in ICRISAT in exploring the possibility of group action for better utilization of watersheds. Pilot action experiments under village conditions would be necessary before collective watershed management is recommended for wide adoption. They can be conducted only with the cooperation of local government agencies and farmer leaders. It is yet to be shown that the net economic benefit of collective management will be much larger than the sum of the net benefits from better management on individual

farms. And even if this is demonstrated, the psycho-political feasibility of group action will have to be proved - particularly in India where the old village community structure has broken down, and modern political party and class conflicts have been added to traditional caste conflicts in rural areas.

228. The economics of well irrigation is an additional area in which more research needs to be organized. Like tank irrigation, well irrigation is widespread in SAT India - though a large proportion of wells yield low and erratic water supplies. The economics of well renovation need to be examined. Variations in well-water readings have to be recorded and analyzed. Some work has begun on the economics of interaction between water levels in tanks and dugwells in Andhra. This has to be developed further in Andhra and other areas. In the State of Maharashtra local studies of this interaction (called percolation) are under way because the Maharashtra Government has invested large sums on the improvement of percolation tanks. Some collaborative work in that State would be especially useful.

Mechanization

229. The IEP produced an extremely useful survey of South Asian literature on the effects of using tractors, which has received attention in India for its demonstration that tractors in themselves have no significant effect on yield and cropping intensity. Where yield and/or intensity are higher the main reason is fertilizer use and/or the availability of irrigation rather than tractors. It has also been shown that labor displacement due to tractors is moderate because in India they are mostly used only for tillage in high-wage areas. Much greater displacement is associated with the mechanization of harvest and post-harvest operations.

230. It is doubtful whether ICRISAT should pursue much more the question of the macro effects of farm mechanization in India. But it is essential that it should monitor the microeconomics of the new hand implements and bullock-drawn equipment designed by ICRISAT and other agricultural engineering institutions. Agricultural machine designers are not always sensitive to the requirements of small farmers, their severe resource constraints, and the prevalence of massive unemployment and low wages. In this context, we note that ICRISAT economists are concurrently monitoring the costs and benefits of newly designed equipment. It is to be hoped that before any new equipment is recommended, it will have been evaluated as economically satisfactory for SAT small farmers. Concurrent economic evaluation of equipment should be a continuing activity of the IEP.

Labor Markets

231. The time allocation data thrown up by the VSP has provided a good base for empirical analysis of labor supply, labor absorption, wages, unemployment and probabilities of employment in different seasons. Data for one village have already been analyzed. It is necessary now to estimate labor market models including supply, absorption and wage determination equations.

232. It is not clear that labor market research needs to be given much priority in terms of the ICRISAT mandate. For in India the labor surplus problem is universal and not peculiar to SAT crops and regions. And macro data are being gathered and analyzed by the National Statistical Service (NSS) and other agencies on a national scale. Nevertheless we have included it in the list of priority research areas in the hope that ICRISAT economists may do some innovative modelling of the complex labor market relationships with the very detailed seasonal time-use data they have collected. However, after some pilot modelling ICRISAT should leave general labor market research to other institutions, and use its own resources mainly to study the employment consequences of new SAT technologies.

SAT Crop Trends

233. Although the monitoring of international, national and regional trends in the acreages, yields, output levels, prices and movements of SAT crops is the main responsibility of FAO, the International Food Policy Research Institute (IFPRI) and other international agencies, ICRISAT needs to organize a regular flow of data from these agencies and its retabulation for its own purposes.

Marketing

234. An interesting study under the IEP presents an equation in which the prices of different varieties of grains are shown to be related to their physical characteristics such as color, moldiness and weight. The study is preliminary but promising because it concretises and decomposes consumer quality preferences and relates them to product price differences. Such studies should provide useful feedback to breeders. But a note of caution is necessary here. Often high price varieties are mainly consumed by high income groups, and low price varieties by low income groups. Therefore, breeding for high value characteristics should not lead to the neglect of the staples of the poor. Subject to this caution, price-variety-preference studies should continue as a useful adjunct to plant breeding. The IEP is already aware of this issue.

235. A related area in marketing which urgently needs exploration is the differential access of small and large farmers to marketing facilities. The usual macro marketing studies ignore the phenomenon of unequal access and the consequence that the small farmer often gets a lower price than the large farmer for the same product in the same area. Since the incentives of different classes of farmers are related not to the average market price but to the actual differential prices they get these differences and their causes deserve serious attention in the marketing economics program.

Priorities

236. On the basis of the foregoing review we recommend that research in the following fields be continued on a priority basis because (a) the results of this research are most germane to the fulfilment of ICRISAT commitments, and (b) they involve new types of conceptualization, modeling, estimation or experimentation:

1. Allocation of research resources

2. Macro SAT crop trends

3. The relationship between varieties and

   Consumer preferences
   Market prices
   Nutritional needs of the population and
     particularly the poor and vulnerable population

4. Risk and uncertainty

   The measurement of various types of instability
   The measurement of subjective risk behavior
   Private strategies to cope with risk
   Public policies to cope with risk

5. The Micro and macro benefits and costs of alternative
   individual technologies and composite farming systems

6. The economics of water management in SAT regions

   Optimum retention-run-off-recycling regimes
   Tank irrigation
   Percolation

7. Monitoring and modelling of labor supply, labor absorption
   and earnings trends in SAT regions at micro levels

Village-Level Studies

237. As noted above the VLS have yielded a wealth of valuable benchmark physical, economic and sociological data. More and more demands for data are being made on this program by professionals of many disciplines.

238. We support the continuation of the program with some modifications. Although a rigorous effort has been made to select the 6 VLS villages so that they are characteristic of many SAT situations in India they cannot possibly represent many other situations which must exist in the 188 districts that comprise the SAT region in India. Therefore extension of the work to other regions is necessary and we endorse the decision to cover a few more villages in the main groundnut and pearl millet/chickpea areas in India.

239. As the schedules, the concepts, the instructions for investigators, and the data recording, processing and retrieval systems have been established by ICRISAT, it would be desirable, less expensive and more productive to transfer its data collection technology to the national data collection institutions (Universities, Agro-economic Research Centers, etc.) and to request them to collect similar data in a large number of villages

in all parts of SAT. Training workshops, data supply and quality control contracts, and some small initial subsidies may be necessary. It will also be necessary to persuade the collaborating units to accept the key principle of having well-trained resident investigators in the villages. We therefore recommend that this policy be pursued. As regards the existing villages in the VLS it may be desirable not to drop any of them until the necessary 10-year time series are completed. But the schedules may be reviewed to cut down the information collected, and the personnel located in these villages may be gradually rotated.

240. Like the Program Committee of 1976 we also recommend that methods be found to put the VLS data in more accessible form so that it can be readily used by others interested in this type of information. In particular, copying, tape-copying and microfilm copy facilities should be available to economic researchers in Indian institutions.

Marketing

241. It will be noted that some lines of current research in the field of marketing economics have been excluded from the list of priority subjects of continuing study given in paragraph 236 above. The topics excluded are:

- The estimation of supply and demand elasticities for SAT crops;
- market flows and market integration;
- regional specialization and equilibrium; and
- estimation of marketed surplus.

242. The criteria for these exclusions are similar to those used in selecting priority topics. Either the work done under the IEP on these topics involves no methodological innovations and/or Indian economists have done considerable work of high quality on the same topics. It would therefore be more efficient for ICRISAT to subcontract to these economists similar work on SAT crops rather than do it with its own core resources.

Supply Functions

243. It is well known that work on the estimation of supply functions for agricultural commodities for developing countries was pioneered by Indian agricultural economists in the 1960s and has been subsequently replicated. Since the main requirement is that more work of the same kind be done for SAT crops in different regions, it can easily be met by subcontracting it to Indian institutions. The data base is secondary and is commonly accessible. The proposed new methodology of generalized least squares estimation of combined time series and cross section data is also familiar to Indian econometricians. If this procedure for estimating supply functions is preferred at

ICRISAT, a few pilot equations can be estimated in the IEP and the replication of such work contracted out.

Demand Functions

244. In the field of demand function estimation, again, a large volume of econometric work with numerous rounds of NSS data has already been completed and published by researchers at the Indian Statistical Institute, the Planning Commission and the Sardar Patel Institute. Almost all alternative functional forms have been tried. And even the complete Linear Expenditure System has been estimated with many rounds of data at many levels of disaggregation. Therefore there is no reason why demand function work on SAT crops cannot be farmed out.

Market Integration

245. As regards market flows and market integration, the empirical propositions established by ICRISAT work so far are interesting. But they have been well-known to Indian economists and policy makers for a long time. The policy implications of these propositions have also been known: market regulation should be accelerated; market density should be increased; transport and communications should be improved; and food zoning is bad. It would not be very rewarding to prove these propositions repeatedly. In any case many agricultural economists are continuing to work on them in different institutions. It would be sufficient to stimulate their work with special reference to SAT crops.

The Productivity of Marketing

246. The point that in addition to technical inputs (seed, irrigation and fertilizer) marketing factors such as market density, road mileage and telephone density should be included in the production function has been effectively made by IEP Research. The replication of such more inclusive functions can now be left to local researchers.

Marketed Surplus

247. Research on marketed surplus models and functions was also initiated and later sustained by Indian economists. In fact the ICRISAT review of the marketed surplus literature has missed many important contributions. A large number of cross-section, and a few time-series marketed surplus functions, comprising all relevant explanatory variables, have already been estimated. Since no new specifications have been proposed under the IEP, it would be sufficient to get more marketed surplus functions for SAT crops estimated by Indian economists.

Regional Specialization

248. Modeling and empirical work in the field of regional specialization and equilibrium is very attractive to professional economists. A model estimated with Indian data was published some years ago. But there is strong

Indian evidence to show that in a labor surplus country policies to change the geographical distribution of crop production cannot be implemented, even if the existing distribution has been shown to be grossly inefficient. Technological changes rapidly change the optimum distribution itself. Millions of people deriving subsistence income in inefficient areas simply cannot be displaced. The employment situation does not allow their reabsorption in other areas or activities. Therefore work on the optimum spatial distribution of population is academically fascinating but it can have no policy payoff and need not be given priority in applied economic research. But, of course, the descriptive monitoring of production shifts due to changes in demand, technology, and policy is indispensable and should be included in research on SAT Crop Trends.

Research Cooperation

249. These judgments on the ranking of research on some topics are unavoidable if the philosophy of the ICRISAT mandate "to assist national and regional programs" is given due weight. This philosophy implies that ICRISAT only pioneers policy-relevant and methodologically innovative research. It is expected to have a comparative advantage in such research because of its high-grade personnel, resources and facilities. But all replicative work on established themes and with known methodologies should be done by national researchers and institutions. Replicative work even with new methods and concepts established by ICRISAT itself should also be similarly delegated. This division of labor alone can bring about a constant strengthening of the national research system and keep ICRISAT resources deployed only for original research.

250. In the administration's overview of IEP it has been stated that the following collaborative studies are in process:

diet-nutrition-time allocation;

village studies;

market surplus;

demand functions;

consumer preferences;

review of West African marketing research;

review of agriculture economic research in West Africa; and

fertilizer demand.

251. There has also been some seminar, training and consultancy collaboration with three institutions. But it seems that only ! a few of these cases has independent work has been assigned to the collaborating consultant (the two West African reviews and fertilizer demand). In the case of diet-

time allocation study and the Nigerian consumer preference study, joint data collection and publication are contemplated. In all other cases the collaboration is almost nominal: it amounts simply to the procurement of data from the collaborating institutions, with all analytical work and its credit reserved for ICRISAT scholars. This is hardly the kind of collaboration calculated to strengthen national research capabilities. And it cannot be justified in a country where a large number of individuals and institutions have done and can do high-grade work. It can only be justified in situations where a national research base is extremely weak or non-existent.

252. The record does not suggest that before taking up a new economic research project a serious enquiry is made about ICRISAT's comparative advantage in undertaking it, and about the national research record and potential in the field. We suggest that in selecting economic research projects in the future, these questions should be regularly asked and the division of work between ICRISAT's own staff and national researchers be determined on the basis of the criteria listed above, namely, policy relevance for SAT, innovation/replication, and the strengthening of national research capability.

253. The mission of international institutions is not only to produce knowledge but to create in the developing nations, in the shortest possible time, the capacity to produce for themselves most of the knowledge they need.

Africa

254. ICRISAT's economic research priorities in Africa can only be determined concretely after surveys of the available literature and ongoing work in existing institutions are completed. The IEP has recently commissioned two such surveys of work on production economics and marketing economics in West Africa. Only preliminary reports of the latter are available. But it is clear that a large mass of research output generated under the auspices of numerous national and international institutions already exists. In addition to French organizations and the IDRC, many U.S. agencies are sponsoring considerable research in agricultural economics in West Africa. Purdue University assisted by USAID is soon to place a sociologist, a production economist and an agronomist in Upper Volta. The IEP for research in West Africa has to be planned against this background.

255. Empirical research in rural Africa is beset with special difficulties which will have to be overcome, and for each study and methodology the clearance of the authorities will be essential.

256. All the themes on which work is being done in India under the IEP (para. 208) are equally pertinent to the African countries. And, in fact, work on subjects not included in the current IEP (land tenure, input supply systems, extension, price policy) will also be necessary in the African context. But for the immediate future we recommend that priority be given in Africa to the following topics in the marketing field:

marketing systems;

price policy

inter-regional trade;

estimation of supply and demand elasticities; and

marketed surplus.

In the field of production economics we recommend the early establishment of a Rural Community Studies Program in Africa and work on the concurrent economic evaluation of new technologies and farming systems including new methods of water management and the use of machinery.

257. As in India, ICRISAT itself should not undertake every piece of priority research. A detailed survey of the existing literature and ongoing work on each topic should first be made. On the basis of such surveys ICRISAT should determine the work which its own staff must do and work which may be sponsored by ICRISAT but done by other institutions or researchers.

258. In respect of programming for small farmers and programming for regions much professional work is already in progress in Africa. (ICRISAT has still to add programming to its own village studies and technology evaluation work in India.) In Africa it can invite African professionals to estimate programming models with the new, detailed data collected under its sponsorship.

259. Work on marketing deserves heavier emphasis in Africa because there market size there limits production; cereal-cash crop price ratios are perhaps unsatisfactory and need to be reviewed; the production effects of dual marketing (parastatal and private) need to be quantified; market surplus and demand estimates and functions are badly needed; and regional flows have to be understood. Again in these areas ICRISAT should concentrate on rigorous modelling and estimation work which is not being done elsewhere.

260. Since in many places a data base is missing, ICRISAT will have to persuade other agencies to make the heavy investments needed to obtain the basic statistics.

Social Anthropology

261. The small-scale social anthropology work at ICRISAT is still at a planning stage. A general survey of the relation between demographic trends and agricultural development has been completed and some involvement in pilot experiments in group action by farmers (to manage watersheds, own and use indivisible equipment, utilize traditional supplemental irrigation etc.) is contemplated.

262. We suggest that since resources are limited the social anthropology work of ICRISAT should be focussed on Africa rather than on India. India has strong demographic and sociological research centers particularly in SAT regions. They can be requested to do any work which ICRISAT regards as essential. The large literature on the diffusion of technology and "peasant rationality" in India has demonstrated that the rate of diffusion of new profitable technology-packages in India has been high and sometimes comparable to that in the West and Japan. The social structure adjusts rapidly to the demands of highly remunerative techno-economic change. In many parts of SAT Africa, on the other hand, the relative lack of "exposure" and infrastructure, traditional community relationships, complex land tenure systems, etc. require deep study in the context of the coming of new technologies.

263. We therefore recommend that when the social anthropology program is included in the core budget it should concentrate on the African SAT.

Resources

264. We noted that the budget allocation for Economics is to rise from about $182,000 in 1978 to $469,000 in 1981, and staff strength from 30 to 62. The number of principal professionals is to increase from 2 to 6 to include a core staff anthropologist and two production economists and one marketing economist for Africa.

265. We consider the proposed overall increases as adequate. But reallocation of the budgeted financial and personnel resources may be necessary to devote more man-years to work on SAT regions outside India, particularly in the field of marketing research, and secondly to shift more and more adaptive and replicative work to Indian national institutions and individuals. The latter policy will enable IEP to obtain a much larger volume of research output relating to many more SAT regions with the given core resources.

266. For work on regions outside India not only should more core resources be diverted but special efforts need to be made to secure additional special project resources for studies in collaboration with established and emerging national institutions and other international programs.

267. Specifically, we recommend that:

(1) A major part of the core staff time of the Marketing Economist (and support staff) should be devoted to work on Africa.

(2) Only one core production economist and one marketing economist should be placed in Africa. The production economist would probably need more support staff in view of the number of countries and distances involved. The question of placing a second core production economist in Africa should be reviewed in 1981.

(3) One of the two new production economist positions (on the core budget) should be converted into the position of an agronomist with specialization in systems analysis. He should work in close collaboration with farming systems staff.

(4) Almost the whole allocation for anthropology when it enters the core budget should be earmarked for work on Africa.

VIII. SUPPORTING PROGRAMS

QUARANTINE

268. Quarantine regulations for the shipment of plant materials are based upon the International Plant Protection Convention, and are modified according to the specific requirements of each of the countries concerned. The ultimate responsibility for plant quarantine clearance rests with the importing country. While it is evident that full respect for the regulations must be maintained, efforts should continue to minimize hindrances on the movement of plant materials.

269. The amount of plant material shipped is increasing continuously and sufficient guarantees must be provided to avoid on the one hand the spread of pests and diseases, while on the other allowing sufficiently speedy transfer for the benefit of improved breeding and production programmes.

270. ICRISAT has been in continuous contact with the Indian authorities in order to establish arrangements satisfactory to both parties. The following facts are of relevance for the current arrangement for plant material import and export.

- the memorandum of agreement with the Government of India authorizes ICRISAT unrestricted movement of seeds and genetic material to and from ICRISAT consistent with the appropriate plant quarantine regulations;

- it has always been fully appreciated that imports should be handled by the Quarantine authority of the Government of India;

- in the case of groundnuts, cuttings of wild species are also imported. This material is first grown in glasshouses at the University of Reading in the UK.

On the basis of the above the following arrangements have been agreed upon.

271. For import, mostly of seed, all material is received by the Central Plant Protection Training Institute at Hyderabad. The Institute was in 1973 declared as plant quarantine authority for ICRISAT's work. It was accordingly equipped with the facilities needed for inspection. After release the material is grown for one generation in a post-entry quarantine isolation area at ICRISAT, for further inspection.

272. For export of seeds the Government of India has agreed to establish an Export Certificate Laboratory at ICRISAT site, under the overall responsibility of the Indian plant quarantine authorities. ICRISAT provides the

building and support staff to carry out the various operations in preparing seed for export. This includes cleaning, screening for pest and disease infection and disinfection. The ultimate examination of the seed is done by the quarantine officer of the Government of India who issues the phytosanitary certificate. Through this procedure quarantine clearance has been reduced from five weeks to one.

273. We recognize and appreciate the importance of these arrangements and were favorably impressed by the positive attitude of the Government of India in finding the best possible solution to this matter. We note that the National Bureau of Plant Genetic Resources will assume responsibility for quarantine arrangements in the future and we trust that this will not adversely affect the above arrangements.

274. Seed material is sent to many countries and due to the different status of their plant quarantine regulations difficulties are sometimes encountered. We appreciate these problems and recommend that every effort be made to inform the authorities in the countries concerned about the precautions taken at ICRISAT to provide the most reliable guarantee of freedom from pests and diseases, while recognizing the fact that final responsibility for plant quarantine operations rests with the national authorities.

BIOCHEMISTRY

275. The Biochemistry Unit has recently had its functions altered from research, as originally planned, to service. This and other considerations resulted in raising the following questions in our minds:

- should the Unit remain a a service function or should it have a program of research in its own right?
- what should its role be in analyzing soils?
- what service should be provided for ICRISAT's cooperative programs particularly in Africa?
- how extensively should the laboratory monitor the cereal breeding material for all nutritional components including vitamins and minerals?

276. We note that, in spite of limited facilities and the initial lack of sufficiently trained personnel, the laboratory has made significant progress in its analytical capability, including its capacity for protein and lysine analyses in cereals, and in chemical analyses of soil samples. In view of the current consensus that caloric intake is probably the dominant nutritional limitation in most poor countries, and because att ntion is being given to basic biochemical studies in many nutritional labora.ories throughout the world, we believe the Unit can perform a more valuable role at ICRISAT as an analytical unit supporting the breeding and farming systems progra

than in conducting biochemical research. We therefore recommend that the Biochemistry Unit remain as a service unit rather than become a research group. It should be equipped to analyze breeding material for the major nutritional components as well as minerals to assure the breeders that adequate amounts of them are maintained in their material. When it is necessary to check materials for vitamin content, we suggest that it might be preferable to contract with capable local laboratories for their analyses. We believe more attention should be given to determining the mineral content of breeding material. The Unit should continue its work in developing and perfecting analytical techniques for these and the other factors already included in routine analyses.

277. The analysis of soils for chemical elements alone will not provide all the soil data needed, particularly in the farming systems program. We urge the laboratory to develop additional competence in analyzing soil physical characteristics.

278. We are concerned that little attention appears to be given to the needs for analytical service to the cooperative programs in Africa. This is less necessary in the cereal breeding work because African materials are included in the programs at ICRISAT Center, but there is a need to check on other African material grown under a wide range of conditions.

279. We note also that as cooperative programs are developed in Africa and the farming systems program expands in that region, ICRISAT will need to judge their effectiveness on criteria other than yield alone in order to understand and explain the results obtained. With the expected establishment of a network of benchmark stations it will be necessary to characterize soils in order to make valid comparisons of results from widely different localities. The physical characteristics and salinity levels of the soils will be of critical importance. We urge ICRISAT to plan to develop this analytical capacity for their African programs, perhaps in cooperation with a well established Center in Africa, such as IITA. This can be done with existing staff resources.

280. Finally we suggest that the name of the Unit be changed to identify more closely than at present its actual and intended function.

COMPUTING

281. ICRISAT has made increasing and effective use of its computing services which now serve scientific, management, and financial functions. In general, we consider that the approach to the use of computer services is efficient. With growing and complex requirements, particularly from the Economics and Biometrics Programs, it will soon be necessary for ICRISAT to have a new and better computer system because the overall demand for computer time will have increased to justify a new system. The present system has a limited memory and is incapable of estimating with speed large simultaneous

stochastic equation systems or activity analysis models with more than a few constraints. Temporarily other computers in Hyderabad can be used subject to available surplus capacity and the difficulties of changing programs across systems. Advance action will need to be taken to have a new system by 1981, but before decisions are taken a professional feasibility study should objectively evaluate ICRISAT's needs.

INFORMATION AND PUBLICATIONS

282. Efficient distribution of publications is the major vehicle through which the IARCs assist the scientific community to improve its knowledge on agricultural production. Consequently the information services are indispensable to the IARCs in carrying out their mandates. At the same time they provide the staff at the IARCs with the necessary communications support. A secondary, but nevertheless important role consists of informing donors about the achievements of the Centers.

283. At ICRISAT the information service, when fully staffed, will consist of an information officer, two principal editors and 18 professional national staff. The service is responsible for the editorial soundness of all publications of the Institute, which include the annual report, journal articles, research reports, information bulletins, proceedings of conferences and workshops, and the newsletters.

284. We were struck by the large number of informal publications which do not allow systematic classification and retrieval by libraries. However, these publications are very useful, often of high quality and serve a definite function in providing up to date information about ICRISAT's latest research findings. They are often a major information source for scientists in the SAT areas who have little access to expensive scientific journals.

285. We therefore recommend that these informal papers should be published more formally and produced in a continuing ICRISAT research publications series. It will often need little additional effort to bring these publications to an acceptable level for release in such a series. We see little need for the general distribution of very preliminary papers. The publication of such a continuing series should not preclude more definitive publication subsequently in recognized scientific journals.

286. We noted that the information service has been instructed to plan for the future publication of the annual report in two separate parts. The first would be a general information document featuring the Director's report and highlights of research accomplishments; the second volume would resemble the present annual report and should be the major report to the scientific community.

287. Experience elsewhere shows that such an arrangement may lead to a situation where every effort is made for early production of the research highlights report, but that the publication of the overall annual report undergoes substantial delays.

288. We recommend that only one annual report is produced each year. It should be considerably shorter than the current annual report and should be presented in a bold straight-forward way highlighting the main research findings with research details reduced to a minimum. Details are better published either in an ICRISAT research publications series or in regular scientific journals.

289. We are aware that users of ICRISAT information are a mixture of researchers and extension workers. However, we consider that the national researchers are the primary clientele and that this category has the responsibility of transforming the information in such a way that it meets the needs of the extension specialists. Specific recommendations for production improvement should be issued at the national level assisted, where needed, by the ICRISAT cooperative program

290. In order to improve further the quality of communication of the individual ICRISAT staff members we recommend that internal courses should be organized on the presentation of information in the written and spoken forms.

291. The publication of conference proceedings preserves the valuable information shared with the audience and extends it to interested individuals unable to attend. However, the value of such publications is decreased when long delays occur between the conference and publication date, and when irrelevant and outdated material is included in the document. We suggest the adoption of a policy which promotes rapid publication of the proceedings and permits exclusion or abridgement of non-significant information.

LIBRARY

292. Library services are an essential tool to conduct and apply research. ICRISAT is endeavoring to develop its library as a world center for literature on sorghum, pearl millet, pigeonpea, chickpea and groundnut. The current collection of the library contains more than 18,000 accessions, 800 microfilms and over 6000 bound volumes of periodicals. It is expanding continuously, and currently receives 598 periodicals.

293. The library has not yet reached its full operational phase and it is continuously improving its lending services. A special effort is made to compile and update certain bibliographies. These include a bibliography of the Indian literature between 1969 and 1973 on ICRISAT crops, except groundnuts, and a bibliography of theses on ICRISAT specialities submitted to Indian universities until 1975. The library also publishes its catalog of periodicals and a monthly awareness bulletin, which give a list of new accessions. The Indian literature on groundnut is currently being compiled.

294. Special mention should be made of the Sorghum and Millets Information Center (SMIC) which was developed under a grant from IDRC. SMIC's objectives include: collection of documents on sorghum and millets dating

from 1969 onwards; the setting up of an appropriate storage and retrieval system; updating of the existing bibliographies; provision of bibliographic search and photocopy services for developing countries; and the issue of a newsletter.

295. We note that the collection of documents in the English language has already led to appreciable results. However, the collection of documents in the French language, relating to activities in francophone West Africa should receive more attention. Consequently we recommend that ICRISAT develops further its contacts with the countries concerned, and in particular in France with the documentation centers at IRAT, IRHO, GERDAT and ORSTOM. GERDAT will be of particular importance due to its special service for the collection and distribution of documents. We suggest that ICRISAT contacts the library at ILCA which is making special efforts to collect scattered and rather inaccessible literature in Africa. Such contacts would probably offer the best opportunity to cover early literature.

296. The number of research workers in SAT countries is likely to expand partly as a result of ICRISAT's training activities and its cooperative programs. This will place a special strain on the library services and we trust that every effort will be made to keep this group of scientists informed and to answer speedily to their requests.

IX. TRAINING

297. Training at ICRISAT is recognized as fundamental to the mission of the center and is, consequently, integrated into all research and support programs at one or other of the different levels at which it is offered. Its organization is essentially towards the transfer of skills, techniques and experience, rather than the assimilation of knowledge for its own sake. Apart from the more obvious benefit to the participating countries in the preparation of technical cadres to strengthen national research and development services, the training program also lays a firm foundation for future national participation in cooperative programs by providing ready made liaison points for the further dissemination of ICRISAT's improved techniques.

298. Training will prove effective only when it is well adapted to the specific capabilities and interests of the trainees. The students are from very different backgrounds and vary greatly in levels of scientific education, amount of experience, language capabilities, motivation, living habits and age. Because of this a major effort is made to adapt each training course as much as possible to individual needs.

299. Training programs are conducted for international interns, research fellows, research scholars and in service trainees. The international interns are recent Ph.D. degree graduates from donor countries. They work with scientists from one to a maximum of two years on problems of direct interest to the on-going programs of ICRISAT.

300. Research fellows are M.Sc. or Ph.D. degree holders from client groups who work with scientists on problems specific to their countries. They are accepted for intervals of time varying from a few months to two years.

301. Research scholars are students enrolled in an advanced degree program who conduct their thesis research at ICRISAT on problems that are relevant to SAT countries and ICRISAT. They are scheduled for 18 to 24 months.

302. In-service trainees constitute the largest group in the total training program and are divided among three areas of interest: crop improvement, crop production and farming systems. Their programs lasts about six months, of which around 60% is practical work.

303. Apprentices are agricultural engineering students who come to ICRISAT, for a one or two month period for practical experience in land development, water management, and the operation, maintenance, and repair of farm machinery. This course was linked with the development activities of the ICRISAT farm, and will be phased out.

304. All applicants are evaluated for admission to various programs by an internal advisory committee on the bases of their sponsorship, interest, and aptitude for work in SAT agricultural programs. This is to ensure that the maximum benefit of the training will be for agricultural development in SAT regions.

305. All training courses are conducted in English. Non-English speaking candidates participate first in an intensive English language training course at Hyderabad. This arrangement has proven to be very successful and well appreciated.

306. Evaluation procedures for measuring training effectiveness have been worked out. They include a pre-course test, regular review of accomplishments, a pre-departure test, and follow-up contacts.

307. The organization of the course is the responsibility of the training officer and his staff. Virtually all scientists collaborate in one way or another in the program.

308. We are pleased to note that in spite of the lack of permanent facilities on the ICRISAT campus, and the inconvenience of housing and feeding students in separate places and transporting students between Hyderabad and the ICRISAT campus, the training program has shown remarkable growth since its initiation in 1974.

309. We observe, however, that the in-service trainee program in particular, is not well balanced between the numbers of African and non-African trainees. We recognize that the overwhelming need which countries in SAT Africa have for trained personnel justifies a preponderance of students from those regions. Nevertheless, we approve ICRISAT's in-service training goal of seeking approximately one third of the program's enrollment from non-African countries, so that trainees may learn from one another and extend ICRISAT's influence into all SAT regions of the world.

310. While reviewing ICRISAT's African program in francophone Africa some concern was expressed to us that French speaking trainees feel handicapped in receiving their instruction in English and were perhaps reluctant to participate because of this. When we visited some of the trainees from francophone Africa at ICRISAT, however, we found to the contrary that nearly all expressed not only satisfaction but also an appreciation of the opportunity to learn enough English to be able to communicate in this language. The policy of English language instruction therefore appears to be sound and justified.

Off-Campus Training

311. We agree that training in the basic disciplines needed to design and analyse experimental programs and in developing an understanding of the principles and concepts underlying successful farming system adoption are conducted best at the ICRISAT Campus where direct contact with the training staff and scientists can occur readily. However, before trainees in the farming systems program can become fully effective in SAT Africa additional training under local conditions will be required. We encourage ICRISAT to develop this aspect of the training program in conjunction with their expanded African research program.

Facilities for Training

312. While there appears to be adequate field facilities for the training program which is necessary to meet the training goals of emphasizing practical experience, we were disappointed to note that only two classrooms for formal instruction are available in the new buildings at ICRISAT. This deficiency will severely limit the ability to develop audio-tutorial instruction which we believe could be used with great advantage to the trainees as well as to the instruction staff. An audio-tutorial system will require additional space and we recommend that it be incorporated into the plans for improving the effectiveness of the training program while relieving the load on the research staff.

Collaboration between Institutes

313. Taking into consideration the facilities offered by other International Institutes in Africa (IITA, ILCA) where ICRISAT plays a major role in the SAT countries, we recommend that active collaboration be established, where appropriate, between these institutes to develop joint courses appropriate to African situations. We believe that instruction in farming systems would especially benefit from such a joint activity.

Advanced Degree Students

314. The training opportunities at ICRISAT for International Interns, Research Fellows, and Research Scholars who are interested in food and agricultural problems of the people in the SAT regions are excellent and unique in aspects requiring extensive field experimentation. While recognizing the demands such advanced students place on the resident scientific staff both in time and resources, we nevertheless believe there are compensating benefits over the long term. These programs should not only yield scientists who have first hand experience with problems associated with agricultural development in the SAT countries when they return to their home institutions, but should also provide a pool of interested and qualified scientists from which to recruit for staffing needs of ICRISAT's programs. Consequently, we encourage the active pursuit of these training programs.

X. COOPERATIVE PROGRAMS AND TECHNOLOGY TRANSFER

315. ICRISAT's research results cannot benefit the farmer until its improved technology is adapted and proven at the national level. To emphasize this need and accelerate the process the institute has set up a "Technology Transfer Committee" which will deal with training, seminars and workshops, the transfer of technology, and relationships with other institutes.

316. As part of its long-term goal for transferring technology to the farmer, ICRISAT must interact with national programs. The description of the programs in India and Africa that follow demonstrate how the center has undertaken this task in these very different agricultural and cultural environments. We have not commented on ICRISAT's future role in Latin America, partly because we were unable to visit the region and assess its problems ourselves, and partly because the possible activities there are not yet clearly defined. Many of our observations about the African program may be relevant to future Latin American activities, and we expect that the next Quinquennial Review of ICRISAT will be specifically asked to examine them in some detail.

INDIA

317. The basis of cooperation between India and ICRISAT is the 1972 agreement between the Ford Foundation (for the CGIAR) and the ICAR. It provides for linkages between ICRISAT and the 5 All-India Programs for sorghum, millets, pulses, oilseeds (groundnuts) and dryland improvement (farming systems), as well as agricultural universities. Separate agreements have been negotiated with 4 agricultural universities (Andhra Pradesh, Haryana, Punjab and Tamil Nadu). The purpose of the agreement with Andhra Pradesh Agricultural University is mainly to enable Indian M.Sc. and Ph.D. candidates to get guidance and field experience at ICRISAT. The agreements with the other Universities provide additional environments for ICRISAT's research.

318. The Indian coordinated trial programs are strong in comparison with those in other developing countries. Large numbers of scientists are engaged in these programs and considerable resources have been allocated for them subject to the overall constraints of a poor country. Some of the varieties released to farmers by national systems are performing well.

319. It is recognized that much of the original ICRISAT germplasm stems from Indian collections. The Central and State Governments have facilitated the establishment and growth of the ICRISAT Center near Hyderabad in many ways, and a large number of scientists of Indian nationality are contributing to ICRISAT research as staff members.

320. There is general appreciation among Indian scientists of the fact that the growing ICRISAT collections of world materials will eventually widen their range of choice. Also, ICRISAT, with its more concentrated resources, will make basic methodological advances in many areas such as pest management, microbiology and intercropping. ICRISAT also contributes to the national system through reciprocal participation in workshops, conferences and symposia. So far the training of Indian personnel at ICRISAT has been mainly in the form of short courses in agricultural engineering and farming systems. For normal training in plant breeding Indian facilities are adequate. But as and when new advanced techniques are developed by ICRISAT in any field it will be most valuable for Indian graduate students to be given intensive training in their use. Courses should be designed for this purpose.

321. A few important issues concerning cooperation between ICRISAT and India need clarification in order to avoid misunderstanding. First, early-stage multi-location testing is necessary for ICRISAT. In the past it has been done by national stations but it has strained their resources. Therefore ICRISAT has recently been given facilities to do station-testing under its own supervision at 5 locations in India. When more of such testing is required in the future either facilities at more station locations will have to be requested or coordinated programs will need to be given supplementary resources by ICRISAT to help them organize additional testing without diverting their own resources.

322. Secondly, although the Director states in his overview paper that the lack of an extension arm is a constraint, we endorse for India the continuation of the current practices namely:

- that large scale late-stage testing or testing on farmers' fields should be done by the national networks of agricultural research and demonstrations and not directly by ICRISAT;

- that ICRISAT should not directly release varieties to farmers;

- that ICRISAT should not have its own extension service.

323. Also, as required by the agreement with the Government of India, all cooperative arrangements within India should be made through the Indian Council of Agricultural Research.

324. In the case of farming systems research a few research trials on farmers' fields have been directly organized by ICRISAT, in the villages of the VLS, in consultation with national scientists. A few more of these may be necessary. But as soon as viable packages are evolved their adaptation and extension must be the responsibility of the national network.

325. Thirdly, there needs to be more reciprocal generosity between ICRISAT scientists and national scientists in acknowledging all the major and minor contributions made by individuals and groups in each network to the common goal of scientific advance.

326. Finally we would urge that extreme care be taken in making statements about national scientists and networks, in order to maintain good relations with the host country.

AFRICA

327. At its inception it was recognized that the siting of ICRISAT in India would call for the development of a strong core-funded regional program in Africa. However, it was decided that the available CGIAR funding should be used for the centers' work at Hyderabad and that special funding should be sought to start programs in Africa. As the table in para. 335 indicates, several sources of funding have been obtained; these are applied to national, regional and international functions of the center's work in Africa. A part of the program is truly national in that it is clearly designed as technical assistance to strengthen national research. Of course the regional and international work also strengthens national research, particularly in training and in provision of superior breeding materials. No clear distinction between these functional roles is possible nor would it be useful.

328. Nevertheless, it is necessary to keep them in mind when discussing the future involvement of ICRISAT in Africa. We regard a cooperative program as one that is totally integrated within the national system and dependent mainly on it for logistic support. Its goals would be those of the national program although the work will also have regional implications. We regard a regional program as one that is largely independent of national programs, in the sense that its goals are based on a synthesis of regional needs. It would do its research on sites where regional needs could best be served, which might involve a number of compromises in terms of accessibility, availability of land and support staff, and political considerations.

329. In terms of sources of funds we agree with the generally accepted CGIAR philosophy that support to national research by IARCs should principally be funded through special project funding of limited duration and that regional projects should be supported by core funds. However, we are concerned that there should be a proper balance between special project activities and core activities and we emphasize that the proposed regional project, as part of ICRISAT's core program, will impose considerable demands on the time of ICRISAT's management and program leaders. A large number of cooperative national programs would add to the burden of what is still a young institute. Since ICRISAT has not yet developed a long term forward plan for its African program we are not clear on how those two functions will develop. Consequently in our discussions on the future development we have concentrated on formulating a model that would be primarily concerned in serving regional needs, once again recognizing that it will help national programs albeit in a more indirect manner.

Cooperative Programs

330. The cooperative programs in Africa started in 1975 but some posts have been filled only recently. It is thus too soon to expect significant advances in the research.

331. ICRISAT says that its main objectives in its African cooperative programs are to strengthen, expand and extend the existing research on sorghum, millets and related cropping systems; to develop varieties, synthetics, and hybrids of sorghum and millet able to produce stable and consistently high yields of grain and having good eating, nutritional and keeping qualities; to develop practical methods for the control of pests, diseases, and Striga, mainly through resistance breeding; to develop improved farming systems; to strengthen the existing African groundnut program in due course; and to train workers in research and production technology.

332. The aim is to complement the national programs and to introduce materials and methodology from ICRISAT for study under African conditions.

333. Geographically, the program concentrates on the Sahelian-Sudanian zone of Africa which constitutes the largest regional (as opposed to national) geographical area in the SAT and the second largest total SAT population after India. The region has recently suffered from severe droughts and has attracted widespread concern. The variation in the research capabilities of different countries tends to make cooperative programs variable in nature and magnitude. The main cooperative program is the ICRISAT/UNDP "West African Project" with headquarters in Dakar, Senegal and cooperative centers in Bambey (Senegal), Kamboinse (Upper Volta), Maradi (Niger), Samaru (Nigeria) and Wad Medani (Sudan). The only other ICRISAT programs in Africa are at Ilonga (Tanzania) which is part of a research project in which CIMMYT and IITA also participate, and a USAID cooperative program in Mali.

334. The program emphasizes work on millet and sorghum (cf. paras. 69-73, 83) which are the two main crops in ICRISAT's mandate and the staple food crops of the West African SAT. No work is done on pigeonpea and chickpea in this region as they are of negligible importance. The groundnut crop is important in many African countries but a cooperative program involving it has not yet been initiated. In francophone West Africa the experimental work on groundnuts, sesame and soyabean is being conducted under the national programs in cooperation with IRHO which is reported to be satisfactory. ICRISAT may play a catalytic role of providing some of the relevant genetic material.

335. ICRISAT's current activities in Africa are summarized in the table below.

SUMMARY OF ICRISAT ACTIVITIES IN AFRICA, FALL 1978

Country (Location)	Crop(s)	ICRISAT Staff	Cooperating Institutions	Sources of (1) funds	Comment
Regional (Dakar)	-	Project Leader	IRAT	IRAT	Coordinates program throughout the region and provides liaison with other institutions
Senegal (Bambey)	Millet	Breeder Entomologist	CNRA Bambey	UNDP	
Mali (Sotuba)	Sorghum Millet	Agronomist Selector	Sotuba Research Station	USAID	USAID funding secured only to June 1979
Upper Volta (Kamboinse)	Sorghum Millet Cowpea (IITA)	S.Breeder Pathologist Agronomist M.Breeder Asst.Agronomist C.Breeder (IITA)	Kamboinse Station, IITA	UNDP IDRC IITA ICRISAT	Future funding of cowpea (IITA) program not yet determined
Niger (Maradi)	Millet	Breeder	INRAN	UNDP	Scientific backup from Kamboinse and Samaru
Nigeria (Samaru)	Millet	Breeder Pathologist	ABU, Samaru, IARI	UNDP Nigerian Govt.	Pathologist also assists national program in Cameroons
Sudan (Wad Medani)	Sorghum Millet	M.Breeder S.Breeder	SARC	UNDP Sudan Govt.	
Tanzania (Ilonga)	Sorghum Millet	S.Breeder M.Breeder (vacant)	IITA Ilonga Research Station	UNDP Sudan Govt.	

Source: ICRISAT Quinquennial Review documentation, Vol.II-b

(1) Excluding cost of overall administration and support provided by ICRISAT headquarters staff.

336. As can be seen from the table ICRISAT's Cooperative Program in Africa is wholly supported by a series of special projects based on agreements involving ICRISAT, the countries concerned, and various donors. This leaves the programs insecure and vulnerable, and can lead to diverse conditions of service for staff funded from different sources.

337. Other constraints on the cooperative program include the difficulties in recruiting scientists with the right combination of professional and personal qualities, delays in the delivery of equipment and supplies, and difficulties of travel and communication to and within the region.

338. Despite the limited experience of three years and the fact that most programs are at an early stage, ICRISAT's activities in African SAT countries are welcomed, especially in countries where the objectives coincide with those of the national program.

Future Directions

339. In projecting the activities of the program in the next few years, we agree with ICRISAT's statement that further expansion of the total outreach system is inevitable if ICRISAT is to fulfill the responsibility with which it has been charged. The regional and cooperative programs should aim for concentration of efforts, rather than spreading them too thinly. ICRISAT should only take on programs for which it is best equipped. It also implies careful selection of programs according to well defined priorities. Care should be taken to ensure optimum resource allocation.

340. We support the emphasis placed on the sorghum and millet crop improvement program. There is need, however, for research into other allied disciplines like soil fertility improvement, soil and water conservation and management, crop protection, socio-economic studies and farming systems research that would also be an extension of ICRISAT's core program.

341. In view of the importance of groundnuts in SAT and the fact that several countries have expressed interest in a cooperative program on groundnut improvement, we support ICRISAT's intention to strengthen other African groundnut research but suggest that the program might be better coordinated from eastern or central Africa (cf. para. 137).

342. Cowpeas are by far the most important pulse crop in the West African SAT, and integral to most intercropping systems with millet and sorghum, as well as to the maintenance of even modest levels of soil nitrogen. They are so central to the farming systems of SAT Africa that it is essential that core funding be provided for the long term breeding of cowpeas adapted to SAT conditions.

343. At present such work is supported on a short term basis by IITA on special project funds, but if IITA is unable to provide core funding for this work, we recommend that ICRISAT be encouraged to do so. IITA would, of course, retain responsibility for the genetic resources of cowpeas, and for all research connected with its use in the humid and subhumid regions.

344. Concerning the future of the African program of ICRISAT the central questions before us were:

- to what extent is core funding justified and desirable for part of the African program?
- what would be the best format for such core-funded work?
- if some core funding is approved, what arrangements should be made for the existing special projects?
- would core funding for some African activities reduce the need for additional core funds at ICRISAT India?

345. It is clear from the 1979-80 budget proposals that the Director and Governing Board of ICRISAT believe that extensive core funding is justified, and that the most satisfactory format for its use would be the establishment of two multi-disciplinary subcenters, one for sorghum and the other for millet, groundnuts and farming systems research.

346. We agree that a substantial amount of core funding for the African program is justified. This is consistent with the view that the criteria for core funding should be:

- that the research should be clearly within the mandate of the institute;
- that it requires long-term support;
- that it should be at least regional in relevance.

347. The first condition is clearly met, as the core funded work in Africa would concentrate on the improvement of sorghum, millet and groundnuts, together with associated farming systems and socio-economic research, all of which urgently needs boosting in Africa. Only cowpea breeding might pose some problems in this respect.

348. As for the second criterion, some of the African work is clearly in need of long term support if it is to be effective. For example, given the short term and uncertain duration of special project funding, most of the current plant improvement work - of which there is a great deal scattered through many countries - stands little chance of producing really worthwhile material without sustained effort and continuity of employment of the program leaders. Repeatedly we were given evidence by the breeders in Upper Volta, Niger, Mali and Nigeria that much, and in some cases virtually all, of the breeding material from Hyderabad is poorly adapted to African conditions, being subject to pests, diseases (such as downy mildew) and parasitic weeds (such as Striga) which exhibit differences in form or incidence from those at the Indian center. There is therefore a need for an African breeding program for millet and sorghum now and in the future.

349. In farming systems, also, there is a need for research under African conditions. These are quite different from Indian conditions in many important ways, such as rainfall patterns, the use of cowpeas, the role of livestock, land tenure, socio-economic conditions, and cultural traditions.

350. As for the third criterion, the work proposed would be mostly regional in application. Although differences in climatic, soil and socio-economic conditions occur throughout the Sahel-Sudanese region, it is nevertheless relatively homogenous in many respects from Senegal in the West to Sudan in the East, and the work would have some relevance to several countries in East and Central Africa. The same crops comprise the significant staple foods throughout the region, and are grown within similar farming systems.

351. The regional population is not large (about 75-80 millions) in relation to the total SAT population but most of the countries are extremely poor in natural resources and support only minimal research systems. Given the poverty of the resources, and the difficult agricultural environment they present, there is a clear need for concerted longer term assistance to strengthen agricultural research in the region.

352. The need for a strong ICRISAT program throughout the area would, we believe, be in no way reduced should ISNAR 1/ be established. That organization could well complement ICRISAT's role with advice and help to the various nations on the building up of their national programs, but ICRISAT's specific expertise with their farming systems and staple food crops will continue to be needed throughout the region.

Structure of the African Program

353. We considered several possible formats for the African program in the semi-arid tropics:

(i) An independent institute with a mandate similar to that of ICRISAT but concentrating on the problems of the African SAT;

(ii) One or several subcenters of ICRISAT, as proposed in the 1979-80 budget;

(iii) A more mobile and less concentrated system of core-funded appointments of senior staff to provide long term continuity for key elements of the program, but minimizing building and capital investment in particular subcenters in order to be more responsive to changing needs and political situations.

353. In considering whether or not it would be better to establish an entirely independent institute in Africa, we noted:

1/ International Service for National Agricultural Research. Proposals for the establishment of this new institution are currently before the CGIAR.

- the different rainfall patterns in Africa compared with India, particularly in their onset, intensity, distribution and length of season;

- the greater predominance of sandy soils with very low levels of plant nutrients and poor structure;

- the different complement of crops, particularly in the ubiquity of cowpeas and relative absence of pigeonpeas and chickpeas;

- the different farming systems, land tenure and socioeconomic conditions;

- the different complexes of pests, diseases and weeds;

- the very different performance of breeding material of the cereals in Africa compared with India; and

- the expressed wish for training programs based in Africa.

355. Nevertheless, we believe that in the long term there is a strong case for only one international center for the SAT, namely that at Hyderabad, on the grounds that one center could most economically and effectively provide:

- a comprehensive center for the collection, multiplication and storage of all genetic resources for the mandate crops;

- a center able to specialize in the hybridization of these genetic resources and on the distribution of plant breeding materials throughout the SAT;

- advanced training on the mandate crops and farming systems;

- initiation and coordination of the overall network of activities of concern to all cooperating countries throughout the SAT, for their mutual discussion and support;

- a centralized comprehensive center for information and documentation, statistical and computer analysis, etc.;

- basic research required to support the attack on field problems; and

- central administration and negotiation with donors.

For all these activities there are real economies of scale which argue in favor of only one center.

356. Although aware of several attractive features of ICRISAT's proposal for two subcenters in Africa, we have serious reservations as to its long term viability. Given the range of problems to be solved in SAT Africa, no one (or two) subcenters could adequately serve them all. Moreover, as knowledge of the African SAT and its agriculture develops, as national research activities develop, or as political situations change, it may be necessary to shift such subcenters to meet previously unrecognized needs. Subcenters also tend to develop a psychology of "subness"

357. We would therefore prefer to see a network of teams which might range from one to several senior scientists on core positions rather than the concentration of these in one or two subcenters. A possible structure of the kind we have in mind would be a core-funded project leader (and some key senior and support staff) with coordinating responsibilities for all the African work in each of the major areas of ICRISAT's mandate, such as millet improvement, sorghum improvement, plant protection, groundnut, cowpeas (if a core position for the African SAT is not provided by IITA), farming systems and socio-economic research.

358. The millet improvement and farming systems units might need to be based at a common experimental station under ICRISAT control, and this could provide the base and support for ICRISAT African operations, but we believe there would be real advantages in at least several of the other team leaders being dispersed around the cooperating national programs, and in their retaining some mobility of location.

359. Almost certainly the sorghum and millet leaders would need to be based in different environments, and the plant protection leader may be best located in yet another environment. The best location for the socio-economist might be where data accumulation and capacity for its analysis are well developed. Indeed each team might best be based in locations where there are strong national cooperative or international programs. Training could be at the main base, or in association with the relevant program leader.

360. In this way a strong, mobile network of leaders in various fields, each with the guarantee of continuity for his work plus some support staff, would be spread throughout the region. The model offers a better guarantee of interaction with, and support for, all the national systems in the region, thereby laying "foundation stones for the future." We commend this concept to the Governing Board of ICRISAT for their consideration in place of the proposed subcenters in the belief that our proposal provides the needed increase and continuity in the African program while retaining flexibility and strengthening the national systems without risk of dominating them or discouraging them from development as strong subcenters might.

361. We endorse the present scale and range of ICRISAT's special projects in Africa, and commend its leader. In some cases the projects appear rather lacking in sufficient support staff for the scale of activities undertaken, and in some cases they are constrained by local procedures and resources but we encountered appreciation of their work among the national systems, and were ourselves impressed by the sense of dedication and mission among the outposted staff.

362. We recommend that a long-term plan for the development of all aspects of ICRISAT's African activities be prepared for consideration of the Governing Board. This plan should set out the scientific rationale for the allocation of core resources between the African and Indian programs, keeping in mind the comparative strengths in scientific resources of the national programs in the two regions, and the need for long term (core funded) projects in the African SAT.

363. We recognize that activities in Africa can be supplemented by special funded cooperative projects but we would emphasize the need for a proper balance in the allocation of core funds between the two regions.

364. We recognize the urgency of expanding work in Africa. However, we have the impression that some activities there are on a somewhat ad hoc basis, and could involve some duplication with the many other agricultural development programs planned or under way throughout the area. In order to ensure that the best use is made of ICRISAT's resources in relation to these other activities, we suggest that a careful review and long-term plan, as requested by the Board should be a precondition to approval by the CGIAR of the full proposal as presented in the 1979/80 budget.

XI. MANAGEMENT

PROGRAM PLANNING AND FINANCE

365. Our general terms of reference require us to comment on "the management of the scientific and financial resources of the Center, and the coordination of its activities". Although we can make general observations in this area, we stress that we are not a team of management consultants, and our views are based on experience elsewhere, informal discussions and subjective impressions, rather than on a rigorous analysis of management structure, communication, and effectiveness. Such a detailed analysis may well prove useful in future, before the move to the new buildings at Patancheru is completed.

366. ICRISAT's achievements over a short period of time and under difficult circumstances suggest that the pragmatic and flexible approach has been successful until recently, but increasing size has imposed strains on the organization. We therefore stress the need for the formulation of a management structure better adapted to the new needs of the Institute, although we fully recognize the damage that too much bureaucracy can inflict on scientific creativity. On the other hand donors providing large amounts of scarce grant funds must be assured that they are being used to achieve the most efficient attack on the problems ICRISAT was set up to solve. We believe that it is possible to deal with both issues, and regard some clearer definition of ICRISAT's management structure and systems as an inevitable part of its reaching full development.

367. As regards the management of the scientific programs we have found that the planning of most of the programs is excellent and it is obvious that the program leaders have developed appropriate strategies for the conduct of their programs over the next few years. In drawing attention to the need for a longer term plan for the off-campus research, we recognize the importance of a realistic approach because the Institute cannot ignore the socio-economic implications of its scientific activities. Nevertheless, ICRISAT is under pressure to develop programs, especially bilateral cooperative programs in many, usually poor countries. In a number of these, not only agricultural research but every aspect of development is weak so that any significant advances can only be made from really long term involvement. We urge ICRISAT and the donors to support programs of longer term work in fewer countries, rather than attempting to mount them in too many countries.

368. ICRISAT was given a ceiling for its 4 year total of capital and operational costs but the attraction of SAT agricultural research to donors is such that the center has not suffered from any real financial constraints. The center now considers that its present 1979-80 budget presents a realistic picture of the ultimate size of the Institute and our review generally supports the proposed level of principal staff in the research programs.

369. As national scientists play a major role in ICRISAT's research, we emphasize that numbers of principal staff should not be used as the only guide to ICRISAT's total research strength for budgeting purposes. This is an area which can continue to grow without this being evident from principal staff numbers, but nevertheless with considerable impact on other direct and support costs. A limit on numbers of principal staff does not therefore impose a limit on growth of the progr

370. We understand that ICRISAT intends to provide computer and staff support for program leaders, whereby they may be relieved much of their routine financial and administrative burdens, while at the same time enabling them to keep better control of the use of their program budgets. We urge that steps in this direction be taken quickly, and that consultation on this subject be maintained between program leaders and the directorate.

371. We expect that ICRISAT will continue to be enthusiastically supported by donors. However, it would be unrealistic to assume that the total funds made available by CGIAR donors will continue indefinitely to match the total requests made by all the IARCs. ICRISAT, in common with the other centers, should have in readiness a set of procedures for dealing with a shortfall in funds, should one occur. While we hope these procedures may not be needed, we believe it important that the directorate and program leaders should jointly reach a clear understanding of the principles on which they would be based.

STAFF & PERSONNEL POLICIES

372. We had neither the time nor the qualifications to make a detailed analysis of personnel questions, and we confine ourselves to some general observations. We are aware that ICRISAT has joined the other IARCs in commissioning a consultant to review personnel policies, with special attention to the nature and scale of benefits.

373. We have drawn attention throughout our report to the achievements made by ICRISAT in a short time, and to the high quality of the staff. ICRISAT is in a uniquely strong position among IARCs by virtue of its location in India, which gives it access to a large number of highly talented and qualified research workers.

International Staff

374. It is ICRISAT's policy, explicitly required by its constitution, to recruit the best qualified person for a position, regardless of nationality. Open advertising of vacancies in professional journals is not generally used, since it has tended to arouse the interest of a large number of underqualified applicants. Instead, vacancies are brought to the attention of many senior research scientists and administrators in relevant fields throughout the world,

who are invited to send recommendations. We suspect that this procedure could result in vacancies not reaching the attention of those staff who are most highly valued by their employers. We suggest that ICRISAT should consider a more open means of recruitment, including some advertising, in the belief that the labor of screening many applications is negligible compared with the potential value of an outstanding scientist.

375. Under the present system, those who seem best suited to ICRISAT's needs are invited to make an application, and a few applicants are interviewed by the Director and other senior ICRISAT staff most directly concerned. There is no formal selection committee for international staff. The Board of Governors keeps ICRISAT's procedures for staff selection under review, but does not wish to approve individual appointments.

376. ICRISAT being a young and vigorous institution, with a challenging mandate, good facilities being developed, excellent supporting staff and an attractive location enjoying varied amenities, has much to appeal to scientists from around the world. One of ICRISAT's strengths is that it has been able to recruit principal scientists who have outstanding expertise and a wide background of relevant experience in all disciplines. Of the 44 man-years of principal staff authorized for 1978, 89% are expected to be filled - indicating successful recruitment during a period of rapid growth. We did however detect some concern over recruitment difficulties for the future, which may be particularly severe for the programs outside India. These concerns arise from a number of perceptions about the relative competitiveness of ICRISAT's benefits compared to those provided elsewhere, particularly in parts of Europe: a declining supply of scientists with experience of tropical agriculture, and a genuine interest in working in a developing country: and family difficulties for schooling or the maintenance of a wife's career. These are, as we have said, perceptions, and though we have no objective means of evaluating them, we note that they seem widely held.

National Staff

377. Recruitment of national staff follows a more formal pattern. Positions are advertised nationally (or in the local press only for the lowest positions). The Personnel Department screens applications, from which some 10 to 15 candidates are invited for interview by a selection committee. Those from the public sector must have obtained the prior permission of their employer to apply. Final selection from a short list of 2 or 3 is made after further interview.

378. The national staff is a unique resource. No other international institute has a comparable body of highly trained, talented and motivated scientists supporting the major research themes. This group forms a pool of human resources that could have a tremendous impact on agriculture in the SAT. Every reasonable effort should be made to encourage these people to grow as scientists. They should be stimulated to do original and innovative work, and to publish it. Those under continuous pressure of field work should be

granted occasional study leave to catch up on the literature, write papers for publication or visit other research organizations. Individuals should always be given full credit for the work they have done. Excellence should be rewarded by raises and promotions. We recommend that ICRISAT give serious and continuing attention to questions of career development for the national scientific staff.

379. We are aware of the Board's concern for the role of women in development, and suggest that this could extend to positive encouragement of the recruitment of women scientists, national and international.

CONSTRUCTION PROGRAM

ICRISAT Campus

380. The buildings on ICRISAT's campus are still under construction, and only some staff housing is occupied. The concept, standards, functional arrangements, and operational and maintenance aspects have been, and remain, controversial. A general consensus among ourselves and many to whom we talked is that while decisions on ICRISAT's capital plan made in the early 1970s were in line with the then-prevailing view of the construction needs of "centers of excellence", times have changed and, were ICRISAT designed today, it might be done differently.

381. The early days of ICRISAT's building program were beset by many difficulties, but there has been some improvement in the rate of completion in the last two years. The program recently suffered a setback when the waterproofing of all the flat roofs was found to be defective, which may result in a delay of some months in the final completion of the building program. In such circumstances, we emphasize the importance of full-time project management to keep tight control over all aspects of the building program.

382. ICRISAT's building needs have changed considerably since the architect's brief was written. Although foreseen in the initial proposal, provision was not made for the groundnut program. Additional responsibilities for germplasm collections have been assumed. Numbers of staff needing office and/or laboratory space are higher. Training demands are likely to exceed the early assumptions greatly. Plant quarantine facilities are now, to ICRISAT's advantage, to be located on campus.

383. ICRISAT's 1979-80 budget summarizes ("Capital Development Program") the expansion proposed to supplement the buildings already under construction, as approved by the Board of Governors. Specific items include (a) a Gene Bank/Germplasm facility, (b) Guesthouse and Reception Center, (c) Plant Quarantine Unit, (d) Scientists office block, (e) Support staff housing, (f) Farmer's Visitors center, (g) Extension to Stores, (h) 16 additional flatlets, (i) furniture and equipment. The total cost of all of these items is estimated in the budget at around $3 million.

384. We believe that the projected staff levels justify the proposed capital expansion. The experience gained during the first phase of construction should enable ICRISAT to draw up a detailed schedule of accommodation for the proposed expansion, so that real needs are met at minimum cost, and with the best operational efficiency. We urge that careful planning of the proposed new space, and for the rearrangement of space already under construction, be completed with the least delay.

West Africa

385. The building program for West Africa is based on the "two sub-center model". Elsewhere (para. 360) in our report we have suggested an alternative which, if accepted by ICRISAT, would change the capital requirements. We recommend that no firm commitments be made prior to the Board's consideration of our suggestions, and their consequent confirmation or redefinition of the capital investment needed in West Africa.

FIELD STATIONS

386. The Farm Development and Operations Unit is responsible for station management and farm services needed to provide multidisciplinary support to all the ICRISAT research programs through resource development, maintenance and routine farming operations. Under the overall supervision of the Associate Director for Research, it is headed by the Principal Agricultural Engineer with a staff of engineers for farm management, development, transport, general services, maintenance of electronic equipment and physical plant. The Unit operates a large fleet of cars, agricultural machinery, and heavy land development equipment, carries out maintenance, and fabricates and modifies some equipment. In addition to field work on the research area which includes seedbed preparation, planting, cultivation and weeding, irrigation, harvesting and threshing, the unit maintains the roads, water ways, tanks, wells and non-cropping areas.

387. Decisions on the distribution of land for experimental purposes are taken by the Farm Research Committee headed by the Associate Director for Research, which has a sub-committee on Plant Protection to advise it on pest and disease problems, and plant protection on the farm. The Land Development Committee headed by the Director is concerned with all land and water resource development.

388. Allocation of farmland for research purposes is based on a long-term rotation of two cereals and a legume. A detailed plan has been evolved which is intended to be put on the computer to assist the annual allocation exercise. Some constraints are beginning to be felt in the allocation of the alfisol areas in view of the pressure for experiments on these soils so typical of the SAT areas. We feel that it may soon be necessary to decide whether to seek additional land and would urge that this decision be not unduly delayed as there seems to be a possibility of obtaining more land in the vicinity now. This possibility might not extend far into the future.

389. It was clearly evident to us that farm development and operations are very well managed. Tremendous progress has been achieved. Land development is almost complete and a modern experiment station farm has been established in a period of about 5 years. Timely services have been provided to various programs with great precision.

390. The main constraints are due to the shortage and delay in the delivery of spare parts, and the loss of technicians and tradesmen to higher paying jobs.

391. The Unit also has certain duties in the development of outstations. The management and operation of the five out-stations located on University farms and used as experimental sites by ICRISAT in cooperation with ICAR can pose problems which may be exemplified by that encountered at Bhavanisagar where ICRISAT has entered into a cost sharing agreement with the University on the preparation of an excellent site. However, the continued management of the newly developed area will require additional resources. The center is properly reluctant to undertake the management of this farm and wishes to assist the University to obtain such resources.

392. We recommend that ICRISAT should work with ICAR and the four concerned Universities in developing long term arrangements for providing the additional resources required.

XII. CONCLUDING OBSERVATIONS

393. The preceding chapters have reviewed the mandate of ICRISAT, its research activities and services, training and cooperative programs and several aspects of its management. They have incorporated most of our recommendations, and in them we have also discussed most of the specific questions referred to us by the Technical Advisory Committee. In this concluding chapter we consider several additional matters and recapitulate some of the more important conclusions specifically in relation to our terms of reference (to which small roman numerals refer).

394. The mandate of the Institute is an important one. Its objectives are difficult and challenging and will require a long term attack. We cannot expect quick solutions to age-old problems. Furthermore, this first Quinquennial Review of ICRISAT has been undertaken at a much earlier stage of development of the center than most similar reviews of other IARCs, and even before occupation of the permanent buildings, which are scheduled for completion in mid-1979. Most of the research programs are still in the formative stage and it is too early to judge their achievements against the objectives of the mandate.

395. We have noted some of the difficulties faced by the lack of congruence among the several elements of the mandate, and some resolution of these differences is required. Nevertheless, the mandate provides a workable basis for both the short and long term role of ICRISAT. It is clearly appealing to donors and is enthusiastically subscribed to by the staff.

396. Apart from greater clarification of whether the geographic or crop mandate has primacy, our main recommendation in relation to the mandate is for a phased withdrawal from work on pigeonpea as a mandate crop, although research on its role in Farming Systems should certainly continue (cf. paras. 125, 129, 130). We make this recommendation in recognition both of the rapid progress that has already been made at ICRISAT on hybrid pigeonpea breeding, and of the strength of the Indian national research system, its concern for pulse production and the indications that this area of work may receive increased resources from the Government of India. We have assumed that one aim of the IARCs is to help national research systems to develop their capacity to the point where they can take over responsibility for work on programs in which they have expertise and national interest. We believe that pigeonpea research in India fulfills these conditions, and hope that ICAR will consider our suggestion as an indication of our high opinion of their All-India Coordinated Pulse Improvement Project.

397. For the next five years we see no strong case for ICRISAT to assume greater responsibility for the minor millets grown in the SAT beyond its acceptance of limited responsibility for the maintenance and interchange

of germplasm (cf. para. 26). But we encourage ICRISAT to use the minor millets and important non-mandate commodities to the full in its farming systems research.

ii a

398. The relevance, scope and objectives of the research programs have been examined in preceding chapters where we have recommended a number of changes for consideration by the Board. A most helpful congruence analysis of the allocation of the Institute's resources in relation to its objectives was prepared for the Quinquennial Review by ICRISAT's economists. The result of this analysis suggests that some shifts in the balances among programs are needed. We are aware of several limitations to such methodology (cf. para. 213) and that it can take no account of changes in the potential importance of various crops that may be induced by intensive research on them. Nevertheless, we support the main conclusion that, relative to the cereals, pulses are receiving too great an allocation of resources and groundnuts too little. We have therefore suggested several ways in which this imbalance can be redressed within the current allocation of the resources of the Institute.

399. Regarding the geographic distribution of effort, our African visits showed us that the program in Africa is an area of weakness, and consequently of concern. This is in harmony with the congruence analysis which indicated a need for a relative increase in research on the problems of other SAT regions vis-a-vis India, especially in the groundnut, economics, and farming systems programs. We also concur with this opinion, and have therefore recommended core funding for team leaders and their support staff in the African program as a first step towards correcting this imbalance (cf. paras. 346-352).

400. The concept of "scale-negative technology" needs some clarification. We agree that new technology should be oriented towards the small farmer as as far as possible. But in strict logic it is not feasible to design technology which is scale-negative in the sense that it yields less per hectare on a large farm, because it is always possible for a large farm to be run as a set of small farms. At best, technology can be scale-neutral in the sense that it yields on the small farm no less per hectare than on the large farm, provided that the input-supply system is also scale-neutral: i.e. it should deliver to the small as well as the large farmer the same amount of credit and material inputs per hectare on the same terms. "Smallness" is a relative concept: "small" farms in one country may be larger than the "large" farms in another. Scale-neutrality can break down where labor shortage requires the use of indivisible capital-intensive equipment.

ii b

401. ICRISAT's relations with other IARCs appear to be constructive and cooperative and we did not discern any problems. Although IITA has the

mandate for research on cowpeas, we found this crop to be such an integral part of SAT African farming systems that we have recommended that if IITA is unable to provide core funding for breeding of cowpeas adapted to SAT conditions, then ICRISAT should be encouraged to do so (cf. para. 343).

402. We discussed whether chickpea would be better placed within the mandate of ICARDA as the crop is temperate by origin, and Hyderabad is near the southern limit of its distribution in India. Neither center can effectively cover the whole range of conditions under which chickpea is grown. ICARDA could not readily handle work related to conditions in India, the main producer of the crop, and ICRISAT has had to post a chickpea breeder to ICARDA to cover the needs of Mediterranean areas where it is grown. In view of the overwhelming importance of India in the production of chickpeas, we have recommended that ICRISAT retain this crop within its mandate, and approve the present arrangement for the breeding of kabuli types of chickpea at ICARDA for Mediterranean climatic conditions (cf. paras. 99, 100).

403. We have also recommended more active collaboration between ICRISAT and the African IARCs in relation to arrangements for:

a. the analysis of plant materials and soil samples for the African programs (with IITA), (cf. para. 279),

b. training (with IITA and ILCA), (cf. para. 313) and

c. documentation (with ILCA) (cf. para. 295).

404. We encourage ICRISAT to adopt a more aggressive approach to the collection of genetic resources of the mandate crops, particularly sorghum (cf. para. 85) and to seek extra support from IBPGR for this purpose.

405. ICRISAT has a wide range of collaborative interactions with other international organizations whose interests bear on its programs. We have noted a number of possibilities for further development of these interactions at several places in our review.

406. We held discussions with each Coordinator of the five All-India Projects relevant to ICRISAT's research, and subsequently with them all together. They appeared to have a clear and consistent view of the desirable division of effort between them and ICRISAT (cf. para. 320). There was agreement that ICRISAT should concentrate on:

- the collection and maintenance of genetic resources;

- the production of advanced breeding materials;

- basic research on the mandate crops;

- the organization of symposia; and

- the dissemination of information.

The Indian national system, on the other hand, should conduct the coordinated trials of all material approaching release, including trials on farmers' fields (cf. para. 321). India has little need for the training courses provided by ICRISAT because of the large corps of highly trained personnel already available. A number of problems in relations between ICRISAT and its host country remain to be solved, but we are confident that this will be done with mutual understanding and generosity. A striking example of effective cooperation between the two parties is seen in the arrangements that have been developed for quarantine procedures (cf. para. 273).

407. The role to be played by ICRISAT in most African countries is quite different from that in India, for example in relation to both training and the need for varietal testing. The African program is still at a formative stage, and subject to many demands. While accepting the need for core funded work in Africa, we believe further experience and analysis is required before the organizational structure is totally determined (cf. para. 362).

408. We were impressed by the African Project Manager's grasp of the complex regional problems and priorities. His knowledge of the extensive work in francophone West Africa by GERDAT and ORSTOM should ensure effective complementation of ICRISAT's program, not only with the national systems in the region, but also with earlier and current French work.

409. We noted that the proposed cooperative program on sorghum with EMBRAPA in Brazil constitutes a first step towards work within the American SAT and that a cooperative project in Thailand will extend ICRISAT's work to other parts of Asia.

ii c

410. So far as we could judge, the scientific strategy and procedures adopted by ICRISAT in carrying out its mandate appear to be sound. We were disappointed that no long term plan was provided to us by the Institute, although some elements of this were covered in the Director's overview. We are especially concerned at the lack of a long term forward plan for the African Program, and are not persuaded that the proposed establishment of two subcenters in Africa is the best strategy for ICRISAT to follow at this stage (cf. para. 360).

ii d

411. Many aspects of ICRISAT's rationale for its allocation of resources and the overall balance of its research programs, support units and cooperative activities have been examined and commented on in the preceding pages. In his opening address to us the Director stated that "ICRISAT's core program is about as large as it is likely to get". We interpret this statement as indicating that, after an initial period of rapid growth, ICRISAT is now approaching a period of consolidation during which staff based at the

Hyderabad Center will increase only slowly. We agree that this is a desirable course to be followed over the next five years, apart from the need to establish effective core funded programs in the other SAT regions. There may be some scope for the transfer of certain current and planned core-funded activities from India to Africa, such as the anthropological work (cf. paras. 262, 263) and the use of the positions for the three consultant scientists (cf. para. 430), but much of the increase in activities outside India will require additional core funding.

412. With regard to the balance between core-funded and cooperative activities, ICRISAT shares a problem with several other IARCs in that nearly all its cooperative programs are with countries in which conditions differ in many respects from those at the Center. Findings and practices at ICRISAT Center will need much local adaptation by the African programs. While this will add to the burden already carried by the program leaders and principal staff at Hyderabad, it will have the advantage of forcing ICRISAT to come to grips with the range of conditions operating throughout its geographic mandate. In this sense, the cooperative programs pave the way for ICRISAT to explore the geographic relevance of its work, and our impression is that the balance between core funded and cooperative activities will be satisfactory when the proposed African core program is established.

iii a

413. The content and quality of the scientific work at ICRISAT has been appraised in the preceding chapters. The center is still too young to have made many major contributions, particularly as a lot of the staff have been appointed relatively recently. Moreover, they have had to work under difficult conditions in crowded and widely dispersed buildings, and we were impressed by their progress under such circumstances. Many of the results presented to us were exciting and promising, and we have no doubts about the excellence of much of ICRISAT's scientific work although we noted slow progress in a few areas.

414. We have made a number of suggestions for possible shifts in emphasis or for new lines of attack in their research. These are offered with full recognition of our imperfect knowledge of many areas of the center's work, and they are in no sense to be interpreted as a criticism of ICRISAT's overall research, which we found impressive in its quality and concentration on the difficult environments of SAT regions.

iii b

415. However, we draw attention to a problem that may increasingly assume significance for ICRISAT in the future. The center's research is organized, with the exception of the economics program, into multi-

disciplinary teams each directed to the goal of improving the genetic constitution and performance of one of the mandate crops or of the farming systems within which they are grown. We agree that this is an effective structure, given the objectives of the center, and our impression is that it is working well, as reflected by the great deal of inter-disciplinary collaboration and integration in all programs. However, such a structure will remain effective in the long term only to the extent that each scientist can maintain his grasp and coverage of related work elsewhere in his discipline. Opportunities to penetrate more deeply into aspects of his research are essential to the maintenance of his skills and disciplinary competence. The All-India Coordinators put it to us that one of the most important roles for ICRISAT in India is to carry out basic research on all the mandate crops and on farming systems, as there has been relatively litle basic research on these crops in the past.

416. Recently appointed senior staff bring their disciplinary skills with them, but these could soon run down under the pressures for work on the shorter term tactical problems unless there is a clear policy for their renewal, both through opportunities for more basic (i.e. strategic) research and for study leave. We suggest that not only the principal staff but also the national staff should be allowed such opportunities (cf. para. 378).

417. Another valuable way of maintaining specialist expertise and awareness of new developments is through visiting post-doctoral and consulting scientists, together with the initiation of collaborative projects with more specialized research institutes. We were impressed by the extent of this component of ICRISAT's activity and by the impact it has had on many of the research programs. The groundnut program is particularly notable in this respect. Such linkages with specialized institutes will undoubtedly contribute a great deal towards increasing basic research on the crops in ICRISAT's mandate. However, it should be recognized that certain areas of such work will need to be pursued at ICRISAT if it is to ensure that its more applied work is not constrained in some areas. A relevant example would be work on the survival of the various rhizobial strains in both alfisols and vertisols under drought-prone conditions.

iii c

418. The information exchange program has produced valuable surveys of literature of millet and sorghum and of all previous Indian and West African research relevant to ICRISAT's mandate. The development of a number of channels for the communication of ICRISAT's findings to research workers throughout the SAT will become increasingly important as ICRISAT's research program matures.

419. The training program has been severely constrained by lack of accommodation and training facilities. Those trainees we interviewed expressed

complete satisfaction with the courses, and particularly with their orientation to individual needs. However, the demands of such training programs on the time of scientific staff must also be considered, and it is for this reason that we have recommended that every effort be made to use audio-tutorial methods as much as possible (cf. para. 312).

iii d

420. The adequacy of the support units is best judged by the research staff, and they were unstinting in their praise for the help given by all the units. Our own impression was also favorable but we have made a number of suggestions in relation to the activities of these units. All operate under considerable pressure, but that is a condition common to most support units anywhere, and indeed to most of ICRISAT's staff.

421. The center's meteorological station and the network of rainfall gauges on the experimental farm deserve particular comment as one of the finest to be seen in any IARC, as is the use to which the data are put in the farming systems and the other programs.

422. The experimental farm at Patancheru is approaching full development and provides quick and excellent service to the research staff. The time is rapidly approaching when accommodation of all experimental needs on the farm may become limiting, at least under certain soil (alfisol) conditions which may be specifically required. We therefore encourage the Farm Research and Development Committees to give continuing attention to the long term needs for experimentation in order to ensure the most effective use of what may soon become a limiting resource for the center's research program (cf. para. 388). However, we wish to commend the foresight of the founders of ICRISAT in setting aside low fertilizer areas on both alfisols and vertisols, areas for natural regeneration of the vegetation and, later, a pesticide-free area. These are already proving to be of great value in research on performance under low input conditions and on biological control and pest management, two areas of research of particular relevance to the mandate which are likely to become increasingly important in the future.

iii e

423. The structure of the programs combined with ICRISAT's system of in-house reviews, Program Committees and Board reviews would seem likely to ensure effective research management. One of the outstanding scientific resources of the center is the dedication, ability and high level of training of its national staff. They have made a very significant contribution to all parts of ICRISAT research, and play a crucial role in sustaining its continuity and impact. We encourage ICRISAT to make every effort to ensure full and generous recognition of their contribution and to provide every opportunity for the national staff to grow as scientists through their work (cf. para. 378).

424. The present system of administration and financial management has developed under conditions of rapid growth of the Institute, whose staff is scattered among many buildings in Hyderabad and spread over the experiment station at Patancheru. With the coming aggregation of the staff in the new buildings there, and the likely transition from a period of rapid growth to one of consolidation, a rather different structure may be required. Therefore, we recommend that a scientific management consultant should be engaged to examine the management structure of ICRISAT as we were unable to give the question due attention. We also trust that more regular meetings between the staff and the Directorate to discuss the management policies and objectives of the center should be possible from now on, and we urge the Director to arrange such meetings.

iv a

425. We believe it is too early to judge the impact of ICRISAT's research. This is particularly so in the area of plant breeding because of the strategy of giving emphasis to population improvement, which takes a long time to develop but which is highly appropriate for plant improvement under SAT conditions. But we are confident that the population improvement approach used in the millet and sorghum breeding programs will in due course have a major impact on cereal yields throughout the SAT (cf. paras. 77, 78).

426. Among many other lines of work at ICRISAT which may also be expected to have a considerable impact are the development of pigeonpea hybrids, the approach towards an integrated pest management system for sorghum, millet and the pulses, the innovative work on intercropping and several other aspects of the farming systems program, and the remarkable success of several of the screening programs for resistance to pests and diseases of the mandate crops. The introduction by the economics program of several new topics in their Village Level Studies, analysis of risk and concurrent evaluation of technology may also have substantial impact.

427. We consider that ICRISAT's objectives are realistic and that the ultimate impact of its work could be very great indeed. However, it must be given adequate time to reach these objectives. Given the severe limitations on crop productivity throughout the SAT imposed by water supply and variability, the small use of inputs such as fertilizers, and the many socio-economic limitations, it must be recognized by donors that the tasks before ICRISAT are particularly complex and difficult. Pressures for premature extension of its findings could be counterproductive, both for the SAT farmers and for the center itself. The SAT farmer has learned to be patient. So must those who seek to help him.

428. In this context, the improved practices and genetic stocks which are developed will increasingly need to be tested on farmers' fields through the appropriate national channels. Some organizational problems may arise, but it is particularly important that such work be carried out wherever possible in order to ensure that the SAT farmer is not exposed to additional risk.

iv b

429. The impact of the training program has so far been relatively small, as is inevitable in view of the limited accommodation so far available for trainees. Training has been focussed primarily on Africa, where the need is greatest and where appreciation of its impact was singled out for mention during our visits there. The relative usefulness of training at the various levels can be evaluated only after more trainees have returned to their countries, but we encourage ICRISAT to give increased attention to training young scientists from Africa.

430. In its 1979-80 budget proposal ICRISAT has indicated that it wishes to establish a team of three consulting scientists: it is envisaged that they "would provide backup support to the ongoing ICRISAT programs, take part in various missions or act as consultants for national programs and agencies such as World Bank, FAO, and UNDP. Requests for the services of these scientists are well beyond what can reasonably be provided without jeopardizing ICRISAT's core and special projects research". We have given careful consideration to this proposal, as specifically requested by TAC, and in the light of the possible establishment of ISNAR. We recommend that it should not be implemented at this stage. We consider that ICRISAT's research under African and American conditions has not yet reached the stage where it could provide the basis for sound and well-tested recommendations, and we believe that the requested core funding would be better used to strengthen the research program in Africa (cf. para. 206). The proposal also indicates a potential for the use of the requested funds for a variety of other purposes (from handling visiting dignitaries to providing interim support for staff in transit) to which we accord a lower priority than the strengthening of ICRISAT's research capacity in Africa.

431. Among the constraints on the work of the centre, the dispersion of its staff among many sites in both Hyderabad and Patancheru, and in many buildings which are mostly old, small and not well suited to their present use must have been a major constraint, but has been surmounted.

432. We have already noted the recent increases in delays and difficulties in securing principal staff of high calibre, particularly from parts of Europe, USA and Canada. It is our impression that living conditions in Hyderabad and the opportunities for cultural and other activities are generally acceptable (cf. para. 376). Thus, the difficulties in recruitment probably lie elsewhere, quite possibly in the salary structure for ICRISAT's principal staff, which is currently being reviewed by a consultant.

433. Another constraint of concern to many of the senior staff is the amount of time they must spend on preparations for, and presentations to, the many reviews, both internal and external, to which they are subjected.

Our impression is that the burden of these reviews has reached a point where it is detracting from the progress in research. We therefore express the hope that this Quinquennial Review may lead to some relief from the burden of reviews, particularly in view of the long lead time that must be allowed for much of ICRISAT's work. We recommend that the interval betweeen successive in-house reviews be extended to a minimum of 2 years.

434. The broad mandate of ICRISAT and the difficulties of the SAT environment inevitably impose constraints on the rates at which progress will be made in the research programs and on when these will begin to have an effect on food production throughout the SAT. These constraints are not underestimated by either the Board or the staff of ICRISAT, and indeed they relish the challenge of the mandate. We have been greatly impressed by their enthusiasm and their dedication to the task, and are confident that ICRISAT's research is effectively directed towards the goals of the center and is likely to have a major impact on the agricultural productivity and development of the SAT. The problems are immense, but the opportunities for improving the lot of many people in many lands depend on their solution. ICRISAT, in cooperation with the many national research programs and international agencies with which it collaborates, has made an impressive start in its attack on these probl

ANNEX I

ITINERARY

I. Discussion with members of Board of Trustees of ICRISAT

Saturday, September 23 Paris

(Messrs. Evans, Arnold, Kendrick, Harlan, Burhan, Krishna, Coulter Fournier and Hayman)

P.M. Discussion with Board members

Sunday, September 24 Paris

A.M. Panel internal discussions

II. Review of ICRISAT's activities in West Africa

(Messrs. Evans, Arnold, Kendrick, Harlan, Burhan, Krishna, Coulter and Hayman)

Monday, September 25 Ouagadougou

Presentation of W. African programs

Tuesday, September 26 Ouagadougou

A.M. Visit to Kamboinse Research Station

P.M. Continuation of presentation of W. African programs

Wednesday, September 27 Ouagadougou

A.M. Visit to Acting Minister of Rural Economy
Continuation of presentation of W. African programs

III. Thursday, September 28 Bombay, Senegal

A.M. Presentation of Senegal program

P.M. Tour of experiment station

Leave for Hyderabad via Geneva and Bombay

IV. Saturday, September 30

P.M. Arrive Hyderabad (Dr. Brader & Dr. Fournier join Panel)

Sunday, October 1

All day visit to Village Level Studies at Aurepalle

Monday, October 2 thru Friday October 6

Manmool Castle, ICRISAT Campus. Presentations of Programs by Director and staff of ICRISAT

Saturday, October 7

A.M. Meetings with All-India Coordinators

P.M. Completion of ICRISAT presentations

Sunday, October 8 thru Friday October 13

Individual meetings with ICRISAT staff, internal discussions, report writing.

Saturday, October 14

Chairman's final presentation to Director and Senior Staff

ANNEX II

People Met by the Panel

People met by the Panel during the mission, included, in addition to ICRISAT staff, the following:-

Paris:

Members of ICRISAT's Governing Board

Dr. C.F. Bentley (Chairman)
Dr. E. Åberg
Dr. I. Kabori
Dr. K. Lampe
Mr. A.R. Melville
Dr. D. Sene
Dr. G. Vallaeys

Upper Volta:

Mr. Dramane Sanou, Minister of Sport and Acting Minister of Rural Economy
Mr. Sie Pascal Kambou, Chef de Cabinet, Ministry of Rural Economy
Mr. Joseph Kabore, Director of Agricultural Services
Mrs. R. Sawwide, Chief of Agricultural Research
Mr. Sorgho, Director, A.U.V.
Mr. Albert Djima, Director, Kamboinse Agricultural Research Station
Mr. Thomas Boyatt, U.S. Ambassador
Mr. John Hoskings,, Director, U.S.A.I.D.
Mr. Richard Meyer, Deputy Director, USAID
Mr. Arlan McSwain, SAFGRAD/USAID
Dr. V.L. Asnani, IITA
Dr. V. Agarwal, IITA
Dr. Suzin, IITA

Senegal:

Dr. Gora Beye, Director, Bambey Agricultural Research Station

India:

All-India Research Project Coordinators

Dr. G. Harinarayana, Millet Project
Dr. N.G.P. Rao, Sorghum Project
Dr. Laxman Singh, Pulse Project
Dr. Vikram Singh, Oilseeds Project
Dr. S.L. Chowdhury, Dryland Project

Dr. A. Appa Rao, Andhra Pradesh Agricultural University

Annex III

Glossary and Acronyms

Kharif	monsoon season
Rabi	dry season
Alfisols	red and grey soils
Vertisols	black soils
mt	millions of tonnes
CGIAR	Consultative Group on International Agricultural Research
ABU	Ahmadu Bello University
CIAT	Centro Internacional de Agricultura Tropical
CILSS	Interstate Committee for the Control of Drought in the Sahel
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo
CIP	Centro Internacional de la Papa
CNRA	Le Centre National de Recerche Agronomique de Bambey
EMBRAPA	Empresa Brasiliera de Pesquisa Agropecuaria
FSR	Farming Systems Research
GERDAT	Groupement d'Etude et de Reserche pour le Developpement de l'Agronomie Tropicale
IARC	International agricultural research center (e.g. ICRISAT, CIAT, etc.)
IARI	Indian Agricultural Research Institute
IBPGR	International Board for Plant Genetic Resources
ICAR	Indian Council for Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
ICIPE	International Centre of Insect Physiology and Ecology

ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDRC	International Development Research Centre
IITA	International Institute of Tropical Agriculture
ILCA	International Livestock Centre for Africa
ILRAD	International Laboratory for Research on Animal Diseases
IRAT	Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres
IRHO	Institut de Recherches des Huiles et Oleagineux
IRRI	International Rice Research Institute
ORSTOM	Office de la Recherche Scientifique et Technique d'Outre-mer
SAT	Semi-arid Tropics
SMIC	Sorghum and Millets Information Center
VLS	Village Level Studies
WARDA	West African Rice Development Association

ANNEX IV

PANEL MEMBERS

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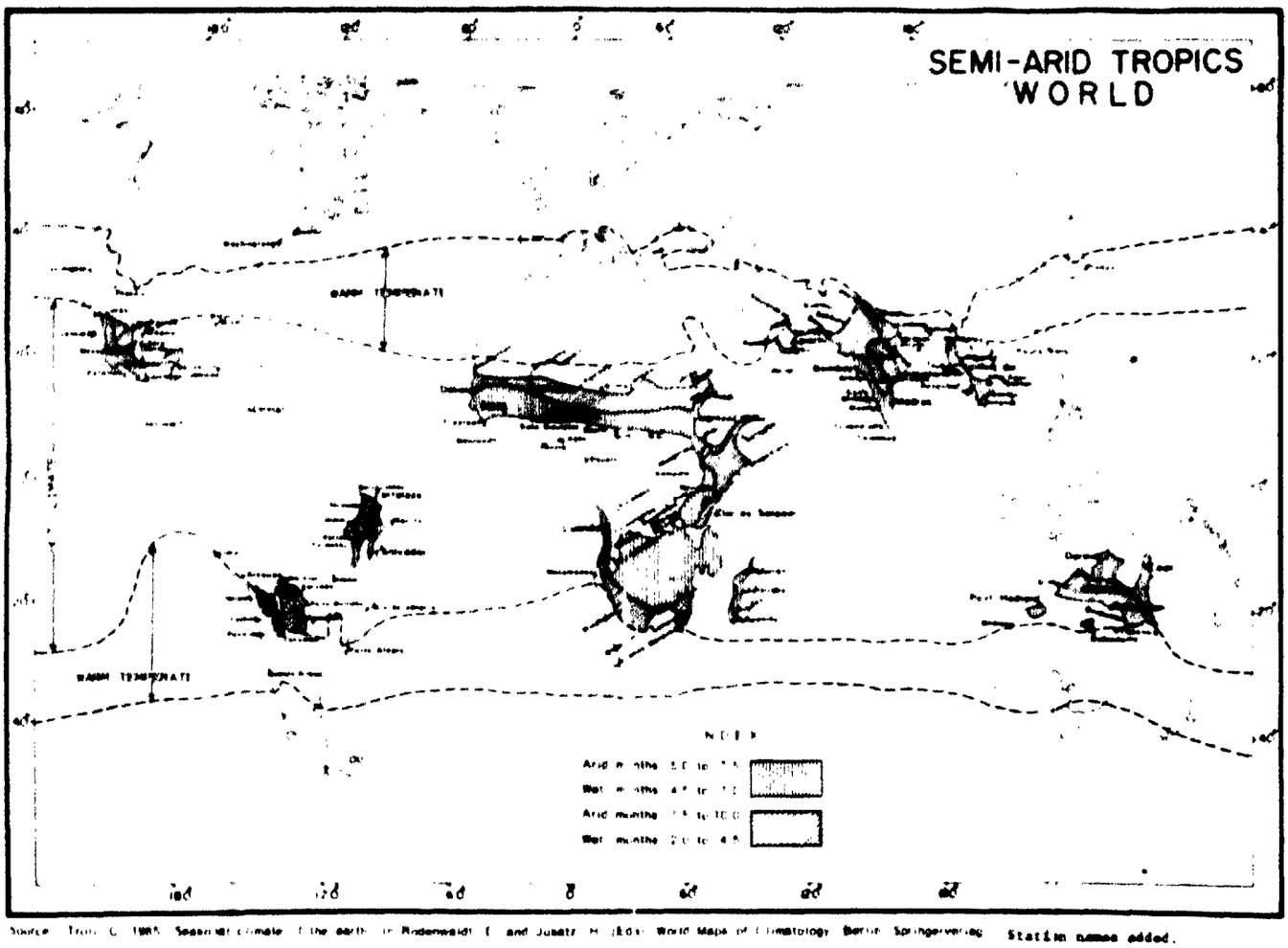
Annex V



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CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH
TECHNICAL ADVISORY COMMITTEE

SUMMARY OF TAC COMMENTS AND RECOMMENDATIONS ON THE REPORT OF THE QUINQUENNIAL REVIEW OF THE INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS (ICRISAT)

TAC Secretariat
April 1979

SUMMARY OF TAC COMMENTS AND RECOMMENDATIONS ON THE REPORT OF THE QUINQUENNIAL REVIEW OF THE INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS (ICRISAT)

1) TAC expressed warm appreciation to the Review Panel for a very thorough and competent review of ICRISAT, carried out under the revised terms of reference and guidelines.

2) Both the Panel Chairman and the Institute's Director General expressed regret that the magnitude of the review task kept the Panel so fully occupied that, within the available time frame, there was insufficient opportunity for professional interaction between ICRISAT staff and the Panel members on scientific issues.

3) TAC commended the report of the Quinquennial Review Panel and recommended that it be forwarded to the CGIAR for consideration at its meeting 3 and 4 May 1979.

4) TAC noted the comments of the Panel concerning the lack of complete coincidence between the area classified as the semi-arid tropics and geographic distribution of the principal crops of concern to the Institute. While it would encourage ICRISAT to continue its efforts to refine the definition and geographic limits of the semi-arid tropics and to direct its farming systems research to this region, it recognized that ICRISAT's global responsibility on the five mandated crops - sorghum, millet, chick pea, pigeon pea, and groundnuts - necessitates its giving attention to appropriate programmes beyond the SAT limits. This lack of complete coincidence of the SAT region and geographic distribution of the specific crops need cause no concern.

5) The Committee endorsed the views of the Panel that pigeon pea is a significant crop throughout India, where a majority of SAT people live, although the potential importance of the crop elsewhere was difficult to assess. TAC endorsed the Panel's recommendation that consultations take place between ICRISAT, the Indian Council of Agricultural Research (ICAR), and the All-India Coordinated Programme for Pulse Improvement on the feasibility of integrating the breeding programme with the national programme over the next five years. It did this in recognition of the strength of the Indian national research system and of the Indian interest in this crop, in the belief that it was the policy of CGIAR to complement the research capacities of national systems, and to withdraw from individual areas of work as national capacity becomes self-sufficient. TAC recommended, however, that in the negotiations to be engaged with ICAR, attention be given to the funding aspects of this transfer and to the international exchange of genetic material which should continue to be assured through ICRISAT facilities. TAC will wish to be kept informed of progress in these discussions and the Institute's future responses to this suggestion.

6) TAC supported the Review Panel's recommendation that the African portion of ICRISAT's programme should receive greater relative emphasis, but that the form of organization and the location and mode of operation of outposted staff in Africa should have further study and development of long-range plans before commitments are made to fixed substations. It is understood that such a long-range plan is being developed and will be considered by the Board in March 1979. TAC will look forward to an examination of this plan in relation to its consideration of ICRISAT's 1980 programme and budget proposals.

7) The strategy adopted by ICRISAT in the selection and testing of genetic materials under both high and moderately-low fertility levels appears to be quite relevant, especially in view of the relatively high risks of the SAT environment, and the limited availability of yield-increasing inputs on so many of the small farms of the SAT.

8) TAC agrees with the Panel that ICRISAT should give low priority to the employment of scientists whose primary responsibility would be to consult with other agencies and governments in developing research plans for utilizing ICRISAT-developed technology, pending a fuller definition of the responsibilities of such persons, and a clearer definition of the need and function for such positions.

9) TAC was pleased to note the overall commendation of the quality and morale of staff and the vigor and relevance of ICRISAT's programme for serving the needs of the Semi-Arid Tropics.