

**Integrated Gene Management: ICARDA's New Research Paradigm
for Improving and Sustaining Crop Production and Food Security
in Dry Areas**

**Report of the Center-Commissioned External Review
of the Integrated Gene Management Research of ICARDA
November 2005**

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Executive Summary

ICARDA's Board of Trustees commissioned a review of its Integrated Gene Management research. This review occurred 9-18 June 2004 at ICARDA, Syria. The team for the Center-commissioned External Review (CCER) comprised Professor Cal Qualset (Chair), Professor Mahmud Duwayri, Professor Ivan Buddenhagen and Dr Mogens Lemonius.

ICARDA's research is organized within five themes according to CGIAR's principal outputs of (1) Germplasm Improvement, (2) Germplasm Collection, (3) Sustainable Production, (4) Socioeconomics and Policy, and (5) Enhancing NARS; however, this CCER was dedicated to a "hybrid" topic, Integrated Gene Management (IGM), which cross-cuts several of the current themes. IGM is featured in the new Medium Term Plan. The CCER team is very happy with the IGM focus and this review strongly supports the use of the concept in ICARDA's strategic planning.

The panel considered a definition and scope of IGM, roughly indicated below, which provides a framework for the evaluation of current programs in Germplasm Program (GP), Genetic Resources Unit (GRU), Integrated Pest Management (IPM), Biotechnology Laboratory (BL), and Seed Unit (SU). IGM represents the continuum of activities relevant to ICARDA's CWANA regional goals and its global goals related to 'dry areas' agriculture and natural resource management and conservation, such as crop orientation (cereals and food and forage legumes). Some of the main components of IGM include:

- ❑ Collecting, conserving, and distributing genetic resources of landraces, wild crop relatives, and species previously unexploited for crop and rangeland environments
- ❑ Designing and implementing research on *in situ* conservation of agrobiodiversity, including restoration of degraded rangelands vegetation and incentives for on-farm conservation of landraces
- ❑ Discovering genetic resources with new or complementary traits
- ❑ Developing understanding of genetic variability, such as discovery of new genes, validating the functional worth of new traits for productivity enhancement, disease and pest resistance, food and feed quality
- ❑ Discovery and deployment of genetic means for mitigating biotic and abiotic stresses on plants
- ❑ Adopting methodology for exploiting genetic variability by direct introduction or through conventional and molecular-assisted plant breeding
- ❑ Diffusing information and seed materials to NARS to enhance the agricultural productivity and income generation in the many countries served by ICARDA
- ❑ Assessing the adoption and impact of new materials and methods among NARS
- ❑ Integrating IPM, cereal quality laboratory, seed services, and socio-economic teams as integral members of plant breeding teams
- ❑ Maintaining close contact and collaboration with NARS

- Training by field tours at the farm level, workshops at ICARDA and NARS, visiting scientists, mentoring M.Sc. and Ph.D. students

The Panel interviewed staff and reviewed program statements, including research and adoption highlights, and concluded that the IGM concept was extremely attractive on scientific, organizational, and administrative bases. At the conclusion of the on-site review in June 2004, a recommendation was made to Center management that IGM should be considered one of the Megaprojects of the Center. The recommendation was accepted by Management and later by the Board of Trustees. Hence IGM is an official program unit of ICARDA. The Panel **recommended** that GP, GRU, IPM, SU, and BL be formally included in IGM.

The Panel agreed that the IGM component units were addressing the major needs and were productive. In fact, the productivity and creativity of the programs were remarkably good, given the rather small number of scientific staff in each of the areas. The panel suggests that bolstering scientific staff in some areas would make the Center much more able to meet its goals and to exploit new opportunities.

Recommendations were made for each of the program areas reviewed as summarized below.

A rather comprehensive set of recommendations have been proposed. We hope these have merit on their own, but the Panel **recommends** that in-house priority assessment of the different activities is necessary in view of the new and redefined efforts as envisioned for IGM.

GENERAL PROGRAM

Recommendation 1.

a) ICARDA has taken leadership in defining the Integrated Gene Management concept and we **recommend** that IGM be adopted as a Megaproject in its new operational plan.

b) The IGM unit is **recommended** to include the GP (Germplasm Program), IPM (Integrated Pest Management), GRU (Genetic Resources Unit), BL (Biotechnology Laboratory), and SU (Seed Unit). The addition of the Crop Quality Laboratory would also be logical addition to IGM, but the Panel did not review the impact of that action.

Recommendation 2.

a) With respect to the crop improvement [breeding] programs, the panel **recommends** that two projects be established for crop improvement: one for food and forage legumes and one for barley, bread wheat, and durum wheat with a Director for IGM and appropriate leadership for each of the component units of IGM.

b) We also **recommend** that representation from two additional program activities be part-time adjuncts to IGM, that is, (1) an animal nutrition specialist with respect to breeding for improved forage quality and (2) a socio-economic specialist for risk assessment and impacts analysis related to adoption of ICARDA' discoveries.

Recommendation 3. The panel **recommends** that the spring and winter bread wheat programs be merged for coordination of activities, sharing of genetic resources to share technical support, efficiency in field and greenhouse operations, and for more efficient in-country collaboration with NARS.

Recommendation 4. The panel **recommends** that the funding for IGM should be increased, from the 2004 percentage of about 35% of the center's budget because of the need for increased support for host plant resistance research in plant pathology and entomology and for increased investment in NARS collaboration, impact and adoption analysis, and policy studies.

Recommendation 5. The Panel **recommends** that conventional breeding should continue to be the basic approach and biotechnology an integral tool for crop improvement.

Recommendation 6.

a) The panel **recommends** that, when possible, the farmer-developed varieties developed with ICARDA's assistance retain genetic variability within the released varieties, as is found in typical landrace varieties, as a means to buffer against annual climatic or biotic stress variances.

b) That IGM should extend participatory plant breeding (PPB) approach to include more crops within the communities' cropping systems as well as to consider the broader issues associated with adopting a PPB approach. Farmers should play a major role in the formulation of the research agenda, management, and evaluation of the trials.

c) The decentralized and farmer PPB approach at ICARDA has high reputation globally. This approach may be expanded to additional NARS, however, the panel **recommends** greater attention be given to choice of parents (including landraces), mating schemes for population development, and central preliminary screening to reduce susceptibilities to pests and diseases before the materials are presented to farmers for selection. Consideration for seed multiplication and distribution of farmer-selected varieties needs clarification to the farmers from the outset to avoid confusion about farmer ownership and commercialization rights.

Recommendation 7. **Recommended** that ICARDA should consider the establishment of a permanent training unit on participatory plant breeding.

POLICY ISSUES

Recommendation 8. The panel **recommends** that, if not already in place, a "white paper" study group be assembled to recommend acceptable policy that can be adopted by NARS for release of farmer-developed varieties that is consistent with ownership and benefit-sharing as described in the International Treaty for Plant Genetic Resources for Food and Agriculture and the Convention on Biological Diversity.

COLLABORATION

Recommendation 9. The panel strongly **recommends** that ICARDA and CIMMYT continue their discussions and forge an alliance to clarify their respective complementing responsibilities for wheat improvement in the dry areas. ICARDA has additional intercenter collaborations, viz. ICRISAT and ILRI, for which updated memoranda of collaboration could be addressed in relation to IGM.

Recommendation 10.

a) The panel is concerned about how ICARDA can carry out sufficient research programs with its limited human and financial resources and at the same time enhances national research and development. The IGM panel **recommends** that, as appropriate, its partnerships target direct NARS involvement with joint funding and NARS scientists dedicated to specific components of locally and regionally relevant research and development projects, whereby the national programs can receive funds for expanding staff that can be seconded to ICARDA for specific topics, either at Aleppo, regional sites, or at the NARS research centers.

b) Collaboration with NARS was not examined in detail during the review because the review was completed at ICARDA headquarters without visits to NARS sites. Of course, enhanced collaborative activities are **recommended** with respect to more direct involvement of NARS scientists in breeding and other programs, even to the extent of preparing a roster of key collaborators as research partners.

PERSONNEL

Recommendation 11. There was ample evidence that ICARDA is a productive Center with generally high quality scientists; however, budget reductions have taken a toll on several of the programs. For example, several of the collections in the GRU suffered for lack of scientific leadership for several years and the faba bean improvement program is guided by a temporary employee. Permanent positions are **recommended to** stabilize these programs. During the review the panel was apprised of limitations to the programs because of lack of scientific staff in several areas. The following summarizes **recommended** positions. The individual sections provide background for these recommendations.

- ❑ Plant pathology: 1 assigned to plant improvement programs
- ❑ Entomology: 1 assigned to plant improvement programs
- ❑ Economist 1 in seed policy and evaluation
- ❑ Social scientist 1 in adoption, impact, and biosafety analysis
- ❑ Plant breeder 1 for forage legume and faba bean
- ❑ Agronomist/Weed Scientist 1 for IPM
- ❑ Crop Physiologist 1 for stress tolerance physiology, genetics, and breeding

Limitations in support staff were noted and should be reviewed throughout the IGM units.

FACILITIES

Recommendation 12. For more effective management of seed stocks, it is **recommended** that the SU construct a seed store building for secure storage and inventory of seed stocks. IGM should prepare a prioritized annual inventory of needs for new and replacement instrumentation and renovation of facilities to Management for action.

SPECIFIC NEEDS FOR CROP BREEDING PROGRAMS

Barley

Recommendation 13. With respect to specific improvements in barley, increased effort is **recommended** to expand production of barley with value-added end-use quality traits, including malting barley, food uses, and nutritional quality (e.g., iron, zinc, and vitamin A).

Recommendation 14.

a) Accelerating the use of marker-assisted selection (MAS) for biotic resistance traits is **recommended**.

b) Expanded research on abiotic stress resistance is **recommended** through collaboration with NARS and ARIs. Emphasis may be placed on genetics of these traits by quantitative trait (QTL) analysis, selection of parental stocks, development of populations for selection with aid of linked molecular markers, and accelerated development of IBIS for information management.

c) The panel recommends that the barley participatory breeding scheme assure that genetic variability be retained within farmer-improved varieties as is found in typical landrace varieties, as a means to buffer against annual climate or biotic stress variances.

Durum wheat

Recommendation 15.

a) The panel **recommends** that the durum program should continue to focus on drought, pest resistance, and grain quality research in collaboration with NARS and ARIs.

b) The current durum program is presently concentrating on NARS with large durum growing areas; however, in the future the panel **recommends** that more attention should be given to smaller production areas, such as in Ethiopia, Jordan, Egypt, Lebanon, and Libya.

Spring and winter bread wheat

Recommendation 16. Serious limitations in numbers of supporting staff were identified. The panel is sympathetic to those needs and **recommends** that the staffing needs be considered jointly with the needs of the proposed combined bread wheat program and personnel shared to the extent possible.

Recommendation 17. **Recommended** that research priorities should address quality parameters of relevance to needs and preferences of the targeted populations, genetic analysis, host plant resistance, and epidemiology.

Recommendation 18. The panel **recommends** that the proposed combined bread wheat-breeding program should delineate its breeding program based on four major types of environments, namely:

- Favorable Irrigated Spring Wheat Environment of CWANA.
- Semiarid (Mediterranean Rainfed) Spring Wheat Environment.
- Favorable Irrigated Winter/Facultative Wheat Environment.
- Semiarid Rainfed Winter/Facultative Wheat Environment.

Food legumes

General recommendations for food legumes

Recommendation 19. Enhance investment to introduce underutilized species into the farming system and diets of CWANA populations, peas for example.

Recommendation 20.

a) Develop markers for various traits and use marker-assisted selection as appropriate.

b) Participatory approaches with farmers and NARS should be systematically studied for comparative purposes with non-participatory methods.

Recommendation 21. For Central Asia, varieties have been released but seed production, processing, and distribution systems should be given higher priority.

Recommendation 22.

The faba bean improvement program should be strengthened by recruitment of a P-level plant breeder.

Forage legumes

The panel offers the following recommendations that, in our view, will make the program more effective.

Recommendation 23. There seem to be practically unlimited prospects for selecting, improving, and distributing additional forage species. The panel recommends further exploration and evaluation of endemic species with the GRU that may enhance rangeland animal productivity if managed properly or reintroduced, but at the same time, evaluate and prioritize the needs for research among the species currently under evaluation.

Recommendation 24. Professional staffing for forages is too small to exploit the many opportunities for research on this very large component of the landscape. We **recommend** a

minimum of 50% assignment of an additional plant breeder, perhaps shared with Vicia faba breeding.

Recommendation 25. The panel believes there are many unmet opportunities in forage improvements, including antinutritional factors (ANF) and **recommends** that ICARDA, in its strategic planning process, develop in-depth partnerships with NARS and ILRI.

Recommendation 26. Continue to develop and disseminate improved germplasm with desirable traits for testing in collaboration with NARS. The panel encourages expansion of farmer participation in germplasm evaluation as a methodology to relate the project's objectives to those of the farmer and vice-versa. An informal farmer-based seed distribution system may be the most effective means of increasing adoption of new varieties; therefore, the panel **recommends** that farmers be encouraged and instructed to engage in community-based on-farm seed production and distribution of improved lines and cultivars.

GENETIC RESOURCES AND BIOTECHNOLOGY

Recommendation 27.

a) As the strategic and action plans for IGM are developed, the panel strongly **recommends** stronger participatory interrelationships of genetic resources specialists, plant breeders, pest management scientists, agronomists, and end-use evaluation specialists through specific research goals and action plans. This is especially critical for GRU as it endeavors to serve the needs for genetic resources by the breeders and pest management group.

b) The study of molecular genetic diversity by the GRU is entirely appropriate and critical for understanding diversity, devising collection and exploration expeditions, and advising the crop improvement teams on promising genetic resources for use in breeding, at the same time, the panel **recommends** greater communication and collaboration with the BL and durum wheat molecular laboratory.

c) The panel **recommends** that the biotechnology team become more formally linked, in the context of IGM project with the crop improvement programs and GRU in regular planning and technical sessions.

Recommendation 28.

a) The in situ conservation research is **recommended** as a long-term component of ICARDA's IGM and extended to other countries in the CWANA region under ICARDA's leadership, taking advantage of the expertise developed and partnerships already existing with NARS.

b) The GEF project has emerged as a global model for in situ conservation and enhancement of natural and agrobiodiversity; it is strongly **recommended** that a means be found to sustain its main activities. Further support for research on a community-based approach for use and conservation of agrobiodiversity, as demonstrated within the GEF project, is warranted and **recommended**, especially for enhanced socio-economic participation.

INTEGRATED PEST MANAGEMENT

The IPM team has recognized some areas of research that need greater attention. The panel agrees with their self-assessment and endorses the following **recommendation**:

Recommendation 29. Further promote and enhance the exploitation of resistance sources by breeders at ICARDA and NARS programs and strengthen/encourage closer consultation between breeders, pathologists, entomologists, and biotechnologists to ensure optimal characterization of resistance sources to aid in the identification of resistance genes.

Recommendation 30.

a) Progressively improve and develop inoculation procedures to facilitate tests for pest and disease status of most, if not all, segregating breeding materials in the breeders' selection plots.

b) Increase the use of molecular marker tools in epidemiological studies.

c) Develop disease and insect pest distribution maps by geographic information systems (GIS) in collaboration with the ICARDA Natural Resource Management Program and validate prediction models for pest development/outbreaks in collaboration with CBSU.

d) Give strong emphasis on the launching of farmer field schools (FFS) with NARS research and extension services in full participation of farmers.

e) Re-enforce the testing of IPM options at ICARDA headquarters and at hot spots with collaborators.

SEED SYSTEMS FOR IGM AND THE NARS

The following recommendations are made to enhance the effectiveness of the Seed Unit:

Recommendation 31.

a) ICARDA should establish a Seed Production and Development Committee (SPDC) with representation from the Crop Development Program, the SU, the International Crop Information System and Nurseries Network, and the Genetic Resources Unit (including the Seed Pathology Laboratory).

b) Senior staff from the SU and NARS should participate in the annual, regional/sub-regional coordination meetings and as many national meetings as appropriate. Senior staff from selected seed systems in countries, where the Center considers that seed problems currently or in the near future may deter the dissemination of Center material, should also participate.

Recommendation 32. The SU is understaffed. It is therefore important that the vacant post of the Seed Economist is filled. To release senior SU staff for seed research, training, and development

work and to improve the management of ICARDA's seed operations and quality control, the following staff at GS level should be employed and attached to the SU:

- A seed storekeeper, a seed-conditioning (processing) plant operator
- A technician to manage the database, handle regular seed quality control and to support seed research and development activities with seed-testing work.

Recommendation 33. The SU should organize its database on seed activities in such a manner that the Unit is able, at any point in time, to provide current, aggregated information about the quantity of seed handled or number of samples tested in respect of line/variety and client/purpose over the last 5 years and maintain inventory lists in a database that would be accessible on the internet for qualified users.

Recommendation 34. When implementing the participatory breeding concept, with respect to seed production and distribution, particular attention should be paid to

- Organization and participatory role of farmers in the selection work
- Organization around and management of the small seed-cleaner supplied by the SU,
- Avenues being explored with local authorities to bring the material selected by and exchanged between farming communities into the operations of the national seed system,
- A transparent understanding about the sharing of benefits (profits) with respect to the sale of the farmers' intellectual property.

Recommendation 35. The CWANA Network Steering Committee should be replaced by a regional seed committee or board with one member from each CWANA country that contributes an annual fee.

QUALITY OF SCIENCE

Recommendation 36. The IGM scientists have been very active in publishing their results in peer-reviewed journals, about two papers per year per scientist, and also in publishing conference proceedings, manuals, and materials to extend the scientific results, about four items per year per scientist. The Panel recognizes that the large service role of the IGM scientists in providing scientific information inside client countries and through workshops and training courses at ICARDA/Tel Hadya has been highly creditable component of 'quality of science'. We urge continued diligence in publication of results and **recommend** wider use of electronic medium, which is largely accessible to the research community in all countries. Print medium is costly to produce and distribute and often not available to those who most need the information.

ADOPTION AND IMPACTS

Recommendation 37.

- a) It is recommended that each research activity should have an impact and adoption assessment included in the project plan from the outset and, further, that specialist in that field be integral member of research team.

b) We recommend that collaboration with NARS be strengthened to maximize the utilization of NARS human resources and contribute to their development in the study of adoption and impact.

c) The panel recommends that the study of impact of adoption of improved varieties be linked with attendant impacts on the quality of natural resources including biodiversity and soil and water quality and pollution from pesticides and fertilizers to sustainable increased productivity taking in consideration risk aspects that require further quantification.

Box 1

What is in a name – a lot!

In Support of “Integrated Gene Management”

- “A Crop Breeding Program” focuses the mind on plant breeders and what they can do.
- “A Crop Improvement Program” expands the thinking to include other disciplines such as pathology and entomology wherein lie organisms greatly influencing performance of any new variety. A deep knowledge from these disciplines and of plant physiology and crop/soils/nutrition (agronomy) applied within a crop breeding program greatly increases ease of development of new varieties with stable and balanced performance for farmers in different agro-ecosystems.
- A program labeled “Integrated Gene Management” broadens the image of the development of new crops to the real activity of capitalizing on evolution itself from wild progenitor to domestication into primitive landraces to selection of superior types to hybridizing existing lines, to manipulating genes from all levels and even from foreign species. It includes the real activity of understanding the domestication of wild-pathosystems and of the naturally evolved enemies of the pests and the pathogens themselves.
- “Integrated Gene Management” is holistic label that can be seen by funding agencies, administrators, and the scientists themselves who are involved in the multifaceted activities leading to an improved agriculture. ICARDA, in a region of origin of domesticated crops is sitting on an immense, hardly tapped, gold mine! All of its crops fit this category!
- Much work has been done here to provide the legacy of many good varieties and much useful knowledge to provide a base for a more holistic and productive future.
- Therefore, “Integrated Gene Management” in this holistic sense can be the central focus for ICARDA’s total activities and the base to link all other activities to positive agricultural change in CWANA.

CCER Panel June 2004

Chapter 1. Introduction

ICARDA's Board of Trustees commissioned a review of its Integrated Gene Management research. The review occurred 9-18 June 2004 at ICARDA, Syria. The team for this Center-commissioned External Review (CCER) comprised Professor Cal Qualset (Chair), Professor Mahmud Duwayri, Professor Ivan Buddenhagen and Dr Mogens Lemonius.

ICARDA is a broad-based center dedicated to the improvement of productivity of global drylands, especially range and croplands with improved genetic resources and crop/land management practices for farmers and grazers. Its scope includes the crops primarily in the West Asia-North Africa (WANA) region, and more recently, in the central Asia and Caucasus countries (CAC), collectively known as CWANA. ICARDA has focused its research and outreach on the major crops of the CWANA, including cereal grain crops and food and forage legumes. ICARDA has a relative long history of productive work with plant germplasm improvement. For example, since 1999, for the eight major crops studied at ICARDA, there were 163 new varieties released by the Center's NARS partners. ICARDA breeding teams develop the improved germplasm, distribute it to the national programs of developing countries and then monitor the performance of the improved germplasm and advise the national program scientists. Varieties are released by the national programs, not ICARDA, but the 163 varieties released had origins from ICARDA. The impact on farmer well-being is under study. In general, when a new variety is widely adopted, the enhanced productivity and improved value, is shown to have substantial positive impacts at the farm and community levels that are contributory to improved national economies. In turn, one of the Millennium Development Goals is to reduce global poverty by 50% by 2015; genetic improvement in the food supply is a relevant player in meeting this goal.

This review focuses on one of the major program areas of ICARDA. In its strategic planning exercises, it was recognized that the identification and use of genetic resources was the central element in its crop improvement program, but also that pest and disease management specialists and others were critical partners. Applications of molecular technologies at the Biotechnology Laboratory are also very much a part of plant breeding research. The Genetic Resources Unit maintains and distributes seeds for evaluation and use in hybridization in the breeding programs. ICARDA proposed to create a program encompassing the major disciplines related to crop improvement. This was labeled the Integrated Gene Management program, or IGM. A Center-Commissioned External Review was commissioned to discover the validity of the IGM concept and its value in an operation mode at ICARDA. This is a report of deliberations of a review panel that investigated the various topics relevant to the IGM concept.

The panel came to full endorsement of the concept and recommended in June 2004 that IGM become one of the Megaprojects of ICARDA's new strategic plan. Within a few months that recommendation had been accepted. Here we report on the deliberations that resulted in our endorsement of IGM as a coherent set of projects, including germplasm development, genetic resources, integrated pest management, biotechnology, seed production and management. We note the many accomplishments by the research teams and also a few constraints or limitations that, if addressed, would enhance the productivity in the various entities that we recommend to be included in IGM.

Chapter 2. ICARDA's Progress in Addressing 4th EPMR Recommendations

The Fourth External Program and Management Review (EPMR, 2000) of ICARDA made four recommendations that are relevant to the review of the IGM activities. The CCER Panel was asked to review progress made to date in addressing these recommendations.

1. *In the light of a diminished expertise in fungal pathology at ICARDA, the Panel recommends that the Center should strengthen its scientific capacity for strategic and applied research in crop pathology, and its pathology support to the Cereal and Legume Enhancement Programs.*

The EPMR recommended to strengthen scientific capacity for strategic and applied research in crop pathology and to strengthen its "pathology support to the Cereal and Legume Enhancement Programmes". This was recommended "in view of a diminished expertise in fungal pathology".

The response so far has been to hire a temporary a senior plant pathologist who is seconded from a local Syrian university to work on diseases of food legumes, including evaluation of breeding materials for the breeding programs. This position will be regularized with a P-level post in legume pathology, which will soon be advertised a second time.

Support from GRDC in Australia has been obtained for funding a post-doctoral fellow in legume pathology, advertised twice and yet to be recruited. The Panel wishes to elaborate, however, that in the EPMR recommendation the wording of "support to" implies that the pathology scientists will be outside of the crop improvement programs rather than an integral part of these programs as equal-stature scientists directly involved in these programs.

While this is commendable progress, the Panel considers that two P-level pathologists should operate from within the cereal and grain and forage legume crop improvement programs, one in each, as full members of a team to enhance directly the input of creative pathology research into the crop improvement programs for more rapid development of new, stably disease resistant germplasm for the NARS and hence useful to farmers. A broader discussion of pathology, along with entomology and IPM will follow in a later chapter.

2. *The [EPMR] Panel recommends that ICARDA should review the opportunities that may be available if it should expand its research role in malting barley in developing countries. In undertaking this review, the Panel would expect ICARDA to complete a social and economic assessment of the potential of work in this area to meet CGIAR priorities.*

Malt is the second largest use of barley, and malting barley is grown as a cash crop in a number of developing countries. Malting barley is not always associated with the production of beer. In Iran malting barley is mainly used to produce malt as a high-energy infant food and for non-alcoholic beer. In the highlands of Ethiopia, Eritrea, and the Andean region, malting barley is becoming an important cash crop for resource-poor farmers in areas where options are very limited, and barley is one of the few possible crops.

As the importance of malting to some NARS is increasing, the barley improvement program has:

- established a collection of well-known malting barleys and made it available to NARS
- conducted a survey in the Arsi Region of Ethiopia in collaboration with the Ethiopia Agricultural Research Organization (EARO). The survey showed that malt barley, in addition to its high value in terms of malt for breweries, is used to prepare traditional foods.

Presently the project is collaborating with the Al-Chark Brewery Company (Syria) in the development of low-cost screening techniques and in the identification of barley lines with good malting profile, and with Anheuser-Busch Co. (USA) on testing germplasm for malting quality.

ICARDA will undertake a more comprehensive review of the need for assistance in malt barley improvement, including an assessment of the potential social, nutritional, and economic returns of research into malting barley.

The CCER panel is satisfied that the IGM is taking appropriate steps before it embarks on a long-term and complex genetic improvement program. ICARDA should support these activities by making the needed resources available.

3. The [EPMR] Panel recommends that as a matter of priority ICARDA seek discussions with CIMMYT to develop mutually acceptable plans for the incorporation of doubled haploids and marker-assisted selection technologies in their joint durum wheat, spring bread wheat and facultative/winter bread wheat breeding programs.

ICARDA has engaged in discussions with CIMMYT concerning research of mutual interest and has prepared collaboratively funded projects. ICARDA has installed growth rooms for culture of doubled-haploids and transgenic plants. It now has an automated DNA sequencer. ICARDA has practically full capability for marker-assisted selection and doubled haploid research and is actively working with cereal and legume crops. The IGM panel is satisfied that the sense of the EPMR recommendation has been appropriately addressed. It considers that continued on-going discussions with CIMMYT are needed to clarify complementarity and not competition of the two centers' activities in wheat research in the CWANA region.

4. Given the reductions in the Genetic Resources Unit staff that have occurred, the demands placed on the Unit for collection and conservation activities, and so as not to threaten its existing activities, the Panel recommends the GRU make a concerted effort to seek additional P and RA level staff from either internal or external sources, if it is to undertake an expanded program of research in in situ conservation, prebreeding and the evaluation of collections using molecular markers.

The Center recruited a P-level regional coordinator for the Agrobiodiversity Project supported by GEF /UNDP. Also two P-level scientists were recruited, a Legume Curator and a Genetic Resource Coordinator for the CAC region. An NPO level scientist has been registered for a PhD in taxonomy. The 3-year grant (US\$ 1.5 million) to upgrade ICARDA's genebank has brought that facility to world-class status. ICARDA has responded positively to this recommendation and this will result in significant accomplishments in the areas of integrated gene management including conservation, characterization, and utilization.

Chapter 3. ICARDA Research Priorities for IGM

In 2004, ICARDA's research was organized within five themes according to CGIAR's principal outputs in:

1. Germplasm improvement
2. Germplasm collection
3. Sustainable production
4. Socio-economics and policy
5. Enhancing NARS

In its MTP 1998-2001, following an in-house priority assessment, ICARDA identified the following research areas for increased attention:

- ❑ On-farm water management, rangeland rehabilitation and management
- ❑ Small ruminant nutrition and management
- ❑ Agroecological characterization
- ❑ Land and water resource management
- ❑ Resource economics
- ❑ Prebreeding and biotechnology
- ❑ Farmer participatory approaches
- ❑ End-use quality and added value
- ❑ Faba bean prebreeding

In May 2001, ICARDA, in cooperation with NARS, conducted a survey to assess agricultural research priorities for the Central and West Asia and North Africa region (CWANA). Results of analyses from 278 respondents indicated the following: 45.7% for crop production, 25.5% for natural resource management, 13.7% for water and irrigation, 6.1% for livestock production, 4.7% for socioeconomics and policy, and 4.3% for food security.

In September 2003 an email conference was set up by CGIAR Interim Science Council to prioritize research activities in case extra funding would become available. Only about 15 scientists from NARS, NGOs, CGIAR, and ARI participated in this exercise over three rounds of iterations. The results indicated the following priorities: germplasm improvement (25.0%), strengthening NARS (23.4%), sustainable production systems and natural resource management (21.3%), policy and socio-economic research (15.7%), and germplasm conservation (14.6%).

At the time of this review in June 2004, ICARDA was revising its portfolio for approval by the Board of Trustees. The new portfolio was approved and now consists of six Megaprojects:

- ❑ MP1: Water scarcity and drought
- ❑ MP2: Integrated gene management
- ❑ MP3: Desertification
- ❑ MP4: Diversification
- ❑ MP5: Poverty and livelihoods analysis
- ❑ MP6: Knowledge management and dissemination

The panel is pleased the Integrated Gene Management (IGM) was adopted as Megaproject 2. Throughout this review IGM is used to represent the consortium of the Genetic Resources Unit, Germplasm Program, Biotechnology Laboratory, and Seed Unit, along with Plant Pathology and Entomology support to plant breeding, as a single operational Megaproject. We **recommend** that representation from other ICARDA Megaprojects, namely (1) animal nutrition with respect to breeding for improved forage quality and (2) socio-economics for risk assessment and impacts analysis related to adoption of ICARDA' discoveries.

Total resources available to ICARDA in 2004 were estimated at US \$23 million. Of these funds, \$10.6 million (46.1%) were assigned to sustainable production research, \$4.4 million (19.3%) were assigned to germplasm improvement, \$3.6 million (15.5 %) for germplasm collection, \$3.3 million (14.2%) for enhancing NARS, and \$1.1 million (4.8%) for policy and socio-economic research. While it is difficult to reconcile the resource allocations to the various activities and priorities identified from the various assessment activities, the 2004 allocation of funds to the high-priority activities seem to reflect reasonably the goals established in priority-setting exercises.

Future planning will need to consider the various components of the Integrated Gene Management Program, which will require some altered assignments of research activities by scientists; especially in the disease and pest sciences areas, where more formal allocation of efforts to gene management are necessary for the IGM program.

The Panel notes that the recent recruitment of P-level staff members on temporary funds in GRU is a positive sign of ICARDA's strong commitment to genetic resources and plant improvement. The Panel urges regularization of these positions as permanent internationally recruited scientists.

Taking into consideration the above priority-setting activities, the Panel is generally satisfied that the research priorities are acceptable; however the detailed priorities set by each Megaproject are critical. The Panel **recommends** in-house priority assessment of the different activities is necessary in view of the new and redefined efforts as envisioned for IGM. The panel **recommends** that funding Integrated Gene Management program should be increased, from the 2004 percentage of about 35% of the center's budget because of the need for increased support for host plant resistance research from plant pathology and entomology and for increased investment in NARS collaboration, impact and adoption analysis, and policy studies. The Panel **recommends** that conventional breeding should continue to be the basic approach and biotechnology a helpful tool for crop improvement.

Chapter 4. Progress in Gene Management: Continuum from Genetic Resources through Release and Adoption by Farmers

The CGIAR centers having responsibility for genetic improvement of crops have adopted the practice of providing improved genetic materials to NARS as nearly-finished varieties and diverse populations. ICARDA follows this practice and assists NARS with in-country evaluations of potential new varieties. New varieties are named and released within each country. Once identified as varieties for release, ICARDA will increase seed stocks and provide them to the NARS making the variety release on an as-needed basis. The Panel reviewed each of crop commodity plant breeding programs and was generally very pleased with the progress and productivity of the various programs. The following notes represent highlights and recommendations concerning these crop improvement activities, especially with regard to application of the research to the CWANA region, but also in other global dry areas, such as the Andean region for barley.

The panel adopted a logical outline of activities that are integral to the IGM concept and commodity crop breeding programs and relevant to evaluation of progress:

- ❑ Goals and selection criteria
- ❑ Availability of genetic resources
- ❑ Gene transfer methods
- ❑ Selection and evaluation, especially for pest management and product end-uses
- ❑ Distribution of genetic resources to NARS and other cooperators as advanced breeding lines or parental lines for NARS breeders
- ❑ Monitoring variety release and basic seed production by NARS
- ❑ Collaboration within ICARDA and with NARS, ARIs, and private sector
- ❑ Outputs and progress
- ❑ Limitations and constraints

ICARDA, since its formation, has adopted a core set of crops that are essential to the food and animal feed systems of the dry areas. Hence there is a long history of research on each of the selected crops. Over time, there have been changes in emphasis and an evolution of traits that are critical to improving and sustaining crop productivity, especially with respect to the identification of site- or region-specific limiting factors. For example, research on faba bean was discontinued and recently reinstated.

The panel received excellent reports for each crop from the plant breeding research leaders and from the leaders of the Genetic Resources Unit, Biotechnology Laboratory, Integrated Pest Management, and Seed Services that, for the most part, satisfied the evaluation criteria mentioned above. The crop improvement teams rely on active participation from combined efforts of all of these groups that collectively compose the IGM program as now constituted. The team visited laboratory and field sites at the Tel Hadya campus. This report presents highlights salient features of each of the crop programs followed by the panel's assessments and recommendations.

4.1. Barley

Barley is grown on 57 million hectares globally, about 33 million of which are in developing countries, including those of Central Asia and the Caucasus. Barley grain is used as feed for animals, malt, and human food. Barley straw is used as animal feed, for animal bedding and as cover material for hut roofs. After harvesting, barley stubbles are grazed in many developing countries. Malt is the second largest use of barley, and malting barley is grown as a cash crop in some 30 developing countries. In Tibet, Nepal, Ethiopia, Eritrea, and Yemen, Andean countries, North Africa; Turkey, Iran, Afghanistan, India, and Russia barley is used as human food either for bread-making (usually mixed with bread wheat flour) or for traditional recipes.

Barley is typically grown in marginal environments, often on the fringes of deserts and steppes or at high elevations in the tropics, receiving modest or no inputs. Because barley is grown in marginal environments and by resource-poor farmers, comparatively little progress has been made through conventional breeding approaches. The barley improvement project aims at a sustainable increase in barley productivity by adapting the crop to the different farming systems and end-uses with special emphasis in those areas where the crop is grown by resource-poor farmers. To achieve its objective, an improvement strategy was adopted that is based on selection for specific adaptation in space and wide adaptation in time.

Within the CGIAR system, ICARDA has a global mandate for coordinating and conducting research and development on barley. The barley program is coordinated at ICARDA/Aleppo. To fulfill the global mandate for the improvement of barley, ICARDA has a barley breeder posted in CIMMYT-Mexico to address the needs of the Andean region in South America, Central America, and Mexico. The panel reviewed the major achievements of the last 5 years and concluded that the barley improvement team has made remarkable progress in developing and delivery improved germplasm to NARS, exploring and implementing a new decentralized plant selection system with farmers, and in the discovery of new information about the genetics and pathology of barley. Some examples are highlighted below:

Genetic resources for resistance to major pests and diseases

Numerous biotic factors limit barley production. Host plant resistance has been identified in collaboration with pathologists, entomologists, virologists, and NARS scientists. Promising parental lines and hybrid populations have been assembled as genepools and made available to National Programs. These include sources of resistance to scald, barley stripe, loose and covered smut, barley yellow dwarf virus (BYDV), Russian wheat aphid (RWA), and barley stem gall midge (BSGM). Specific screening for resistance to BYDV for Brazil and Uruguay was started. New sources of resistance to BYDV (other than from *Yd-2* gene) were identified in Ethiopian landraces held at the Vavilov Institute and ICARDA.

Improved germplasm with higher and stable yield, better abiotic and biotic stress resistance and better quality

- Twenty-three new barley varieties were released by NARS since 1999 in 12 countries; four spring barley lines have been proposed for release in Azerbaijan and Kazakhstan; one winter barley line has been proposed for release in Kazakhstan.

- ❑ Locally adapted landraces from Latin America have been extensively used in targeted crosses designed with colleagues in the NARS, and segregating populations were distributed.
- ❑ Barley lines, derived from crosses with *Hordeum spontaneum*, were identified with resistance to extreme drought conditions.
- ❑ Resistance to BYDV and RWA was transferred into genetic backgrounds adapted to North Africa, and the resistant lines were distributed to National Programs; transfer of RWA resistance into Ethiopian landraces is underway.
- ❑ New sources of tolerance to cereal cyst nematodes (CCN) were identified in Syria and Australia. ‘Tadmor’, ‘Zanbaka’, *H. spontaneum*, and other landraces showed the best level of tolerance.
- ❑ Collaboration with the El-Chark Company (Syrian brewery) started with the objective of identifying barley lines with good malting profile. One line was identified as promising and is under multiplication at the ICARDA Tel Hadya farm.

Methodology to enhance adoption

- ❑ Participatory plant breeding projects have been initiated in several countries (Syria, Morocco, Tunisia, Yemen, Eritrea, Jordan and Egypt).
- ❑ Decentralized breeding started in both Central Asia and the Caucasus (CAC) and is underway in Latin America.
- ❑ Institutionalization and scaling-up of participatory plant breeding started in Syria by transferring the program currently conducted by ICARDA to the Ministry of Agriculture and Agrarian Reform of the Syrian Arab Republic, and by expanding the approach from Aleppo to other Provinces, to other crops (wheat, lentil, chickpea and cumin) and to a larger group of farmers. In Jordan, participatory research was institutionalized at the National Center for Agricultural Research and Transfer of Technology (NCARTT). The institutionalization is well-developed in the barley breeding program, and has been initiated in the durum and bread wheat breeding programs.
- ❑ Village-based seed production started in six villages in Syria with the distribution of locally-made seed cleaners. One mechanical seed cleaner was sent to Yemen.

Breeding methodology for stress environments.

- ❑ The genealogy management system and the data management system of the International Barley Information System (IBIS) are being developed. ICARDA hosted an ICIS training course attended by ICARDA, CIMMYT, and Turkish national program staff.
- ❑ To improve the precision of germplasm evaluation and testing, REML (residual maximum likelihood) method was introduced in 2000 and used routinely ever since. It is also used routinely by some NARS in Latin America. Two new GENSTAT programs were developed in collaboration with CBSU to analyze unreplicated trials with systematic checks and replicated trials.
- ❑ Increased use of doubled-haploid techniques (anther- and isolated microspore culture systems) for the development of mapping populations. One DH population was developed for study of the genetic bases for osmotic adjustment as a drought tolerance mechanism.

- Marker-assisted selection (MAS) was conducted for resistance to BYDV in F₂ populations.
- Linkage maps to identify quantitative trait loci associated with performance under stress conditions were developed in collaboration with Risoe National Laboratories in Denmark and the Cooperative Research Center for Molecular Plant Breeding in Adelaide, Australia.
- AFLP markers linked to the *Mlg* locus controlling resistance to powdery mildew were identified and mapped on chromosome 4H. The identified markers will be converted to sequence-tagged site (STS) markers, to be used for marker-assisted selection.

New methodologies disseminated

- More than one hundred reports, manuals, journal and newsletter articles were published and/or presented at International Conferences, and regional meetings. The participatory barley breeding project in Egypt was considered as “an excellent first example of full participatory adaptive research” in the Matrouh Resource Management Project by a World Bank Mission. An International Workshop on “Food barley improvement”, organized by ICARDA, FAO, and IRESA, and with the financial support of the OPEC Fund, was held in Tunisia more than 30 participants from 13 countries. During the workshop some of the major quality characteristics for barley as human food were identified.
- One project publication received the CG Chairman’s Science Award at ICW2000 for Best Scientific Paper.
- In Jordan and Yemen the participatory approach has been extended to other crops. The Challenge Program for Water and Food review panel stated “this approach is what the CP has been seeking. The new way of doing business”.

NARS research capacity strengthened

- More than 40 National Program scientists were trained on participatory plant breeding, molecular marker technology, exploitation of G x E interaction in plant breeding, and breeding for stress environments, breeding for biotic (diseases, insect, virus) stress resistance, grain quality, data and information management in a breeding program, data analysis of PPB trials using REML as individual trainees or in courses.
- Two graduate students are currently conducting their research in the barley project.

Future directions

- Marker-assisted selection (MAS) will be used in breeding for resistance to biotic stresses and possibly for cold tolerance. At the same time MAS will be made available to NARS.
- Research on grain end-use quality will be expanded, including malting, food uses, and nutritional quality (iron, zinc, and vitamin A).
- Research on salinity tolerance will be initiated in response to an increasing demand from National Programs, in collaboration with NARS and ARIs.
- Promotion of the efficient development and use of the barley information system (IBIS).

- ❑ Development of drought response gene expression profiles using drought microarrays.
- ❑ Identification of chromosome regions responsible for adaptation to drought.
- ❑ Extension of training on participatory plant breeding.

Observations and recommendations

With respect to specific improvements in barley, increased effort is **recommended** to expand production of barley with value-added end-use quality traits, including malting barley, food uses, and nutritional quality (e.g., iron, zinc, and vitamin A).

Accelerating the use of marker-assisted selection for biotic resistance traits is **recommended**.

Expanded research on abiotic stress resistance is **recommended** through collaboration with NARS and ARIs. Emphasis may be placed on genetics of these traits by QTL analysis, selection of parental stocks, development of populations for selection with aid of linked molecular markers, and accelerated development of IBIS for information management. The decentralized and farmer participatory plant breeding approach at ICARDA has high reputation globally. This approach may be expanded to additional NARS, however, the panel **recommends** greater attention be given to choice of parents (including landraces), mating schemes for population development, and central preliminary screening to reduce susceptibilities to pests and diseases before the materials are presented to farmers for selection. Consideration for seed multiplication and distribution of farmer-selected varieties needs clarification to the farmers from the outset to avoid confusion about farmer ownership and commercialization rights. The in-country training and demonstration activities are excellent and should be expanded.

4.2. Wheat

The Panel concludes that the wheat research at ICARDA has been effective and productive. Two issues emerged: The programs of ICARDA and CIMMYT must be reconciled with respect to traits, geographic emphases, evolving plant breeding methodologies, genetic resources management, and administrative aspects. Second, the panel concludes that the bread wheat programs could be combined into a single program to effect efficient use of genetic resources, personnel use, and management leadership.

4.2.1. Durum wheat

The CWANA region is the global leader in durum wheat production, producing more than 90% of the global crop. Durum is used in quite different ways from common or bread wheats, thus the many food preparations from durum wheat enrich diversity in the diets of people in many countries. For example, in Ethiopia some 20 types of food and drink are made from durum wheat. Durum is a traditional food crop in the CWANA with annual per capita consumption of about 200 kg. Much of the planted area of durum is subjected to wide variation in environmental factors and much of the soils are marginal for agricultural production. In addition, there are numerous diseases and insect pests that limit productivity. Thus, durum wheat is a prime target for ICARDA in its efforts to improve the well-being of the CWANA people; it also has potential in the dry areas of Latin America. The durum wheat breeding team conducts a broad-based genetics and plant breeding program which has been very productive in developing and publishing new information, distributing improved breeding lines to many NARS, collaborating effectively with ARIs and NARS, and providing training opportunities for NARS scientists and

others for short-term, or long-term periods as graduate students. Highlights of this program, along with some observations and recommendations are presented below.

Genetic resources

The crossing block (CB) of the durum breeding program has 848 parental lines comprising durum landraces (40%), improved and released varieties (40%) from different durum-producing countries, and wild relatives (20%). The wild relatives comprise primitive tetraploids (7%), diploids (3%), and *Aegilops* species (10%). These materials are screened for grain quality, drought, and disease and insect resistance.

More than 6,000 crosses were made, of which 60 % were improved \times improved durums for germplasm development, 28% were improved varieties \times landraces hybrids, and 12% for durum \times wild relatives. Marker-assisted selection is used to select parental lines for gluten strength, yellow pigment, alpha-lipoxygenase, and drought tolerance (carbon isotope discrimination); and has been initiated for resistance to Hessian fly, leaf rust, and fusarium head blight. More than 200 markers (conversion of RFLPs, COS, and candidate genes) were developed for the chromosomal regions of interest.

Durum genetics and genomics research

The ICARDA durum group has developed two mapping populations. The JKC population of recombinant inbred lines from the cross Jennah Khetifa \times Cham1 was developed to address genetics of adaptation; biotic stresses, mainly leaf rust, powdery mildew, and *Septoria tritici*; and grain quality. The second population, MDM, Omrabi5/*T. dicoccoides*// Omrabi5 was designed to investigate genetics of drought, yield potential, and grain quality.

- The JKC map was constructed with 504 markers: 170 RFLPs, 186 SSRs, 136 AFLPs, 8 SSPs, three known genes (one pyruvate decarboxylase and two lipoxygenases), and one morphological character (grain color).
- The MDM map was constructed with 124 SSRs, 149 AFLPs, and 6 SSPs.
- Markers were developed to saturate regions of interest (drought and quality) using directly ESTs or ESTs with the homology with rice genomic sequence for COS markers; as well as primers for drought candidate genes, and SNPs.
- QTLs for genetic effects and for QTL \times E interactions were identified for drought tolerance by carbon isotope discrimination, provitamin A content, protein content, gluten strength, and flour extraction rate.

Selection and evaluation

On annual basis more than 12,000 segregating populations and around 2000 advanced lines are tested under 15 contrasting environments for water availability, temperatures extremes, and hotspots for diseases and insects. A double-gradient selection technique was developed to image the abiotic and biotic stresses in the CWANA for the temperature extremes varying from cold to hot and for the water regime varying from severe drought to well-irrigated conditions. The pedigree method of selection is used to select individual plants from the populations that were selected across sites and environments.

Distribution of materials, parental lines, segregating populations, and advanced lines

Multi-locational testing is conducted for specific nurseries, performance trials, and screening nurseries conducted by the pathology and entomology groups are distributed annually to more than 50 sites in the CWANA region. Syria, Morocco, and Algeria are the major receiving countries, followed by Turkey, Tunisia, Egypt, Iran, Jordan, and Lebanon. The nurseries are targeted to different agroecological environments. The continental areas receive the highest number of sets, followed by temperate and high elevation areas. The results of uses by NARS show that the International Durum Yield trial (IDYT), Mediterranean Durum Yield trial (MDYT), International Durum Observation Nursery-Continental Areas (IDON-CA), Mediterranean Durum Observation Nursery-Temperate Areas (MDON-TA), and Mediterranean Durum Observation Nursery-High Altitude Areas (MDON-HAA) nurseries are the main sources of varieties for release and adoption. Very little use is made from the segregating populations. More than 90% of the varieties released were from the two trials, IDYT and MDYT. The national programs select the genotypes from ICARDA durum trials and nurseries and test them under their conditions for 2 to 3 years. The promising genotypes are advanced to on-farm trials under farmers field conditions for another 2 to 3 years before release. NARS sometimes also request large numbers of promising varieties in their respective countries. Several countries have released ICARDA durum genotypes and the impact of these releases is reflected in the increase in the production; e.g. Syria has moved from a durum importing to an exporting country; it exports 1.5 to 2 million tonnes or more; a similar trend is found in Turkey and Morocco. The adoption by farmers of improved durum cultivars is very high in the region and is around 95% in Syria, Morocco, and Tunisia. It surpasses 75% in Turkey and Algeria.

Observations and recommendations

Three major durum-producing countries have achieved production levels beyond their internal needs. This is a sign of effective research and high adoption rate of improved varieties and production practices. Detailed analyses of these how these accomplishments were achieved are a very interesting appropriate research activity for the Center's impact studies. What is the impact of the excess production in some countries on the economy and food availability in other countries of the CWANA region? What are the implications for ICARDA's research agenda?

As ICARDA is a world-leading center for durum research, it is of paramount importance to reinforce further the success of the durum wheat in CWANA countries by responding to the NARS needs. The panel **recommends** that the durum program should continue to focus on drought, pest resistance, and grain quality research in collaboration with NARS and ARIs.

The current durum program is presently concentrating on NARS with large durum growing areas; however, in the future the panel **recommends** that more attention should be given to smaller production areas, such as Ethiopia, Jordan, Egypt, Lebanon, and Libya.

The panel suggests that training young NARS scientists in relevant applications of molecular-based breeding methods should be continued in collaboration with the Biotechnology Laboratory.

4.2. 2. Spring Bread Wheat

The main agroecological wheat production zones in CWANA Region have been identified along with the biotic and abiotic constraints to production in each zone. In the past, research has

focused on low-rainfall areas, but now the needs of all wheat-growing areas in CWANA, ICARDA's regional mandate, will be addressed. The expansion of the scope for ICARDA's wheat improvement program was due to a change in the role of CIMMYT in wheat research in this region in 2003. Prior to that time CIMMYT stationed two wheat breeders at ICARDA, but withdrew support for winter and spring wheat breeding in 2003. Then ICARDA, recognizing the great need for sustained wheat breeding research in the region, employed the two breeders and assumed responsibility for wheat breeding in CWANA. The future definition of CIMMYT and ICARDA collaboration is still under discussion.

In the last five years 35 spring bread wheat varieties have been released in collaboration with NARS in 10 countries in the region. In CWANA the adoption of improved spring bread wheat cultivars is generally very high (90%). As a result of the increased productivity, it is anticipated that adoption of these cultivars will contribute to improving the livelihood of farmers and secure food for the fast-growing population.

A breeding methodology was developed which emphasizes selective use of locally adapted cultivars and wheat wild progenitors coupled with multilocation testing. Because rust epiphytotics are common throughout the CWANA, a strategic change was adopted, i.e., a shift from using single-gene resistance to multigenic resistance, which is believed to be less vulnerable to shifts in virulence in the pathogen. This resistance is seen as slow progression of the disease and reduced symptom expression. These plants show little damage and small yield loss. While some yield loss is realized, the likelihood is reduced of total loss of the crop due to a pathogen race change that makes single-gene resistance ineffective against a new race. The panel agrees with this strategy and suggests that major gene stacking using molecular markers may be an efficient means to build multigenic resistance.

Enhancing the efficiency of breeding

Plot layout designs have been improved to increase the precision of estimating yield and other traits. The wheat breeding program has adopted spatial analysis to detect environmental effects and incomplete block treatment designs, such as alpha lattice, that enhance the efficiency and accuracy of detecting differences among tested cultivars under the highly variable field conditions in rainfed sites.

Increased use of synthetic wheat has been implemented to introgress variability from both *Ae. tauschii* and durum wheat into bread wheat to broaden the genetic base for biotic (Hessian fly, septoria leaf blotch, and Sunn pest) and abiotic (drought, cold, and heat) stresses in spring bread wheat.

Doubled-haploid techniques permit reaching homozygosity in one plant generation. This technique has been adopted to permit selection and fixation of traits in a single step. It is also being used to develop mapping populations. Currently three populations are under development (Hessian fly, yellow rust resistance and heat tolerance).

Elite germplasm, combining high yield and tolerance/resistance to prevailing biotic and abiotic stresses, has been developed and annually is made available to National Programs through six Spring Bread Wheat International Nurseries, namely: Regional Wheat Crossing Block (RWCB), Wheat Observation Nursery for Dry Areas (WON-D), Heat Tolerance Observation Nursery (HTON), Regional Wheat Yield Trial-Moderate Rainfall (RWYT-MR), Regional Wheat Yield

Trial-Low Rainfall-Continental Areas (RWYT-LR-CA), and Regional Wheat Yield Trial-Low Rainfall-Sub-Continental Areas (RWYT-LR-SC).

Sources of resistance to the major diseases and insect pests limiting wheat production in CWANA have been identified in collaboration with pathologists, entomologists, and NARS. These include sources of resistance to rusts (leaf, stem and stripe rust), septoria leaf blotch, Hessian fly (HF), Russian wheat aphid (RWA), and barley yellow dwarf virus (BYDV). These sources are being used in breeding and annually made available to National Programs.

Recently, grain end-use quality has received greater attention in CWANA Region. Eighty-one adapted elite lines suitable for flat and raised bread have been identified and are being used in the crossing programs, as well as being made available to NARS. Similarly, in response to the needs of the private sector, the program has embarked on identifying genotypes suitable for biscuit-making. Currently 24 lines are under multiplication.

Hands-on training in breeding and selection techniques, exchange of visits, workshops and consultancies were conducted to enhance and upgrade human resource capabilities of NARS scientists. In addition to graduate student training (3 M.Sc., 1 Ph.D.), in the past 5 years, of 30 researchers from NARS in the region have benefited from training in spring bread wheat (SBW) improvement at ICARDA.

Constraints

The spring wheat program staff identified the following constraints to progress in the breeding program.

- ❑ Operational budget: The operational budget of the program ranks 5th among all seven MTP in GP. This does not reflect the importance of crop in CWANA. Support staff: The program has only two support staff (one B.Sc. level and one technician). Four more support staff are needed.
- ❑ Support to end-use quality research: Both equipment and technical support are not up to the required standards. Currently only 25% of the time of the cereal technologist is dedicated to SBW. There is a need to furnish the Quality Lab and assign full-time quality research to SBW.
- ❑ Pathology support: Currently only 25% of the time of the cereal pathologist is dedicated to support the program. A full-time cereal plant pathologist is required.
- ❑ Physiology Support: Currently physiology support is based on informal collaboration with the University of Barcelona. Stress physiology is crucial to making advances in dryland research. A full-time stress physiologist is required.

Observations and recommendations

Judging by the number of released varieties by NARS, 35 in the past 5 years, the joint spring wheat program has been very effective. The Panel hopes that this rate of productivity can be sustained.

The Panel concurs that ICARDA could concentrate its efforts on varietal improvement in:

- ❑ Favorable irrigated spring wheat environments of CWANA.

- Semiarid (Mediterranean rainfed) spring wheat environments of CWANA.

Serious limitations in number of support staff were reported by the scientists. The panel is sympathetic to those needs and **recommends** that the staffing needs be considered jointly with the needs of the winter wheat program.

In view of the limitations on personnel, the panel **recommends** that the spring and winter wheat programs should be merged to share technical support and for coordination of activities.

Recommended research priorities should address quality parameters of relevance to needs and preferences of the targeted populations, genetic analysis, host plant resistance, and epidemiology.

4.2.3. Winter and Facultative Bread Wheat

The International Winter Wheat Improvement Project (IWWIP), a partnership between CIMMYT, ICARDA, and Turkey's national agricultural research system, and in close collaboration with Iran and other NARS in Central Asia and Caucus countries, are continuing to develop and identify improved facultative and winter wheat varieties and associated technology to achieve yield increases, reduce yield fluctuation, and improve grain quality in the CWANA.

Achievements

- 21 winter/facultative wheat cultivars selected from IWWIP were released by NARS during the last five years, in Turkey (13), Iran (1), Afghanistan (1), Uzbekistan (1), Georgia (1), Kyrgyzstan (3), and Pakistan (1).
- 28 cultivars Turkey (5), Armenia (5), Kazakhstan (2), Uzbekistan (1), Georgia (1), Kyrgyzstan (8), Turkmenistan (5), and Azerbaijan (1) have been selected for release or are currently under seed multiplication, selected from the IWWIP.
- Improved germplasm has been made available to NARS through international nurseries, and used by a large number of cooperators in the region. The project distributes six international FWW nurseries annually to 120 breeding programs in 50 countries annually. This reflects improved targeting of germplasm for specific growing conditions in CWANA.
- The newly-bred wheat cultivars and associated improved production technology are adopted by farmers through active joint participatory work among researchers, extensionists, and farmers. The new technology increases farm grain yield by up to 30% or more, and reduces production fluctuation, a typical characteristic of rainfed wheat. One supplementary irrigation at planting was found to prevent the risk of poor stand or crop failure and to lead to substantial yield increases (up to over 50%) in the cold-winter highlands of Iran.
- Germplasm resistant to yellow rust, a devastating disease in the highlands, increased significantly. Genetic stocks with yellow rust and Russian wheat aphid resistance have been developed, used in crossing programs and made available to NARS.
- Project effort continued to contribute to wheat research in CAC through the promotion and support of technology transfer, by conducting on-farm demonstrations and by ensuring fast seed multiplication of promising new lines and conducting traveling workshops. The resulting new varieties, and their respective production technologies, were subsequently transferred to farmers.

Observations and recommendations

The winter/facultative wheat breeding program has shown good performance in terms of providing NARS with advanced breeding lines that have been released (21) or in final testing and seed multiplication stages (28). These are products of the long-standing CIMMYT-ICARDA International Winter Wheat Improvement Project centered in Turkey. The program is familiarly known as “TCI”, Turkey, CIMMYT, and ICARDA, because of the extensive and long-term collaboration in Turkey.

The panel **recommends** that for the winter wheat breeding program, ICARDA could delineate its efforts in winter wheat breeding based on two major types of environments, namely:

- Favorable irrigated winter/facultative wheat environment: example site, Bishkek, Kyrgyzstan.
- Semiarid rainfed winter/facultative wheat environment: example sites, Tel Hadya, Syria for facultative wheat and Marageh, Iran for winter wheat.

Advanced methods of characterizing wheat environments using GIS should be adopted in concert with GIS specialists at ICARDA.

The panel strongly **recommends** that ICARDA and CIMMYT continue their discussions and forge an alliance to clarify their respective complementing responsibilities for genetic improvement of wheat in the dry areas.

Because of the lack of improved production technology in most of the winter and facultative wheat areas, especially in CAC countries, decentralization of the project activities will be strengthened by working more closely with NARS, and through them, with farmers so that the seed of new cultivars is delivered along with an improved, adoptable technology.

Because of the need to intensify agriculture in most countries of Central Asia and the Caucasus (CAC), the project should place special emphasis on providing high-yielding and early-maturing germplasm to accommodate double-cropping systems (where wheat is grown in the winter followed by maize or cotton in the summer).

The project maintains close collaboration with Iran (through the ICARDA/Iran Project) by providing segregation populations of targeting crosses including Iranian landraces and varieties.

In view of the limitations on number of personnel, the panel **recommends** that the spring and winter wheat programs could be merged effectively to share technical support and for coordination of activities.

4.3. Legumes

Legumes are an integral component of the agrobiodiversity scene for food and fiber. In both cropping and in grazing systems legumes have an appropriate place, e.g., crop rotation and rotational schemes. ICARDA has good research and reasonable coverage of breeding needs for food legumes. For forage legumes, some outstanding research has been accomplished and the products adopted. As noted later, the panel believes that forage legumes are underinvested and that the livestock component is not well represented.

4.3.1. Food legumes

Food legumes supply much of the protein needs for the human diets of the CWANA population. It is critical that the production status of each of the species be monitored for vulnerability to pests and that production levels do not decline, but increase. The panel became aware of economic issues with food legume production: (1) For the spread of improved cultivars, secured marketing and market prices should be sufficient to pay a profit to the farmer. In most countries there is no support price for these crops and farmers are dependent on the market price at the time of harvest, which in general is not favorable to the farmer. In case the production of these crops is high the farmers do not know whether they will receive any benefit from increased production. Such fluctuations are discouraging the farmers in many countries, including Syria, Iran, Iraq, India, Pakistan, Morocco, and Uzbekistan from increasing their planted hectares to the improved varieties; (2) the second factor is that seed supply and distribution system are erratic and inadequate, respectively. ICARDA has a Seed Unit that has effectively addressed this problem and must continue to provide guidance to national seed systems.

The review team was pleased with the progress in the food legumes breeding programs. Some recommendations are made below.

General Recommendations: Food Legumes

- ❑ Consider investment to introduce underutilized species into the farming system and diets of CWANA populations, peas for example.
- ❑ Develop markers for various traits and use marker-assisted selection as appropriate.
- ❑ Participatory approaches with farmers and NARS should be systematically studied for comparative purposes with non-participatory methods.
- ❑ There is an immediate need to study the adoption and impact of released cultivars in different countries.
- ❑ For central Asia, a number of varieties have been released, but seed production, processing, and distribution systems should be given higher priority.
- ❑ The faba bean improvement program should be strengthened by recruitment of a P-level plant breeder
- ❑ The legume program requires one plant pathologist and one entomologist.

Genetic resources

The GRU has a rich collection of food legumes, totaling 33,477 accessions. Roughly one-third of these are each represented by domestic and wild accessions of chickpea, lentil, and faba bean. About 70% of the accessions have been characterized. Electronic inventory, passport, documentation, characterization, and evaluation data are available on ICARDA-wide intranet and SINGER internet database. In the past, hardcopy catalogs were produced, but now all information is conserved electronically. Molecular data will be collected in the CGIAR Generation Challenge Program and also conserved on electronic database and fully integrated with passport and other information, including evaluation data.

4.3.1.1. Chickpea

Chickpea has a higher value than lentils in CWANA. Even a small area can provide a valuable source of income for small landholders. Chickpea is planted in spring making use of residual moisture from winter rains and is therefore grown in the more favorable, higher rainfall areas. Local landraces are highly susceptible to cold and *Ascochyta* blight. Spring planting largely avoids losses from these risks. However, the area planted to chickpea depends on the rainfall received in any given season and therefore the chickpea area fluctuates dramatically from year to year. Thus, the challenge has been to find means to improve chickpea production without exposing the farmers to greater risk. Research has focused on developing germplasm and associated technologies for winter planting. Winter planting has several advantages: (1) it can double the efficiency of rain water use; (2) the crop has a higher numbers of pods/m² at maturity, (3) it is suitable for mechanical harvesting; and (4) the crop can be harvested earlier than the traditional spring sown crop, thus avoiding terminal drought and heat stress.

Breeding

For chickpea, pedigree and bulk-pedigree selection for the improvement of biotic and abiotic stress resistance and seed size are routinely used. In the past few years the program gained experience with single-pod descent in F₂ and F₃ generations, followed by pedigree selection, resulting in greater efficiency for selection for increased seed size and resistance to biotic (*Ascochyta* blight and *Fusarium* wilt) and abiotic stresses (drought and cold).

Transgenic plants with Bruchid resistance have been developed in Australia. ICARDA will participate in evaluations, but release of transgenic lines will depend on NARS policy for transgenic crops.

Development of recombinant inbred populations for resistance or tolerance to *Ascochyta* blight, *Fusarium* wilt, cold, and drought are in final stages for applying marker-assisted selection. Molecular markers will be identified in the near future.

Selection and evaluation

Chickpea germplasm and breeding materials are evaluated for major stresses including cold, drought, *Ascochyta* blight, *Fusarium* wilt, cyst nematode, and leaf miner. Methods have been developed that are effective for detecting resistance or tolerance. Some highlights of accomplishments:

- ❑ *Cold tolerance*: *Cicer reticulatum* has a much higher level of resistance to cold than cultivated chickpea and this resistance has been successfully transferred to chickpea.
- ❑ *Ascochyta blight*: Tolerant varieties have been developed and distributed to NARS. Cold tolerant and *Ascochyta* blight tolerant materials have helped in advancing the planting date from spring to early spring or late winter, making the crop suitable for mechanical harvesting due to tall plant type. Various NARS have identified high-yielding adaptable cultivars from the materials supplied to them and released these for general cultivation in their countries.
- ❑ *Fusarium wilt*: Resistant lines have been shared with NARS. In 2004, a large-seeded line with resistance to *Fusarium* wilt and *Ascochyta* blight was released in Tunisia.

- ❑ *Cyst nematode*: There is no resistance to cyst nematode in the cultivated chickpea, but it has been transferred from *C. reticulatum*, a wild species, and the lines were registered in *Crop Science* for use by the NARS. This is the first report of the transfer of cyst nematode resistance from wild to cultivated chickpea.
- ❑ *End-use quality*: The canning industry in Chtaura, Lebanon is procuring large quantities of seed of the released lines from Syria and Lebanon for preparing boiled chickpea and *hummos bitehineh*.

International distribution of breeding materials

ICARDA distributes various kinds of germplasm to NARS breeders, but does not make formal release of varieties for the NARS. For countries with active breeding programs, sets of lines selected as parental lines are sent with information about the valuable traits of each of the lines. This includes advanced lines selected for specific traits at ICARDA and accessions from the GRU. Segregating populations in F₃ generation are sent for NARS breeders to observe under various conditions where plants can be selected for advancement in the local breeding program. NARS are most interested in elite improved materials because these lines are most likely to be suitable as new varieties with very little further research.

Release and impact

The NARS select lines that meet their needs. After a period of registration tests, the local registration authorities approve varieties for release for general cultivation. ICARDA sometimes assists with on-farm and demonstration trials for faster adoption of improved lines. All varieties, either from materials selected from nurseries supplied by ICARDA or developed by NARS, are released by NARS. ICARDA breeders and the Seed Unit have provided basic seed for multiplication of NARS-approved varieties.

The participatory approaches, whereby farmers observe the field trials and report their preferences to the breeders, aid in rapid adoption of new varieties. In case of chickpea about 175, 000 ha in countries in the CWANA region are planted with varieties released from ICARDA's involvement. The main countries with adoption of these cultivars are Turkey, Syria, Iran, Lebanon, and Jordan. Work in the CAC countries began rather recently and good progress is being made toward development of new chickpea varieties.

Chickpea for winter planting

ICARDA has worked closely with NARS in the development of winter chickpea production technology. As a result, high yielding, *Ascochyta* blight resistant and cold tolerant cultivars developed at ICARDA have been released by NARS for winter or early spring cultivation in Syria, Lebanon, Iraq, Cyprus, Georgia, Azerbaijan, Morocco, Afghanistan, Iran, and Turkey. ICARDA scientists have had great success in developing chickpea for winter planting. Economic analysis of the adoption of kabuli chickpea using partial budgeting techniques conducted in Syria and Morocco indicated a net benefit of 45-65% from the winter-planting technology. An added benefit to poorer farmers is that winter-sown chickpea can be harvested a month or more earlier than the traditional spring-planted landraces, which usually coincides with barley and wheat harvest. By temporal separation of chickpea and wheat harvests, the farmers take advantage of dispersing family labor over a longer time, realizing off-peak lower wage rates

for hired labor, higher chickpea prices before the glut of spring-sown harvest, and a cash income that allows them to pay off debts and to finance the upcoming cereal harvest.

In Syria, more than 40,000 ha of spring-planted chickpea have already been replaced by new cultivars and an integrated management package. With two new large-seeded varieties, 'Ghab 4' and 'Ghab 5', resistant to *Ascochyta* blight, it is hoped that spring planting will soon be replaced by winter-planted crops to the extent of 60,000 ha. Overall, about 175,000 ha of kabuli chickpea are winter or early spring planting, leading to about 30% increase in production in Syria, Turkey, Jordan, Lebanon, Cyprus, Morocco, Iraq, and Algeria. Additionally, in Iran about 15,000 ha are planted in the autumn and the seed remains ungerminated during low temperatures and germinates in early spring when snow has melted (called *entzari* planting).

Observations and Recommendations

The chickpea program has and remains a cornerstone of ICARDA's crop breeding efforts. This program could benefit from additional professional and technical staff. See General recommendations.

4.3.1.2. Lentil

Lentil is grown largely on small farm holdings in rotation with barley in the drier areas and with wheat in the more favourable areas of WANA, and in rotation with rice or other cereals in India and Bangladesh. Harvesting is largely not mechanised, except in Syria and Turkey. On smallholdings family members can do harvesting; on larger holdings hand-harvesting is largely done by hired labor, primarily women. As labor costs have increased, lentils have fallen out of favor with larger farmers, who have shifted to cereal monoculture. ICARDA has worked on the development of mechanised harvest systems to reduce the cost of harvest and to encourage expansion of the crop, while at the same time ensuring continuation of employment opportunities through associated activities in collecting, threshing, and cleaning the crop.

Half the world's lentil area is in South Asia (India, Bangladesh, and Pakistan). A network of researchers is targeting relay sowing of lentil into rice paddy and the development of early lentil to sow after long-season rice. These two production systems offer scope for a major expansion in production of lentil.

Lentil suffers from cold and drought, much like chickpea, and also is affected by *Ascochyta* blight, *Fusarium* wilt, rust, stemphylium, and viruses. The ICARDA breeding program has addressed each of these abiotic and biotic stresses. Cold tolerant and *Ascochyta* blight resistant materials have been developed and are in use for winter planting in high altitude areas in Turkey, Iran, Afghanistan, Pakistan, and Ethiopia. Winter plantings of lentil have given almost double the seed yield compared to spring-planted lentils. Various NARS have identified high-yielding cultivars from the materials supplied to them and released these for general cultivation in their countries.

Breeding and selection

Breeding methods for lentils parallel the methods used for chickpea. Hybridization followed by bulk advancement of hybrid populations and pedigree selection system are used. Decentralized participatory selection in on-farm trials is applied in a few of the NARS. Marker-assisted selection will be applied when markers and trait linkages have been identified. Evaluation

environments for environmental and biotic stresses have been identified and used effectively by collaborating ICARDA and NARS scientists. Examples:

- ❑ Cold tolerance: Ankara, Turkey, and Gazvin and Maragheh, Iran under field conditions.
- ❑ Drought tolerance: Tel Hadya, ICARDA in boxes, Breda, Syria and Ethiopia under field conditions.
- ❑ Very good success has been achieved for drought and cold resistance.
- ❑ Fusarium Wilt: Tel Hadya, ICARDA in a 'sick plot', and Giza, Egypt.
- ❑ Ascochyta blight: Islamabad in Pakistan and Pantnagar, India, under field conditions using artificial inoculation by debris and spore suspension.
- ❑ Rust: Ethiopia, India, and Pakistan under field conditions.
- ❑ Stemphylium: Bangladesh under field conditions.
- ❑ Quality evaluation: Seed size, seed protein content, cooking quality parameters are evaluated from samples taken from advanced NARS Participatory Varietal Selection or International Nursery trials.

Parental lines, segregating populations, elite lines, and international nurseries are assembled at ICARDA and shared with collaborating NARS.

Release and impact

See chickpea discussion for evaluation and variety release procedures that are applicable to lentil. In Syria, Turkey, Yemen, Bangladesh, and Nepal farmer participatory approaches are being used for final evaluation of lines to be proposed for release through NARS procedures.

- ❑ A recent study assessing the impact of ICARDA's improved lentil germplasm in seven countries (Bangladesh, China, Egypt, Iraq, Jordan, Pakistan, and Syria) showed that the yield advantage of improved varieties over the local cultivars ranged from 16 to 45% (mean 25%). The adoption of improved lentil varieties ranged from 12 to 30% among lentil growers.
- ❑ In some of the poorest and most marginalized areas of CWANA, winter-hardy lentil lines with resistance to ascochyta blight and high yield potential have been identified from ICARDA-generated germplasm in high altitude regions of Turkey, Iran, Afghanistan, and Pakistan. Some of these lines have been introduced at farmer's level and these are expected to shift lentil cultivation from traditional spring sowing (with poor yield) to winter sowing.
- ❑ Improved production packages developed by ICARDA in collaboration with NARS (seed rate, sowing date, weed management, harvest mechanization, weed control, and other practices) that aid in realizing the full yield potential of improved cultivars have been adopted by farmers in a number of countries.
- ❑ The on-going collaboration between Bangladesh and ICARDA has greatly contributed to poverty alleviation, nutritional security of the rural poor, and the country's economy. With the cultivation of improved varieties and adoption of appropriate production technologies, Bangladeshi farmers are producing an additional 28,000 t of lentil annually,

worth US \$12.6 million. An impact analysis found that the extra income earned from lentil cultivation was used by farmers to buy clothes (15.6%), other personal items (19.5%), rice and other foods (9.9%), for cultivation of the next crop (16.6%), children's education (14.8%), medical treatment (13.7%), to pay down loans (5.8%), and other purposes (4.1%), such as purchase of cattle, threshers, to make brick houses, and repair farm implements.

- ❑ With the release and dissemination of rust resistant and high yielding varieties ('Alemaya', 'Gudo' and 'Ada'a') lentil cultivation is expanding in Ethiopia.
- ❑ Three recently released red lentil varieties in Syria have been adopted by farmers.
- ❑ In Nepal, improved varieties have moved to the Mid-hills where these varieties are aiding in meeting protein requirements of the tribal people.
- ❑ In Morocco, Lebanon, and Tunisia improved varieties/lines have been identified from ICARDA-supplied materials, and some have been adopted by farmers.

Observations and recommendations

Lentil is important component of the food production system and diets of people in the CWANA region. Research should be continued to protect the gains already made in plant type and resistance breeding. General recommendations made above are appropriate for lentil program.

4.3.1.3. Faba Bean

Faba bean breeding had been curtailed at ICARDA and resumed on advice of a previous review team. The program is small and staffed by a short-term appointee. The current goal is not to produce advanced lines practically ready for release in NARS, but to develop lines with desired traits for distribution to NARS for further breeding, selection, and evaluation.

Faba bean is widely used in the CWANA for both green and dry beans, is grown in rotation primarily with wheat in dryland systems globally, with potatoes and cereals in the Andean region, and under irrigation in Egypt and Sudan. The crop has a high yield potential, which is often reduced by biotic stresses. The main target of the ICARDA faba bean improvement program is to introduce host-plant resistance into populations to raise actual farm yields closer to potential yields and hence boost rural incomes, and to reduce environmental pollution by lowering the need for agrochemical application.

Genetic Resources, Gene Transfer, Selection, and Evaluation

Genetic resources of faba beans are documented and available from the GRU. Evaluations for foliar diseases (chocolate spot, rust, and *Ascochyta* blight) and *Orobanche* (plant parasite) resistance are done by the breeders and plant pathologists.

Gene transfer is achieved using conventional breeding methods (pedigree, pureline, and backcross methods). Segregating S₁ populations are mainly used by NARS for recurrent selection.

During the past 6 years, 71 breeding lines for resistance to chocolate spot, 36 for resistance to *Ascochyta* blight, and 24 lines combined resistance to both diseases, and 84 lines for resistance and/ or tolerance to *Orobanche* were developed at ICARDA.

Selection and evaluation for resistance to foliar diseases and self-fertility are being done under heavy natural and artificial inoculation with chocolate spot disease in screen houses at Lattakia, Syria and for *Ascochyta* blight resistance under open-field conditions at Tel Hadya. Selection and evaluation for resistance to *Orobanche* are being achieved under heavy natural infestation with *Orobanche* at Tel Hadya; however, evaluation for quality and other agronomic traits (aphid resistance, tolerance to water-logging, soil-borne diseases, and drought) are evaluated in cooperation with NARS in Egypt, Sudan, and Ethiopia.

Distribution of parental materials is done through international nurseries for improving the local adapted lines, or direct release as a new varieties, such as 'ICARUS' (BPL 710) in Australia, 'Giza Blanca' (Reina Blanca) in Egypt, and 'S.L.L.' in China.

Impact

- With the cultivation of improved faba bean varieties, yield increases of 20-35% over the local varieties have been achieved in China, Egypt, Ethiopia, Morocco, Sudan, Tunisia, and Yemen.
- Multiple disease resistant varieties with high yielding ability and early maturity had an impact, not only on yield but also on reducing the need for chemical inputs. For example, the new resistant cultivars for chocolate spot and rust diseases released in the Nile Delta of Egypt, reduced the fungicide application by about 50%, and *Orobanche*-resistant varieties reduced the use of herbicide by about 50%.
- An early maturing variety, resistant to chocolate spot and rust, which is used to precede cotton in the rotation in Egypt, resulted in doubling the farmer's income and reduced nitrogen fertilizer requirements for the subsequent cotton crop by 40%.
- In Middle and Upper Egypt faba bean is successfully grown intercropped with sugar cane.
- A newly released cultivar, derived from ICARDA material, responded very well to calcareous soil, due to its low water requirement, in the western desert of Egypt and yielded 50% more than the local varieties. These varieties continue to be disseminated to farmers through the national technology transfer program.
- Results of a study of the adoption of faba bean production packages in Egypt and Sudan indicated that adoption rate by farmers was higher for older, more experienced farmers and those with higher levels of education. The introduction of high yielding, disease/pest resistant and early maturing varieties improves soil fertility, reduces the need for fertilizers, herbicides and pesticides, allows relay and intercropping within cereal and cotton rotations, and avoids yield losses attributable to late season drought and/or heat stress.

Observations and Recommendations

Faba bean is a widely grown crop in the CWANA and it is important that ICARDA continues to provide germplasm development and to monitor the status of the crop across the region. Although progress seems minimal, the program has been running for only a few years. The panel **recommends** that a permanent position should be established for faba bean; perhaps the

position could be shared with another legume position (grain or forage). See General recommendations for food legumes.

4.3.2. Forage Legumes

The forage legume improvement project is directed to improvement of animal feeds by producing new varieties and encouraging the improvement of crop rotations and other on-farm management practices. The work involves collaboration with ICARDA animal scientists and numerous NARS. The research program is primarily dedicated to several species of *Vicia* and *Lathyrus*. Targeted traits include reduction in anti-nutritional factors (ANF), resistance to the parasitic plant broomrape (*Orobanche*), cold tolerance, non-shattering, and erect plant type,

The main thrust in improving on-farm feed production has been the promotion of rotations that include alternative improved germplasm of forage legumes (e.g., species of *Vicia* and *Lathyrus*) in rotation with barley.

Extensive work has been done in identifying legume species and promising lines that are adapted to the low rainfall areas of the region which have been tested on-station and in farmers' fields.

Major achievements from plant breeding and variety introduction:

- ❑ 19 cultivars of *Vicia* spp., and *Lathyrus* spp. were released in several countries of CWANA and Australia. This has encouraged farmers to reduce cereal monoculture by introducing a nitrogen-fixing forage legume into the crop rotation, thereby improving soil properties.
- ❑ The discovery of broomrape (*Orobanche*) resistant lines of wooly-pod vetch (*Vicia dasycarpa*) and Ochrus chickling (*Lathyrus ochrus*) is a significant development for areas where *Orobanche* is an endemic problem.
- ❑ The release of 'Velox' narbon vetch (*Vicia* sp.) having low sulfur-containing amino acid gamma-glutamyl-S-ethenyl cysteine (GEC), which reduces palatability of the grain for livestock for dry areas between 200-250mm annual rainfall, is of a great value as a crop for grain and straw for winter fattening of lambs.
- ❑ High-yielding lines with low levels (< 10 times) of antinutritional factor, β -cyano-alanin (B-CA) in common vetch was developed and is new on farmers' fields.
- ❑ For high elevation areas, improved varieties of *Vicia panonica*, *V. dasycarpa*, and *V. ervilia* with improved cold tolerance have been developed in collaboration with the national programs of Turkey, Pakistan, Iran, China, and CAC countries.
- ❑ The released variety 'Kuhak-96' of wooly pod vetch is cultivated in Balochistan, Pakistan on approximately 20,000 ha and recently 3 tonnes of seed were dispatched from ICARDA to Afghanistan for winter-sowing.
- ❑ Non-shattering and erect types of common-vetch have been developed that increase grain yield, reduce the problem of volunteers in subsequent cereal crops, improve the opportunity for mechanical harvesting, and increase flexibility in time of harvest. Increased grain yield results in reduced price of seed and allows farmers to increase the area cultivated with common vetch and so increase livestock production, for example in Iraq, Jordan, Turkey, and Syria.

- The identification of self-regenerated amphicarpic (underground) vetch (*Vicia sativa* ssp. *amphicarpa*), and improving its herbage yield played a great role in rejuvenation of marginal non-arable lands. For example, in Turkey about 400 ha of non-arable marginal lands are now cultivated by underground vetch. Underground vetch is also tested in marginal lands in Armenia, Iran, Syria, and northwest coast of Egypt, and Jordan.
- Improved lines of grass pea with less than 0.1% β -ODAP of the neurotoxin were developed using conventional breeding methods and tissue culture techniques. Seeds of these lines were tested on-station and on-farm. Quantities of seeds were distributed to farmers. Evaluation of improved lines of grass pea has shown stable lines with low neurotoxin, high yield potential, and tolerance to powdery mildew, aphids, and broomrape. A package of technology includes improved lines, appropriate sowing date and zinc sulfate basal dressing was developed and is ready for tests on farmers' fields. This will support the release of some low neurotoxin lines as cultivars.
- Research activities on grass pea have been reactivated in Ethiopia and are in progress through the financial support of DFID. Ethiopian scientists who have been trained at ICARDA through this project are heavily involved in activities of grass pea improvements in Ethiopia.

Promotion of rotations that enhance on-farm feed production

The alternative utilization of forage legumes (forage mixtures, hay-making, grazing, or harvesting at maturity for stored feed) and their advantages in terms of livestock production have been demonstrated through on-farm trials.

Results from Iraq, Jordan, and Syria showed average daily weight gains of lambs grazing *Vicia sativa* ranging from a low of 90g to a high of 275g. Results from Iraq showed an average increase in milk production of 175 g/ewe/day from grazing on *V. sativa*.

Recognizing that availability of seed has been a constraint to the wider adoption of *Vicia*, some countries have initiated an informal seed production system, in association with farmers, for seed production and distribution.

The barley/vetch rotation provides a stable and sustainable farming system, enhances crop/livestock integration, utilizes the land more intensively and improves soil fertility. The barley/vetch rotation produced 20-60% more dry matter than barley/fallow and barley/barley. The introduction of common vetch into rotation provided high quality feed. Barley grown following vetch gave 32% more grain yield than barley following barley.

Monoculture barley has been reduced by 50-85% in Jordan, Syria, Iraq, Turkey, Lebanon, and Cyprus, and the best returns to farmers were from barley/'Baraka' common vetch rotation, which involved direct grazing in Ramtha, Jordan where the annual rainfall rarely exceeds 250 mm. In Iraq, the area of common vetch and narbon vetch increased from 5,000 ha to 180,000 ha in the last 10 years. In Syria, El-Bab area, where rainfall is around 300 mm, the economics of sheep grazing on Baraka (# 715) common-vetch was good. Grazing eliminates the need for weeding, where selective herbicides are not available. The daily weight gain with a grazing intensity of 30 lambs per hectare has been about 230 g/lamb without supplementary feeding. The average weight of 5-month-old lambs raised on vetch was about 40 kg, the best market weight.

Training

The project provided many training opportunities (individual training, in-country training, short-term training, traveling workshops on forage legume germplasm evaluation, breeding methodologies, selection criteria and quality assessments). The project also offers opportunities to graduate students from developed and developing countries to conduct their research within the project research activities. One M.Sc. and one Ph.D. completed their degrees.

Observations and recommendations

The forage project has utilized collaborations with NARS and NGOs to validate the genetic materials that have been developed. It certainly has demonstrated major progress in genetic improvement of usual agronomic traits, but also for antinutritional factors. The project also interfaces with natural resources conservation with respect to plants, but also as contributing to reduced soil erosion and improved quality due to biological nitrogen fixation. The forage legume component of IGM management is fully consistent with general goals for the CGIAR in global natural resources enhancement.

Among its major achievements was the discovery of grass pea with very low concentrations of the neurotoxin that is debilitating to humans. In Ethiopia, for example, the consumption of seeds by humans is high when food supplies are limited. The low-toxin plants are expected to be introduced and hence should provide relief from this condition. Underground vetch is another very interesting discovery for self-seeding of rangelands. Focus should be continued on the needs of major target environments, with effort increasing for cold high-elevation areas, where good progress has been made in increasing cold tolerance of *Vicia sativa* and *V. panonica* for Iran, Turkey, and CAC alpine grasslands, and Gansu province, China.

The panel offers the following recommendations that, in our view, will make the program even more effective.

- ❑ There would seem to be practically unlimited prospects for selecting, improving, and distributing additional forage species. The panel **recommends** further exploration and evaluation of endemic species with the GRU that may enhance rangeland animal productivity if managed properly or reintroduced, but at the same time, evaluate and prioritize the needs for research among the species currently under evaluation.
- ❑ The panel was pleased with the collaboration of the plant and animal scientists in the forage program; we suggest formal collaboration of animal scientists as associates with the IGM group.
- ❑ Professional staffing for forages is too small to exploit the many opportunities for research on this very large component of the landscape. We **recommend** a minimum of 50% assignment of an additional plant breeder, perhaps shared with *Vicia faba* breeding.
- ❑ The panel believes there are many unmet opportunities in forage improvements, including ANFs and **recommends** that ICARDA, in its strategic planning process, develop in-depth partnerships with NARS and ILRI.
- ❑ Continue to develop and disseminate improved germplasm with desirable traits for testing in collaboration with NARS. The panel encourages expansion of farmer participation in germplasm evaluation as a methodology to relate the projects objectives to those of the farmer and vice-versa. An informal farmer-based seed distribution system

may be the most effective means of increasing adoption of new varieties; therefore, the panel **recommends** that farmers be encouraged and instructed to engage in community-based on-farm seed production and distribution of improved lines and cultivars.

Chapter 5. Participatory Crop Improvement

Traditional plant breeding methodologies are used at ICARDA, but innovations in experimental design of breeding trials and data analysis were introduced. New methods for selection using tagged genes and transgenic plants are being developed in cooperation with other labs. Traditional hybridization and selection schemes have been modified to invoke direct farmer participation by visual selection in plots on farmers' fields.

The method is labeled decentralized-participatory plant breeding (D-PPB) and is described in a popular leaflet, published in 2004 and in a book chapter (Ceccarelli and Grando, 2004, in press). The objective is to develop an alternative way of conducting plant breeding that is much more efficient and brings new varieties to farmers more rapidly than conventional center-based breeding programs, and ensures that the new varieties are adapted to farmers' specific environments and end-uses. The program is based on the following concepts:

The trials are grown in farmers' fields using the host farmer's agronomic practices.

- ❑ Selection is conducted by farmers in farmers' fields, so farmers are the key decision-makers.
- ❑ The traditional linear sequence Scientist to Extension to Farmer is replaced by a team approach with scientists, extension staff, and farmers all participating in the selection phase for variety development.

In a conventional breeding program, the most promising lines are released as varieties, their seed is produced under controlled conditions (certified seed) and only then farmers decide whether to adopt them or not. In many developing countries the process results in many varieties being released and only a small fraction being adopted. The major consequence of the D-PPB concept is that the process transforms the delivery phase of a plant-breeding program.

Under D-PPB, it is the initial farmers' preferences which drive the decision of which variety to release. As a consequence adoption rates are expected to be higher and more rapid, and risks are minimized, as intimate knowledge of varietal performance is gained as part of the selection process. Last, but not least, the public investment in seed production is nearly always paid off by farmers' adoption.

The ICARDA barley program has pioneered the development and use of a farmer participatory selection method whereby bulked-hybrid populations are planted in farmers' fields and subjected to selection by the farmers and breeders according to the farmers' ideotype for an improved variety. The farmers and breeders make selections and the bulked seeds from selected plants are planted back with the same farmers. At the same time, single progenies from the farmer-selected bulk population are taken to ICARDA/Tel Hadya for study and advancement as progeny rows. This process is repeated and eventually the populations that have produced progeny that have superior performance traits and can be multiplied for distribution as a variety. The farmer-selected bulk populations are advanced for three generations and the resulting population, which could be called a modern landrace, can be retained by the farmer(s) as their new variety. The

progeny row-derived materials can be considered for release as pure-line varieties, but there is no assurance that these purelines will have the same adaptation characteristics as the bulk-population-derived materials developed at the farmer's fields. This process permits selection for adaptation in a relevant environment to the local farmers, rather than selection at a research center where selection for specific adaptation might not fit a wide range of local conditions of the farmers.

The program started in Syria in 1996 and was expanded to Tunisia, Morocco, Yemen, Eritrea, Egypt and Jordan. Four types of impact have been observed:

- ❑ Variety development: new varieties were spontaneously disseminated from farmer to farmer as early as three years after starting the program. In Syria several thousand hectares are planted with two varieties and about 30 varieties are under farmers' large-scale testing.
- ❑ Institutional: in several countries, D-PPB has generated considerable changes in the attitude of policy-makers and scientists towards the benefits of participatory research, and generated changes in national breeding programs.
- ❑ Farmers' skills and empowerment: the cyclic nature of the D-PPB programs has considerably enriched farmers' knowledge, improved their negotiation capability, and enhanced their self esteem. By the same token, scientists (breeders) have been enriched by the farmers' indigenous knowledge of the crops they grow and the environments in which they grow them.
- ❑ Enhancement of biodiversity: different varieties have been selected in different areas within the same country, in response to different environmental constraints and users' needs.

Participatory barley breeding has been implemented in 28 villages in Syria and in a small number of villages in Jordan, Egypt, and Eritrea. Collectively, these trials represent a D-PPB program.

The barley breeders are convinced that D-PPB is an effective system for selection of locally adapted varieties. A key to the effectiveness is that the basic gene-pool given to farmers has appropriate gene content for meeting the farmers' needs. The breeders create variable populations by hybridizing parents, including local landraces and improved varieties. The breeders anticipate the needs at the farm level and select parental lines for hybridization that have traits that complement the perceived needs of the farmers.

The method of plant breeding used is bulk-pedigree, in which the bulks (starting with F_3 bulks, each derived from a different cross) are yield-tested in farmers' fields for three years: the F_3 bulks in the first year, the selected F_4 bulks in the second year, and the selected F_5 bulks in the third year. The selection is done by farmers under their own conditions. In parallel with the yield testing, pure-line selection within the selected bulks is conducted on-station where the head-rows from selected bulks are tested for resistance to diseases and insects. Thus, the farmer-maintained bulks do not have the benefit of elimination of pest and disease susceptible component lines as identified in on-station screening trials. This deficiency can be rectified by conducting F_3 progeny-row selection for disease and pest resistance before submitting the bulk populations to farmers. After progeny row selection the remaining lines can be bulked for planting in the farmers' fields.

ICARDA scientists point out that the method exploits the genetic variance between and within populations, and produces varieties with three different types of genetic structure: (i) populations that have similar genetic structure as landraces of self-pollinated crops, (ii) pure-lines, and (iii) mixtures of pure lines. The method can be adjusted by National Programs to produce the type of finished product that can be officially released as a variety. Or the varieties can remain with the farmers without official release because they are the owners of the populations.

The populations taken to farmer-fields are bulked populations of single-crosses. Each bulked cross is planted in a replicated trial and farmers and breeders visually evaluate each plot and select single spikes that are planted plant to row at ICARDA headquarters. The selections are also bulked and planted again with the same farmers. The results are twofold: (1) improved bulk populations that represent the farmer-selected varieties and (2) pureline varieties that can be released for farmer use that are genetically uniform (pure-lines). The system, as described, seems to rely on national seed system processes for approval and release of varieties. Could the national authorities deny release of varieties as selected by the farmers? If so, or if the seed authorities require that the uniform pure-lines be used as the seed source for the new varieties, the benefits of genetic diversity within varieties, as widely known for landraces, will be lost. Local seed authorities in some countries will not approve mixtures as varieties, hence the need for uniformity. Clarification is needed on these points because if a farmer or a group of farmers have participated in the breeding process on their farms, they could legitimately claim ownership and control production and distribution of the varieties. The panel believes that transparency is required regarding intellectual property rights of farmers, seed authorities, and NARS regarding varietal production, distribution, and sale of seed when the farmers are invited to participate in an ICARDA-led activity, likewise if a NARS initiates on their own, such a farmer participatory enterprise.

Observations and recommendations

The panel **recommends** that, if not already in place, a “white paper” study group be assembled to recommend acceptable policy that can be adopted by NARS for release of farmer-developed varieties that is consistent with benefit-sharing as described in the International Treaty for Plant Genetic Resources for Food and Agriculture.

The panel **recommends** that, when possible, the farmer-developed varieties retain genetic variability within the released varieties, as is found in typical landrace varieties, as a means to buffer against annual climate or biotic stress variances.

Recommended that IGM should extend PPB approach to include more crops within the communities’ cropping systems as well as to consider the broader issues associated with adopting a PPB approach. Farmers should play a major role in the formulation of the research agenda, management, and evaluation of the trials.

Recommended that IGM should consider the establishment of a permanent training unit on participatory plant breeding.

Chapter 6. Genetic resources at ICARDA

The genetic resources of ICARDA are its legacy, should the center close or be made inoperable by any means, only the genetic resources are vital--the Number 1 priority for ICARDA.

The Genetic Resources Unit (GRU) is a full-service unit for *ex situ* conservation of plant genetic resources. It has more than 131,000 accessions of crops and wild species for which ICARDA has responsibility as defined by the CGIAR. The accessions are mainly from the CWANA region, but also from many other countries having extensive dry areas. Its activities include all of the functions in genetic resources management. Its facilities for cold storage are being upgraded and in the view of the panel are sufficient. But with respect to collections, GRU has problems. It was without a legume curator for several years, the documentation work fell behind and seed stocks were not monitored sufficiently resulting in misidentifications that were eventually corrected with the help of a Visiting Scientist. The GRU has one curator on core funds; other staff should be provided regularized appointments.

GRU also makes and observes field plantings that simulate *in situ* conservation and, for the past three years has coordinated and managed a four-country project on *in situ* conservation and restoration of agrobiodiversity. Examples of the activities of the GRU since 1999 are given below as indication of the scope of the activities of the GRU. It is meant to function to provide genetic resources support to ICARDA and NARS plant breeding programs as well as serve as a CGIAR component for the “genetic resources in-trust” initiative of UN/FAO. Hence, ICARDA has designated certain of its genetic resources as being “in-trust” and ICARDA is the conservator, but not owner, of those genetic resources.

Germplasm collection and acquisition

- ❑ Collection missions to Armenia, Azerbaijan, Georgia, Jordan, Kazakhstan, Kyrgyzstan, Lebanon, Romania, Syria, Tajikistan and Turkmenistan yielded 2801 unique accessions of crop wild relatives, landraces and pasture and rangeland species. The new barley and wheat wild relative and landrace accessions collected from central Asian countries were screened at Germplasm Program and sources of resistance to yellow, leaf, and stem rusts and septoria were identified.
- ❑ The number of accessions curated by GRU reached 131,191 in May 2004, an expansion of 11,679 in the past five years. These include 4,467 accessions of cereal and food legume received from the Vavilov Institute for Research (VIR), St Petersburg, Russia and collected mostly by Vavilov himself and his colleagues in the former USSR and CWANA region.

Germplasm regeneration

- ❑ 36,329 accessions were multiplied in the field or greenhouse and seed availability of difficult species has significantly increased. With 2003/2004 season multiplications more than 93% accessions held at ICARDA genebank will be available for distribution.

Documentation and characterization

- ❑ 30,600 accessions were characterized in the field or plastic house for a number of agro-morphological descriptors and data entered into the database. In addition, 8,400 accessions were planted in the field or plastic house for taxonomic identification.

- ❑ During 2000-04 the functionality and content of the GRU database have been enhanced through normalization, filling the gaps and accuracy of information in records regarding the collections sites. Now the database holds geo-referenced data for over 69,000 accessions, i.e. 56% of total holdings. The geo-referenced site data were linked with spatial databases and 67 new environmental variables were generated. The new information for 56,729 accessions, including 53,004 of CWANA and 3,636 Mediterranean Europe origins, was added to GRU/ICARDA databases and is now available to NARS and others.
- ❑ A global register of barley with nearly 180,000 accessions from 43 major genebanks was developed.
- ❑ Ecogeographic database was developed for GEF/UNDP agrobiodiversity project.

Molecular characterization and genetic diversity

- ❑ 550 accessions of wheat and barley were characterized by molecular markers.
- ❑ Two types of microsatellite markers, simple sequence repeats (SSRs) and expressed sequence tag (EST)-derived SSRs, were tested on a set of barley accessions to assess the most effective method for studying genetic variation in wild and cultivated barley populations. The EST-derived SSR markers developed in cultivated barley were found to be polymorphic in wild barley, cultivated landraces, and improved varieties. Eight out of nine functional primers were polymorphic across the accessions studied. The EST markers showed differences. The EST-derived SSRs provide a resource that can be exploited quickly in barley genetic studies.

Ecogeographical characterization

- ❑ Subsets of 150 wild and cultivated barley and 160 wheat and wheat wild relative accessions collected from drought-affected sites were established using 67 GIS-generated ecological variables.
- ❑ A subset of 750 bread wheat accessions collected from drought-affected sites were identified for inclusion in combined ICARDA, VIR, and Australian bread wheat collections.
- ❑ The newly generated GIS information was also used in univariate and multivariate statistical analyses of the ecological relationships among 25 wild-relative species of wheat. The study was based on more than 12,000 accessions from more than 3,500 different collection sites with known geographical coordinates. These accessions are held in genebanks throughout the world, and are included in the Wild Wheat Global Database, which was developed by IPGRI and ICARDA, and which is upgraded and maintained by ICARDA.

Distribution of genetic resources

- ❑ 76,648 seed samples were distributed on request from GRU/ICARDA genebank, including 60% external shipments outside ICARDA. The remaining 40% were sent to ICARDA Germplasm Program scientists.

Facility development

- ❑ New cold store construction was planned and is under construction.

Seed health

- ❑ 100% of incoming and outgoing seed samples are tested for seed-borne pathogens. During 2002, approximately 12,000 incoming and 18,000 outgoing seed samples were tested at the GRU Seed Health Laboratory.
- ❑ 1042 accessions were tested at ICARDA's Virology Laboratory for the presence of seed-borne viruses and cleaned from the viruses.
- ❑ The GRU assisted in developing seed health laboratories and provided training in Iran, Afghanistan, and United Arab Emirates.

Pre-breeding

To facilitate the use of wheat wild relatives in conventional breeding programs, a wheat pre-breeding activity started at GRU/ICARDA in 1994. Preliminary results of gene introgression from wild diploid progenitors, *Triticum urartu*, *T. boeoticum*, *Aegilops speltoides* and *Ae.*

tauschii, and tetraploid *T. dicoccoides* into common and durum wheat are encouraging. Crosses with wild diploid *Triticum* spp. yielded high variation in plant and spike morphology. Synthetic hexaploids were produced from crosses of a local durum wheat landrace 'Haurani' with two *Ae. tauschii* accessions originating from low-rainfall sites. Backcross progenies with agronomically desirable traits, i.e. high spike productivity, short plant stature, earliness, drought tolerance, and high number of fertile tillers were identified in crosses of durum wheat with wild *Triticum* spp. and in a cross of one of the hexaploid synthetics with a locally adapted bread wheat, 'Cham 6'. Resistance to yellow rust was found in durum wheat crosses with the three wild *Triticum* spp. and *Ae. speltoides* and leaf rust resistance was identified in crosses with *T. boeoticum* and *Ae. speltoides*. These results confirm work by others that wheat progenitors may be a valuable and readily accessible source of new genetic diversity for wheat improvement.

- ❑ Homogenous durum wheat lines of BC₁F₇ or BC₂F₆ generations with stripe and/or leaf rust resistance were transferred from wild *Triticum* species and *Aegilops speltoides* are available for genetic studies and use in crop improvement.
- ❑ Genetically highly diverse material was produced from crosses 10 bread wheat varieties with two new synthetic wheats. The advanced lines are being used by GP bread wheat breeder in crosses with improved varieties.
- ❑ 458 lines developed at GRU/ICARDA from wide crosses were distributed to the breeders, entomologists, and plant pathologists in the ICARDA cereals program.

Outreach assistance to genetic resources programs in NARS

- ❑ The Uzbek Research Institute of Plant Industries genebank was upgraded with ICARDA's assistance.
- ❑ Establishment of the Kyrgyz, Tajik, Azeri, and Georgian genebanks was started and basic facilities are in place.
- ❑ A web page for the CAC plant genetic resources programs was constructed.
- ❑ GR units were set up in all collaborating countries.

- ❑ Nationwide inventories of *ex-situ* collections were completed in three countries and partially complete in the rest.
- ❑ 12 scientists participated in intensive English language courses.
- ❑ Agroecological Zoning system was developed for Northern Hemisphere.
- ❑ Continuous surface databases for long-term averages for monthly temperature rainfall and daylight hours were developed.
- ❑ Lat/long data for more than 3,000 bread wheat landrace collection sites were established for VIR and Australian collections.
- ❑ Software was developed to enable access to combined VIR, ICARDA, and AWCC bread wheat landrace database on a website.
- ❑ Collaboration with the Vavilov Institute for Research was established. More than 2,500 accessions of species within ICARDA's mandate were received from VIR.

Assistance to Afghanistan

A training course on germplasm collection and the use of global positioning systems (GPS) was given to 13 participants from the provinces of Kabul, Kunduz, Baghlan, Takhar, and Badakshan. These participants included representatives from the Aga Khan Development Network (AKDN), the Kunduz Rehabilitation Agency (KRA) and ICARDA staff stationed in Kabul and Baghlan provinces. The course was given by GRU staff, and covered the various aspects of germplasm collection missions. The course included a practice collecting mission to an area 20 km west of Kabul. At the end of the course, four collecting groups were formed, each consisting of two course participants, a representative of the provincial Ministry of Agriculture and Livestock, and a driver. Separate germplasm collection missions were then scheduled for 2-3 weeks in June 2003 in the provinces of Kunduz, Badakshan, Baghlan, and Takhar.

In 2003, GRU provided assistance to identify a suitable site for Afghanistan's new Genetic Resources Unit. It was recommended that a functional genetic resources unit be established at Badam Bagh research station in the city of Kabul. A new building at this site has been planned.

In situ conservation activities at ICARDA: GEF project

ICARDA recognizes the need to complement its *ex situ* conservation activities by a strong component of *in situ* conservation and sustainable use of genetic diversity within its natural habitats and in farmers' fields. The most significant *in situ* conservation research project that ICARDA has undertaken was proposed, with ICARDA leadership, to UNDP as a Global Environment Facility (GEF) dryland agrobiodiversity project within the predominant agroecosystems representative of the Fertile Crescent region.

This regional project is executed by the National Research Institutes in Jordan (NCARTT), Lebanon (LARI), and Syria (GCSAR) and by the Ministry of Agriculture and UNDP/PAPP in Palestine. ICARDA is responsible for the regional coordination and networking among the national components and provides, in cooperation with IPGRI and ACSAD, the needed technical backstopping and training. The project aims at promoting *in situ* conservation of landraces and wild relatives of cereals, lentils, forage legumes, *Allium* species, and fruit trees (fig, olive, almond, pistachio, plum, apricot,) originating from the Fertile Crescent center of diversity. Field

activities are conducted at two targeted areas in each country covering diverse ecosystems ranging from desert in Muwaqqar, arid lands in Khalil, Aarsal, and Sweida to high elevation and semi-arid areas in Ajloun, Jenin, Ham/Nabha, and Al-Heffeh. The holistic approach adopted is based on knowledge of the status and trends of local agrobiodiversity and its major factors of degradation, the demonstration of low-cost technologies and management actions, the investigation of add-value technologies and alternative sources of income, capacity building of farmers and agricultural agents, increasing general public awareness, and development of policy and legislation reforms.

- ❑ The project was approved for three years, a very limited time-frame in the panel's view. Significant progress has been made as exemplified by the following activities:
- ❑ Significant shift in the use of native species of fruit trees for afforestation and reforestation efforts of the Forest Departments. More than 3.5 million seedlings were multiplied actually from an initial number of less than 20,000 in 1999. More than 230,000 seedlings were planted at the project sites so far. In case of Palestine, the project initiated an informal seed increase program that has provided 35 tons of seeds of landraces of wheat, barley, lentil, and vetch to more than 450 farmers. The Departments of Forestry have issued an order to its different services to use indigenous species in their reforestation programs.
- ❑ The project has provided technical assistance for the creation of seven private and two community fruit tree nurseries for multiplying mainly landraces. The project provides diverse seeds of targeted species to the government nurseries. It has contributed more than 480 accessions of cereals and food and feed legumes to ICARDA and National genebanks.
- ❑ The national research institutes in Jordan, Lebanon, and Syria have created national agrobiodiversity programs which include both *in situ* and *ex situ* conservation. The Ministry of Agriculture in Palestine and the Department of Forestry created Agrobiodiversity units for the first time.
- ❑ 15 sites were selected for *in situ* conservation under natural habitats and their management plans are being developed and will be discussed with major stakeholders for their designation. Sites for natural reserves were identified for consideration by national authorities.
- ❑ Training was provided to more than 2,800 farmers and agricultural agents, including 34 M.Sc. and PhDs. More than one-third of the trainees were women who had previous training on value-added technologies and generation of alternative sources of income.
- ❑ Collaboration with the Ministries of Education to introduce biodiversity conservation within the education system including extra-curricular activities. Methodological and scientific guides are developed for the teachers.
- ❑ Diverse public awareness supports were used, including documentary films, environmental clubs, websites, and newsletters.

This project has broad and comprehensive goals. It has demonstrated that a multi-country effort can be effective. Other CWANA countries have expressed interest in developing this approach within their genetic resources conservation programs.

Observations and recommendations

The GRU is a very good unit--- world class in scope, operations, innovative research and service to NARS. The GRU will need to increase its attention to policy issues driven by the international Convention of Biological Diversity and the International Treaty for Plant Genetic Resources in Food and Agriculture. The issues are Center-wide, but it is appropriate for GRU to take leadership on two main issues: access and benefit-sharing. ICARDA should encourage inter-center attention to these issues through the CG Systemwide Genetic Resources Program.

As the strategic and action plans for IGM are developed, the panel strongly **recommends** stronger participatory interrelationships of genetic resources specialists, plant breeders, pest management scientists, agronomists, and end-use evaluation specialists through specific research goals and action plans. This is especially critical for GRU as it endeavors to serve the needs for genetic resources by the breeders and pest management group.

The study of molecular genetic diversity by the GRU is entirely appropriate and critical for understanding diversity, devising collection and exploration expeditions, and advising the crop improvement teams on promising genetic resources for use in breeding. The panel **recommends** greater communication and collaboration with the biotechnology laboratory and durum wheat molecular laboratory.

The *in situ* conservation research, particularly the GEF project, but other GRU research as well, is **recommended** as a long-term component of ICARDA's Integrated Gene Management Program and extended to other countries in the CWANA region under ICARDA's leadership, taking advantage of the expertise developed and partnerships already existing with NARS. This will enhance the development of sound scientific methodologies and the harmonization of the policy and legislation actions on agricultural biodiversity. This could be achieved through strengthening the GRU staffing and through new projects on *in situ* conservation aspects.

The GEF project has emerged as a global model for *in situ* conservation and enhancement of natural and agrobiodiversity; it is strongly **recommended** that a means be found to extend this project. Conservation of agrobiodiversity, as demonstrated within the GEF project, is warranted and **recommended**, especially for enhanced socio-economic participation.

ICARDA has increased staffing at the GRU, as recommended in the recent EPMR report; however, with temporary positions that the panel **recommends** should be funded on permanent basis as soon as possible. The quality of some of the GRU collections had degraded because of vacancies in curator positions and lack of supervision to technical staff.

Chapter 7. Integrated Pest Management: An Integral Component of IGM

The IPM group, often referred to as Plant Health Group, includes research activities of three laboratories in IGM: Cereal and Food Legume Entomology, Cereal and Food Legume Virology, and Food Legume and Cereal Pathology. The IPM group collaborates in research and development as it pertains to pests and provides assistance services to the plant breeding and GRU groups within ICARDA. For example: hosting visiting scientists from NARS, ARIs, and co-adviser to graduate students; screening breeding lines and GRU wild relative accessions for reaction to major pests and diseases; seed testing for viral diseases; and individual training courses as requested by NARS.

Beyond providing services to GRU and the plant breeding programs, the IPM group develops and evaluates pest control methods using various integrated pest management strategies in collaboration with NARS and ARIs. This includes pilot on-farm site implementation studies of IPM packages and assistance with on-farm field days and joint pest surveys. NARS scientists carry out joint evaluations of breeding lines and special nurseries for detecting pest resistance. Significant collaborations with other CGIAR centers and universities in North America, Europe, and Australia have been conducted through special project funding of projects of mutual interest.

IPM activities are undertaken by NARS partners while the IPM group provides back-up information and recommendations on implementation of selected options, and ensures the establishment of links between research, extension and farmers at national levels.

Training of graduate students

The IPM group has provided training and in return has expanded its scope in research with an extensive group of M.S. and Ph.D. students that carry out field and lab research within the IPM agenda at ICARDA and complete their degrees at their home university. IPM staff are formal co-advisers to the students' degree program. Some examples:

- ❑ Ph.D. students from the University of Damascus conducting research at ICARDA and University of Manitoba, Canada (Toxin research on tan spot disease)
- ❑ Ph.D. student at Risoe, Denmark (Molecular characterization of Eritrean barley population-host genotypic variation and association with resistance to blight diseases)
- ❑ Ph.D. students from the University of Aleppo conducting research at ICARDA and INRA-Rennes, France (molecular genetic and phenotypic characterization of diversity in cereal cyst nematodes)
- ❑ Ph.D. students from SPII-Iran conducting research in collaboration with at ICARDA and PBI-Sydney, Australia (Isogenic line development and molecular characterization of stripe rust populations and inheritance of resistance to stripe rust)
- ❑ Ph.D. students from Ethiopia at the Jordan University conducting research at ICARDA and ETH-Zurich, Switzerland (Molecular characterization of *Rhynchosporium secalis* from Ethiopia, Jordan, and Syria)

- Ph.D. students from University of Tunis conducting research at ICARDA and ETH-Zurich, Switzerland (Molecular characterization of *Rhynchosporium secalis* from North Africa)

Screening for disease resistance

Screening methods have been developed to evaluate of large numbers of lines for field reaction (adult growth stages) in plastic greenhouses and growth chambers for seedling evaluation and testing resistance levels to biotypes/races of fungal diseases and insect pests.

Resistance sources

IPM group has identified sources of resistance to diseases and insect pests in breeding lines, landrace cultivars, and wild relatives. Sources are made available to breeders and distributed to NARS on request.

- Effective resistance genes to wheat stripe rust were determined for CWANA (*Yr5*, *Yr15*, *Yr3V*, and *YrCV*). *Yr5* and *Yr15* were found to be effective resistance genes in wild relatives while *Yr25*, *Yr26*, and *Yr28* were non-effective. Effective genes in winter wheat are *Yr10*, *Yr3V*, and *Yr3N* and in spring wheat and facultative winter wheat *Yr1*, *YrSP*, and *YrCV* were effective. All available cultivated wheat varieties in Western Asia, Central Asia, and the Caucasus were characterized for resistance to stripe rust.
- Inheritance studies for resistance to Russian wheat aphid and Hessian fly have been completed.

Epidemiology studies

- Characterization of fungal and viral diseases as well as insect pests using morphological and molecular tools is on-going for several host-pathogen systems.
- Monitoring distribution and incidence of diseases and insect pests is conducted with NARS scientists in most cereal and food legume growing areas.

Examples of successful projects of the IPM group

Diagnostic Reagents for Virus Diseases

The Virology Laboratory at ICARDA developed diagnostic kits for the detection of viruses affecting cereal and legume crops in WANA. The detection kits employ two different techniques; the first is based on the double antibody sandwich ELISA (DAS-ELISA) and the other is based on tissue-blot immunoassay (TBIA). So far, 20 kits for the detection of five cereal viruses and 15 legume viruses are being distributed to NARS scientists in CWANA. Each kit has enough reagents to test 2,000 plant samples. To date, more than 500 diagnostic kits or antisera were sent to collaborators in at least 22 countries.

Integrated Management of Chickpea stunt in chickpea fields in northern Sudan

Chickpea stunt caused by chickpea chlorotic dwarf virus (CpCDV) is an important disease of chickpea in central and northern Sudan. Among the IPM components tested by Agricultural Research Company (Hudeiba) in Sudan, the combination of tolerant cultivars, late planting, and short irrigation interval greatly reduced the incidence of CpCDV in chickpea.

Effective IPM option for viral disease management in faba bean in Egypt

Virus epidemics in 1992, 1998, 1999, and 2000 caused yield losses up to 80%. Farmers lost confidence and interest in growing faba bean; hence the area planted to faba bean was reduced from 20,000 ha in 1991 to 800 ha in 2000. An IPM pilot site was established in Beni Suef Governorate in Middle Egypt. The following IPM “best bet” options were tested: (1) improved cultivars ‘Giza 429’ and ‘Giza 843’ tolerant to Orobanche, (2) sowing date during 2nd half of October, (3) seed rate of 150 kg/ha, (4) chemical control of aphids with a systemic aphicide, and (5) roguing of faba bean virus-infected plants early in the growing season. The percentage increase in yield in the fields of the participating farmers in El-Fashn district as compared to non-participating farmers ranged from 23 to 125%, with an average of 68%. The mean seed yield of the fields of participating farmers in the El-Fashn was 4.5 t/ha compared to 1.4 obtained by non-participant farmers. These farmers have regained confidence in faba bean production following their participation in the IPM-Pilot site activities and by getting involved with ARC research scientists and extension specialists.

IPM of Ascochyta blight in winter chickpea

Chickpea varieties with acceptable levels of genetic resistance or tolerance were developed in response to the widespread threat of Ascochyta blight disease. However, the ability of the fungus populations to produce new variants (races) that can overcome the resistant cultivars prevents complete reliance on genetic resistance, especially in those areas where environmental conditions conducive to disease development prevail. ICARDA, in collaboration with the Syrian national program, has investigated IPM options at three sites representing different agroecological zones.

The new options were compared to traditional spring plantings using the local variety without seed-dressing or foliar spray. Results indicated the importance of delayed planting till January, the positive effect of seed treatment, the advantage of sowing a tolerant variety versus the local ones, and the benefit of one or two foliar sprays with fungicide.

The fields where the IPM options were applied performed far better (3, 000 kg/ha) than those planted with the same tolerant cultivars, even in researcher-managed trials (600-700 kg/ha). The spring planting was a complete failure due to poor germination because of drought. The Syrian national program has been advertising the IPM options to farmers through radio/television programs, a flyer, and demonstrations at numerous field days. Adoption has been increasing over years.

IPM of Hessian fly in wheat in Morocco

Hessian fly causes heavy losses on wheat in North Africa. In Morocco yield losses have been estimated at about 35%. For the last 3 years, several IPM pilot sites have been established in farmers’ fields in Hessian fly prone areas, and where the following package has been demonstrated: resistant wheat varieties to Hessian fly, early planting date, in addition to proper management practices such as weed control and fertilization. Around each IPM pilot site a farmer field school each comprising 30 farmers was established. The number of farmers adopting the IPM package has been increasing very rapidly, and we expect that most of the farmers will be using the recommended package in the next few years. The adoption of the IPM

package by farmers would save Morocco about \$200 million, the annual estimate of the losses caused by Hessian fly in the country.

IPM of Sunn pest

Sunn pest is a very destructive insect pest of wheat in West and Central Asia. Apart from the direct reduction in yield, the insects also inject chemicals that greatly reduce the baking quality of flour made from infested wheat grain. If as little as 2 to 3% of the grain is affected, the whole grain lot might be rendered unacceptable for baking.

Sunn pest infestations affect about 15 million hectares annually, which can lead to 100% crop loss in the absence of control measures. About US\$40 million is spent each year on pesticides in the Sunn pest-prone areas.

In collaboration with its partner national agricultural research systems in West and Central Asia, along with the University of Vermont, USA; CABI Bioscience; and the Natural Resources Institute, University of Greenwich, UK, ICARDA has been developing IPM options by using adult and egg parasitoids, entomopathogenic fungi, host plant resistance, sex pheromones, and altered cultural practices, such as adjusting planting date and using early-maturing varieties.

The IPM options are extended to farmers through a participatory approach using farmer field schools (FFS) formed around each of three IPM pilot sites established in Syria, Iran, and Turkey. National governments have adopted a pesticide application policy as the main control Sunn pest. This policy needs to be changed. Through the ICARDA IPM team involvement with farmers and policy-makers, some positive changes in the policy from aerial to ground spraying and some devolution of decisions to farmers for their means of controlling Sunn pest. For example, Turkey has recently decided to expand the IPM of Sunn pest work to the whole country, using Government funds. A dramatic decrease in the area sprayed by insecticides and increased adoption of IPM options is expected in the next few years, which will help in keeping the environment clean, reduce health risks to farmers, and save resources while stabilizing the wheat production.

Observations and recommendations

The panel is very pleased with the relevance, innovations, productivity, and dedication of the IPM group in its attempts to address the plethora of pest issues for the cereal and food legume crops of the CWANA region. The group has maximized its efficiency by developing productive collaborations with NARS, ARIs, visiting scientists, and above all, graduate student research.

The panel considers that Integrated Gene Management is so dependent and interwoven with pathology, entomology, and IPM, that these three subjects must be considered together, both for the IGM thrust and also for their own place in ICARDA.

The IPM team has recognized some areas of research that need greater attention. The panel agrees with their self-assessment and endorses the following **recommendations**.

- Further promote and enhance the exploitation of resistance sources by breeders at ICARDA and NARS programs and strengthen/encourage closer consultation between different scientists (breeder, pathologist, entomology, biotechnology) to ensure optimal characterization of resistance sources to aid in the identification of resistance genes.

- ❑ Progressively improve and develop inoculation procedures to facilitate tests for pest and disease status of most, if not all, segregating breeding material in the breeders' selection plots.
- ❑ Increase the use of molecular tools in epidemiological studies.
- ❑ Develop disease and insect pest distribution maps by GIS in collaboration with the ICARDA Natural Resource Management Program and prediction models for pest development/outbreaks in collaboration with CBSU.
- ❑ Strong emphasis should be given to the launching of farmer field schools with NARS research and extension services and the full participation of farmers be re-enforced.
- ❑ Testing IPM option at ICARDA headquarters and at hot spots with collaborators will be re-enforced.
- ❑ Upgrading of laboratory equipment is needed to keep up with new science and technology developments.

Plant pathology, entomology and IPM

First it must be emphasized that two senior plant pathologists should be integrated into the two reorganized (legumes and cereals) crop improvement programs. The same should be for the two required entomologists. Thus a new senior post in entomology should be established. From within the crop improvement programs, these scientists can also build up their own individual projects in their science and, through appropriate students and postdocs, have good careers in the fields of their expertise. They can also develop projects with visiting scientists on nematode and virus problems and in studying the important virus diseases at the field level.

The existing virology post is well-served at that level by the excellent diagnostic services and preparation of kits, etc. This activity is of high quality and should be continued and be part of the biotech group.

The part-time pathologist working in the seed laboratory of the GRU is in a good position to do creative research on the role of seed transmission in relation to the perpetuation of various diseases in the field. This research should not be so isolated, and work plans should follow good interaction with the senior pathologists in legumes and in cereals.

IPM is singled out for major emphasis in the redefining of an operationally effective program, essential to IGM and to ICARDA. Three posts are needed:

- ❑ IPM Plant Pathologist
- ❑ IPM Entomologist
- ❑ IPM Agronomist/Weed scientist

These three need to work as a team. These three need to be field-oriented scientists and they would be key people to work with the NARS in relation to assessing and evaluating farm problems and new germplasm deployment in relation to disease, insect problems and soil/weed/nutrition situation. The entomologist would be able also to look for and evaluate the role of parasites of crop pests for potential biocontrol.

This IPM group in a sense would be the prime conduit of information of real problems in various agroecosystems back to the breeders and the discipline scientists in the IGM programs. Joint

projects could be developed to study important diseases and insect problems in the field in the IPM sense, with students, NGOs, and NARS scientists. Understanding of diseases and insect pests in the field, their epidemiology, and the biology of the key pathogens is an important need.

The panel is convinced the human resource assignment to IPM and service to GRU and plant breeders is seriously limiting and **recommend** that one plant pathologist and one entomologist be added to the IPM team, with direct assignment of each to support breeding programs.

Chapter 8. Seed systems: ICARDA's Responsibility and Ability to Service Seed Production and Distribution by NARS

Breeding and releasing varieties is not enough. Impacts of new varieties will not materialize if NARS do not have a system for production and distribution of high quality seed. Most developing countries do not have an efficient system for diffusing new varieties to farmers. ICARDA has long understood the need for backing up its own and national breeding programs with large-scale production of advanced breeding lines and varieties. This activity is done by ICARDA's Seed Unit (SU), which not only provides important services to support the Center's Integrated Gene Management approach (or efforts) in cereals, grain legumes and forage crops, but SU also formulates, implements, and documents an increasing amount of seed research and development work.

The Unit's contribution thus falls in two parts: At the Center, the SU carries out a range of seed production, testing, storage, and documentation activities which are important for the implementation of the crop improvement work. However, a major part of the Unit's work takes place in the countries receiving ICARDA genetic material. This work, which is very much development oriented, includes supply of early generation seed for further multiplication by national seed agencies and for various research work; organization of small seed enterprises (set-up, equipment, and, in the case of Afghanistan, initial capital); contribution to a more enabling environment both at the national level (better policies, acts, and regulations) and the regional level (harmonization), training, and emergency assistance (combining the above interventions with support to the procurement and supply of seed and rehabilitation of institutions, as has been the case under the rehabilitation project in Afghanistan during 2002-03).

However, SU resources and skills being deployed at ICARDA headquarters could be better utilized. When breeding/testing of ICARDA genetic material in a country results in a new variety being released, the national seed program will often approach the ICARDA breeder for a quantity of "source seed" for multiplication purposes. Whether the breeder has seed available for this purpose does not always seem to be subject to systematic advance planning by the breeder in consultation with the SU. In some cases seed is therefore not available and this situation is subsequently registered as a "seed problem". In other cases grain stocks held at ICARDA by the Breeder may be available and shipped without supervision by seed specialists at the SU.

In various storage facilities in the ICARDA research fields, in breeders' working areas near the SU facilities, and in other stores near the Center, quantities of seed are stored under arrangements which do not seem to be clearly defined. In the case of valuable breeding materials ("active" as well as material currently stored for possible later use) the available storage facilities are not adequate in design, capacity, or management.

The CCER is making the following recommendations that, if implemented, will improve seed storage conditions, facilitate closer collaboration concerning development of improved germplasm and seed supply, secure a more professional management of genetic resources designated as seed, and provide more efficient service to the countries seeking to introduce new varieties based on genetic material provided by ICARDA.

Establish at ICARDA a Seed Production and Development Committee

Recommendation: ICARDA should establish a Seed Production and Development Committee (SPDC) with representation from the Germplasm Program, the SU, the International Crop Information System and Nurseries Network (ICIS), and the Genetic Resources Unit (including the Seed Pathology Laboratory).

The ADG Research should chair the Committee. It should meet every second month. Brief minutes should be submitted to Management and to other units within ICARDA. At the discretion of the Chair, representatives from other ICARDA units may be invited to participate in meetings. The first tasks of the SPDC would be to (i) formulate clear policies and allocation of responsibilities concerning multiplication, storage, and supply of seed by and from the Center, and (ii) consider the need for formulation by the SPDC of a brief position paper concerning introduction of fees for services involving seed.

Encourage ICARDA representation from SU in regional and national seed system meetings

Recommendation: Senior staff from the SU and NARS should participate in the annual, regional/sub-regional coordination meetings and as many national meetings as appropriate. Senior staff from selected seed systems in countries, where the Center considers that seed problems currently or in the near future may deter the dissemination of Center material, should also participate.

Construction of a high quality seed storage facility for breeders stocks and prerelease varieties

Recommendation: ICARDA should construct a high quality seed store with temperature control and capacity to hold active breeding materials and other valuable seed products. This store would also hold breeding materials presently stored at the Genetic Resources Unit. At the same time, all other genetic materials should be placed in the existing seed store. Both storage facilities should be managed by the SU, which will acknowledge receipt of seed stocks; provide tagging, testing, storage, regularly report status of the seed lots; and eventually release and deliver/ship consignments of seed as are requested and under proper documentation. Besides small quantities that are handled by the breeders in the field or in the breeder's shed, there should not be seed stocks held at the Center, which are not under the management of the SU.

SU staffing needs

Recommendation: The SU is understaffed. It is therefore important that the vacant post of the Seed Economist is filled. However, at the GS-level the Unit remains short of staff to handle day-to-day operations at the seed processing and storage and laboratory facilities. As a result senior level staff is spending time on routine seed work. To release senior SU staff resources for seed research, training, and development work and to improve the management of ICARDA's seed operations and quality control, the following staff at GS level should be employed and attached to the SU:

- ❑ A seed storekeeper, a seed-conditioning (processing) plant operator
- ❑ A technician to manage the database, handle regular seed quality control and to support seed research and development activities with seed-testing work.

Seed inventory and history database

SU activities are reported in the Unit's annual report with tables providing only the total quantity or number of samples for each of the crops that were handled during that particular year. Considering the need to assess in more detail how the Unit's work contributes to Integrated Gene Management, two dimensions are missing in this reporting: (i) Information about the lines/varieties handled for various purposes and (ii) the development in data over time. This information is already available in the Unit's computers but the filing of data may need to be reorganized.

Recommendation: The SU should organize its database(s) on seed activities in such a manner that the Unit is able, at any point in time, to provide current, aggregated information about the quantity of seed handled or number of samples tested in respect of line/variety and client/purpose over the last 5 years and maintain inventory lists in a database that would be accessible on the internet for qualified users. Printouts of these data should be at meetings in ICARDA about seed issues and during the annual coordinating meetings.

Reconciling national seed system policies with informal development of varieties via participatory plant breeding

The CCER did not have the opportunity to assess the organization and efficiency of the SU's development work on-location in the countries where ICARDA provides improved germplasm and crop production technologies. However, documentation produced by the SU suggests that the current portfolio of activities and results is very relevant for the promotion and dissemination of the Center's improved germplasm, both in the short term (supply of high quality source seed, development of small-scale commercial seed operations, support to relief operations) and in the long term (development of regional institutions, harmonization of seed regulations).

ICARDA's clients are small-scale, resource-poor farmers in dry and marginal areas and many of the Center's mandate crops do not offer attractive business opportunities for commercial seed companies. At the same time, governments are also not always providing the necessary support to seed production and supply. Farmers depending on these crops therefore often do not have access to improved germplasm and technologies developed by ICARDA. The SU's efforts to analyze the organization and economics of community-based seed schemes and to facilitate their organization are therefore important. Where appropriate, such seed production schemes should go hand in hand with participatory plant breeding and variety evaluation. The participatory breeding concept for variety improvement and evaluation currently being developed in Syria by ICARDA's Barley Improvement Project in collaboration with its SU has already been described in previous sections of this report.

Recommendation: When implementing the participatory breeding concept, with respect to seed production and distribution, particular attention should be paid to the:

- ❑ Organization and participatory role of farmers in the selection work
- ❑ Organization around and management of the small seed-cleaner supplied by the SU,
- ❑ Avenues being explored with local authorities to bring the material selected by and exchanged between farming communities into the operations of the national seed system,
- ❑ A transparent understanding about the sharing of benefits (profits) with respect to the sale of the farmers' intellectual property.

A significant result of the SU's work at the regional level has been the organization of the CWANA network of which 19 countries are members and have designated a senior representative from a key seed organization in the country as the focal point for the Network. Network collaborators have contributed a substantial amount of information about varieties, stakeholders, seed systems, and regulatory arrangements in the member countries. An important ongoing SU contribution to this effort is the dissemination of this information through the CWANA Seed Newsletter and the printing and distribution of various reports based on documentation provided by focal points. Besides this, the Network currently functions with minimum of support from the SU.

Establishing a public Regional Seed Committee

Exchange of information about various national seed systems is an important prerequisite for the introduction of better national policies and regulatory environments, and for the organization of meaningful regional consultations concerning collaboration and harmonization. This information has facilitated SU support to the revision of seed policy statements in some countries and has created awareness in others concerning critical issues.

The current MTP 2004-06 (Sep 2003) indicates that the CWANA Network should be turned into a regional seed association. The CCER panel does not consider this to be the most appropriate next step. Experiences from both Asia and Africa suggest that private companies soon dominate regional associations, because these companies, through their membership fees, provide essential funding to the association. As a result the association loses some of its credibility with high-level government organizations and international development agencies as it seeks to address national and regional issues.

Recommendation: The CWANA Network Steering Committee should be replaced by a regional Seed Committee or Board with one member from each CWANA country that contributes an annual fee.

Board members should be the heads or senior representatives from key national government seed organizations. For each country an indicator, such as GNP/capita may determine the fee level (which in the case of poor countries should be low). The Committee should organize a secretariat in a suitable location in the Region, set up an account, and employ a Director. The Director, under the guidance of the Committee, organizes activities such as conferences on technical and regulatory issues (and connected with seed-trading activities), documentation, and policy initiatives. Sources of funding may include: Countries' membership fees, conference

fees, advertising fees, and eventually service charges for the implementation of technical assistance projects.

Contrary to a regional seed association dominated by private sector members, the Regional Seed Committee or Board will be able to mobilize the same sources of funding and at the same time retain credibility as an appropriate counterpart for donor-supported initiatives to improve policies and harmonize regulations. Without initial “seed” funding it will take time to establish this organization.

ICARDA is now completing the establishment of agroecologies for its mandate crops. The definition of these agroecologies is based on analyzing a large number of trials for significant and consistent genotype-by-environment interactions, thereby defining environments (agroecologies) within which consistent ranking of genotypes can be assumed. This effort is an essential prerequisite for the development of more efficient variety testing programs in CWANA countries and for the introduction of regional variety release procedures. The organization of arrangements for regional variety release will stimulate private sector activity and facilitate exchange of varieties and seed between countries in the Region.

With a credible, functioning Regional and local Seed Committees in place and with access to information about well-defined agroecologies, regional consultations concerning harmonization can be more efficiently pursued. Analyses of constraints to the movement of seeds in a region suggest that key areas are: variety release, export-import restrictions, including requirements for plant quarantine, and seed certification standards.

The panel suggests that the SU should review in detail the consultative processes applied and the outcomes of harmonization efforts in East Africa and in SADC and, based on lessons from those processes, design and budget a detailed and doable plan of action for similar work in the CWANA Region.

Chapter 9. Biotechnology

The biotechnology laboratory at ICARDA is not an official organized program unit at ICARDA, but is designed to support the cereal and legume breeding programs by adopting and developing technology to aid in gene transfer and gene discovery. This work is broadly identified in four categories, briefly described below with examples of projects undertaken with the plant breeders.

- *Tissue culture.* Many thousands of somaclonal lines of grass pea (*Lathyrus*) were produced and evaluated to discover mutants having low concentration of β -ODAP, a toxin that causes serious debilitating effects and even death in humans who consume the seeds. Using conventional breeding methods and tissue culture, somaclone lines with < 0.06% β -ODAP were developed.
- Doubled-haploids were produced in barley and wheat from isolated anther microspores for use in the breeding programs and for the development of mapping populations.
- *Molecular markers.* The lab was an early contributor to development of molecular maps of barley, durum wheat, lentil, and chickpea genomes and has used a wide array of types of molecular markers to characterize genetic resources for disease

screening and marker-assisted selection in the breeding programs. For example, molecular markers were used in lentil breeding populations to discover linkages of the markers for frost tolerance and Fusarium wilt resistance. The wild *Hordeum spontaneum* progenitor of barley has been found to be a rich source of useful genes for barley improvement. Mapping studies identified quantitative trait loci for six yield-related traits. In chickpea, molecular markers were used to map resistance genes to Ascochyta, a major disease of chickpeas. A number of markers are already being used for marker-assisted selection e.g. virus and scald resistance in barley.

□ *Genomics.* The biotech laboratory is making use of recent developments in microarray technology by using Affymetrix genome chips for the identification of drought-induced genes in barley. This work is being carried out with advanced labs in Europe. Tilling and Ecotilling protocols are being adopted to exploit allelic variation for crop improvement in collaboration with advanced laboratories.

□ *Genetic engineering and biosafety.* ICARDA has engaged in programs of genetic transformation with collaborative programs with AGERI in Cairo and laboratories in Australia and Germany on cereals and grain legumes. The laboratory has sought sources of cloned genes and obtained the rights to use them from many sources. ICARDA now has biosafety containment facilities to conduct research with transgenic plants

□ *Training.* Numerous training workshops and short-courses have been conducted in the laboratories at ICARDA and in Egypt, Iran, Iraq, Morocco, Sudan, and Algeria. The target audience for the training has been NARS scientists. In addition, the lab has hosted long-term training of graduate students.

The Biotechnology laboratory has developed expertise to apply modern molecular methods to a wide range of activities. It has clearly supported several of the plant breeding programs with specific applications. The lab is well linked to several ARI groups and is taking advantage of new technology as it emerges. The lab recently acquired a capillary DNA sequencer that is critical to developing single nucleotide polymorphisms, a valuable tool for gene tagging for plant breeding purposes. The NARS are particularly benefiting from the numerous workshops at ICARDA and elsewhere. The panel is favorably impressed with the dedication and productivity of the staff and effective leadership of the lab director. However, for biotech at ICARDA to be even more effective the panel **recommends** that the biotechnology team become more formally linked, in the context of IGM project with the crop improvement programs and GRU in regular planning and technical sessions.

Chapter 10. IGM Partnerships at ICARDA

The IGM review panel received information on the various collaborations that have been formalized with each of the program areas under review. The panel was pleased to learn about the large number of partnerships and networks that are active. We learned of many successes in the IGM program. However, the panel did not make field visits to the various partners in advanced laboratories, with the NARS, private sector, or NGOs.

The panel also reviewed the report of the CCER on ICARDA's outreach activities (March 2004). This report had benefit of panel on-site visitations to some of the countries of active program work. That review emphasized interrelationships with NARS, whereas the charge to the IGM panel was much broader. However, ICARDA's goals affect some 30 countries in the region and genetic improvements and genetic resources management and conservation are integral to all of them, hence the Outreach CCER report has strong relevance to the IGM CCER. The IGM panel suggests that the Outreach CCER report be considered very positively in its deliberations for strategic planning for IGM. In particular, three recommendations are especially relevant:

- ❑ *“... that ICARDA reviews the possibilities of expanding its role as an honest broker in triangular arrangements involving the Center, specialized research institutes and countries in CWANA, for the promotion of research activities on problems outside its traditional mandate.”*
- ❑ *“... in the light of the new funding realities leading to more limited permanent staff resources, the Center revises its current training policy to facilitate the employment of students.”*
- ❑ *“... that ICARDA explores with the national partners the opportunities for strengthening linkages with rural development and related projects as a means to increase the financial contributions to agricultural research.”*

ICARDA, as with most CGIAR centers, have very limited numbers of scientists and support staff to meet the grand expectations of the CGIAR and for the Millennium Development Goals of poverty alleviation, enhanced productivity, and protection of environmental quality. This set of recommendations speaks to more effective leveraging of talent to meet regional needs. Jointly funded NARSs, ARIs, and ICARDA projects can be very effective for producing locally relevant genetic materials, training of young scientists, enhancement of capabilities for mid-career NARS scientists, and result in more effective use of ICARDA staff as project leaders. This suggestion speaks to specific problem and site orientations. The IGM panel **recommends** that, as appropriate, its partnerships target direct NARS involvement with joint funding and NARS scientists dedicated to specific components of locally and regionally relevant research and development projects.

The IGM panel was briefed on partnerships that are active within the activities of the programs within IGM.

ARIs: ARI are involved in collaborative genomics, biotechnology, plant breeding, GRU, and IPM projects. It is clear that these collaborations are vital to the health and effectiveness of ICARDA as a research institution. Effectiveness of the ARI collaborations can be seen in the peer-reviewed research papers. Many papers have been published, many coauthored by ARI

scientists. In some cases, more than one country is represented by ARI coauthors. ICARDA has received training in advanced technologies and have hosted graduate students from ARIs. The panel compliments the IGM groups for the very active and productive associations with ARIs.

Private sector: Collaboration is important in biotechnology research because important molecular products, such as cloned gene libraries, vectors, promoters, and other tools have been developed and patented by the private sector. Agreements have been achieved by ICARDA scientists to gain access to these materials. In the barley improvement activity, private sector collaboration has been arranged for the assessment of malting quality and in the sharing of germplasm. Partnerships with the private sector can provide a means for distributing research products to the user community of farmers, seed handlers, and post-harvest processors. ICARDA can provide a vital role to establish commercial linkages for commercialization of research products, but implementations are best handled nationally by NARS or other in-country organizations.

NGOs: NGOs generally do not conduct research, but many of them are involved in adaptation trials, distribution of seeds, and educational materials to local farmers. ICARDA's impacts can be greatly enhanced by providing information and materials to NGOs. CGIAR is calling for more activity by the Centers in the deployment of products of research to users. This can consume considerable scarce resources and since the geographic scope is enormous, efficient strategies are needed. For ICARDA this may mean greater investment in outreach with NGOs and national extension services than in the past. Certainly the on-going workshop and field demonstration activities are widely used modus operandi by all ICARDA programs. The Outreach CCER has addressed this topic and presented case studies of successful programs.

The panel is satisfied that IGM has made very significant linkages and collaborations within each of the programs as evidenced by research results in publications, onsite outreach, adoption of new technologies, sharing of information in country and campus-based workshops, training of NARS students and scientists, and distribution of seeds. The panel did not undertake interviews with ARI, private sector, or NGO representatives so we could make a complete assessment.

Our major recommendation, outlined above, concerns a dual issue of how ICARDA can carry out sufficient research program with its limited human and financial resources and at the same time enhance national research and development. We **recommend** greater use of extramurally funded joint programs with NARS whereby the national program can receive funds for expanding staff that can be seconded to ICARDA for specific topics, either at Aleppo, regional sites, or at the NARS research centers.

Chapter 11. Quality of Science of IGM Research at ICARDA

The IGM contributed to the development of agricultural sciences and the related fields through many publications as shown in the table and figure below for the 11-year period 1993-2003. Many of these publications were coauthored with resident postdoctorals, scientists at NARS, other Centers, and advanced institutes. Several M.Sc. and Ph.D. theses were produced. Analyses of research productivity as measured by numbers of papers published must be taken into the context of the functions of the research organization. Each scientist has considerable outreach activity in the ICARDA client countries. Another responsibility of scientists in IGM is

servicing clientele by providing diagnostics for the NARS, whether it be insect, disease or genetic materials. Breeders spend time evaluating materials to identify desired traits, and so on. The scientists have considerable teaching responsibilities with workshops, field days, hosting visitors, meeting with panel reviewers, Board of Trustees, and donors. In spite of all of these non-research activities the mean publication rate per scientist is nearly two research papers per year and more than four other publications. The panel considers that the IGM program scientists are adequately productive and fully consistent with their assignments at an applied research center.

The peer-reviewed research papers based on original research have been published in the leading journals, an indicator high quality research. Much of the research published was done early in the development of a new research area, also an indicator of high quality and timely research.

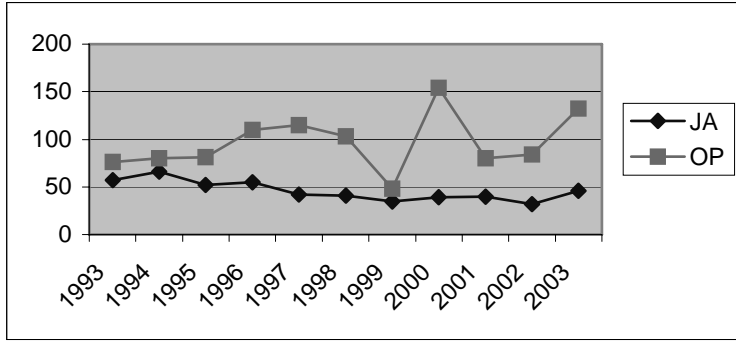
Beyond original discoveries through publication are the media used to extend the information to users. Again, the IGM scientists have a very good record of presenting their results to international workshops and symposia. Several extremely well-done guidebooks or manuals have been produced that are directly usable by growers, for example, for pest and disease identifications.

The panel commends the IGM group for their originality, practicality, and timeliness of publication of their discoveries.

We urge continued diligence in publication of results and **recommend** wider use of electronic medium, which is largely accessible to the research community in all countries. Print medium is costly to produce and distribute and often not available to those who most need the information.

Publication rates for IGM scientists for the period 1993-2003 of peer-reviewed journal research articles (JA) and other publications (OP), such as manuals, production guides, proceedings of meetings, and popular items

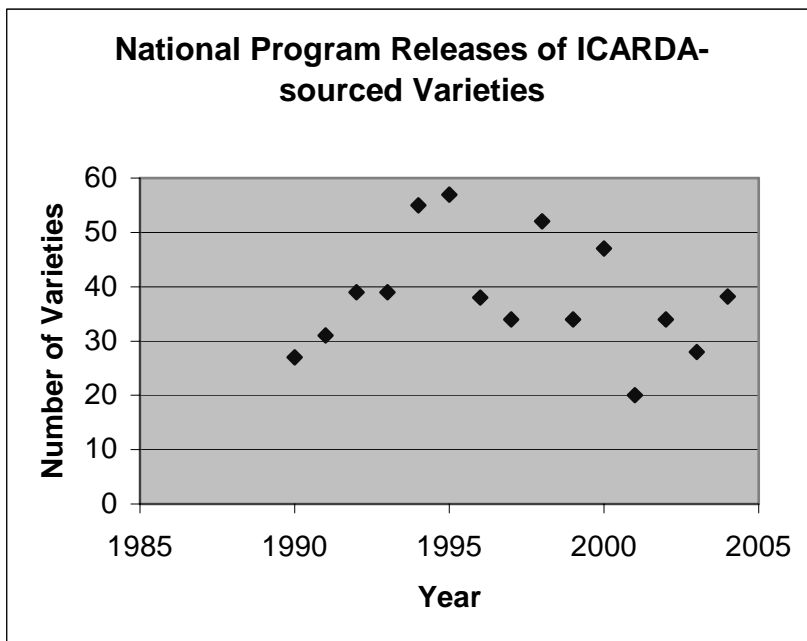
Year	Journal articles	Other Publications	Number of scientists		Total scientists	Ratio JA/Int	Ratio OP/Int
			Internat.l	Postdocs et al.			
1993	57	76	26	9	35	2.19	2.92
1994	66	80	25	9	34	2.64	3.20
1995	52	81	25	9	34	2.08	3.24
1996	55	110	24	9	33	2.29	4.58
1997	42	115	23	9	32	1.82	5.00
1998	41	103	22	9	31	1.86	4.68
1999	35	48	21	9	30	1.66	2.28
2000	39	154	21	11	32	1.85	7.33
2001	40	80	21	12	33	1.90	3.81
2002	32	84	21	14	35	1.52	4.00
2003	46	132	21	15	36	2.19	6.28



Chapter 12. Quantified and Publicized Impact of IGM Research

Efforts to document and quantify the adoption and impact of improved germplasm research and technologies have intensified as methodologies have been developed to study impact assessment. Social scientists have endeavored to detect improvements in the well-being (health and wealth) of rural and urban societies as related to improved agricultural productivity or specific factors such as adoption of new crop varieties. There are many factors, such as migration and off-farm income that confound the analyses.

The development and disbursement of cultivars is one measure of impact. During the period 1990-2004, 570 varieties (38.2 per year) over all crops were released by NARS that had origin with ICARDA breeding contributions. In the 5-year period (1999-2003) prior to this review, 163 varieties were released (32.6 per year). This is a remarkably high number, of course, mere release of varieties does not address the ultimate impact of adoption, yield levels, nor economic value. However, it is a guide to the effectiveness of the breeding programs and usefulness of the science discoveries, such as gene discovery.



Impact analysis must be broader in scope to assess the effectiveness of a research organization. The adoption of new practices may have subtle and hardly detectable effects on the human populations. For example, introduction of new varieties and improved management of grazing lands may improve soil and water conservation that may have great benefits in the long term but not easily measured in the short term. Genetic resources collections and *ex situ* conservation may have great impacts decades from the time collections were made. On the other hand, some new discoveries have large impacts that are easily seen, even if not easily documented in all respects.

Another complication is that the sponsors want positive impacts of the research to be evident in the short term, but many good discoveries have slow adoption rates and the impacts may not be realized until many years have passed.

In spite of the complexity of impact analysis, considerable progress has been made at ICARDA and at other CGIAR Centers in demonstrating and quantifying impacts as seen by the quality and number of publications various scientific journals, books, and reports. The process of assessing impact was implemented in full cooperation and interaction with Center Scientist, NARS, advanced institutes and international organizations. The joint work has contributed to the harmonization of data collection procedures, methods of analysis and networking and exchange of experience.

Over the past 10 years ICARDA social scientists, with collaboration from the crop scientists, have conducted and published several important studies on adoption rates and impacts. The impact of farmer adoption of germplasm improved by ICARDA and released in CWANA countries was quantified at farm, community, national, and international levels. Adoption and impact studies covered durum and bread wheat varieties, barley, food legumes, and forages. These studies clearly demonstrated the large impact of ICARDA on the food security status on CWANA region. For example, an estimate of the impact of modern agricultural technology on wheat production in Syria, published in 2003, indicated an annual increase of 1.66 million tonnes of durum wheat. This is equivalent to an increase in national income of about \$US 348 million/an. About 38% of this increase is due to the impact of the use of improved varieties from ICARDA germplasm research.

Farm surveys and impact assessment studies clearly demonstrated the efficiency of research investment in crop production technologies. A study published in 2004 showed that new barley cultivars, for example, have increased total productivity (net yield gain) in targeted zones/communities by as much as 35% compared to local varieties. This increase in barley production has contributed greatly to household food and feed security.

Another study in Iraq indicated that the introduction of vetch (forage legume) into a two-year barley/vetch rotation increased barley yields by 20% compared to barley/fallow system and up to 50% compared to continuous barley. The adoption rate of vetch in Jordan was 29% among farmers of mixed crop and livestock production systems. In Tunisia adoption rate of vetch is 10%. In another study it was found that the internal rate of return of barley improvement research ranged between 22 and 51% in Algeria, Ecuador, Egypt, Ethiopia, Iraq, Jordan, Morocco, Syria, and Tunisia.

These studies document the high pay-off for investment in agriculture of improved germplasm research for which IGM research at ICARDA and NARS can legitimately claim as positive outcomes of their research.

Meanwhile, the spillover impact of ICARDA research on Australian agriculture was estimated at A\$13.7 million per year (in 2001) over the period to 2022 primarily from gains in the faba bean and lentil industries.

The GEF project on restoration of agrobiodiversity, discussed earlier, has effected short-term impacts on biodiversity in Jordan, Syria, and Palestine Authority through the distribution of landraces of major crops and the production, distribution, and planting of large numbers of tree seedlings.

Another measure of ICARDA's impact is its activity in human resource development. The Center has hosted and mentored many advanced degree students who receive degrees from universities from the CWANA region, the U.S., Europe and other places. A total of 158 students completed degrees from 1994-2003; representing a mean of 15.8 graduates per year that has been relatively constant over the past 10 years. No follow-up data on employment history was available.

Numbers of students who completed M.Sc. and Ph.D. degrees in joint ICARDA-University programs, 1994-2003.

Program/theme	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
Germplasm enhancement	9	11	14	6	6	19	8	17	20	17	127
Seed Unit	4	3	2	2	2	1	-	-	1	-	15
GRU	1	3	3	1	3	1	1	2	1	-	16
Total	14	17	19	9	11	21	9	19	22	17	158

Observations and recommendations

The panel is pleased that ICARDA has invested in research to understand the impacts of their research in the CWANA region. This is a vital component of each of the Center's research and outreach programs. Generally, we consider that impact studies are done to document positive results from the investment of funds and human resources. However, it is just as important to judge impacts that might not be so positive. This information is needed for strategic planning to alter research directions and investments. Such decisions should be based on scientific data as well as intuition. The results of impact studies can be used widely to enhance awareness among policy makers, research organizations; farmers' organizations, NGOs and donor communities toward more investment in dryland agricultural research.

The panel notes that there is a relationship between the study of adoption and impacts with examination of risks and benefit analysis. The latter being exemplified by the biosafety concerns with crops having transgenes. This relevant to the IGM program and to all research conducted at ICARDA.

It is essential that ICARDA sustain its research on adoption and impacts of the outputs of its research programs. It is **recommended** that each research activity should have an impact and adoption assessment component included in the project plan from the outset and, further, that specialists in that field be integral members of the research team. Although outside of the panel's purview, this recommendation seems relevant to all of ICARDA's programs.

Impacts of ICARDA's research outputs are realized in the CWANA countries, largely through NARS, but also through NGOs and private sector. We **recommend** that collaboration with NARS be strengthened to maximize the utilization of NARS human resources and contribute to their development in the study of adoption and impact.

The panel **recommends** that the study of impacts of adoption of improved germplasm be linked with attendant impacts on the quality of natural resources, including biodiversity, soil quality, water quality and availability, and pollution from pesticides and fertilizers to sustainable increased productivity taking in consideration risk aspects that require further quantification.

Acknowledgments

The Panel appreciated very much the assistance of the ICARDA IGM team throughout the review. Their summaries and presentations were clear and availability for consultation was excellent. We especially are grateful to Dr Ali Abd El Moneim for serving as the review liaison person, and, of course Dr Willie Erskine, Deputy Director General, for his guidance and patience, and finally to Director General Dr Adel El Beltagy for his interest and advice. The secretaries and food service met our every need. Our only regrets are that we could have had a few more days to extend our learning about a complex center.

ICARDA has a good idea in advancing IGM and it will work. Thanks to a qualified scientific staff who will have a more efficient programmatic and administrative structure and collegiality for carrying forward the goals of ICARDA for the people of the CWANA and beyond.

Annex I
Schedule of Center-Commissioned External Review
For Integrated Gene Management

10-17 June 2004
ICARDA, Aleppo, Syria

Wednesday, June 9th

Arrival of Panel Members

Thursday, June 10th

12:00-12:45

(Dr Nour Auditorium)

Lunch

Presentation by RPMs

12:45-13:00

Welcome opening, Acting ADG(R)

R Thomas

13:00-13:30

Project 1.1: Barley Improvement

S Grando

13:30-14:00

Project 1.2: Durum Wheat Improvement

M Nachit

14:00-14:30

Project 1.3: Spring Bread Wheat Improvement

O Abdallah

14:30-15:00

Project 1.4: Facultative Bread Wheat Improvement

M Mosaad

Friday, June 11th

(Dr Nour Auditorium)

Presentation by RPMs (cont'd)

08:30-09:00

Project 1.5: Food Legume Improvement

R S Malhotra

09:00-09:30

Project 1.6: Forage Legume Improvement

A Abd El Moneim

09:30-10:00

Biotechnology Research at ICARDA

M Baum

10:00-10:15

Coffee Break

10:15-10:45

Project 2.1: Integrated Pest Management

A Yahyaoui

10:45-11:15

Project 3.3: Agro-biodiversity

J Valkoun

11:15-11:45

Project 5.1: Seed Systems

A van Gastel

11:45-12:45

Lunch

12:45-15:00

Reading Day for Panel Members

Saturday, June 12th

09:00-09:30

Orientation to ICARDA

W Erskine

09:30-10:30

Visit ICARDA facilities

(Biotechnology, GRU, SU, IPM & Breeding fields)

10:30-12:00

Interaction with Scientists

(to be programmed by CCER team)

12:00-13:00

Lunch

13:00-15:00

Interaction with Scientists

(to be programmed by CCER team)

Sunday, June 13th

09:00-10:00	Meeting with Barley Project	I Buddenhagen/ M Duwayri/ M Lemonius
09:00-10:00	Meeting with Seed Unit	M Lemonius
10:00-11:45	Meeting with Spring Bread Wheat Project Winter & Facultative Wheat Project	M Duwayri/ C Qualset
10:00-11:30	Meeting with Pathology (Dr B Bayaa)	I Buddenhagen
11:30-11:45	Meeting with IPM	I Buddenhagen/ M Duwayri/ M Lemonius
14:00-15:30	Meeting with GRU	I Buddenhagen/ M Duwayri/ C Qualset

Monday, June 14th

08:30-12:00	Interaction with Scientists (to be programmed by CCER team)
12:00-13:00	Lunch
13:00-15:00	Interaction with Scientists (to be programmed by CCER team)

Tuesday, June 15th

08:30-12:00	Report writing by Panel Members
12:00-13:00	Lunch
13:00-15:00	Report writing by Panel Members

Wednesday, June 16th

08:30-12:00	Report writing by Panel Members
12:00-13:00	Lunch
13:00-15:00	Report writing by Panel Members

Thursday, June 17th

08:30-12:00	Report writing by Panel Members
12:00-13:00	Lunch
13:00-15:00	Report Presentation to Staff by Panel Members

Annex II

Composition of CCER Panel and Biographical Information

Dr Calvin O Qualset, Panel Chair
Professor Emeritus
University of California
Davis, California USA 95616

Qualset is a retired professor at the University of California, Davis, and recently retired as the founding director of the Genetic Resources Conservation Program, a statewide unit of the Division of Agriculture and Natural Resources. He is currently interim director of the Agricultural Sustainability Institute in the College of Agricultural and Environmental Sciences at UC Davis.

Since retirement in 1994 he continues to serve as Research Professor and conducts and coordinates research on plant genomics, and *in-situ* and *ex-situ* conservation of crops. He has served on several review teams that have examined scientific basis for biotechnology policy and genetic resources conservation. He served on numerous reviews of Centers, served various boards and committees, including the Board of Trustees of the International Rice Research Institute. He has conducted collaborative research projects in Turkey, Mexico, Spain, and Italy, and is presently developing a research and demonstration farm in Lithuania through a U.S. nonprofit foundation.

With some 50 graduate students and other colleagues, more than 20 varieties of wheat, triticale, and oat were developed and released and published more than 350 research papers, reviews, and reports. He served terms as Department Chair, Associate Dean, and Director of the Foundation Seed and Plant Materials Service in the College of Agricultural and Environmental Sciences at UC Davis. Cal received his B.Sc. in Agriculture at the University of Nebraska and M.Sc. and Ph.D. at UC Davis in Agronomy and Genetics, respectively.

Dr Ivan W Buddenhagen, Member
Professor Emeritus
University of California
Davis, California USA 95616

Ivan Buddenhagen is a Plant Pathologist/Plant Breeder. He remains active in international consulting and personal plant breeding in banana and chickpeas since his retirement from the Department of Agronomy, University of California, Davis. He has been a cereal crops program director at IITA [rice and maize], Professor and Plant Pathology Department Chair, University of Hawaii, and served numerous consultancies. He has written extensively on plant disease biology and plant breeding strategies for pest resistance. His academic degrees include B.Sc. in Botany (1953), M.Sc. in Plant Pathology (1954), and Ph.D. in Plant Breeding and Genetics (1957) all from Oregon State University.

Dr Mahmud Duwayri, Member
P.O. Box 264
Amman, Jordan

Mahmud Duwayri is presently a professor in the Faculty of agriculture, University of Jordan, Amman, Jordan. Dr Duwayri received his Ph.D. in plant breeding and plant genetics from the University of Wisconsin, Madison, Wisconsin in 1973, and his M.Sc. and B.Sc. from the American University of Beirut in 1970 and 1968, respectively.

Professor Duwayri served in Jordan as Minister of Agriculture, Vice-President of the University of Science and Technology, Dean of the Faculty of Agriculture in the University of Jordan, and Director General of Agricultural Research and Technology Research (NCARTT) in Jordan. He also served as Dean of the Faculty of Agricultural Sciences in El Ain, United Arab Emirates, and as Director of the Plant Production and Protection Division in the Food and Agricultural Organization of the United Nations (FAO), Rome.

Mr Mogens Lemonius, Member
Seed Specialist
Homensvej 6
Ebeltoft
DK-8400 Denmark

Mr Lemonius, from Denmark, was educated at the Danish Royal Veterinary and Agricultural University with a M.Sc. degree in agricultural economics. He is an expert on technical and organizational aspects of the seed industry and has served in several capacities in Denmark, including national adviser to the Federation of Danish Seed Growers' Associations. From 1978 he was employed by FAO in Swaziland for four years to organize a seed production program, processing, and marketing for hybrid maize and potato. Later he served for FAO in Thailand as Regional Seed Programme Manager in Asia-Pacific for 15 years. There he organized 80 training courses for 2500 seed technicians and managers. After that he served for FAO as Regional Seed Programme Manager in Asia-Pacific for 15 years and assisted countries with training, seed center strengthening and policy development. This work was completed with the organization of the now self-sustainable Asia and Pacific Seed Association. Since 1997 Mr Lemonius has participated in 30 missions fielded by FAO, FAO Investment Centre, European Union and private consultancy companies to several countries to design seed policies, and to plan and evaluate seed activities in the public and private sectors.

Annex III

Terms of Reference for the Center Commissioned External Review (CCER) on Integrated Gene Management at ICARDA

A CCER on Integrated Gene Management (IGM) would address, among other aspects given in the terms of reference below, the following recommendations of the Fourth External Program and Management Review (EPMR) of ICARDA held in the Year 2000:

1. In the light of a diminished expertise in fungal pathology at ICARDA, the Panel recommends that the Center should strengthen its scientific capacity for strategic and applied research in crop pathology, and its pathology support to the Cereal and Legume Enhancement Programs.
2. The Panel recommends that ICARDA should review the opportunities that may be available if it should expand its research role in malting barley in developing countries. In undertaking this review, the Panel would expect ICARDA to complete a social and economic assessment of the potential of work in this area to meet CGIAR priorities.
3. The Panel recommends that as a matter of priority ICARDA seek discussions with CIMMYT to develop mutually acceptable plans for the incorporation of doubled haploids and marker-assisted selection technologies in their joint durum wheat, spring bread wheat and facultative/winter bread wheat breeding programs.
4. Given the reductions in the Genetic Resources Unit staff that have occurred, the demands placed on the Unit for collection and conservation activities, and so as not to threaten its existing activities, the Panel recommends the GRU make a concerted effort to seek additional P and RA level staff from either internal or external sources, if it is to undertake an expanded program of research in *in situ* conservation, pre-breeding and the evaluation of collections using molecular markers.

This review should examine:

1. ICARDA's progress in addressing EPMR recommendations on:
 - Pathology research
 - Malting barley
 - Biotechnology research with CIMMYT
 - Critical mass on Genetic Resources
2. Progress in integrated gene management of barley, bread and durum wheat, lentil, kabuli chickpea, faba bean and forage legumes spanning the continuum from gene conservation and documentation, through exploitation to adoption.
3. Are current ICARDA research priorities for IGM appropriate?
4. What is the science quality of IGM research at ICARDA?
5. Has the impact emanating from IGM research been quantified and published?
6. Are appropriate routes to adoption with improved seed being explored/followed?

7. Are current partnerships with advanced research institutions, civil society, national programs and the private sector appropriate to advance ICARDA's integrated gene management research?
8. How effective are ICARDA's seed activities in supporting both ICARDA's breeding programs and national seed programs regionally?
9. Scope and effectiveness of ICARDA's genetic resources activities, including both *ex situ* and *in situ* ecosystem approach in agrobiodiversity conservation/utilization; PGR documentation and characterization, and the impact of new International Treaty on PGR conservation and exchange.

Annex IV

List of Documents Provided to the CCER Panel ICARDA

- Belaid, A., M. Solh, and A. Mazid. 2003. Setting Agricultural Research Priorities for the Central and West Asia and North Africa Region
- CGIAR/FAO TAC Secretariat. 2001. Report of the Fourth External Programme and Management Review of the International Center for Agricultural Research in the Dry Areas (ICARDA). CGIAR. Rome.
- ICARDA. 1998. Strategic Plan. ICARDA
- ICARDA. 2000, 2001. Dryland Agrobio-Conservation and Sustainable Use of Dryland Agrobiodiversity Funded by GEF/UNDP. ICARDA. Aleppo, Syria.
- ICARDA. 2000. Healthy Food for the Poor. ICARDA. Aleppo, Syria.
- ICARDA. 2004. WANA Seed Network: A Catalyst for Transformation and Development
- ICARDA. 2004. Durum Collaboration with ARI
- ICARDA. 2004. Germplasm Program and the Private Sector
- ICARDA. 2004 List of Restricted Projects on Integrated Gene Management
- ICARDA. 2004. ICARDA Interactions with NGOs
- ICARDA. 2004. Durum in Syria – Research Delivers Bountiful Harvest
- ICARDA. 2004. Interactions with NGOs (Project 1.6, Forage Legumes)
- ICARDA. 2004. Seed Unit and NGOs
- ICARDA. 2004. Collaboration with Advanced Research Institutes and Regional and International Organizations
- ICARDA. 2004. Collaboration with Advanced Research Institutes and Regional and International Organizations in Wheat Research
- ICARDA. 2004. Collaboration with Advanced Research Institutes and Regional and International Organizations in Integrated Pest Management (IPM) Research
- ICARDA. 2004. Biotech Collaborations
- ICARDA. 2004. ICARDA's Board and Management Joint Response and Follow-up to the Report of the 4th External Program and Management Review-Action Update 19 May 2004
- ICARDA. 2004. Center-Commissioned External Review of ICARDA's Outreach Activities
- ICARDA. 2004. ICARDA Annual Report 2003
- ICARDA. 2004. Rebuilding Agriculture in Afghanistan
- ICARDA. 2004. Genetic Resources Unit. Progress Report 1998-2003
- ICARDA. 2004. Decentralized-Participatory Plant Breeding.
- ICARDA. ND. Farmers Breed Better Barley
- ICARDA. 2000. Lentil: Good for Food, Good for the Environment
- ICARDA. 2000. Working with Nature: The Success Story of Winter Chickpea
- Haddad, N., E. Al-Karablieh, and E. Bailey 1997. Development and Transfer of Improved Technologies for Integrated Crop-Livestock production in Low-Rainfall Zones
- Muehlbauer, F.J., C. Francis, and B. Gregg. 1996. Report of the Center Commissioned External Review of Projects Concerning Cool Season Legumes and Seed Production at ICARDA, Aleppo, Syria. ICARDA, Aleppo, Syria.
- Plucknett, D.L., M. Duwayri, P. Franck, K. Hammer, W. Powell, and G. Wilde. 1997. Report of the Center Commissioned External Review of Cereal Germplasm Improvement and Genetic Resources and Integrated Management of Pests and Diseases of Cereals and Legumes. ICARDA. Aleppo, Syria.
- Rajaram. S. 2004. Strategy for Wheat Germplasm Improvement in CWANA Region. ICARDA. Aleppo. Syria

Annex V
Glossary of Abbreviations and Acronyms

Abbreviation/Acronym	Name
ACSAD	The Arab Center for the Studies of Arid Zone and Dry Areas
AFLP	Amplified Fragment Length Polymorphism
AGERI	Agricultural Genetic Engineering Research Institute, Egypt
ANF	Anti Nutritional Factor
ARI	Agricultural Research Institute
BL	Biotechnology Laboratory
BSGM	Barley Stem Gall Midge
BYDV	Barley Yellow Dwarf Virus
CAC	Central Asia and Caucasus Countries
CB	Crossing Block
CBSU	Computer and Biometrics Service Unit
CCER	Center-Commissioned External Review
CCN	Cereal Cyst Nematode
CIMMYT	Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico (International Maize and Wheat Improvement Center)
COS	Conserved Ortholog Set
CP	Challenge Program
CpCDV	Chickpea chlorotic dwarf virus
CWANA	Central and West Asia and North Africa
DAS-ELISA	Double Antibody Sandwich-ELISA
DFID	Department for International Development, UK
D-PPB	Decentralized-Participatory Plant Breeding
EARO	Ethiopian Agricultural Research Organization
EPMR	External Program and Management Review
EST	Expressed sequence tag
ETH-Zurich, Switzerland	Swiss Federal Institute of Technology (ETH)-Zurich, Switzerland
FAO	Food and Agricultural Organization
FFS	Farmers' Field Schools
FWW	Facultative Winter Wheat
GEC	Gamma-glutamine-S-Ethenyl-Cysteine
GEF	Global Environment Facility
GIS	Geographical Information System
GP	Germplasm Program
GRU	Genetic Resources Unit
HF	Hessian Fly
HTON	Heat Tolerance Observation Nursery
IBIS	International Barley Information System
ICIS	International Crop Information System

ICRISAT	International Crop Research Institute for Semi Arid Tropics, India
IDON-TA	International Durum Observation Nursery-Temperate Area
IDYT	International Durum Yield Trial
IGM	Integrated Gene Management
ILRI	International Livestock Research Institute, Kenya
IPGRI	International Plant Genetic Research Institute, Italy
IPM	Integrated Pest Management
IRESA	Institution for Agricultural Research and Higher Education, Ministry of Agriculture, Tunisia
IWWIP	International Winter Wheat Improvement Program
JA	Journal articles
JKC	Jannah Khetifa/Cham1
LARI	Lebanese Agricultural Research Institute
MAS	Marker Assisted Selection
MDM	Omrabi5/T.dicoccoides//Omrabi5
MDON-HAA	Mediterranean Durum Observation Nursery – High Altitude Area
MDON-TA	Mediterranean Durum Observation Nursery - Temperate Area
MDYT	Mediterranean Durum Yield Trial
MTP	Medium-Term Plan
NARS	National Agricultural Research Systems
NCARTT	National Center for Agricultural Research and Technology Transfer, Jordan
NPO	National Professional Officer
OP	Other Publications
OPEC	Organization for Petroleum Exporting Countries
PPB	Participatory Plant Breeding
QTL	Quantitative Traits Loci
REML	Residual Maximum Likelihood
RWA	Russian Wheat Aphid
RWCB	Regional Wheat Crossing Block
RWYT-LR-CA	Regional Wheat Yield Trial-Low Rainfall-Continental Areas
RWYT-LR-SC	Regional Wheat Yield Trial-Low Rainfall-Sub-Continental Areas
RWYT-MR	Regional Wheat Yield Trial-Moderate Rainfall
SLL	Syrian Local Large
SADC	Southern African Development Community
SBW	Spring Bread Wheat
SNP	Single Nucleotide Polymorphism
SPDC	Seed Production and Development Committee
SPII	Seed Production Institute, Iran
SSR	Single Sequence Repeat
STS	Sequence-Tagged Site
SU	Seed Unit
TBIA	Tissue-blot immunoassay
TCI	Turkey/CIMMYT/ICARDA

UNDP	United Nations Development Program
UNDP/PAPP	<u>UNDP Program of Assistance to the Palestinian People</u>
VIR	Vavilov Institute for Research
WANA	West Asia and North Africa
WON-D	Wheat Observation Nursery for Dry Areas

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