

**Plant Genetic Resources Newsletter**

**Bulletin de Ressources Phytogénétiques**

**Noticiario de Recursos Fitogenéticos**



**No. 102, 1995**



**Food and Agriculture Organization of the United Nations and the International Plant Genetic Resources Institute**

**Organisation des Nations Unies pour l'alimentation et l'agriculture et l'Institut international des ressources phytogénétiques**

**Organización de las Naciones Unidas para la Agricultura y la Alimentación y el Instituto Internacional de Recursos Fitogenéticos**

# Plant Genetic Resources Newsletter

## Aims and scope

The *Plant Genetic Resources Newsletter* publishes papers in English, French or Spanish, dealing with the genetic resources of useful plants, resulting from new work, historical study, review and criticism in genetic diversity, ethnobotanical and ecogeographical surveying, herbarium studies, collecting, characterization and evaluation, documentation, conservation, and genebank practice.

## Management

The *Plant Genetic Resources Newsletter* is published under the joint auspices of the International Plant Genetic Resources Institute (IPGRI) and the Plant Production and Protection Division of the Food and Agriculture Organization of the United Nations (FAO).

## Availability

The *Plant Genetic Resources Newsletter* appears as one volume per year, made up of four issues, published in March, June, September and December. *Plant Genetic Resources Newsletter* is available free of charge to interested libraries of genebanks, university and government departments, research institutions, etc. The periodical may also be made available to individuals who can show that they have a need for a personal copy of the publication.

## Types of paper

### Articles

An article will publish the results of new and original work that makes a significant contribution to the knowledge of the subject area that the article deals with. Articles, which should be of a reasonable length, will be considered by the Editorial Committee for scope and suitability, then assessed by an expert referee for scientific content and validity.

### Short communications

A short communication will report results, in an abbreviated form, of work of interest to the plant genetic resources community. Short communications in particular will contain accounts of germplasm acquisition missions.

### Other papers

The *Plant Genetic Resources Newsletter* will publish other forms of reports such as discussion papers, critical reviews, and papers discussing current issues within plant genetic resources.

Book reviews will be printed, as well as a News and Notes section. Suggestions for books to review are invited, as are contributions to News and Notes.

## Submission

In the first instance papers may be submitted in typescript form or as an Email message. The final version may be submitted as an Email file or as an MS-DOS-readable file on diskette.

## Editorial office

Manuscripts submitted for publication and other communications on editorial matters should be addressed to:

Managing Editor  
Plant Genetic Resources Newsletter  
IPGRI  
Via delle Sette Chiese 142  
00145 Rome  
Italy.

Phone: (39-6)51892233. Telex: 4900005332(IBR UI) [via USA].  
Email: P.STAPLETON@CGNET.COM or IPGRI@CGNET.COM.  
Fax: (39-6)5750309

Cover: Local farmer inspecting rice plants, Bhutan

The designations employed, and the presentation of material in the periodical, and in maps which appear herein, do not imply the expression of any opinion whatsoever on the part of IPGRI or FAO concerning the legal status of any country, territory, city or area or its authorities, or concerning the delimitation of its frontiers or boundaries. Similarly, the views expressed are those of the authors and do not necessarily reflect the views of IPGRI or FAO.

All rights reserved.

©IPGRI/FAO 1995

# Bulletin des ressources phytogénétiques

## Domaine d'intérêt

Le *Bulletin des ressources phytogénétiques* publie des articles en anglais, en espagnol et en français, sur les ressources génétiques de plantes utiles, fruit de nouvelles recherches, d'études historiques, d'examen et de critiques concernant la diversité génétique, d'études ethnobotaniques et écogéographiques, d'études d'herbiers, d'activités de collecte, de caractérisation et d'évaluation, de documentation, de conservation et les pratiques des banques de gènes.

## Parrainage

Le *Bulletin des ressources phytogénétiques* est publié sous les auspices de l'Institut international des ressources phytogénétiques (IPGRI) et de la Division de la production végétale et de la protection des plantes de l'Organisation mondiale de l'alimentation et de l'agriculture (FAO)

## Distribution

Le *Bulletin des ressources phytogénétiques* paraît une fois par an en un volume regroupant quatre numéros publiés en mars, juin, septembre et décembre. Il est distribué gratuitement aux bibliothèques des banques de gènes, universités, services gouvernementaux, instituts de recherche, etc. s'intéressant aux ressources phytogénétiques. Il est aussi envoyé sur demande à tous ceux pouvant démontrer qu'ils ont besoin d'un exemplaire personnel de cette publication.

## Types de documents publiés

### Articles

Un article contient les résultats de travaux nouveaux et originaux qui apportent une contribution importante à la connaissance du sujet dont traite l'article. Les articles, qui doivent être d'une longueur raisonnable, sont d'abord examinés par le Comité de rédaction qui en évalue la portée et la validité, puis par un expert qui en examine le contenu et l'intérêt scientifiques.

## Brèves communications

On entend par brève communication un texte contenant, sous une forme abrégée, les résultats de travaux présentant un intérêt pour tous ceux qui s'occupent de ressources phytogénétiques. Elle contient en particulier des comptes rendus des missions d'acquisition de matériel génétique.

## Autres documents

Le *Bulletin des ressources phytogénétiques* publie d'autres types de rapport tels que des documents de synthèse, des études critiques et des articles commentant des problèmes actuels concernant les ressources phytogénétiques.

Le Bulletin publie une revue de livres ainsi qu'une section intitulée Nouvelles et Notes. Les auteurs sont invités à envoyer leurs suggestions pour les livres à passer en revue ainsi que des contributions aux Nouvelles et Notes.

## Présentation

En premier lieu, les documents doivent être soumis dactylographiés ou par courrier électronique. La version définitive doit être présentée en fichier de courrier électronique ou sur disquettes compatibles MS-DOS.

## Rédaction

Prière d'adresser les manuscrits présentés pour être publiés et d'autres communications sur des questions de rédaction à:

Managing Editor  
Plant Genetic Resources Newsletter  
IPGRI  
Via delle Sette Chiese, 142  
00145 Rome  
Italie

Téléphone: (39-6)51892233. Téléc: 4900005332(IBR UI) [via USA]. Courrier électronique: P.STAPLETON@CGNET.COM ou IPGRI@CGNET.COM. Télécopie: (39-6)5750309.

Couverture: Fermier en train d'inspecter des plants de riz au Bhutan

Les appellations employées dans cette publication et la présentation des données et cartes qui y figurent n'impliquent de la part de l'IPGRI et de la FAO aucune prise de position quant au statut juridique des pays, territoires, villes ou zones, ou de leurs autorités, ni quant au tracé de leurs frontières ou limites. Les opinions exprimées sont celles des auteurs et ne reflètent pas nécessairement celles de l'IPGRI ou de la FAO.

Tous droits réservés.

# Noticario de Recursos Fitogenéticos

## Objetivos y temas

El Noticario de Recursos Fitogenéticos publica documentos en inglés, francés y español que tratan de los recursos genéticos de plantas útiles para la humanidad, y que son el fruto de nuevos trabajos, estudios históricos, revisiones y análisis críticos relacionados con la diversidad genética, investigaciones etnobotánicas y ecogeográficas, estudios de herbarios, trabajos de colección, caracterización y evaluación, documentación, conservación, y prácticas en bancos de germoplasma.

## Dirección

El Noticario de Recursos Fitogenéticos se publica bajo los auspicios conjuntos del Instituto Internacional de Recursos Fitogenéticos y la Dirección de Producción y Protección Vegetal de la Organización de las Naciones Unidas para la Agricultura y la Alimentación.

## Distribución

El Noticario de Recursos Fitogenéticos aparece como un tomo anual compuesto por cuatro números, que se publican en marzo, junio, septiembre y diciembre. Se distribuye gratuitamente a las bibliotecas de bancos de germoplasma interesadas, facultades universitarias y ministerios estatales, centros de investigación, etc. También pueden obtener la revista las personas que necesiten una copia de la publicación.

## Tipos de Documentos

### Artículos

Los artículos, que deberán tener una extensión razonable, divulgarán los resultados de un trabajo nuevo y original que contribuya de modo importante al conocimiento del tema tratado. El Comité de redacción examinará la pertinencia e idoneidad de los artículos y posteriormente una comisión de expertos juzgará su contenido y validez científicos.

## Comunicaciones breves

Las comunicaciones breves informarán de modo conciso sobre los resultados de un trabajo de interés para las personas que se ocupan de los recursos fitogenéticos. Las comunicaciones breves incluirán, en particular, resúmenes sobre las misiones de adquisición de germoplasma.

## Otros documentos

El Noticario de Recursos Fitogenéticos publicará otros tipos de informes, como documentos de trabajo, análisis críticos, y documentos que examinen cuestiones de actualidad relacionadas con los recursos fitogenéticos.

El Noticario publicará una reseña de libros así como una sección de Noticias y Notas. Las propuestas de libros para reseñar y las contribuciones a la sección de Noticias y Notas serán bien acogidas.

## Presentación

Los documentos deben entregarse, inicialmente, en forma de texto mecanografiado o de correo electrónico. La versión final debe presentarse como un archivo de correo electrónico o en disquete compatible con el sistema operativo MS-DOS.

## Oficina de redacción

Los manuscritos para publicar y otras comunicaciones sobre asuntos relativos a la redacción deberán dirigirse a:

Managing Editor  
Plant Genetic Resources Newsletter  
IPGRI  
Via delle Sette Chiese 142  
00145 Roma  
Italy

Tel: (39-6)51892233. Télex: 4900005332 (IBR UI) [via USA].  
Email: P. STAPLETON CGNET.COM o IPGRI@CGNET.COM.  
Fax: (39-6)5750309

Portada: Campesino inspeccionando plantas de arroz en Bhutan

Las denominaciones empleadas, y la forma en que aparecen presentados los datos en esta publicación, no implican, de parte del IPGRI o la FAO, juicio alguno sobre la condición jurídica de países, territorios, ciudades o zonas, o de sus autoridades, ni respecto de la delimitación de sus fronteras o límites. Asimismo, las opiniones expresadas son las de sus autores y no reflejan necesariamente la opinión del IPGRI o la FAO.

Todos los derechos están reservados.

©IPGRI/FAO 1995

**REVIEW****Translating genetic resource rights into sustainable development: gene cooperatives, the biotrade and lessons from the Philippines\*****Walter V. Reid<sup>1</sup>, Charles V. Barber<sup>1</sup> and Antonio La Vina<sup>2</sup>**<sup>1</sup> World Resources Institute, 1709 New York Avenue NW, Washington, DC 20006, USA<sup>2</sup> Institute for International Legal Studies, University of the Philippines Law Center, Diliman, Quezon City, Metro Manila, The Philippines**Summary**

The 1992 Convention on Biological Diversity marks a basic change in the international status of genetic resources. Prior to the Convention, these resources were considered to be the "heritage of mankind". Although the intent of this open-access regime was to ensure the widespread availability of genetic resources for agriculture and industry, commercial use of the resources provided no additional economic incentive for conservation by source countries. The Biodiversity Convention corrects this policy failure by establishing that states have sovereign rights over their genetic resources, thereby enabling market incentives to complement various multilateral mechanisms that might directly fund biodiversity conservation. A number of obstacles face countries that are translating this broad right to regulate access into specific policies, laws and regulations designed to meet conservation and development objectives. A review of these obstacles and of trends in technological development suggests a set of actions that nations and developing country institutions should take to develop access legislation and Material Transfer Agreements, establish biodiversity 'cooperatives' and intermediary institutions to facilitate information exchange, develop minimum standards for access legislation, and extend obligations for prior informed consent of local communities to all biodiversity collectors. A review of recent legislation on genetic resource access regulation in the Philippines illustrates that while these recent steps provide an essential framework, many options and decisions lie ahead.

**Introduction**

International law, it is often noted, tends to follow rather than lead technological, political and social developments. Not so in the case of genetic resources. The changes now underway in laws and policies governing the ownership of, and access to, genetic resources are remarkable in their scale, speed and implications. The policy formulation and experimentation taking place today will establish a new legal framework for biodiversity trade likely to remain for decades to come. A window of opportunity now exists to ensure that this framework meets economic, social and environmental objectives consistent with sustainable development and the human rights of affected sectors. But dialogue within countries and their societies on how to do this has barely begun, and many emerging technological and policy issues are not yet well understood.

The longstanding international regime governing genetic resources, based on the principle that biodiversity was a "heritage of mankind" (FAO 1983), reached an unstable threshold in the late 1980s. Technological change

had increased the value of biological diversity for agriculture, pharmaceuticals and biotechnology, and awareness of this value had grown even more rapidly. Expansion of intellectual property rights made it ever more possible to earn significant profits from this growing economic value. Concerns about the equitable sharing of benefits from the use of biological materials with the innovators or protectors of those resources stimulated both grassroots and national criticisms of the *status quo*. And, despite the commercial value of biodiversity, it was apparent that the open-access regime resulted in little additional economic incentive for conservation.

The Convention on Biological Diversity, signed in 1992 and entering into force in December 1993, formalized central elements of a new international regime designed to conserve biodiversity, ensure its sustainable use and ensure equitable sharing of benefits from its use. The Convention reaffirms the sovereign rights of nations to their biodiversity, establishes a right to regulate access to genetic resources and creates an obligation for countries to provide prior informed consent before collecting genetic material from another country. By linking objectives of conservation, benefit-sharing and technology transfer, the Convention also established a framework to strengthen economic incentives for conservation by seeking

\* This paper is a revised version of a manuscript published in "Biodiversity Prospecting: Expectations and Realities" (1995, A.H. Zakri, Editor), Genetics Society of Malaysia, Kuala Lumpur and is published with the permission of the Society.

complementarities between commercial, conservation and development goals.

But having established general international rights and obligations, the Convention stopped short of specifying how those rights would be defined and enforced. Nations are now translating these broad principles into specific policies, laws and regulations designed to meet conservation and development objectives. This paper first examines two factors central to the design of appropriate policies for genetic resources: technological change and mechanisms for sharing benefits. The influence of these factors on the content of new policies will have far-reaching implications for the success of this new regime. The paper then examines one legislative effort underway in the Philippines to implement the principle of national sovereignty over genetic resources—through the drafting and promulgation of a Presidential Executive Order regulating biodiversity prospecting—and assesses how this new regime will fare in light of the issues raised in the discussion of technological change and benefit-sharing mechanisms.

### Technological change

The rapid technological change that helped stimulate a re-thinking of genetic resource policies continues apace; biotechnology is one of the most rapidly evolving fields of science today. Consider the transformation that is taking place in the seed industry. Just a decade ago, traditional crop varieties and wild crop relatives were the only sources of new genetic material for the seed industry. Moreover, because of the expense and time involved, private firms largely relied on public breeders to conduct the wide-crossing that introduced novel genes into breeding lines from distantly related varieties. Individual genes could not be patented, no restrictions were placed on farmers' ability to save and re-grow seeds, and the few countries that provided intellectual property protection to breeders limited it to relatively narrow Plant Breeders Rights. Under the FAO International Undertaking on Plant Genetic Resources, genetic material was considered to be a 'common heritage' resource.

Today, breeders can move genes from unrelated species into agricultural crops through genetic engineering. These genetically engineered crops are likely to become commonplace in commercial agriculture in developed countries within the next decade. Increasingly, commercial innovation and R&D have shifted from public institutions to private. Using screening techniques similar to those used by the pharmaceutical industry, breeders are screening plant extracts for anti-fungal or anti-viral activity and, when simple proteins are responsible for the activity, isolating and transferring the genes responsible for those chemicals into elite crop lines in a matter of days. On the horizon, breeders may be able to create apomictic crop varieties that would enable the self-replication of hybrids (Jefferson 1993). These changes have

both stimulated and benefited from a rapidly evolving system of property rights. A number of countries now allow gene patenting or plant patenting, and some are considering prohibitions on farmers' ability to freely save and re-grow seeds. Advances in DNA sequencing technologies will make monitoring and enforcing this broadened intellectual property right protection increasingly inexpensive.

Dramatic changes have also taken place in the use of biodiversity in the pharmaceutical industry, primarily as a result of advances in screening technologies. With the exception of microorganisms which have always been collected in small quantities and cultured in laboratories, natural products drug discovery processes have traditionally required substantial quantities of material. In the case of plants, samples of anywhere from 1 to 10 kg have been required for initial extraction and screening. If an extract showed promising activity, substantially larger samples were then required for activity-directed fractionation, isolation, structure elucidation of active compounds and further biological testing. Because of the complexity of many natural chemicals, their isolation, characterization and synthesis has been a time-consuming and expensive process.

Today, techniques for extraction, screening, fractionation and chemical identification are becoming routine and inexpensive. New chemical and analytical methods help increase the efficiency of natural product screening. Using separation techniques such as High Performance Liquid Chromatography (HPLC) and High Performance Centrifugal Counter Current Chromatography (HPCCC) and analytical methods such as High Field Nuclear Magnetic Resonance Spectrometry, samples can be fractionated and characterized in a small fraction of the time formerly required. Prior to the 1980s, using test-tube and *in vivo* assays, a lab could screen 100-1000 samples per week. Now, using 96-well microtiter plates and robotics, labs can screen 10 000 samples per week in a broad range of mechanism-based assays. For example, hundreds of thousands of microorganism cultures are screened by Merck each year (B. Boris, Merck & Co., pers. comm., 19 Sept. 1994). Where the screening of 10 000 plant extracts would have cost \$6 million one decade ago, it can now be accomplished for \$150 000 (J. Devlin, Applied Research Resources and Technologies, Inc., pers. comm., 19 Sept. 1994). In the next decade, with further miniaturization and high-speed robotics the throughput could grow by another one or two orders of magnitude. Miniaturization also reduces the quantity of raw material required. Samples of only 200 to 500 g of dry plant material are now needed for isolation, structure elucidation and secondary testing of a novel plant metabolite. A single 10-mg extract sample is now sufficient for 20-30 assays and preliminary characterization of major constituents by on-line spectroscopy (HPLC-DAD and LC-MS). It is now routine to obtain full chemical characterization from just 50 mg of a pure compound.

And, tissue and cell culture—the next frontier of natural products research—now allows the collection and screening of small samples of plants without any need to return for further supplies. A company can obtain seeds or samples of a variety of plants, establish the material in cell culture and challenge that culture with various chemicals or environmental stresses to stimulate the expression of new chemicals. The companies Phytera Inc. and Phytopharmaceuticals, for example, base their drug discovery process on plant cell culture methodologies.

Finally, advances in screening methodologies have been accompanied by tremendous improvements in the bioassays themselves, which has significantly decreased the likelihood of false positive 'hits'. Using cell-based and receptor-based assays, activity can be detected at concentrations several orders of magnitude lower than were required for *in vivo* tests.

These technological trends are also blurring the distinctions between agricultural, industrial and pharmaceutical applications of biodiversity. A small quantity of material from a plant or microorganism can be maintained in culture and screened for potential use in any of these industries. New technologies influence both what is possible and what is desirable for public policies. Consider the issues of the value of genetic resources, the ability to monitor their use and the control of illegal trade.

### Value

New technologies continue to increase the economic value of wild biological diversity for two reasons. First, the potential commercial use of any sample of material has expanded considerably. Any organism is now a source of chemical and genetic innovation with potential application in the pharmaceutical, agricultural or industrial chemical industries. Second, the cost of working with new genetic material or identifying and isolating new chemicals is decreasing rapidly.

However, while the economic value of genetic resources in general is increasing, the same cannot be said for the commercial value of any given species or extract. The same technological advances that increase the demand for genetic resources have vastly increased the effective supply. Plant breeders no longer need to restrict their search for new genes to crop relatives, or even to the plant kingdom. At no additional cost, pharmaceutical companies can now search more species, by orders of magnitude, than was possible a decade ago. And, scientists are continuing to discover abundant new species diversity. For example, a tremendous genetic and biochemical diversity exists among invertebrates and microorganisms in any square meter of soil anywhere in the world, and microbiologists are also discovering unique species in the deep sea through such programs as the Japanese Deepstar project (Myers and Anderson 1992). (Microorganisms near hydrothermal vents on the marine floor may be particularly valuable to industry because of their heat-stable enzymes.) Exclusive of

microorganisms, estimates of species diversity have grown from 3 million to possibly as many as 80 million species (Reid and Miller 1989). Microorganisms themselves, which have proven to be the most valuable source of biodiversity for the pharmaceutical industry in the past, have an immense unstudied diversity. Finally, this vast and growing biological supply of chemical diversity is increasingly competing with chemicals from synthetic libraries and combinatorial chemistry.

While in the near term there is competition among firms for access to a relatively small number of quality suppliers of raw biochemical and genetic material, over the long term the large supply of material and the decreasing costs of natural product research are likely to hold the 'market' value of samples of raw materials very close to the direct labour cost of obtaining the sample.

### Monitoring

Like information, genetic material can be reproduced easily and inexpensively, making it difficult to establish and enforce property rights. The property rights regimes that have been developed—such as Plant Breeders Rights—also had to confront the difficulty of determining how similar or dissimilar a 'new' organism was from other protected varieties. Plant Breeders Rights traditionally relied only on the presence of phenotypic differences among varieties (e.g. flower colour) and the right extended only to an ability to market the variety under the certified name.

Today, the ability to identify specific genes in plants enables not only the establishment of patent protection for those genes (when moved into unrelated species), but also the ability to monitor their subsequent use in other plants. Similarly, in some instances it is technologically feasible to ascertain whether specific genes (or organisms) used in an industrial process came from a particular species.

But while technological advances enhance monitoring of the use of genetic material in agriculture, they hinder monitoring in the pharmaceutical industry. As the quantity of material required for the initial stages of drug discovery continues to shrink, source countries and institutions lose an important means of monitoring the drug development process. It has always been far more cost-effective for companies to return to the source for more material after obtaining initial positive results than to attempt to synthesize each promising 'hit'. By providing coded extracts to users, source institutions also could ensure that users would not simply obtain further supplies of the species involved from other sources (Reid *et al.* 1993). Now, because initial phases of drug discovery can be completed with much less material, there is less need to return to source countries. At the same time, tissue and cell culture allows companies to establish plant material outside of the source country and explore it without any need to return for more material.

### **Controlling illegal trade**

An important factor that helped maintain the 'common heritage' principle for as long as it survived was the inability of nations to effectively control access to genetic resources. History is replete with failed attempts to protect such resources, including Brazil's efforts to protect its rubber germplasm, and Andean nations' attempts to prevent the export of Cinchona (the source of quinine). The Biodiversity Convention provides a more secure basis for countries to regulate access because signatories agree to respect sovereign rights to genetic resources.

However, many new technologies, while improving opportunities to monitor some aspects of genetic resource trade, may also facilitate illicit trade in these resources. It remains virtually impossible to prevent genetic material from leaving a country. Moreover, with advances in tissue culture and micro-screening, far less material is needed for any potential genetic or biochemical application. Indeed, it is now possible to explore herbarium specimens for chemicals and even to establish cultures from surviving seeds collected from herbarium sheets. Even though techniques do exist to identify and monitor the use of genetic material, the ability to use such techniques to stop illegal trade in genetic material is limited since it would be difficult to pinpoint the species or country of origin (for widespread species) and impossible to determine whether it had been obtained before the Biodiversity Convention entered into force.

### **Equitable sharing of benefits**

Although the Convention on Biological Diversity establishes the principle of fair and equitable sharing of benefits arising from the use of genetic resources, it does not establish the specific mechanism for realizing this objective. Moreover, the Convention says little about how benefits are to be shared within nations, although it does encourage equitable sharing of benefits arising from traditional knowledge, innovations and practices.

The allocation of benefits from the use of biodiversity (both among and within nations) must balance the need to: (i) promote technological innovation, (ii) provide incentives for conservation, and (iii) reward both physical and intellectual contributions of individuals who protected, developed or explored the biological diversity involved. Appropriate policies must also balance indirect benefits received by individuals and nations from the use of their genetic resources, with direct benefits that can provide more targeted incentives and compensation (i.e. to particular people, communities, regions or institutions) but typically at a higher transaction cost. Even where targeted payments may be desirable in theory, the associated transaction costs may make such mechanisms impractical.

### **Are indirect benefits sufficient? the case of taxol**

Under what conditions is a targeted payment or incentive appropriate? An instructive example demonstrating the

difficulties of balancing indirect and direct benefits to meet objectives of innovation and conservation is the development and commercialization of the anti-cancer chemical taxol, derived from the Pacific Yew, a tree found in the northwestern states of Oregon and Washington, USA. The anti-cancer activity of taxol was discovered in 1963 by the Natural Products Branch of the US National Cancer Institute (NCI). NCI, a publicly funded agency, developed the compound through Phase II clinical trials, and in 1991 signed a Cooperative Research and Development Agreement (CRADA) with Bristol-Myers Squibb, under which Bristol-Myers was given exclusive rights to the clinical and preclinical data necessary to obtain approval of the new drug (DeFuria and Horovitz 1993). In 1992, taxol was approved for treatment of ovarian cancer and approval for breast cancer treatment is pending (Leary 1992).

This type of arrangement is not unusual. Under the US Technology Transfer Act of 1986, public agencies that have found promising new candidates for drugs can negotiate an exclusive licence for the patent to the drug with a private company through a CRADA. (In the case of taxol, the structure of the compound had previously been published and thus it could not be patented. Exclusive rights to the test results, however, gave Bristol-Myers effective protection for the drug since it would take any potential competitor a number of years to replicate the clinical studies.) A company involved in a CRADA typically pays nothing to the federal government for that licence, but is subject to negotiated limits on prices it can charge for the new drug if it is commercialized. The company then provides the financing to complete clinical testing and, if the tests are successful, for commercializing the product.

Although the American taxpayers 'give away' a valuable product to a private firm through such a CRADA, they receive an indirect return of benefits in the form of the new health care product. Such an arrangement makes sense as long as the primary goals of the policy are improved health care, and provided that those who pay for the public sector research are also those who receive the indirect benefits from the new drugs. However, within the framework of the Convention on Biological Diversity an additional goal now exists in the case of natural products research: the need to provide incentives for conservation through benefit-sharing.

Putting aside the issue of whether Bristol-Myers is receiving an unduly large share of benefits from taxpayer-financed research (a subject of Congressional hearings in 1991; House of Representatives 1992), there remains the question of whether economic benefits from the commercialization of taxol should be returned to the Pacific Northwest where the compound originated. While the conservation of these forests will provide substantial ecological and economic benefits to society as a whole in the Pacific Northwest, reductions in timber harvest associated with protecting more forest and establishing more

sustainable forestry practices will cause specific and obvious economic problems for workers in the timber industry, and contribute to ongoing declines in the industry in rural communities in the region. Clearly, these communities would see greater reason to protect these forests for biodiversity conservation if they obtained identifiable commercial benefits from that protection.

The region has already received some economic benefits through the sourcing of yew bark for extraction of taxol. In the early 1990s, over 1 million pounds (447 000 kg) of dry Pacific Yew bark were harvested from Federal lands annually, providing employment for an estimated 1115 workers in 1992 (USDA 1993). (Typically, timber harvest would also provide revenues to local government in the form of a portion of the stumpage fee for timber harvest on federal lands. However, to reduce the cost of yew to Bristol-Myers the federal government waived the stumpage fee on yew, thereby reducing local benefits from its harvest.) Regional employment for yew sourcing peaked in the early 1990s as methods of extracting taxol from several species of yew trees (including species found in Canada, China and Japan) were developed. Various species of yew are now being cultivated in a variety of regions to provide a source of material. Moreover, new partial syntheses from precursors could become commercially practical within the next few years (DeFuria and Horovitz 1993).

While the CRADA clearly provided an incentive to Bristol-Myers to complete the commercialization of taxol and the nation as a whole received a substantial return on their tax dollars in the form of the new health-care product, it seems likely that the direct benefits from a short period of supplying bark of the Pacific Yew provided relatively little incentive for biodiversity conservation in the Northwest (especially considering the reduction in local tax revenues). Just as the long-term future of biodiversity conservation in developing countries has been enhanced by the Biodiversity Convention's stipulation that benefits from the use of biodiversity be shared with the country of origin, the long-term protection of biological diversity in the Pacific Northwest would be significantly enhanced if the region stood to receive a share of the profits from drugs developed from local biological diversity.

Taxol is not the only example of this situation in the United States. The microorganism *Thermus aquaticus*, collected from a hot-spring in Yellowstone National Park, for example, was the source of Taq polymerase, the thermostable DNA-copying enzyme that is the basis for the polymerase chain reaction (PCR), a patented process worth millions of dollars annually for the Swiss pharmaceutical firm Hoffmann-LaRoche (Milstein 1994). The US Park Service is now questioning whether a share of royalties from further exploration of biodiversity should be returned to the national parks. A number of companies, including Genencor International, Stratagene Corp. and New England Biolabs have collected microorganisms from Yellowstone.

### **Mechanisms for targeting benefits**

One of the principal achievements of the Biodiversity Convention is that it provides an international legal framework to foster establishment of mechanisms to increase direct or targeted benefits to nations that conserve and make available their biodiversity. In the case of plant genetic resources, the FAO International Undertaking on Plant Genetic Resources was premised on the notion that the indirect benefits to developing countries of obtaining new, high-yielding crop varieties from international agricultural research stations more than outweighed the investment these countries had made by providing genetic material to the research institutions. Indeed, all countries receive more genetic material from the international exchange of genetic resources than they contribute (Cooper *et al.* 1994). Nevertheless, some countries contribute much more genetic diversity into the international exchange than others, and, within countries, some farmers are more responsible for saving and adapting traditional varieties of crops than others.

The indirect benefits implicit in a system of free access and use of genetic diversity thus did not adequately ensure that farmers maintaining agricultural diversity benefited from the labour (and opportunity costs) involved in maintaining these varieties, or ensure that countries particularly rich in genetic diversity had a greater incentive to conserve that diversity. The Biodiversity Convention thus provides a framework for creating these more targeted benefit-sharing arrangements.

Any number of mechanisms could serve to target benefits to particular individuals, communities or countries. The biodiversity convention now enables the establishment of a link between an individual biochemical extract or genetic sample and a claim on economic returns from commercial use of that sample—the ultimate in targeting of returns—but other types of mechanisms may often be more appropriate. Several factors influence the design of such mechanisms, but two of particular importance are how clearly the target can be defined, and whether the transaction costs associated with more precise targeting outweigh the added benefits of that targeting.

Consider the issue of returning benefits to traditional healers who provided information of value in drug development. If a decision to investigate a particular plant was made exclusively on the basis of information obtained by a single individual or community, then a benefit-sharing arrangement (typically through a contract) with that source of innovation (and conservation) makes good sense. More typically, however, drug discovery that makes use of traditional knowledge involves information from a number of different individuals and groups who might use a particular species or set of related species in a number of different ways. For example, Shaman Pharmaceuticals Inc. proposes to return benefits from any potential profits to all of the indigenous federations with which it is working, regardless of where the actual plant samples or infor-

mation originated. And, for most firms, that information is now obtained through the use of databases like Napralert, rather than through field inquiry. Given this more diffuse source of information and the indirect link between the information and the final commercial product, the policy rationale behind direct targeting of benefits to the particular sources of that information is weaker. For such a case, a reasonable mechanism might involve the establishment of a fund that received an initial payment and royalty from users of a database of traditional knowledge, with those resources distributed back to all groups that were the source of information held in the database.

The relative transaction costs associated with mechanisms for targeting benefits compared with the potential profits involved in the transaction also influence the design of appropriate benefit-sharing arrangements. In the case of pharmaceuticals, the potential profits ('market potential' *sensu* Barton and Siebeck 1994) from new drugs are large, a single contractual relationship between the supplier of a natural product and the firm commercializing it establishes the terms of the agreement, and typically only one source of raw material is involved (the 'input structure' involves only one source of raw material, *sensu* Barton and Siebeck 1994).

In contrast, new plant varieties typically do not generate large profits, the genetic material comprising a new variety is obtained from a variety of sources, and frequently that material has passed through the hands of more than one institution or breeder before ending up in the final product. Consequently, the potential profits that might flow to the source of the raw material are small to begin with, and the transaction costs entailed in identifying how profits should be divided and who should receive them are likely to be large. By one estimate, the commercial seed market in 2000 will be roughly \$7 thousand million dollars, of which breeding royalty payments would amount to approximately 10% or \$700 million (WWF 1989). Currently, the International Agricultural Research Centres (IARCs) distribute approximately 110 000 germplasm samples annually. Even if as much as 10% of the breeder's royalty was returned to the country of origin, this would amount to less than \$1000 per sample (and not all of these royalty payments would be to developing countries). Using a different method, Barton (1991) estimates that the total revenue that might be gained by developing countries for unimproved genetic material would amount to less than \$100 million annually.

However, the increasing use of patent protection for genes and, in a few countries, for plant varieties, may alter these economic considerations in agriculture. Patent protection will enable patent holders to obtain larger profits from the development of new plant varieties, and from the genetic technologies used to develop them. In these instances, with a higher market potential and simpler input structure it may become cost-effective for suppliers of genetic material to negotiate benefit-sharing arrangements.

### Strategies for the biotrade

The market for raw genetic material (plant, animal, or microorganism samples or extracts) will be increasingly competitive and profits relatively small. The profitability of trade in raw genetic material or chemical extracts is limited by the tremendous diversity of species (and the diversity of chemicals within those species). Competition among suppliers, as well as the potential development of a black market in genetic and biochemical material, will result in low prices (both initial payments and contingent prices) for these materials.

At the same time, expectations of contingent returns must be tempered by the real probabilities of discovery of new agricultural, industrial or pharmaceutical applications (Reid *et al.* 1993). Of the 70 000 extracts that the National Cancer Institute screened between 1985 and 1994, none have advanced to clinical trials (although six are in some stage of pre-clinical trials). Unless an institution or nation is providing hundreds of thousands of samples, the odds are that no pharmaceutical product will be developed. Even if a product is developed, it will most likely be a derivative of the natural product, thereby reducing, or in some cases precluding, royalty returns.

Institutions or nations seeking to obtain long-lasting benefits from the international biotrade thus need to follow one of two basic strategies. First, an institution could seek to become a low-cost supplier by providing substantial quantities of diverse material to industry at low cost. Because of the difficulty of actually monitoring how samples are used, the low-cost supplier would probably place relatively low value on contingent payments, and prefer higher up-front payments. An example of such an institution is Microsource Discovery Systems, Inc. in Connecticut, which advertises 'one-stop shopping' with 'no rights retained' for screening for pharmaceutical, biotechnology and agrochemical industries from over 100 000 compounds "including diverse botanical extracts from the Amazon rain forest." Similarly, the Montana firm of J-K Research Inc. is engaged in the business of searching for novel microbes in Yellowstone and delivering samples to large biotechnology companies (Milstein 1994).

Alternatively, an institution (or a country) could aim to become a value-added supplier by providing particularly valuable material with known characteristics from screening or ecological or anthropological research, or providing other unique services such as access to particularly diverse materials, high assurance of re-supply, taxonomic sophistication, etc. Increasingly, product development firms are seeking quality and novelty of samples, rather than quantity. Adding value in this manner makes most sense if it can be done more cheaply by the supplier than by the firm receiving the samples (Simpson *et al.* 1995). However, as processes for genetic manipulation and biochemical screening become increasingly routine, economic incentives grow for firms to undertake a greater

portion of the screening and initial evaluation of materials in source countries. As the need for highly skilled and therefore high-cost labour is diminished, labour costs favour a shift to developing countries. In addition, extraction and screening close to the source of material can be advantageous for pharmaceutical research, since it increases the likelihood of discovering chemicals that may decay rapidly after material is collected and enables evaluation of species under different conditions (season, time of day, pest attacks, etc.) that could result in the production of different chemicals.

An additional incentive for undertaking a greater portion of the value-added work near the source may well be the access regulations established under the Biodiversity Convention. Even assuming that these regulations are not overly burdensome, they will nonetheless increase incentives to make the initial determination of the potential use of the genetic material within the source country before seeking to transfer it to another country.

National policies can foster the conditions that make greater domestic value-added work economically attractive. Nations with a knowledgeable workforce, appropriate intellectual property legislation and appropriate access legislation are more likely than others to be the recipient of such technologies. Indeed, source countries receiving substantial benefits from trade in biodiversity are more likely to be those with substantial human capacity and an appropriate policy framework than those that simply have high levels of biodiversity.

Institutions such as the Center for Natural Products Research (CNPR) in Singapore and the National Biodiversity Institute (INBio) in Costa Rica are examples of such value-added institutions. CNPR, established by the National University of Singapore, the Economic Development Fund of Singapore and Glaxo Pharmaceuticals, is engaged in high-throughput screening of some 1000 samples of plants, microorganisms and marine organisms each week. INBio primarily provides extracts and microorganisms to firms, but provides unique ecological and taxonomic expertise, assured re-supply, and is increasingly undertaking initial screening of materials. Examples of value-added suppliers are not restricted to developing countries: the firms Paracelsian, Inc. and Pacific Liaisons in Ithaca NY advertise that they will provide traditional Asian natural medicines screened for anti-neoplastic activity against human breast cancer using their proprietary assay.

What steps could countries or institutions supplying the international biodiversity trade take to increase the potential economic, technological and conservation benefits they receive?

#### **Seek stable partnerships with firms involved in product development**

For an institution or country primarily involved as a low-cost supplier, there is no particular advantage to the de-

velopment of partnerships. Such suppliers will place greater weight on up-front payments and will not be concerned with expanding their technological capacity. In contrast, there are substantial benefits that value-added institutions can receive through partnerships.

First, partnerships provide greater security that the terms of agreements will be respected. Because of the complexity of the technologies involved in the biodiversity trade, some attributes of agreements cannot be feasibly incorporated into written contracts and must be based on good will between parties (Lesser 1994). A country exporting seeds, microorganisms, or a sample of a plant or animal to another country is, in effect, exporting a small chemical factory complete with sophisticated blueprints and its own source of venture capital. Just as a firm is not likely to export technology without both legal and institutional assurances that its property rights will be protected, it makes little sense for countries to export germplasm without such assurances. (Indeed, all else being equal, given the difficulty of monitoring and protecting rights to genetic resources, there is a premium on countries exporting chemical samples in lieu of genetic material where possible.) For their part, pharmaceutical firms are extremely unlikely to transfer their proprietary cell-based or receptor-based bioassays unless that transfer is part of a joint venture that assures their rights to the screens and control over results of the screening.

Second, stable partnerships enable each institution to benefit from each other's comparative advantages. For example, as part of a partnership, a firm may be willing to transfer bioassays and screening technologies to an institution that could never have purchased them if it was only involved in cash transactions as a supplier. Even though these materials would be proprietary, they increase the expertise of researchers and provide the basis for further innovation within the country (e.g. development of a new or modified bioassay).

Even within developed countries, it is increasingly common for large research institutions to establish external alliances with companies that can provide extracts, chemicals or access to novel drug screens. These developed country alliances even include partnerships for collection of natural products, such as the 3-year agreement that Pfizer and the New York Botanical Garden announced in 1993 to collect plants from the United States for screening. Within developing countries, Merck has renewed its 2-year partnership with INBio and is discussing other partnership possibilities with institutions in Thailand, and Glaxo established the abovementioned 10-year agreement with Singapore's CNPR. With support from the International Cooperative Biodiversity Group Program of the American government, 5-year agreements have been signed between G.D. Searle and Co. and institutions in Peru; Bristol-Myers Squibb and institutions in Costa Rica, Cameroon and Nigeria; and American Cyanamid Co. and institutions in Argentina, Chile and Mexico (Leary 1993).

Finally, Sandoz Pharma AG is in the process of selecting five developing country institutions for long-term collaborations involving the isolation and selection of strains of microorganisms for drug development.

### **Add value and decrease risk through supplier cooperatives**

Institutions supplying raw genetic and biochemical resources could increase their economic returns and create the potential for more value-added activities by establishing partnerships or cooperatives. Independent providers face a number of disadvantages. The more suppliers that exist, the greater will be the competitive pressure holding down direct and contingent prices. Moreover, below a certain threshold of size and technical capacity, a supplier will not be in a position to benefit from technology transfer or value-added strategies that would be available to larger suppliers. Also, small suppliers will find it difficult to attract the investment needed to increase their capacity or technology. The only secure profits in such a business are the up-front payments for material. Unless significant quantities of samples are involved or considerable value has been added to the samples, there is a very good chance that no commercial products at all will be derived from samples provided by one institution (or even one country).

Such considerations have led to some support for the notion of a cartel of suppliers of genetic resources or a multilateral agreement among suppliers that could hold benefits above the level that would result from a multitude of competitive bilateral negotiations (S. Pollack, *Sussex, pers. comm.*, October 1994). Given the widely different technical capacity, levels of biodiversity and technology policies in supplier countries, however, the notion of agreement on anything but basic guidelines among supplier countries seems unlikely. A more reasonable approach may be for nations to establish cooperatives for marketing genetic resources. Like an agricultural cooperative (Peterson 1982), a biodiversity cooperative could provide three basic advantages to developing country suppliers: economies of scale, vertical integration of services and bargaining power.

The key element of such a cooperative would be that institutions (or nations) would supply raw material or extracts to the cooperative in return for a payment based on the number of samples provided and a contingent payment based on a proportionate share of royalties received for all products developed from material provided by the cooperative. (For example, an institution providing 25% of the samples traded would receive 25% of the royalties, even if the 'hit' did not come from its samples.) The cooperative would handle negotiations with firms seeking samples and develop alliances with product-development firms. Each member of the cooperative would have to provide samples or extracts at a specified level of quality and taxonomic precision, with appropriate approval from

their country's government, and with assurance that the material could be re-supplied. Each member would also have to be committed to the conservation components of appropriate bioprospecting ventures. In return, each member would receive a standard up-front and contingent payment. Additional value-added work by the cooperative (e.g. extraction or screening) would be done by individual members under terms negotiated by the group.

The members of the cooperative would benefit from the risk-sharing provision of the royalty agreement. On their own in the market, a few would earn substantial benefits from successful products, while most would earn little, if any, profit. Cooperative members would also benefit from economies of scale. Costs associated with negotiations would be reduced since the cooperative would be involved in more negotiations than any single supplier (and thus have more skill in negotiating), but fewer negotiations than the total that would have taken place if each institution was independent. If the cooperative chooses to centralize some of its processes (e.g. extraction or screening), this too would reduce the average cost of that process. A larger institution like this would be more likely to interest a product development firm in a long-term partnership, thereby setting the stage for more technology cooperation than otherwise would have taken place. And, if cooperatives were established on a regional basis, the arrangement would address the disputes that otherwise will inevitably arise when a new product is developed from a species found throughout a region if the royalty payments only went to the institution or country originally supplying the species.

Product development firms would also benefit from such an arrangement, since they would then have better access to a wider diversity of species. Indeed, to provide high levels of diversity, cooperatives could be established that pool material from countries around the world. Because transaction costs would also be reduced, pharmaceutical or agricultural companies would be able to obtain diversity more cheaply, even though the cooperative would be able to negotiate for higher returns than would a group of independent suppliers. They would also benefit from the greater security associated with a larger supplier in terms of the likelihood of being able to obtain re-supplies of material and the assurance that the governments involved had provided appropriate approval for the collecting.

A cooperative of this nature could be a public or private sector institution. While a group of countries could establish one such entity and require that all genetic trade pass through that institution, this would probably be far less beneficial than simply allowing institutions to join the cooperative as they saw fit. A country might have one institution providing material directly to industry and another channeling material through a regional cooperative. An institution with a unique product, e.g. samples collected through ecological research methods, would be

better off negotiating independent agreements, while other institutions would be better off joining a cooperative for marketing. Such cooperatives would also be appropriate recipients of development assistance funding, financial transfers under the Biodiversity Convention, or venture capital investments from the proposed IFC Biodiversity Fund.

While a cooperative could be developed *de novo*, it would make more sense to base it on an existing technological infrastructure. An institution like INBio, for example, could lease some of its facilities and administration capacity to a cooperative involving Costa Rica and other Central American states or other nongovernmental institutions in Central America. Or, a university with screening capacity could create a cooperative arrangement with suppliers from the region that would provide extracts. Already, the network of Bioresources Development and Conservation Programs in Nigeria, Cameroon, Mali and Ghana provides the basis for such a cooperative arrangement.

In the area of agricultural genetic resources, the IARCs of the Consultative Group on International Agricultural Research would be an appropriate setting for the establishment of such a cooperative; in this case, a global cooperative of agricultural genetic resource providers. Rather than simply requiring that commercial users of the genetic resources held by the IARCs negotiate benefit-sharing agreements with source countries (Barton and Siebeck 1994), they would establish a schedule of up-front and contingent payments from commercial users of the resources, pool these funds, and distribute the funds back to source countries in proportion to the contribution of genetic diversity from the countries (ideally through some mechanism that ensured that funding went to support genetic resource conservation, and particularly to provide benefits to farmers still maintaining traditional varieties).

The biggest disadvantage of a cooperative mechanism is likely to be the increased separation between the commercial supply of biodiversity and the conservation of biodiversity. The biggest obstacle to the development of effective cooperatives may thus be the substantial differences among nations in their conservation networks. For such a system to function effectively, all members must have sophisticated information on the taxonomy and distribution of species they are collecting, and must have a strong system of biodiversity conservation that ensures that samples can be re-collected as needed. Moreover, all members must share a commitment to returning benefits from the cooperative to support biodiversity conservation activities. Without these preconditions, a cooperative venture could meet profit goals, but not development and conservation goals. An even stronger incentive to ensure that conservation commitments are upheld would be to make contingent payments themselves partially contingent on effective *in situ* conservation (Artuso 1995).

### **Protect rights to genetic resources and help ensure equitable economic returns through Material Transfer Agreements and Contracts**

Even before countries adopt legislation governing access to genetic resources, contracts and Material Transfer Agreements (MTAs) that spell out the arrangements and rights that will apply to specific samples of genetic or biochemical materials are assuming particular importance in the international biodiversity trade. Contractual relationships have become a standard element of biodiversity prospecting arrangements for the pharmaceutical industry. Contracts typically spell out terms such as obligations for technology transfer, up-front and contingent payments, and rights of ownership (Laird 1993). MTAs are types of contractual arrangements, but they range from letter statements to detailed, negotiated contracts. MTAs are commonly used within the biotechnology industry, particularly in the USA, and are increasingly being used for transfers between public-sector laboratories and between public and private laboratories (Barton and Siebeck 1994).

Appropriate contracts and MTAs can meet many of the goals of conservation, technology transfer and benefit-sharing under the Biodiversity Convention. Where the specific use of a chemical sample (e.g. for screening for specific diseases) or genetic sample is known in advance, detailed contractual arrangements can meet the needs of both suppliers and recipients. However, the trend will be increasingly toward situations where genetic material will be evaluated or screened for a wide range of potential uses in pharmaceuticals, industry and agriculture and the final use of the material, if any, will be highly uncertain.

Given the substantial uncertainty of any particular sample being commercially valuable, combined with the uncertainty about how the material might be utilized, source institutions are in a poor position to negotiate equitable returns. One solution will be for suppliers to make use of MTAs that allow the material to be used for research but reserve the right to negotiate benefit-sharing arrangements until commercial applications are discovered. (Imposing such a requirement will probably involve a significant reduction in up-front payments for samples.) Assuming that firms report potential commercial applications to suppliers (thus the benefit of using MTAs within stable partnerships), once the commercial use is identified it is in the interest of the firm to pay for the right to use the material and for the source country to undertake the negotiation to secure and monitor its rights.

The proposed use of MTAs for genetic material held in trust by the IARCs would be an example of such a mechanism (Barton and Siebeck 1994). Genetic material collected after the Biodiversity Convention came into force in December 1993 would be transferred to private companies with the stipulation that the recipient would be required to negotiate an equitable arrangement with the source country in the event of successful commercialization of research products deriving from the material. The recipient would be required to estab-

lish a similar restriction when material is transferred to a third party and notify the source country of that transfer. The source country would be acknowledged in publications and variety descriptions. The success of such an arrangement clearly hinges on the long-established partnerships between the IARCs and both the countries and private companies involved. (This type of arrangement would probably be second-best to an arrangement that created a cooperative of agricultural genetic resource suppliers as described above.)

Such application of MTAs, however, could also be used in partnerships between suppliers and individual firms. Conditions could be attached to the export of, for example, microorganisms, that prevent transfer of the organisms to third parties, allow research by the recipient firm, but require negotiation of benefit-sharing arrangements in the event of discovery of a commercial application. In the International Cooperative Biodiversity Agreement involving Cameroon, Nigeria, Smithsonian, Shaman, Bristol-Myers and Walter Reed Army Institute of Research, Bristol-Myers will screen material and has the first right to negotiate terms for development of promising compounds. However, if mutually agreed terms cannot be reached with the suppliers, the suppliers can seek to negotiate an agreement with another firm.

Both the interest of a recipient firm in entering into such an agreement and the security of the source country or institution that it would be notified of a commercial result from such an arrangement is clearly enhanced if the agreement takes place as part of a stable and dependable working relationship. Such relationships are attractive to the recipient firm because the firm receives greater assurance of confidentiality, exclusivity and future supply of material and can take greater advantage of cost savings of shifting certain portions of the technology development to the source institution or country. They are more attractive to the source country because they involve greater technology transfer, greater opportunity to benefit from commercial products, and a larger probability of fair dealing on the part of a long-term commercial partner.

**Nations should adopt a set of minimum standards, or develop model legislation, for the sustainable use of genetic resources**

The goals of the biodiversity convention will be undermined if nations continue to mine their genetic resources; that is, trade resources at costs lower than would be needed for reasonable benefit-sharing and technology cooperation. Given the complexity of the technologies, wide differences in levels of biodiversity and technical capacity in countries, and wide differences in the needs and capacities of various users, it is unreasonable and unworkable to require specific terms of trade for genetic resources. Nevertheless, both suppliers and users would benefit from a set of minimum standards (Artuso 1995).

Harmonized national standards and requirements for biodiversity trade would lessen the hurdles facing users

of biodiversity since use agreements would not need to be developed *de novo* for each country and situation. They would help supplier countries by preventing unfair competition whereby institutions or nations could sell material at discounts in the form of minimal technology transfer or benefit-sharing provisions. If a certification system were established in conjunction with such standards, they could also help reduce illicit trade in genetic resources (Artuso 1995). In addition to the basic elements of legislation as identified by de Klemm *et al.* (1994) (e.g. establish a national focal agency, define the scope of application of Prior Informed Consent, create an application process or procedure for access determinations, identify general restrictions, identify requirements for reporting and identify enforcement provisions and penalties), national legislation might require the following (Reid *et al.* 1993):

- That MTAs or contracts be used for any transfer of genetic material and that these agreements: (i) either contain terms for benefit-sharing and technology transfer from commercial exploitation of the resource, or oblige the user to negotiate such terms upon discovery of a commercial application of the material; (ii) specify that the recipient must require any third party to negotiate similar arrangements with the source country; (iii) require that the source country and source region/community be acknowledged in any publication of the material. MTAs or contracts would typically also be desirable for the export of chemical samples; however, for some countries not seeking to develop value-added capacity, sale of extracts without contingent payments could sometimes be appropriate. Currently, this situation is the exception; firms typically include small contingent payments in agreements for samples or extracts.
- That any collection of material does not endanger biological diversity.
- That some mechanism exists to return benefits to support conservation of biodiversity. Some countries may meet this objective through permit fees or user fees; others may require that conservation components are built into access arrangements.
- That collectors recognize traditional resource rights, obtain the prior informed consent of individuals claiming ownership of land where material is to be collected, and provide equitable compensation to individuals providing knowledge about the potential use of biological diversity.

**Establish institutions to provide information and legal assistance to source countries and local communities**

Greater equity can be achieved in genetic resource transfer

agreements if suppliers have more information about potential markets for their material, characteristics of existing MTAs and contracts and legislation, and access to legal assistance. Cooperatives, such as the model proposed above, partially obviate this need since they would more quickly develop expertise on the issues involved. Both the information clearinghouse being established under the biodiversity convention and nonprofit intermediaries such as that proposed by Lesser and Krattiger (1994) could play a useful role in meeting these needs. The World Information System on plant genetic resources being established by FAO would also facilitate the exchange of information on plant genetic resources and related technologies. Already, the IARCs serve as an intermediary institution meeting some of these needs in the case of agricultural applications.

**Recognize that the rights of prior informed consent and benefit-sharing extend to local communities**

The biodiversity convention is premised on the notion that unless countries receive benefits from the use of their resources, they will have insufficient incentive to conserve them. Governments were quick to accept this principle, but did not emphasize that the same principle must govern relationships with local communities within the country. Ultimately, these communities should receive benefits from the use of their resources if they are to have an incentive to conserve them. If the Convention is to achieve its goals, then the key elements of the convention—prior informed consent prior to collecting material and sharing of benefits on mutually agreed terms—should apply to private land-owners, local communities and indigenous groups with territorial claims.

The mechanisms for achieving benefit-sharing with local communities are likely to be as diverse as the mechanisms for returning benefits to nations and will involve both direct and indirect benefits. For example, exploration for new drugs based on indigenous knowledge often involves information from many different local communities or healers. Shaman Pharmaceuticals therefore makes it general policy not to make arrangements with specific individuals (with the exception of direct local employment), but rather to target benefits at the levels of national institutions and federations or organizations of traditional healers. The National Biodiversity Institute in Costa Rica provides direct benefits locally in regions where it conducts biodiversity prospecting, primarily by generating employment. However, by agreeing to return a share of the profits to the government, the state is then in a position to return benefits locally to communities surrounding areas where biodiversity prospecting is conducted. Regardless of the specific mechanism adopted within a country, any negotiation should be premised on the acceptance of both the right of local communities to regulate access to these resources and the desirability of providing economic incentives for the conservation of the resource.

**Emerging national strategies: the case of the Philippines**

The Philippines, once one of the most biologically diverse countries in Asia, has experienced a veritable 'biological meltdown' over the past several decades, losing most of its dipterocarp forests, mangroves and coral reefs and experiencing extinction rates unparalleled in Southeast Asia, and perhaps anywhere in the world (Johnson and Alfonso 1991). Indeed, it has been observed that the Philippines represents "the single worst case scenario ... of loss of biological biodiversity in tropical Southeast Asia" (Louis Berger International 1989).

Faced with this crisis, both the government and the country's large and active community of nongovernmental organizations (NGOs) have moved rapidly over the last decade to establish a policy framework to slow the loss of biodiversity and set a course for sustainable use of the country's biological and genetic resources (see GOP 1993). Notable initial achievements have been the establishment of the Philippine Council on Sustainable Development and the promulgation of a National Integrated Protected Areas System law in 1992, ratification of the Biodiversity Convention in September 1993, development of a framework National Biodiversity Conservation Strategy in early 1994 and, currently, promulgation of a Presidential Executive Order (EO) establishing a regulatory framework for biodiversity prospecting within the country. Here, we examine this Executive Order, and assess its suitability for dealing with the technological and benefit-sharing issues already discussed.

**The Presidential Executive Order on biodiversity prospecting**

The draft Executive Order Prescribing Guidelines and Establishing a Regulatory Framework for the Prospecting of Biological and Genetic Resources, Their By-Products and Derivatives for Scientific and Commercial Purposes, and for Other Purposes was developed during 1994 through a process of consultation involving diverse government agencies, scientific and technical experts and institutions, and NGOs. It is expected to become law by mid-1995\*. Its development was spurred both by the Biodiversity Convention and by concern on the part of scientists, NGOs and policymakers over the lack of an appropriate regulatory framework to govern the growing number of biodiversity prospecting initiatives underway in the country. Issuance of an Executive Order does not preclude more comprehensive legislation originating in the Congress in the future, and debate on such legislation

\* This discussion is based on a final draft of the Executive Order, which resulted from discussion and revision at three technical and policy workshops through September 1994. Final revisions are being made by legal experts of government agencies and the draft under discussion should not be treated as the final, authoritative text.

is expected during 1995. Many policymakers and observers, however, felt it important to establish an initial regulatory framework through the EO process, given the perceived urgency of the situation and the generally slow pace of congressional legislation. Using this process was also perceived as more flexible inasmuch as an EO is easier to amend than a statute from Congress. The EO initially sets out basic state policy:

It shall be the policy of the State to regulate the prospecting of biological and genetic resources to the end that these resources are protected and conserved and put to the sustainable use and benefit of the national interest. The development of science and technology and the economic development of the local communities in which the resources are found shall be given due consideration.

Biodiversity prospecting is defined in the EO as "the research, collection and utilization of biological and genetic resources for purposes of applying the knowledge derived therefrom to scientific and/or commercial purposes."

The EO establishes a framework to regulate biodiversity prospecting with three basic elements: (i) a system of mandatory Research Agreements between collectors and the government containing minimum terms concerning provision of information and samples, technology cooperation and benefit-sharing; (ii) an Inter-Agency Committee (IAC) to consider, grant, monitor and enforce compliance with Research Agreements, as well as to coordinate further institutional, policy and technology development; and (iii) a requirement and minimum process standards for obtaining prior informed consent from local and indigenous communities where collection of materials is carried out.

All biodiversity prospecting would require a Research Agreement, except for traditional uses of biological resources by local and indigenous communities. Recognized Philippine academic and research institutions, government agencies and intergovernmental institutions (such as IARCs) are eligible for Academic Research Agreements (ARA), while all research and collection directly or indirectly intended for commercial purposes may only take place under a more stringent Commercial Research Agreement (CRA). All private persons and commercial firms, whether foreign or domestic, are legally presumed to have commercial motives and must obtain a CRA.

The two types of Research Agreements share the following provisions:

- A status report of the research and the ecological state of the area and/or species concerned must be submitted to the Inter-Agency Committee.
- There must be a limit on samples that the Collector may obtain and export, and the approved list and amount of the samples taken from the area must be followed strictly.
- A complete set of all specimens collected must be deposited by the Collector with the National Museum or a duly designated entity, while holotypes designated by the author must be deposited at the National Museum.
- The Collector (or, under a CRA, if applicable, the principal for whom the collector is an agent) must disclose to the government as well as the affected local and indigenous communities all discoveries from the activity conducted in the Philippines if a commercial product is derived from such activity.
- Access to collected specimens and relevant data must be allowed for all Filipino citizens and Philippine governmental entities whenever these specimens are deposited in depositories abroad.
- There must be an agreement on royalties to be paid to the national government and local or indigenous communities in case commercial use is derived from the resources taken. Where appropriate, other forms of compensation may be negotiated.
- There must be provision allowing the Philippine government to unilaterally terminate the agreement whenever the Collector has violated any of its terms. It may also be terminated on the basis of public interest or welfare.
- A fee (fixed for a CRA, minimal for an ARA) must be paid to the government in accordance with a schedule of fees formulated by the IAC.
- Maximum terms for Agreements are set: 3 years for a CRA and 5 years, renewable for another 5 years, for an ARA, provided that each agreement be reviewed annually to determine compliance with its terms.

ARAs, unlike CRAs, may be comprehensive in scope and cover as many areas as may be projected. It may stipulate that all scientists and researchers affiliated with an institution eligible for an ARA need not apply for a different ARA but may conduct research and collection under an existing ARA. The institution party to the ARA is then held responsible for ensuring that all of its researchers comply with the terms of the Agreement. It is also mandated to ensure that the prior informed consent of local and/or indigenous communities have been obtained by a researcher. CRAs have additional minimum requirements:

- If the Commercial Collector or its Principal is a foreign person or entity, it must be stipulated that scientists who are citizens of the Philippines must be actively involved in the research and collection process and, if so determined by the IAC, in the technological development of any product derived from any material collected. This involvement shall be at the cost of the Commercial Collector. In addition, the Commercial Collector shall be encouraged to utilize the services of Philippine universities and research institutions and may, in some cases, be required to transfer equipment to them.
- In cases where a commercial product is derived from biological or genetic resources endemic to the Philippines, a stipulation requiring compulsory licensing of the patent to the Philippines is required.

It should be noted that the distinction between academic and commercial research agreements is at best nebulous. Academic research in the field of biotechnology often leads directly or indirectly to commercial application. The real difference, therefore, between the two types of agreements is the nature of the entities that qualify for ARAs and the extent of governmental control over their research activities. Through the use of the ARA, the draft EO provides more flexibility to Philippine academic and governmental institutions and to intergovernmental institutions and allows these institutions to exercise greater self-regulation. The intention is to spare national and international institutions from the bureaucratic hurdles and delay that might characterize the system as well as to give the regulatory body more time to monitor private commercial parties. On the other hand, foreign commercial collectors of biodiversity often rely heavily on local academic institutions as suppliers; thus the differential regulatory attention may prove counterproductive.

In addition to these minimum terms for Research Agreements, the EO stipulates that any and all prospecting activities or their results must not directly or indirectly harm the biological diversity, ecological balance or the inhabitants of the area where collection is undertaken. It also provides that all collection under a Research Agreement must comply with all applicable environmental laws, regulations and procedures.

Application for a Research Agreement is made to the IAC, through the Department of Environment and Natural Resources (DENR), via a proposal stating the purpose and duration of the proposed research, and including a list of genetic materials and the amount to be taken (although ARA proposals may be more general, as noted above). A copy of this proposal must also be submitted to the recognized head of the local or indigenous community or communities that may be affected. No action on the proposal may be taken then for a period of 60 days, to

give the local or indigenous community an opportunity "to oppose such application on the basis of possible harm" to the local environment and way of life. Written and other positive proof of local consent must be presented to the IAC before it may act on the proposal.

The IAC is established as "the regulatory body to ensure that the provisions of this Executive Order are enforced and implemented." Chaired by the DENR and co-chaired by the Department of Science and Technology, the IAC includes as members representatives of the Departments of Agriculture and Health, the National Museum, two representatives of the Philippine scientific community, one representative of the community of NGOs active on biodiversity issues and one representative from a Peoples' Organization with a membership consisting of indigenous communities or their organizations. The EO also establishes a Technical Committee, headed by the Director of the DENR Protected Areas and Wildlife Bureau and staffed by agencies represented on the IAC.

The powers and functions of the IAC include the following:

- Process applications for Research Agreements and make recommendations to the DENR (the agency with which Agreements are signed by collectors).
- Determine the list of species and amounts of material that may be collected.
- Ensure that the terms of Agreements are strictly observed, and deputize appropriate agencies to do so.
- Ensure that the rights of indigenous and local communities under the EO are protected, especially with regard to informed consent procedures. In this regard, the IAC is charged with drawing up detailed procedures to implement the EO's consent provisions.
- Involve local scientists in decision-making by creating a permanent Technical Advisory Body and other such entities as may be necessary to facilitate local involvement in the research, collection and utilization of biological and genetic resources.
- Study and recommend to the President and Congress new and more appropriate laws on utilization of biological and genetic resources, and develop a conceptual framework for significantly increasing and disseminating knowledge of Philippine biodiversity.

The requirement that all biodiversity prospecting be subject to the prior informed consent of local and indigenous communities runs strongly through the EO, which establishes a procedure for assessing, obtaining and verifying that consent, as noted above. The underlying policy is strong and clear: "No prospecting of biological and

genetic resources shall be allowed without obtaining the prior informed consent of the affected local communities." In the case of indigenous communities, the EO further specifies that no prospecting shall be allowed "within the ancestral lands and domains of indigenous cultural communities without the prior informed consent of such communities. For purposes of this Executive Order, this consent must be obtained in accordance with the customary laws of the concerned community."

With this draft Executive Order, and the processes it will set in motion when it becomes law, the Philippines has become a pioneer in the fast-moving development of national laws and policies to give effect to the provisions of the Biodiversity Convention on national sovereignty over genetic resources, access regulation and benefit-sharing. Other nations may look to the Philippines' EO as a model for potential adaptation to their own needs and circumstances. How is the Philippines' model likely to work in practice? Consider once again the questions of technological change and benefit-sharing raised in previous sections.

#### **Implications of technological change**

Imagine first a world in which the recent technological innovations previously discussed have become the norm in the international biodiversity trade: plant breeders routinely move genes from unrelated species into crops through genetic engineering, these new varieties—and their genetic components—are increasingly protected by patents, and these patents are more easily enforced by monitoring methods based on new DNA sequencing technologies. In the pharmaceutical industry, companies can screen 10 000 to 100 000 samples per week at a fraction of current costs, and can do so using a fraction of the raw material needed in the past. Advances in cell and tissue culture eliminate the need in many cases for the firm to return to the source country for further supplies of raw material. One such sample can be utilized for research and product development in agriculture, pharmaceutical and industrial applications. Monitoring by source countries, and control of illegal trade, become increasingly difficult. As a result of these technological changes, the market for raw genetic material is increasingly competitive, made more so by a growing black market, resulting in lower initial and contingent (royalty) payments for source countries and institutions.

Does the Philippines' new EO provide an effective framework to ensure that the country can benefit from, or at least not be unfairly exploited by, this brave new world? Perhaps. It is an important first step, but its eventual efficacy will depend greatly on the steps taken to implement it, and the revisions made based on experience and changing circumstances.

Consider the issue of developing stable, long-term partnerships with product development firms and institutions. The EO restricts CRAs to 3 years, with no provision for renewal. Like a short-term timber concession,

this may result in a 'collect and run' (or 'collect and then culture') mentality for some collectors, discourage technology transfer, and preclude the establishment of good-faith personal and institutional relationships that are only possible (although by no means inevitable) in longer-term relationships, but which will be crucial to develop under the new technological scenario. Given that the EO reserves a unilateral right of termination to the government, and stipulates an annual review of compliance, there seems to be no compelling policy reason to restrict CRAs to only 3 years, but rather some good reasons for allowing long-term CRAs to be negotiated.

The participation of Philippine scientists and institutions in product development based on collected material raises similar issues. The EO requires such participation, but presumably that participation would be limited to the 3-year term of the CRA. If product development research were to begin, say, 1 year into the agreement (an optimistic scenario), then Philippine scientific participation would last only 2 years, far shorter than the time line for development and testing of a pharmaceutical product (although possibly adequate for participation in genetic engineering of a new crop variety).

On the other hand, assuming the 3-year limit on CRAs is revised, the EO's requirements for technology cooperation and equipment transfer make good sense if the Philippines is to become a high-value supplier of genetic resources to the biotrade, rather than a mass-marketer of raw, random samples. Under the technological scenario noted above, it seems clear that countries or institutions able to supply 'niche markets' (e.g. high-quality extracts, endemics, samples based on ethnobotanical prescreening, etc.) in the biotrade based on their own comparative advantage, will be in a better position. Given the country's relatively high levels of scientific skills and personnel (compared with many other medium-sized developing countries), high levels of endemism, and many indigenous communities possessing specialized knowledge about local biodiversity and its uses, the Philippines seems to be fairly well situated to become a high-end source country in the medium term. Additionally, if the provisions on local and indigenous community consent are effectively realized, and if the country's new and innovative Integrated Protected Areas System is effectively conserved, the Philippines may acquire additional biotrade clout in the 'green market' niche which grants a premium to sources which conserve their biodiversity and respect the rights of their indigenous and local communities.

Much depends on the EO's mandate for the IAC to develop and implement a conceptual framework to "significantly increase knowledge of Philippine biodiversity" and to foster development of scientific and technological capacity. Recent plans to establish an ASEAN Biodiversity Center in the country may provide one important step in this direction. The Philippines is already host, however, to two international institutions with significant scientific

capacities related to genetic resources and biotechnology, the International Rice Research Institute and the International Center for Living Aquatic Resources Management. Given the mandate of the new EO, and the imperatives of coming to grips with the growing biotrade, it may be time for the Philippines government and scientific community to re-examine its relationships with these institutions, and develop new relationships which can better contribute to building domestic scientific and technological capacity in areas relevant to saving, studying and sustainably using genetic resources.

### **Prospects and options for optimizing benefit-sharing**

The EO provides a strong framework for benefit-sharing, but it does not elaborate many specific mechanisms, apart from the provisions on technology cooperation and transfer discussed above. All agreements are to contain a provision on royalties, and other forms of compensation may also be negotiated in appropriate cases. What mechanisms should be developed in the Philippines to optimize benefit-sharing? Given the EO's stress on recognizing indigenous and local knowledge and resource rights and ensuring that all prospecting activities be supportive of conservation, some level of benefit-targeting seems called for under the EO, but how much should be targeted to whom, and through what mechanism? Is the concept of a genetic resources cooperative in the ASEAN or broader Southeast Asian region feasible?

Consider first the possible kinds of compensation, including royalties contingent on development of a commercial product, up-front payments at the beginning or during the course of a Research Agreement, and commitments to technology transfer and cooperation. Recognizing that the optimum mix of benefits will vary from deal to deal, the EO allows for considerable flexibility, although some level of technology cooperation is mandated for all CRAs, and compulsory licensing is mandated where a product or process is based on an endemic species. This latter provision is required by other Philippine statutes and reflects concern that the nation retain its rights to its own unique heritage. Notwithstanding this ethical concern, from a policy standpoint such a provision for compulsory licensing is likely to entail significant economic costs to the country. An approach that would better meet economic and conservation objectives in the Philippines would be for the IAC to analyze benefits of negotiating licences for patented products or processes for use in the Philippines on a case-by-case basis. For example, through negotiations with British Technology Group, INBio obtained an exclusive licence for developing and marketing a nematocide developed from a local tree in Costa Rica. In many instances, it would not make economic sense for the Philippines to hold a licence since their costs of production or marketing could be far higher than the original patent holder. The most significant disadvantage of a

compulsory licensing approach is that it could dramatically reduce the commercial interest in exploring biodiversity in the country or result in a situation where the firm developing a new product simply avoids seeking a patent in the Philippines out of concern over loss of property rights.

Contingent royalties are the most uncertain form of compensation, given the small statistical likelihood of a commercial 'hit', the possibility that a given sample ultimately plays a small part in a final product, and the difficulty of monitoring the ultimate use of material outside the country, particularly given the 3-year limit on CRAs. On the other hand, even a small share of potential profits from a major drug discovery could dwarf any possible initial payments.

The optimal current negotiating stance for the Philippines would seem to be a strong stress on technology cooperation and transfer, moderate up-front payments, and reservation of the right to negotiate a royalty or licence if a commercial application is discovered. High and low royalty limits would have to be negotiated in advance, as would the factors affecting the final royalty rate (e.g. relative contribution of the material to the product, whether it is endemic or not, etc.). The Philippines may not be able to get all of this in every given deal, but is in a strong position to begin negotiation with these terms.

How should benefits be targeted in the Philippines? The only clear direction in the EO is that the participation of Philippine scientists in collection and, in some cases, product development, should be funded by the collector or its principal. The EO also states that the rights of indigenous and local communities in their traditional knowledge must be 'respected and rewarded' and that royalties or other forms of compensation must be paid not only to the national government but also to the local or indigenous communities from which resources are taken. The mechanism for doing so is not specified, though. Transactions costs to collectors of making individual targeted payments to local and indigenous communities are likely to be prohibitively high. In any case, such collectors are unlikely to understand the local political situation well enough to avoid making mistakes and creating divisive community conflicts in paying compensation. Clearly, a suitable mechanism under national or local government supervision, but with strong local and indigenous participation, will need to be created if benefits are to be effectively targeted to local communities.

The issue of 'cash versus in-kind' will need to be dealt with also. Cash payments to local communities may be subject to misappropriation and fraud, may divide the community, and in any case may leave no lasting benefit. If payments are made in-kind, however—say, through budgetary support for demarcation of ancestral domain lands—local communities may feel that their share of compensation is just being used as budgetary support for government activities already due them, with no additional benefit.

While the EO at least begins to establish a framework for targeting of benefits to local communities and to scientific and technological development, it is silent on the return of benefits to the conservation of biological diversity. If the EO is to serve conservation as well as development and commercial goals, it is imperative that a significant share of potential benefits from the biodiversity trade flow to conserving the country's fast-dwindling wildland areas, particularly those within the newly established Integrated Protected Areas System. Without clear and specific earmarks providing new and additional funding for conservation, experience in many countries shows that funds that enter a government's general budget rarely emerge to support biodiversity conservation on the ground. Such funds need not, however, necessarily all be earmarked for the government conservation agency. Indeed, a major Global Environment Facility grant to the Philippines in support of its protected areas system is being managed and implemented by a consortium of NGOs, with technical assistance and oversight from the DENR.

How would the EO affect potential Philippines interest in a regional genetic resources cooperative? Biodiversity prospecting is underway in a number of ASEAN countries and the countries of Indochina. While institutions in each of these countries could undertake bioprospecting through independent agreements, some institutions may find it attractive to provide raw material to a cooperative with the advantages elaborated above. Many of the provisions of the Philippine EO would not affect the likely utility of a cooperative arrangement for institutions in the Philippines. Because the Philippines EO does set a higher performance standard for biodiversity prospecting than is likely to be found in other countries in the region, it becomes somewhat more costly for a Philippine institution to provide samples than for an institution in another country. Nevertheless, since the same costs would apply to independent agreements this would not substantially influence the desirability of a cooperative arrangement from the Philippine perspective. However, because stipulations defined by the EO or the IAC for specific royalties or compulsory licensing provisions for samples provided by the Philippines would require independent negotiation with product development firms, this would preclude the incorporation of Philippine samples in a regional cooperative. If other countries were to adopt similar minimum standards related to commercial arrangements and conservation commitments, however, the cooperative mechanism would be appropriate, but even minimal harmonization among the diverse countries of ASEAN, let alone the wider Southeast Asian region, is a daunting and probably unrealistic challenge.

## Conclusion

Technological advances related to the use of biological diversity both constrain the opportunities available for formulating policies that ensure appropriate recognition of the rights of countries to their plant and animal genetic

resources, and suggest specific policies that are likely to be most beneficial to nations in this regard. One of the most difficult issues that nations will have to confront in designing these policies is achieving the appropriate balance between local and national benefits and between direct and indirect mechanisms in achieving the objectives of the conservation and sustainable use of biological diversity.

The Philippines has taken an important and promising first step in developing a national policy framework to confront these issues, through development of its 1994 Presidential Executive Order on Biodiversity Prospecting. Turning that promise into practical and effective policies, practices and mechanisms which will at once conserve biodiversity, realize its commercial benefits and ensure its contribution to sustainable and equitable development is an enormous and complex task. With broad dialogue and cooperation among all affected sectors of government and civil society, and the development of beneficial relationships with international actors, the stage is set for meaningful progress in this area of such great importance for the human prospect in the 21st century.

## Acknowledgements

The help of Jason West with the research on the development of taxol is gratefully acknowledged. We would also like to thank Anthony Artuso, John Barton, David Downes, Matthias Hamburger, Kerry ten Kate, Steven King, James McChesney and Daniel Putterman for their valuable comments on earlier drafts of this manuscript. This work was funded in part by grants from the Swedish International Development Agency, Sasakawa Peace Foundation and the Netherlands Ministry of Foreign Affairs in support of WRI's Program in Biological Resources and Institutions.

## References

- Artuso, Anthony. 1995. Economic analysis of biodiversity as a source of pharmaceuticals. *In* Emerging Connections: Biodiversity, Biotechnology, and Sustainable Development in Health and Agriculture. Pan American Health Organization, Washington, DC.
- Barton, J.H. 1991. Relating scientific and the commercial worlds in genetic resource negotiation. Paper presented at the symposium on property rights, biotechnology, and genetic resources, African Centre for Technology Studies and World Resources Institute, 10-14 June, Nairobi, Kenya.
- Barton, J.H. and W.E. Siebeck. 1994. Material transfer agreements in genetic resources exchange—the case of the International Agricultural Research Centres. *Issues in Genetic Resources* No. 1. International Plant Genetic Resources Institute, Rome, Italy.
- Cooper, D., J. Engels and E. Frison. 1994. A multilateral system for plant genetic resources: imperative, achievements and challenges. *Issues in Genetic Resources* No. 2. International Plant Genetic Resource Institute, Rome, Italy.
- DeFuria, M.D. and Z. Horovitz. 1993. Taxol commercial supply strategy. *J. Nat. Cancer Institute Monogr.* No. 15:195-198.
- de Klemm, C., A. Tolentino Jr., F. Burhenne-Guilmin, R.G. Tarasofsky, L. Glowka and D. Craig. 1994. Conserving biodiversity: The legal and institutional issues. Paper presented at the Regional Conference on Biodiversity Conservation, Asian Development Bank, 6-8 June, Manila, Philippines.
- FAO (Food and Agriculture Organization of the United Nations). 1983. International Undertaking on Plant Genetic Resources. CPGR/87/Inf. 3. FAO, Rome.
- GOP (Government of the Philippines). 1993. Conservation of Biologi-

- cal Diversity in the Philippines. Department of Science and Technology & Department of Environment and Natural Resources, Manila.
- House of Representatives of the United States Congress. 1992. Exclusive agreements between federal agencies and Bristol-Myers Squibb Co. for drug development: Is the public interest protected? Hearing before the Subcommittee on Regulation, Business and Energy of the Committee on Small Business, July 29, 1991. US Government Printing Office, Washington.
- Jefferson, R.A. 1993. Beyond model systems: new strategies, methods, and mechanisms for agricultural research. *Biotechnol. R&D Trends*, Ann. New York Acad. Sci. 700:53-73.
- Johnson, N. and P. Alfonso. 1991. Philippines Biodiversity Survey and Action Plan. World Resources Institute, Washington, DC and Haribon Foundation, Manila.
- Laird, S.A. 1993. Contracts for biodiversity prospecting. Pp. 99-130 in *Biodiversity Prospecting: Using Genetic Resources for Sustainable Development* (W.V. Reid, S.A. Laird, C.A. Meyer, R. Gamez, A. Sittenfeld, D.H. Janzen, M.A. Gollin and C. Juma, eds.). World Resources Institute, Washington, D.C.
- Leary, W.E. 1992. Drug made from rare tree is approved to treat cancer. *New York Times*, 30 December 1992.
- Leary, W.E. 1993. U.S. aids program to produce drugs in developing nations. *New York Times*, 8 December 1993.
- Lesser, W.H. 1994. Institutional mechanisms supporting trade in genetic materials. United Nations Environment Programme, Environment and Trade V. 4, Nairobi, Kenya.
- Lesser, W.H. and A.F. Krattiger. 1994. Marketing "genetic technologies" in South-North and South-South exchanges: The proposed role of a new facilitating organization. Pp. 291-304 in *Widening Perspectives on Biodiversity* (A.F. Krattiger, J.A. McNeely, W.H. Lesser, K.A. Miller, Y. St. Hill and R. Senanayake, eds.). IUCN - The World Conservation Union, International Academy of the Environment, Geneva, Switzerland.
- Louis Berger International and Institute for Development Anthropology. 1989. Sustainable Natural Resources Assessment - Philippines: A Review of the Present Status With Recommendations for Future Directions. Report prepared for the US Agency for International Development D-2.
- Milstein, Michael. 1994. Yellowstone managers eye profits from hot microbes. *Science* 264:655.
- Myers, F.S. and A. Anderson. 1992. Microbes from 20,000 feet under the sea. *Science* 255:28-29.
- Peterson, S.B. 1982. Government, cooperatives, and the private sector in peasant agriculture. P. 84 in *Institutions of Rural Development for the Poor* (D.K. Leonard and D.R. Marshall, eds.). Institute of International Studies, Research Series No. 49. University of California, Berkeley, CA.
- Reid, W.V. and K.R. Miller. 1989. Keeping Options Alive: The Scientific Basis for Conserving Biodiversity. World Resources Institute, Washington, DC.
- Reid, W.V., S.A. Laird, C.A. Meyer, R. Gamez, A. Sittenfeld, D.H. Janzen, M.A. Gollin and C. Juma, eds. 1993. *Biodiversity Prospecting: Using Genetic Resources for Sustainable Development*. World Resources Institute, Washington, DC.
- Simpson, R.D., R.A. Sedjo and J.W. Reid. 1995. In *The Commercialization of Indigenous Genetic Resources: Values, Institutions, and Instruments. Their Seed Preserve: Strategies for Preserving Global Biodiversity* (L. Guruswamy and J. McNeely, eds.). (in press).
- USDA (United States Department of Agriculture). 1993. Pacific Yew: Final Environmental Impact Statement. USDA Forest Service, Washington, DC.
- WWF (World Wide Fund for Nature). 1989. Funding mechanisms for the Fund for Biological Diversity. WWF, Gland, Switzerland.

### Résumé

*Les droits concernant les ressources génétiques au service du développement durable: coopératives de gènes, commerce de matériel biologique et enseignements à tirer de l'expérience des Philippines*

La Convention de 1992 sur la diversité biologique marque un changement fondamental dans le statut international des ressources génétiques. Avant la Convention, ces ressources étaient considérées comme le "patrimoine de l'humanité". Quoique l'intention de ce régime d'accès libre ait été d'assurer la disponibilité généralisée des ressources génétiques pour l'agriculture et l'industrie, l'utilisation commerciale des ressources n'a pas fourni d'incitation économique supplémentaire pour la conservation par les pays fournisseurs. La Convention sur la diversité biologique y remédie en stipulant que les Etats ont des droits souverains sur leurs ressources génétiques, permettant de cette façon que des incitations économiques complètent divers mécanismes multilatéraux qui pourraient financer directement la conservation de la diversité biologique. Plusieurs obstacles se présentent aux pays qui traduisent ce droit général à réglementer l'accès dans des politiques, lois et règlements spécifiques visant à répondre aux objectifs de conservation et de développement. Un examen de ces obstacles et des tendances du développement technologique suggère un train de mesures que des nations et des institutions de pays en développement devraient prendre pour élaborer des lois d'accès et des accords de transfert de matériels, établir des "coopératives" de diversité biologique et des institutions intermédiaires afin de faciliter l'échange d'informations, mettre au point des critères minimums pour la législation régissant l'accès et étendre les obligations relatives au consentement préalable donné en connaissance de cause des communautés locales à tous ceux qui sont chargés de la collecte de la diversité biologique. Un examen des lois adoptées récemment aux Philippines sur la réglementation de l'accès aux ressources génétiques montre que, si ces initiatives fournissent une structure de base, nombre d'options et de décisions restent encore à prendre.

### Resumen

*Traslado de los derechos sobre recursos genéticos al desarrollo sostenible: las cooperativas de genes, el biocomercio y la experiencia de Filipinas*

La Convención sobre Diversidad Biológica de 1992 marcó un cambio radical en la apreciación de los recursos genéticos a nivel internacional. Antes de la Convención se los consideraba pertenecientes a la "herencia de la humanidad". Si bien la intención de este régimen de libre acceso era asegurar a la agricultura y a la industria la más amplia disponibilidad de los mismos, su utilización comercial no ofrecía suficientes incentivos para tratar de conservarlos en los países de origen. La Convención sobre Diversidad Biológica corrigió este vacío legal al establecer que los Estados poseen derechos soberanos sobre sus recursos genéticos, medida que estimuló la adopción de incentivos comerciales, como complemento de algunos mecanismos multilaterales, que sirvieran para financiar de manera directa la conservación de la biodiversidad. Los países empeñados en traducir este derecho general de regulación del acceso en medidas específicas de política y en leyes y reglamentos para la conservación y el desarrollo de sus recursos enfrentan numerosos obstáculos. Del examen de dichos obstáculos y de las tendencias del desarrollo tecnológico surge una serie de actividades que la comunidad y las instituciones de los países en desarrollo deben emprender para establecer una legislación sobre accesos y Acuerdos de Transferencia de Materiales; crear "cooperativas" de biodiversidad e instituciones intermedias que faciliten el intercambio de información; fijar normas básicas aplicables a la legislación del acceso, y hacer extensiva a todos los recolectores de biodiversidad la obligación de obtener el consentimiento previo y fundado de las comunidades locales. El examen de la reciente legislación filipina que regula el acceso a los recursos genéticos muestra que, si bien estas medidas recientes proporcionan un marco esencial de referencia, muchas opciones y decisiones quedan aún por ser tomadas.

## X-ray analysis of empty and insect-damaged seeds in an *ex situ* wild species collection

S. Linington, J. Terry and J. Parsons

Royal Botanic Gardens, Kew, Seed Conservation Section, Wakehurst Place, Ardingly, West Sussex, RH17 6TN, UK

### Summary

Results are presented from the X-ray analysis of seeds of wild plant species incorporated into the Royal Botanic Gardens, Kew Seed Bank. They show the plant families in which the presence of 'empty' seeds and insect damage to seeds have been found to be most prevalent in seed collections even after cleaning. The relative requirements for satisfactory X-ray radiographs with different families are indicated. The importance of determining the 'empty' and damaged seed fractions is stressed in relation to the operations of wild species seed banks.

### Introduction

For many wild or semi-domesticated plant species with desiccation-tolerant seeds, *ex situ* conservation by seed is a valuable adjunct to *in situ* activities, both as an act of insurance and as a means of improving utilization. In an increasing number of situations, *ex situ* conservation is the only option. Many botanic gardens are establishing seed banks (Groombridge 1992) for these reasons. The proportion adhering to the Genebank Standards produced by the Commission on Plant Genetic Resources (FAO 1993) is unclear but certainly low. However, these new 'biodiversity banks' will achieve their objectives only if they carefully adopt and modify procedures used by the crop seed banks.

The greatest challenge facing banks that hold wild species is viability monitoring. For users of the bank's material to maximize the release of genetic potential within a collection, seed dormancy, often present in wild species, must be fully broken and a variety of treatments may need to be utilized (see for instance Ellis *et al.* 1985). Consequently, banks need to advise users on the best way to germinate each collection. As tetrazolium analysis of seed has been established for only a few wild species (ISTA 1985), viability assessment in wild species' seed banks is best carried out by means of a germination test. However, misinterpretation of such germination test data is easy due to the prevalence of 'empty' (including aborted, prematurely harvested, shrivelled and incompletely formed) or damaged seeds/fruits. Damage is often the result of insect attack. The situation is summarized for a given set of conditions:

$$\text{total seeds in germination test} = G + Dt + Dd + E$$

where  $G$  is the number of seeds that germinate,  $Dt$  is the number that are dormant,  $Dd$  is the number that are dead and  $E$  is the number that are 'empty' or damaged (see Simak and Sahlén 1981). The situation is slightly complicated by the fact that if, for instance, insects have attacked

seeds but not damaged their embryos, then germination may still sometimes take place and in the case of hard-coated seeds may even be encouraged. The 'empty' and damaged seed fraction can be assessed by X-ray analysis or a cut test either at the end of cleaning or after a viability test. While forestry workers have long realized the problems posed by 'empty' or insect-damaged seed (Willan 1985; Simak 1991), it is our experience that those embarking upon seed conservation in botanic gardens and elsewhere consider them insufficiently.

The contents of a seed collection in a seed bank reflect environmental effects on seed production, the timing of harvest and post-harvest treatment (such as cleaning) prior to banking (Smith 1995). There have been a number of reports in the literature relevant to the problems of poor seed production in seed collections. Marshall and Ludlam (1989), for example, described the production of empty florets in *Lolium*. Differences between seed abortion in annual and perennial species (Wiens 1984) and embryo abortion due to reproductive failure (Wiens *et al.* 1989) have also been reported. Seed predation by insects has been cited in a number of studies and in particular in legume genera such as *Acacia* (Southgate 1983) and *Prosopis* (Johnson 1983). Crawley (1993) gives figures for predation in a number of species while Jansen (1969) indicates the seed sizes for which bruchid attack is a possibility. For recent reviews of general aspects of seed and fruit production, see Fenner (1985), Doust and Doust (1988) and Marshall and Grace (1992).

The Kew Seed Bank has been involved with the conservation of wild plants since 1974 and now holds some 9250 collections of 3750 species. Increasingly, the emphasis has been on species from the world's arid and semi-arid regions (Prendergast *et al.* 1991) in addition to those from the United Kingdom. Since 1976, the Kew Seed Bank has been routinely examining its collections after cleaning using X-ray technology. Over the years, many data have been accumulated on computer and punch cards.

The purpose of this paper is to present some of these data, to indicate the plant families where particular problems might be encountered by those involved with *ex situ* biodiversity conservation.

## Methods

Principles and methods for assessing the fraction of 'empty' or damaged seed in a seedlot have been well reported (e.g., Simak and Sahlén 1983; Ellis *et al.* 1985; Chavagnat 1987; Simak 1991). There are a number of advantages of using X-ray analysis compared with a cut test (Simak and Sahlén 1981). However, a simple surgical analysis of the seed will often suffice and the results below incorporate a small proportion of data gathered in this way. In some cases the two methods were combined so that uncertainty of interpretation with the X-ray analysis was overcome by a cut test using a binocular microscope.

Samples of seeds were X-rayed using a Torr X-Ray Corporation Radifluor 120 (1976-1990) and a Todd Research Ltd. radiation-proof cabinet with high definition water-cooled X-ray tube (1990 onwards). Data on 'empty' and damaged seed fractions within seedlots of different plant families combine results used by both machines, but for consistency the information about X-ray dosage relates solely to the latter machine. The Todd machine has a narrow voltage range of 0-50 kV (giving greater safety and allowing more refined adjustment than machines with a wider range), amperage control of 0-30 mA and a timer (in seconds). Prior to 1990 both Kodak Industrex 620 Paper (processed using Kodak S11 Activator and Kodak S40 Stabilizer) and Kodak Industrex MX Film (processed using Kodak DX80 Developer and Kodafix Fixer) were used and developed according to the manufacturer's instructions. Since 1990, the Industrex MX film has mainly been used. This film has ultrafine grain and is recommended by the manufacturers for critical work.

The direct X-ray method (Simak 1991) was used throughout and the seeds placed into chambers within a thin paper-backed plastic grid (collimator) which in turn was seated onto lugs on an aluminium plate. The radiography film was slotted between the grid and the plate under safe-light conditions and then located under the X-ray source within the machine by means of a Perspex guide. Where radiographic paper was used, the seeds were placed directly onto the paper in the machine. To all intents the object to film surface distance (OFD) was zero. The focus to film distance (FFD) was set at 40 cm (Torr machine) and 47 cm (Todd machine).

For a given machine, once the film (and developing time) has been selected and the OFD and FFD fixed, the only variables influencing radiograph quality are kilovoltage, milliamperage and exposure time. The voltage applied to the X-ray tube determines the wavelength of the X-ray beam, the penetration of the tissues and consequently the contrast in the image while the multiple of the amperage and exposure time affects the density of

image obtained on the film (Simak 1991).

As with recommended genebank procedures (Ellis *et al.* 1985), tests were carried out on seed samples which had been cleaned prior to banking. Normally 50 seed samples were used. However, where the seed numbers were low in the collection, lower seed numbers were used in the analyses. Samples which had been X-rayed were normally discarded due to the slight risk of genetic damage. Because data relate to cleaned collections, they should be interpreted with caution by those such as ecologists interested in the levels of 'empty' and insect damage at seed harvest. Although the results broadly mirror the field situation, ease of cleaning will be strongly reflected.

The use of family and generic names throughout this paper relates to those given in Brummitt (1992). The term 'seed' is used in its most loose context covering achenes, caryopses and other single-seeded fruits. Species representation is both temperate and tropical, though there is some bias toward species from northwest Europe, the Mediterranean Basin and arid/semi-arid Africa and Latin America. Few wet tropical species are included.

## Results and discussion

### Kilovoltage, milliamperage and exposure times

Experimentation at the Kew Seed Bank using the machine specified has shown that satisfactory images are obtained for a wide range of seeds with 8-25 kV, 10 mA, an exposure time of 10-25 sec, a FFD of 47 cm and Kodak Industrex MX film. The optimal conditions presented do relate to the particular machine and conditions described but should indicate relative effects between different families and give those new to such work a strong indication of the likely operating conditions of any equipment, given the plant family.

The kilovoltage required depends upon the species, its seed size (particularly density), shape and structure. Table 1 shows the kilovoltages found to give acceptable results for plant families where data for more than 20 accessions

**Table 1.** Kilovoltages used for X-ray analysis of seeds of different families in the Kew Seed Bank collection

Family	Kilovoltage		Accessions examined		
	Avg. value	Range	No.	Species	Genera
Caryophyllaceae	10.9	10 - 13	23	15	11
Chenopodiaceae	12.0	10 - 17	50	43	13
Compositae	11.2	8 - 16	112	84	56
Cruciferae	11.8	10 - 15	45	30	21
Cyperaceae	11.5	10 - 15	25	17	9
Gramineae	11.0	8 - 15	289	183	82
Labiatae	11.6	10 - 14	42	30	18
Leguminosae	13.9	10 - 25	284	191	91
Malvaceae	12.6	10 - 15	22	15	6
Scrophulariaceae	11.1	10 - 13	27	23	17
Solanaceae	11.9	10 - 15	52	37	10
Tiliaceae	14.3	11 - 20	20	13	3
Umbelliferae	11.6	10 - 12	30	14	14

are available. With some of the better-represented genera of the Leguminosae analyzed, the kilovoltages required are shown in Table 2.

Analysis of 1410 records suggests that having chosen an appropriate kilovoltage and fixed the milliamperage at 10, an exposure time in seconds slightly greater than the numerical value of the kV gave a result that could be quickly analyzed. This works well in the range 8-19 kV but above this the exposure time should not be increased as much. This empirical relationship, generated without a careful check on image density, should be used with

**Table 2.** Kilovoltages used for X-ray analysis of seeds of different Leguminosae genera in the Kew Seed Bank collection

Genus	Kilovoltage		Accessions examined	
	Avg. value	Range	No.	Species
<i>Acacia</i>	14.9	12 - 20	53	26
<i>Bauhinia</i>	14.9	13 - 18	10	3
<i>Crotalaria</i>	13.2	12 - 15	13	11
<i>Indigofera</i>	12.7	10 - 15	20	15
<i>Mimosa</i>	14.5	12 - 18	13	5
<i>Sesbania</i>	12.8	12 - 18	13	9

**Table 3.** Kilovoltages used for X-ray analysis of seeds of poorly represented plant families in the Kew Seed Bank collection

Low 10 - 11 kV	Low to medium 10 - 15 kV	Medium 12 - 17 kV	Medium to high 16 - 19 kV	High 18 - 25 kV
Acanthaceae	Agavaceae	Anacardiaceae	Burseraceae	Balanitaceae
Aizoaceae	Alismataceae	Araceae	Corylaceae	Bombaceae
Alliaceae	Aloaceae	Asclepiadaceae	Ebenaceae	Fagaceae
Begoniaceae	Amaranthaceae	Asparagaceae	Lauraceae	Palmae
Betulaceae	Asphodeliaceae	Bignoniaceae	Moringaceae	Rhamnaceae
Buddlejaceae	Balsaminaceae	Bromeliaceae	Sapotaceae	Simmondsiaceae
Campanulaceae	Boraginaceae	Buxaceae	Stylobasiaceae	
Crassulaceae	Cactaceae	Canotaceae		
Droseraceae	Capparaceae	Caprifoliaceae		
Epacridaceae	Cistaceae	Cochlospermaceae		
Gesneriaceae	Gentianaceae	Colchicaceae		
Hyacinthaceae	Guttiferae	Combretaceae		
Hydrophyllaceae	Liliaceae	Cucurbitaceae		
Juncaceae	Linaceae	Dioscoreaceae		
Melanthiaceae	Lythraceae	Dipsacaceae		
Melastomataceae	Myrtaceae	Dipterocarpaceae		
Molluginaceae	Onagraceae	Dracaenaceae		
Phytolaccaceae	Plantaginaceae	Euphorbiaceae		
Primulaceae	Plumbaginaceae	Flacourtiaceae		
Resedaceae	Polemoniaceae	Fouquieriaceae		
Saxifragaceae	Polygonaceae	Fumariaceae		
Typhaceae	Rosaceae	Geraniaceae		
	Rubiaceae	Goodeniaceae		
	Sterculiaceae	Iridaceae		
	Zygophyllaceae	Malpighiaceae		
		Menyanthaceae		
		Monimaceae		
		Moraceae		
		Myricaceae		
		Nepenthaceae		
		Nyctaginaceae		
		Oleaceae		
		Papaveraceae		
		Pedaliaceae		
		Portulacaceae		
		Proteaceae		
		Puniaceae		
		Ranunculaceae		
		Rutaceae		
		Sapindaceae		
		Simaroubaceae		
		Smilacaceae		
		Theophrastaceae		
		Ulmaceae		

caution. It is merely presented because the images produced yielded satisfactory information. It is also likely that the relationship is machine specific.

As an approximate guide (based on rather limited data) the kilovoltages presented in Table 3 were found to be useful for other plant families. The situation could change with species representation.

No clear pattern was found with collections from the Cupressaceae, Ericaceae and Verbenaceae.

### 'Empty' seeds in Kew Seed Bank collections

Data on a total of 4361 accessions, 2175 species and 163 families were analysed. In order to focus the results on better-represented families within the collection, only those where more than 20 accessions have been examined are included. Table 4 is based on the examination of 135 610 seeds after cleaning.

'Empty' seeds were identified in all the families examined and where sufficient data were available. The three families leading the table for frequency of 'empty' seeds are also those families where the average percentage of 'empty' seeds per accession is highest. This reflects the difficulty of cleaning such collections as well as the field situation. Interestingly, the majority of accessions in these three families are trees or shrubs. Families where cleaning is relatively easier (e.g.

Cruciferae and Caryophyllaceae) occur lower down in Table 4. It should also be noted that few accessions were recorded as being 100% 'empty'. This may reflect great care taken at collecting to avoid very immature material.

Table 5 contains information on the proportion of 'empty' seeds in the Leguminosae and Gramineae at a generic level for genera represented by more than 20 accessions.

As might be expected with such a diverse collection, there is a large difference between genera within families. In the Leguminosae, although collections containing 'empty' seeds are frequent, the average percentage of such seeds in the collection is only 4%. Within the Gramineae, those genera where accessions with 'empty' seeds are most frequent are also those where the level of damage within each accession is also high. In contrast to the Leguminosae, the average percentage of 'empty' seeds per collection is as high as 36%. With the Gramineae data, there is no obvious taxonomic pattern, with the top six genera in the table coming from five different tribes and three subfamilies.

### Insect-damaged seeds in Kew Seed Bank collections

As with the analysis of 'empty' seededness, 4361 accessions were examined and only those families with more

**Table 4.** Frequency of 'empty' seeds within collections of different families held in the Kew Seed Bank after cleaning

	Accessions with 'empty' seeds (%)	Average 'empty' seeds/ accession (%)	Accessions with 100% 'empty' seeds	Total accessions examined		
				Number	Species	Genera
Tiliaceae	73	19	1	37	15	4
Combretaceae	70	41	2	33	14	5
Rhamnaceae	67	28	1	21	9	6
Umbelliferae	56	5	1	84	40	32
Polygonaceae	55	5	0	29	21	8
Malvaceae	54	8	1	48	30	12
Cistaceae	54	7	0	24	13	2
Labiatae	53	5	1	88	57	31
Rosaceae	53	4	0	49	33	18
Cucurbitaceae	52	5	0	44	25	14
Cyperaceae	51	12	4	55	33	13
Compositae	49	8	2	244	173	100
Solanaceae	46	5	0	138	69	14
Capparaceae	45	2	0	24	13	4
Rubiaceae	44	4	0	27	18	12
Chenopodiaceae	42	3	0	170	70	16
Ericaceae	42	10	0	24	17	10
Cruciferae	36	2	0	95	50	32
Gramineae	33	6	15	1112	370	123
Amaranthaceae	33	3	0	55	17	11
Leguminosae	27	2	1	1199	442	134
Convolvulaceae	25	3	0	24	13	7
Ranunculaceae	17	1	0	59	33	9
Caryophyllaceae	17	1	0	41	31	14
Scrophulariaceae	10	2	0	51	38	22

**Table 5.** The frequency of 'empty' seeds within collections of Leguminosae and Gramineae genera held in the Kew Seed Bank after cleaning

Genus	Accessions with 'empty' seeds (%)	Percentage of 'empty' seeds/accession		Accessions examined	
		Avg.	Range	No.	Species
<b>Leguminosae</b>					
<i>Prosopis</i>	48	3	0 - 8	23	6
<i>Crotalaria</i>	37	3	0 - 26	41	25
<i>Acacia</i>	35	3	0 - 52	176	40
<i>Neonotonia</i>	34	<1	0 - 20	114	1
<i>Senna</i>	32	4	0 - 90	59	18
<i>Sesbania</i>	32	2	0 - 10	41	15
<i>Indigofera</i>	30	4	0 - 76	66	27
<i>Tephrosia</i>	28	1	0 - 10	32	10
<i>Trifolium</i>	27	1	0 - 40	115	25
<i>Mimosa</i>	25	3	0 - 32	24	12
<i>Desmodium</i>	22	<1	0 - 2	23	10
<i>Stylosanthes</i>	21	<1	0 - 10	39	8
<i>Medicago</i>	13	<1	0 - 7	24	11
<i>Lotus</i>	3	<1	0 - 2	29	24
<b>Gramineae</b>					
<i>Setaria</i>	65	36	0 - 100	23	10
<i>Festuca</i>	61	19	0 - 100	31	6
<i>Bromus</i>	59	13	0 - 100	30	17
<i>Lolium</i>	59	5	0 - 61	44	2
<i>Paspalum</i>	50	16	0 - 92	24	10
<i>Aristida</i>	50	5	0 - 20	24	14
<i>Panicum</i>	39	7	0 - 96	38	15
<i>Pennisetum</i>	19	<1	0 - 20	223	9
<i>Phleum</i>	17	1	0 - 13	23	2
<i>Sporobolus</i>	16	2	0 - 38	25	17
<i>Cenchrus</i>	16	1	0 - 10	32	7
<i>Eragrostis</i>	7	<1	0 - 34	85	42
<i>Dactyloctenium</i>	2	<1	0 - 2	60	5

than 20 accessions are included below. It should, however, be noted that the Bignoniaceae, Agavaceae, and Sapindaceae which are not included have been found to be problematic with respect to insect damage. Results shown in Table 6 are based on the examination of 127 458 seeds after cleaning. Figures in Table 7 give the breakdown for the Leguminosae where accession number exceeds 20.

In some cases, both empty and insect-damaged seed can be present within the same accession (see Fig. 1).

Insect damage to seeds occurs widely within the plant kingdom and although is most frequent among large-seeded species (Janzen 1969), occurred within all the plant families examined and where sufficient data were available. The average damage in each accession was low (3% or lower). However, Table 7 demonstrates that damage in individual collections can be complete. Although outside the scope of this paper, it is hoped at some future date to correlate these results with other data held on the Kew Seed Bank computer.

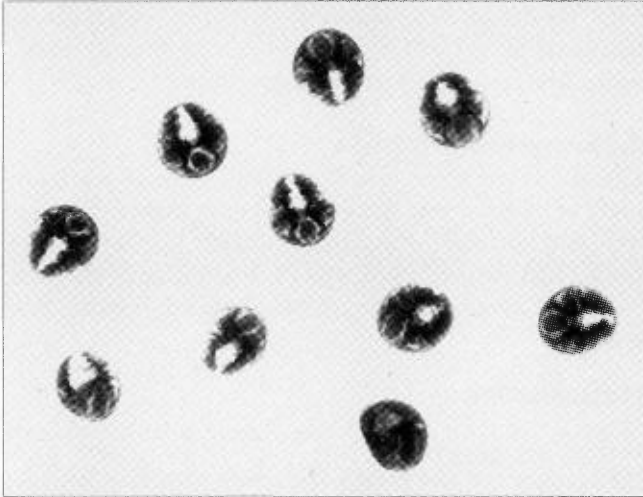
**Table 6.** Frequency of insect-damaged seeds within collections of different families held in the Kew Seed Bank after cleaning

Family	Accessions with insect-damaged seed (%)	Average % of insect damage/accession	Total accessions examined		
			No.	Species	Genera
Leguminosae	26	3	1199	442	134
Umbelliferae	15	1	84	40	32
Malvaceae	13	1	48	30	12
Rosaceae	8	1	49	33	18
Convolvulaceae	8	1	24	13	7
Cucurbitaceae	5	<1	44	25	14
Cruciferae	4	<1	95	50	32
Amaranthaceae	4	<1	55	17	11
Labiatae	3	<1	88	57	31
Ranunculaceae	3	<1	59	33	9
Tiliaceae	3	<1	37	15	4
Polygonaceae	3	<1	29	21	8
Gramineae	2	<1	1112	370	123
Compositae	2	<1	244	173	100
Cyperaceae	2	<1	55	33	13
Chenopodiaceae	1	<1	170	70	16
Solanaceae	1	<1	138	69	14
Combretaceae	1	<1	33	14	5

**Table 7.** Frequency of insect-damaged seeds within collections of Leguminosae genera held in the Kew Seed Bank after cleaning

Genus	Accessions with insect-damaged seed (%)	Percentage of insect damage/accession		Accessions examined	
		Avg.	Range	No.	Species
<i>Acacia</i>	63	12	0 - 100	177	40
<i>Prosopis</i>	56	3	0 - 20	23	6
<i>Mimosa</i>	46	10	0 - 60	24	12
<i>Senna</i>	27	2	0 - 22	45	18
<i>Sesbania</i>	22	2	0 - 27	41	15
<i>Lotus</i>	21	4	0 - 32	29	24
<i>Crotalaria</i>	17	2	0 - 28	41	25
<i>Desmodium</i>	17	<1	0 - 6	23	10
<i>Indigofera</i>	12	<1	0 - 4	66	27
<i>Tephrosia</i>	6	<1	0 - 8	32	10
<i>Stylosanthes</i>	5	<1	0 - 12	39	8
<i>Neonotonia</i>	4	<1	0 - 16	114	1
<i>Medicago</i>	4	<1	0 - 5	24	11
<i>Trifolium</i>	3	<1	0 - 10	115	25

Those involved in the curation of seed collections should be mindful of the value to entomologists of any insects found with seedlots. Those hatching out from a known plant host where there is good passport data (provenance and harvest date) can be of great entomological interest and the increased biological information adds scientific value to the collection.



**Fig. 1.** X-radiograph (positive printed) of fruit of *Fraxinus chinensis* (Oleaceae, collected South Korea 1983). Conditions used 14 kV, 10mA and 14 seconds. OFD = 0, FFD = 47 cm. Four insect-damaged fruits, two immature fruits and one fruit with an aborted seed are present

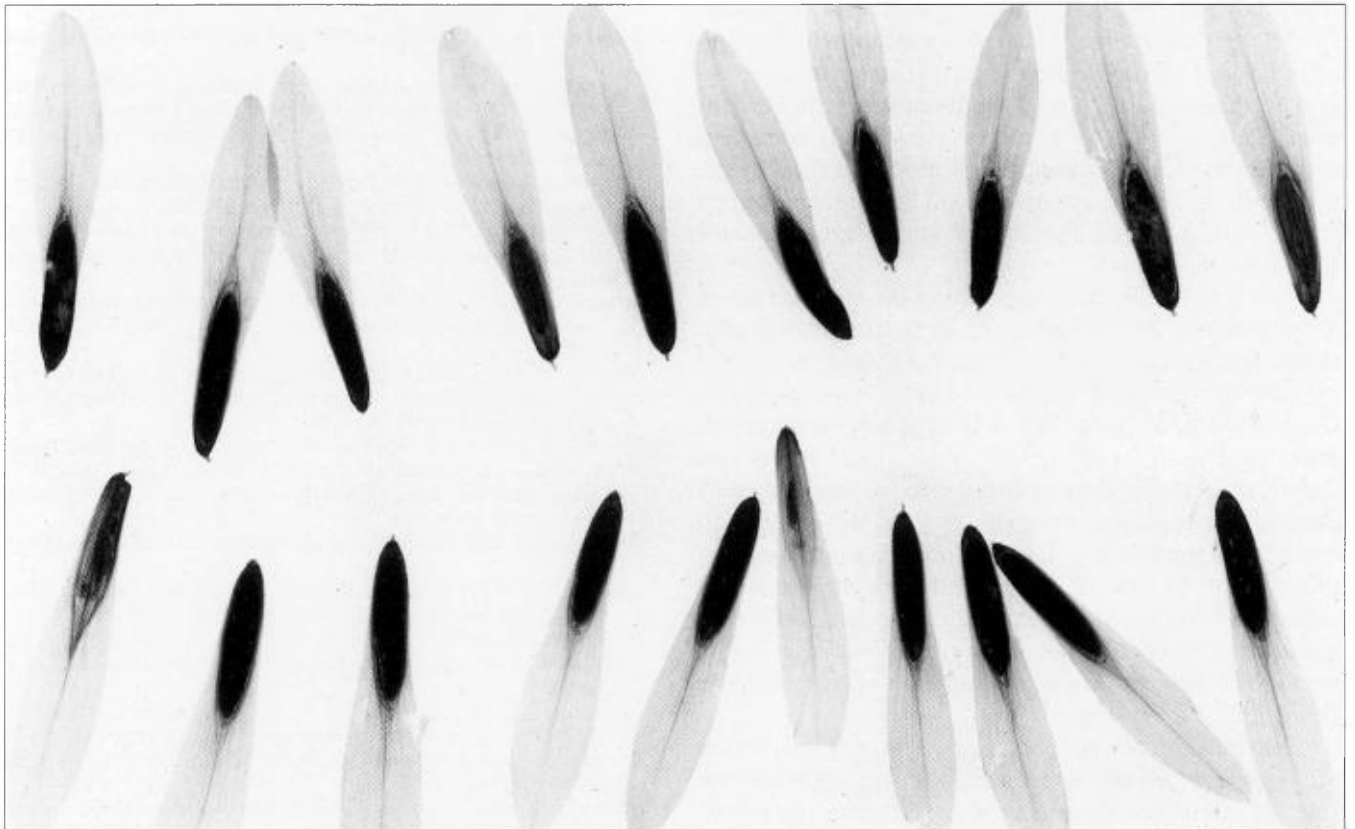
### Conclusions

The results demonstrate that the problem of 'empty' and insect-damaged seeds is widespread among seed collections of wild species. Even the best cleaning will not

remove the problem entirely and seed bank curators should adopt appropriate techniques for assessment, be they X-ray analyses or cut-tests if errors in viability monitoring and distribution of seeds are to be avoided.

By entering onto a computer the number of 'empty' or damaged seeds assessed after cleaning and before viability testing, those staff carrying out the testing will be alerted to the fact that a proportion of the seeds in the test will be incompetent. Seed numbers can be increased to compensate and ensure that the test is still statistically significant. At the Kew Seed Bank, information on the proportion of 'empty' or damaged seeds is printed at the top of the germination test sheet. Assessment of 'empty' and damaged seeds remaining at the end of a germination test can be added to the computer information to give an overall figure for percentage unusable. This figure can then be used when distributing seed to users. For instance, if there is a figure of 50% unusable (bearing in mind sampling error), the computer can automatically double the quantity of seed to be despatched. If insect damage is noted during assessment then this is valuable information that can be provided to the recipient.

If the assessment method is X-ray analysis, curators will have to evaluate the appropriate dosages in terms of kilovoltage, milliamperage, seconds and film focus distance for a given film speed and machine. This paper has



**Fig. 2.** X-radiograph of seed of *Stictocardia macalusi* (Convolvulaceae, collected Oman 1992). Conditions used 20 kV, 10mA and 20 seconds. OFD = 0, FFD = 47 cm

shown the relative requirements for seeds in a wide range of plant families. Obviously seed/fruit size, shape and structure are key determinants.

Although assessment can be carried out by a cut-test, X-ray analysis has several advantages. Firstly, in carrying out a surgical analysis or cut-test, detail of the seed's contents may be destroyed. X-ray analysis often detects surprising structural detail (see *Stictocardia macalusi* seed showing detail of the tightly packed cotyledons in Fig. 2). In some cases seedling morphology can be assessed by X-ray analysis of the seeds (van der Burg *et al.* 1994). Secondly, in some cases it is impractical to clean seeds out from their fruits before banking and an X-ray analysis may allow a clearer determination of the number of seeds per fruit than is possible with a cut test. This information when combined with the number of fruits in a collection can allow for an estimation of total seed number. In a few cases, fruits may contain several seeds, some of which are empty. Given suitable computer software it is then possible to ensure that the correct number of filled seeds are despatched to a user. Thirdly, a cut-test can be very difficult with certain types of dispersal unit. Where seeds have a thick testa or fruits a substantial pericarp, surgical examination can often be more lengthy than X-ray analysis. In the case of very small seeds which are impossible to cut, a radiograph can be magnified on a microfiche reader to reveal the necessary information. A radiograph allows a clear interpretation of the original analysis even years later and may, in addition with poorly described wild species, provide anatomical information which gives added value to each collection. Finally, by making the grid asymmetrical, each seed and its contents can be identified and the filled seeds picked out for a germination test. Because low kilovoltages are used, the risks of genetic damage are low but should not be ignored. For this reason resultant seedlings should not be grown on for seed regeneration.

Cost is the main factor precluding the wider usage of X-ray analysis. At the Kew Seed Bank, the main capital outlay has been an X-ray machine, purchased for £12 950 in 1990 (from Todd Research Ltd., Robjohns Road, Chelmsford CM1 3DP, UK), a G-M tube contamination meter purchased for £85 in 1977, a microfiche reader and darkroom facilities. Because X-ray techniques are used by university metallurgy and geology departments, the alternative to such capital outlay is to develop the appropriate links. As can be seen from the results, a machine offering a kilovoltage range of 8-25 kV giving soft X-rays is required. Such equipment may have added value to botanical institutes for the examination of leaf venation (Wing 1992), for instance.

Consumable costs are not great. One pair of 10-L bottles of the appropriate developer and fixer (approximate total cost £60) allow the analysis of about 500 accessions of 50 seeds, while on average each sheet of Kodak Industrex MX 9x12 cm film (£0.35) will hold two such accessions.

Film has the advantage over X-ray paper (which can be processed more rapidly) in that it can be magnified on a microfiche reader and tends to store better.

## Acknowledgements

The results presented represent many hours of work carried out by Kew Seed Bank staff. Special thanks are given to E.A.M. Ormerod for technical assistance. N. Hornsby from Todd Research Ltd. and R. Probert from the Kew Seed Conservation Section both provided helpful comments.

## References

- Brummitt, R.K. 1992. Vascular Plant Families and Genera. Royal Botanic Gardens, Kew.
- Chavagnat, A. 1987. Use of soft X-ray radiography for studying seed quality in horticulture. *Acta Horticult.* 215:153-158.
- Doust, J.L. and L.L. Doust (eds.). 1988. *Plant Reproductive Ecology, Patterns and Strategies*. Oxford University Press.
- Ellis, R.H., T.D. Hong and E.H. Roberts. 1985. *Handbooks for Genebanks: No. 2, Handbook of Seed Technology for Genebanks, Volume I, Principles and Methodology*. IBPGR, Rome.
- FAO. 1993. The Commission on Plant Genetic Resources, Fifth Session, Rome, 19-23 April 1993, Genebank Standards CPGR/93/5 Annex. FAO, Rome.
- Fenner M. 1985. *Seed Ecology*. Chapman and Hall.
- Groombridge, B. (ed.). 1992. *Global Biodiversity, Status of the Earth's Living Resources*. A report compiled by the World Conservation Monitoring Centre. Chapman and Hall.
- ISTA. 1985. Biochemical Test for viability, Annex to chapter 6. *Seed Sci. Technol.* 13(2):464-483.
- Jansen, D.H. 1969. Seed-eaters versus seed size, number, toxicity and dispersal. *Evolution* 23:1-27.
- Johnson, C.D. 1983. *Handbook on seed insects of Prosopis species*. FAO, Rome.
- Marshall, C. and J. Grace, (eds.). 1992. *Fruit and Seed Production, Aspects of Development, Environmental Physiology and Ecology*. Society for Experimental Biology Seminar Series 47. Cambridge University Press.
- Marshall, C. and D. Ludlam. 1989. The pattern of abortion of developing seeds in *Lolium perenne* L. *Ann. Bot.* 63:19-27.
- Prendergast, H.D.V., R.D. Smith, S. Linington and M.F. Newman. 1991. Seeds for use and conservation. *Development in Practice* 1:120-127.
- Simak, M. and K. Sahlén. 1981. Report of the forest tree seed committee working group on X-ray testing 1977-1980. *Seed Sci. Technol.* 9(1):205-227.
- Simak, M. and K. Sahlén. 1983. *Bibliography on X-radiography in seed research and testing*. Rapport, Institutionen för Skogsskötsel, Sveriges Lantbruksuniversitet No. 12.
- Smith, R.D. 1995. Collecting and handling seeds in the field. Pages 419-456 in *Collecting Plant Genetic Diversity* (Luigi Guarino, V. Ramanatha Rao and Robert Reid, eds.). CAB International, Wallingford, Oxon, UK.
- Southgate, B.J. 1983. *Handbook on seed insects of Acacia species*. FAO, Rome.
- van der Burg, W.J., J.W. Aartse, R.A. van Zwol, H. Jalink and R.J. Bino. 1994. *J. Am. Soc. Hortic. Sci.* 119(2):258-263.
- Wiens, D. 1984. Ovule survivorship, brood size, life history, breeding systems, and reproductive success in plants. *Oecologia (Berlin)* 64:47-53.
- Wiens, D., D.L. Nickrent, C.I. Davern, C.L. Calvin and N.J. Vivrette. 1989. Developmental failure and loss of reproductive capacity in the rare palaeoendemic shrub *Dedeckera eurekensis*. *Nature* 338(6210):65-67.
- Willan, R.L. 1985. *A guide to forest seed handling - with special reference to the tropics*. FAO Forestry Paper 20/2. FAO, Rome.
- Wing, S.L. 1992. High-resolution leaf X-radiography in systematics and paleobotany. *Am. J. Bot.* 79(11):1320-1324.

**Résumé**

*Examen radioscopique de semences vides et endommagées par les insectes dans une collection d'espèces sauvages ex situ*

On présente les résultats de la radioscopie de semences d'espèces sauvages incorporées dans les Royal Botanic Gardens, Kew. Ils montrent que les familles de végétaux dans lesquelles la présence de semences "vides" et endommagées par les insectes s'est révélée prédominante dans les collections de semences même après nettoyage. Ils indiquent aussi les conditions requises pour des radiographies satisfaisantes pour différentes familles. L'importance de déterminer les fractions de semences "vides" et endommagées est soulignée concernant les modes d'opération des banques de semences d'espèces sauvages.

**Resumen**

*Análisis mediante rayos X de semillas vacías y dañadas por insectos en una colección ex situ de especies silvestres*

Se presentan los resultados del análisis con rayos X de semillas de especies vegetales silvestres incorporadas al Jardín Botánico Real de Kew. Figuran las familias de plantas que en la recolección registraban con mayor frecuencia semillas "vacías" y dañadas por insectos, incluso después de las operaciones de limpieza. Se indican los requisitos necesarios para obtener radiografías satisfactorias de diferentes familias. Se destaca la importancia de distinguir con precisión las fracciones de semillas "vacías" y dañadas, con relación al manejo de bancos de especies silvestres de semillas.

# Accession regeneration in genebanks: seed production environment and the potential longevity of seed accessions

R.H. Ellis<sup>1</sup> and M.T. Jackson<sup>2</sup>

<sup>1</sup> Department of Agriculture, The University of Reading, Earley Gate, PO Box 236, Reading RG6 2AT, UK

<sup>2</sup> Genetic Resources Center, International Rice Research Institute, PO Box 933, 1099 Manila, Philippines

## Summary

This article summarizes a programme of collaborative research between the Department of Agriculture, The University of Reading, and the Genetic Resources Center of the International Rice Research Institute. The research programme first identified the cause of poor seed quality in certain accessions of *japonica* rice. It then developed different seed production practices which not only avoided the problem in these accessions but also provided better seed quality in accessions of *indica* rice as well. The results of this programme may have implications for seed accession regeneration procedures elsewhere, and in crops other than rice.

## Introduction

Seed accessions require regeneration either when the number of seeds is insufficient for continued conservation and utilization or when viability falls below a minimum value (the regeneration standard). Although there is a general belief that an accession should be regenerated in the environment from which it was collected, such individual attention to the requirements of each accession is not feasible in many large genebanks. In such cases, regeneration may be carried out either where resources (field site, equipment, labour, etc.) are under the direct control of the genebank, or where it can be contracted out most efficiently to meet the desired objective.

The genebank at the International Rice Research Institute (IRRI), Los Baños, Philippines, maintains a total of more than 80 000 accessions of both cultivated rice species and their wild relatives. For many years, it had been the practice of the genebank to regenerate rice seed accessions at Los Baños (14° 11' N, 121° 15' E, elevation 21 m a.s.l.) during both the wet-season months (July–October), and the dry-season months (November–May).

Over the years we had become concerned that the quality of the seeds of the *japonica* rice accessions in the IRRI genebank were poorer than those of the other ecogeographic races of rice. This led us to question whether the seed storage characteristics of *japonica* rices were intrinsically poorer than the *indica* rices, or whether they were a consequence of the seed production environment, given that the wet season at Los Baños is somewhat warmer than the conditions in which the *japonica* rices evolved.

## Research in the UK

An investigation of the relations between seed longevity and seed storage moisture content confirmed that *japonica*

accessions showed poorer longevity than *indica* accessions when seed lots of the same quality were stored in the same environment (Ellis *et al.* 1992). However, in addition to this intrinsic difference among the ecogeographic races of *Oryza sativa*, that research also confirmed the generally poor initial quality of the *japonica* accessions regenerated in the wet season at Los Baños.

We therefore approached the Overseas Development Administration (ODA) of the UK Foreign and Commonwealth Office for the support of investigations to develop experimental approaches with which to determine whether or not *japonica* rice seed quality was particularly sensitive to the seed production environment. The ODA funded an initial 12-month investigation at the Plant Environment and Seed Science Laboratories of The University of Reading.

In that research, changes in seed quality (assessed by potential longevity, i.e. the value of the seed lot constant  $K_i$  of the seed viability equation) in three contrasting cultivars of rice were monitored during seed development and maturation in two temperature regimes, *viz.* 28/20°C and 32/24°C (12/12h), provided by controlled environments (Ellis *et al.* 1993). The cooler temperature regime mimicked a warm temperate seed production environment (Tsukuba, Japan), and the warmer that pertaining at Los Baños during the wet season.

Mass maturity (defined as the end of the seed-filling phase) varied only between 18 and 20 days after 50% anthesis. In five of the six treatment combinations maximum potential longevity was not achieved until 12–19 days after mass maturity. In contrast, the maximum potential longevity of seeds of a *japonica* rice cultivar produced in the warmer regime was obtained soon after mass maturity. After mass maturity, the potential longevity of the *japonica* rice seed lots

produced in the warmer environment was much less than that for the cooler environments.

Maximum potential longevity was also consistently greater in the cooler than in the warmer regime for the two *indica* cultivars, although the difference in  $K_i$  was small (0.3–0.5). The deleterious effect of increase in temperature on seed quality development was not detected until after mass maturity. Maximum potential longevity in the cooler regime was greatest in the glutinous *indica* cultivar ( $K_i = 3.9$ ) and least in the *japonica* cultivar ( $K_i = 3.1$ ). It was concluded that the *japonica* cultivar is not as well adapted to warm seed production regimes as the *indica* cultivars. Hence, this research suggested that the seed production of *japonica* cultivars for long-term genetic conservation should be undertaken, whenever possible, in warm temperate environments.

These differences between seed production environments on the potential longevity of a *japonica* rice were confirmed in another investigation (Fig. 1). This further research also showed that the increases in potential longevity which were recorded were associated with the onset of the ability of the seeds to tolerate desiccation to very low moisture contents (Ellis and Hong 1994).

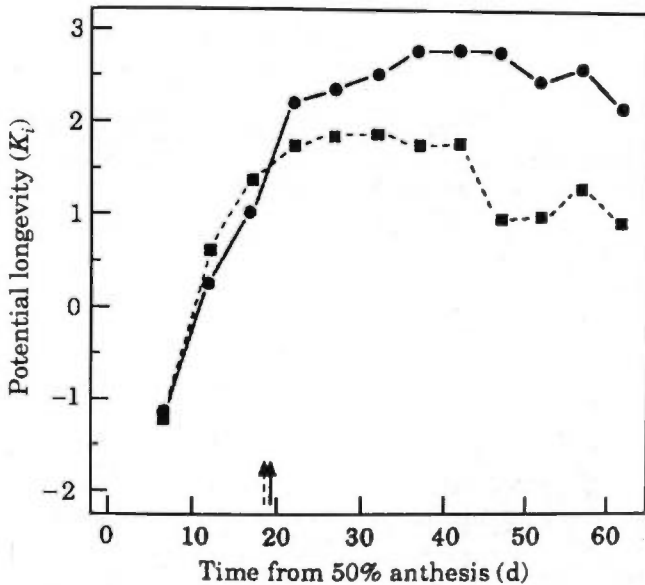


Fig. 1. Changes in the potential air-dry storage longevity ( $K_i$ ) of seeds of a *japonica* rice during seed development and maturation in controlled environments of 28/20°C (●) or 32/24°C (■). Solid and broken arrows indicate the end of the seed-filling phase (mass maturity) in the cooler and warmer regimes, respectively (from Ellis and Hong 1994).

Tolerance of desiccation to low (4%) moisture contents improved until 22 and 14 days after mass maturity in the cooler and warmer regimes, respectively, when maturation drying had reduced seed moisture contents naturally to 24 and 32% moisture content, respectively. Further delays to seed harvest reduced desiccation tolerance, particularly in the warmer environments. Compari-

son among 15 samples of seeds harvested at different times in the two environments showed a strong correlation ( $r = 0.947$ ,  $P < 0.01$ ) between longevity ( $K_i$ ) and desiccation tolerance (to 4% moisture content) (Fig. 2). It is possible, then, that the regulation of desiccation tolerance to low moisture contents and potential air-dry longevity during seed development and maturation may have a common cause.

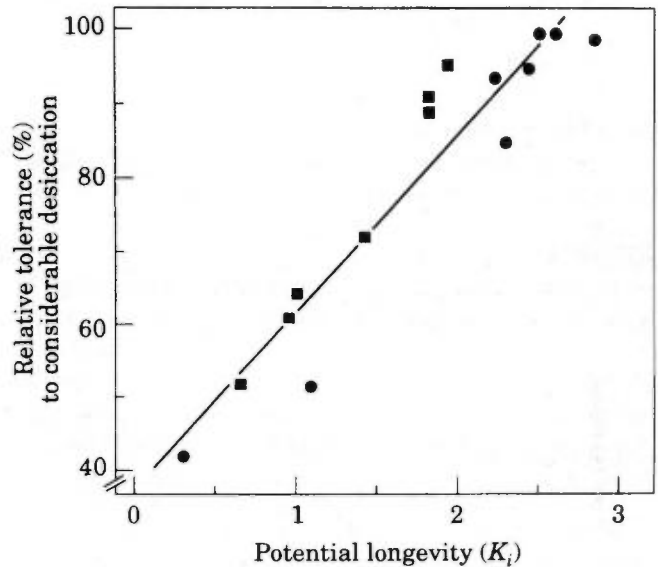


Fig. 2. Association between the relative tolerance to desiccation to 4% moisture content and potential storage longevity (determined at 15% moisture content) for seeds of a *japonica* rice harvested at different times during development and maturation from plants grown in controlled environments of 28/20°C (●) and 32/24°C (■) (from Ellis and Hong 1994).

Hence, this research in the UK demonstrated that one *japonica* rice cultivar was particularly sensitive to seed production environment and that both subsequent seed storage longevity and desiccation tolerance were much improved in the cooler seed-production environment. The research also showed that, provided seeds were produced in suitable environments, maximum seed quality was obtained if seeds were harvested at the developmental stage described as harvest maturity (when seed moisture content has declined naturally to below about 20%).

### Research in the Philippines

The research then switched to the Philippines, using a wider range of cultivars. On the basis of the results of the research at Reading, the experiments at Los Baños were all conducted during the dry-season months. A comparison of *japonica* rices in the field and growth chamber was also made. The research has confirmed several points.

1. The cooler dry season provides a better seed production environment than the warmer wet season for all rice accessions; better in this case means greater subsequent seed storage longevity.

2. The seed production environment at Los Baños during the dry-season months is not harsh for *japonica* cultivars.
3. Estimates of potential longevity in *japonica* cultivars were high and close to those of the *indica* cultivars. However, lowland *japonica* cultivars, large-seeded accessions, and *Oryza glaberrima* cultivars do have shorter storage longevity than *indica* rices, but from a practical conservation standpoint this is not a problem.
4. Advancing the planting date of *japonica* cultivars so that flowering and grain-filling coincide with the cooler and drier segment of the dry season at Los Baños, and harvesting between 28 and 35 days after flowering, significantly improve potential longevity in these rice accessions.

### Impact

As a consequence of this collaborative programme of research, the IRRI genebank now regenerates rice accessions only during the dry-season months at Los Baños. Moreover, in view of the particular sensitivity of the *japonica* rice accessions to warm temperatures during seed development and maturation and the fact that the seasonal trend in temperature toward the end of the dry season is upward, the *japonica* rice accessions are sown first (and as early as possible) during the dry season. This ensures that the grain-filling period coincides with the coolest nights in January.

We have shown that the environment at Los Baños is conducive for the regeneration of rice accessions originating from a wide geographical area. Furthermore, armed with this enhanced knowledge about the interaction be-

tween the effects of seed production environment and genotype in rice on seed quality, we have been able to set higher initial viability standards than in the past for *indica* as well as *japonica* rices.

Thus the quality of germplasm regenerated at this single site in Los Baños has improved. While it is not possible to provide optimum regeneration conditions genotype by genotype, we have identified those factors that have the greatest pre-harvest effect on subsequent storage longevity. Coupled with changes in seed-drying procedures, under which recently harvested seeds equilibrate to 15% RH at 15°C over several weeks, we now have in place a set of procedures aimed at maximizing seed quality and thus extending storage potential.

Insofar as the IRRI genebank is concerned, then, this collaborative research between The University of Reading and IRRI has had considerable impact on its practices. We believe that the research may also be of interest to certain other organizations. First, to those maintaining (and so regenerating) rice accessions in genebanks elsewhere, and second, to those genebanks maintaining seed accessions of other species.

### References

- Ellis, R.H. and T.D. Hong. 1994. Desiccation tolerance and potential longevity of developing seeds of rice (*Oryza sativa* L.). *Ann. Bot.* 73:501-506.
- Ellis, R.H., T.D. Hong and M.T. Jackson. 1993. Seed production environment, time of harvest and the potential longevity of seeds of three cultivars of rice (*Oryza sativa* L.). *Ann. Bot.* 72:583-590.
- Ellis, R.H., T.D. Hong and E.H. Roberts. 1992. The low-moisture-content limit to the negative logarithmic relation between seed longevity and moisture content in three subspecies of rice. *Ann. Bot.* 69:53-58.

### Résumé

*Régénération des obtentions dans les banques de gènes: l'environnement de la production des semences et la longévité potentielle des obtentions de semences*

Cet article résume un programme de recherche mené en collaboration par le Département de l'agriculture, l'Université de Reading et le Centre de ressources génétiques de l'Institut international de recherche sur le riz. Le programme de recherche a d'abord identifié la cause de la qualité médiocre des semences dans certaines obtentions de riz *japonica*. Ensuite, il a mis au point différentes méthodes de production de semences qui, outre qu'elles ont évité le problème dans ces obtentions, ont fourni une meilleure qualité de semences dans les obtentions de riz *indica*. Les résultats de ce programme pourraient avoir une incidence sur les méthodes de régénération des obtentions de semences ailleurs et pour des plantes cultivées autres que le riz.

### Resumen

*La regeneración de accesiones en los bancos de genes: influencia del medio ambiente en la producción y la longevidad potencial de las accesiones de semilla*

En el presente artículo se resume un programa de investigación realizado por el Departamento de Agricultura en colaboración con la Universidad de Reading y el Centro de Recursos Genéticos del Instituto Internacional de Investigaciones sobre el Arroz. Se identifica en primer lugar la causa de la escasa calidad de las semillas de ciertas accesiones de arroz *japonica*. A continuación se examinan diferentes técnicas de producción que no solamente evitan el problema en estas accesiones sino que también proveen semilla de mejor calidad en accesiones de arroz *indica*. Los resultados de este programa pueden ser aplicables a los procedimientos de regeneración de accesiones de semillas empleados en otros lugares, así como en cultivos distintos del arroz.

## Aspects of pomegranate culture in Turkmenistan

**Gregory M. Levin**

The Turkmenian Experimental Station of Plant Genetic Resources, Garrygala, 745160, Turkmenistan, CIS

The Turkmenian Experimental Station of Plant Genetic Resources at Garrygala in southwestern Turkmenistan has the world's largest pomegranate collection: 1117 cultivars and forms. The focus of pomegranate research in the past 30 years has been the selection of soft-seeded and frost-hardy cultivars.

### Soft-seeded pomegranate

Big and hard seeds are a considerable drawback of many pomegranate cultivars, although many cultivars and forms of the pomegranate are quite heterogeneous for this quality. The hardness of the seed rind varies greatly, as does that of the seed cover. This hardness is present, for example, in local populations of wild pomegranate in the West Kopetdagh region of Turkmenistan. Hardseeded cultivars prevail among the cultivated ones, but along with them there are varieties with thin, frail and soft covers, i.e. soft-seeded ones. There are also cultivars in which the corneous cover is rudimentary and not present in every seed (the so-called seedless cultivars).

The notion of seedlessness in the pomegranate is rather relative. It is connected not with the complete absence of seeds, but with their underdevelopment, which makes them hardly perceptible when eaten. Absence of seeds is a desirable economic trait that improves the dietetic and consumptive qualities of fruits, for example in bananas, oranges, grapes and pineapples.

The first mention of seedless pomegranates occurred in antiquity. Theophrastus pointed out that in Kilikia (Asia Minor) they grew pomegranates without seeds. Rome received seedless pomegranates from Carthage. Among other varieties Darwin notes the pomegranate with seedless fruits. Seedless pomegranates are found in Afghanistan, Iran, Turkey, Palestine, Yemen and Cyprus.

Apparently seedless pomegranate cultivars are restricted to a narrow ecological region. Experiments on the culture in central Asia were a failure; there, seeds developed in seedless pomegranate fruits. Even in Afghanistan, outside the valley of Tagob, seedless cultivars produce fruits with seeds. At present in this country there are no seedless pomegranate cultivars in any collection.

The pomegranate collection of the Turkmenian Experimental Station of Plant Genetic Resources (TES PGR) includes soft-seeded cultivars (132 samples) having a narrow geographical distribution at present. They have a soft seed, high gustatory qualities, give relatively a lot of

juice when processed, and are suitable for dessert. Soft-seeded cultivars are less frost-hardy and are frost-bitten at -11 to -12°C, hard-seeded cultivars at -15 to -16°C and lower.

Over the last 30 years B.S. Rosanov, A.D. Strebkova, N.I. Zaktreger and others have selected and grown a group of soft-seeded cultivars having a sweet or sweet-acid taste. From 1950 to 1970 over 30 soft-seeded cultivars and elite seedlings were grown at the TES PGR by N.I. Zaktreger, O.F. Mizgiriyova and A.D. Strebkova.

The soft-seeded pomegranate cultivars vary in time of ripening and taste: early ripening cultivars are sweet, late-ripening ones are sweet-acid. The cultivar 'Sverkhramniy' (selected by G.M. Levin) ripens in August; cultivars 'Andalyb', 'Zelily', 'Seidy', 'Syunt', 'Khasardagh' and 'Shikhimderinskiy' (selected by N.I. Zaktreger and others) in September; such cultivars as 'Ariana', 'Vkusniy', 'Girkania', 'Dakhistan', 'Kemine', 'Makhtumkuly', 'Messarian', 'Molla Nepes', 'Myagkosemyanniy rozoviy', 'Nisa', 'Neozhidanniy', 'Parfianka' and 'Sumbarskiy' (selected by N.I. Zaktreger and others) ripen in October.

In Tadzhikistan the selection of soft-seeded cultivars of sweet and sweet-acid taste is aimed at developing low-growing varieties which are easier to harvest by machines.

At a high agrotechnical level the soft-seeded cultivar 'Sverkhramniy' gave 10 kg per bush, a 15-year-old 'Shikhimderinskiy' produced 33 kg per bush. At the period of full maturity soft-seeded cultivars can yield an average of 10-15 t/ha and more in the open (when planted 5x5 m or 5x4 m), and 20-25 t/ha when covered (planted 4x2.5 m or 4x2 m). Sweet pomegranates can be stored for 3 months and sweet-acid cultivars for 5-6 months under the conditions of unregulated temperatures and air humidity, and even longer in storehouses with regulated environmental conditions.

It is desirable to plant soft-seeded cultivars of pomegranate separately from those with hard seeds because cross-pollination may cause metaxenia (or second-order xenia) which can lead to formation of hard seeds in some cultivars.

The pomegranate soft-seeded cultivars from the TES PGR collection have been widely distributed to the collections of scientific institutions. For the past 25 years they have been transferred to 37 selection centres of Central Asia and the Transcaucasus.

### Frost-resistant pomegranate

The Sumbar River valley is the northern border of open pomegranate industrial culture in Turkmenistan. In the past 50 years there were no fewer than 15 winters with temperatures reaching down to the level at which the pomegranates were damaged ( $-12^{\circ}\text{C}$  and lower). Thus, in nearly one-third of Garrygala winters frost-shattering occurs. Despite these conditions, the pomegranate industry there is still quite profitable, but the profitability is determined by the period of frost damage. We noted damages of different character and level caused by the frost-shattering effect of low temperatures: bud shattering of different degrees; frost damage to the ends of 1-year sprays; frost damage of separate stems; complete ruin of the aboveground part; frost damage of roots; frost ruin of the root system and frost burns on trunks.

Frost burns of trunks are often seen in the open pomegranate culture zone. The dead bark usually falls off, revealing a roll of growing callus. Sometimes frost burns cover the whole stem in the form of a long stripe. It often happens that separate branches and whole stems developing relatively well after a cold winter will go dry in the middle of summer. This occurs after considerable frost damage and extensive frost burns. The burns are not only caused by critically low temperatures; they may appear after relatively mild frost in sunny weather.

Scientists usually consider temperatures from  $-9.4^{\circ}\text{C}$  down to  $-13^{\circ}\text{C}$  as ruinous for the pomegranate. At  $-17.8$  to  $-18^{\circ}\text{C}$  it is destroyed down to the ground, but the CIS research data show a somewhat greater frost-hardiness. At  $-14$  to  $-15^{\circ}\text{C}$  the upper parts and some buds of one-year sprays are damaged, at  $-16$  to  $-17^{\circ}\text{C}$  the skeletal branches are considerably damaged, at  $-18$  to  $-20^{\circ}\text{C}$  all are damaged. There are few reports of the frost-hardiness differences in cultivars.

Garrygala is an optimal place for studying the intraspecific polymorphism of this culture as to the rate of frost-hardiness. During the past 70 years there have been three severe winters (1929/30, 1949/50, 1968/69), when the pomegranate was ruined down to the ground. In those winters temperatures went down to  $-17.1$  to  $-19.8^{\circ}\text{C}$ .

In the years with fewer hard frosts different degrees of frost damage were observed on 1-2 year sprays, with little effect on fruiting. Sometimes the pomegranate is considerably damaged by relatively weak frosts that come after the end-of-winter dormancy. This happened in the winter of 1975/76 when a frost of  $-11.5^{\circ}\text{C}$  occurred in the third week of February after a very warm end of December and January and severely damaged the wild and cultivated pomegranates.

Having an idea of the pomegranate frost-hardiness in the regions of its open culture on the whole, we can differentiate between winters in respect to the pomegranate frost-resistance:

1. mild winters: air temperature lowers gradually, frosts are no lower than  $-10$  to  $-11^{\circ}\text{C}$ , the pomegranate does not suffer from the frosts;
  2. mildly cold winters: frosts of  $-12$  to  $-15^{\circ}\text{C}$ , insignificant (considerable in some cultivars) damage;
  3. cold winters: air temperatures reach  $-15$  to  $-17^{\circ}\text{C}$ , some cultivars are destroyed to the ground surface, others are considerably damaged;
  4. severe winters: frosts reach down to  $-17^{\circ}\text{C}$ , and practically all cultivars have the part aboveground destroyed.
- Thus, for the last 35 years in Garrygala, 60% of winters were mild, 23% mildly cold, 14% cold and 3% severe (certainly corrections should be made for each definite region).

Frost-hardiness of the same cultivars varies in different winters, which may be connected with age, the state of the plants, the agrotechnical level and the time of winter minimum temperatures. Cultivars of the same type display a similar frost-hardiness level, for example 'Kazake'. Soft-seeded cultivars are usually not frost-hardy, nor are their seedlings obtained from free pollination and artificial hybridization.

The pomegranate cultivars also show different frost-hardiness in different regions. It may be connected above all with the ecological demands of the cultivars, an almost unexplored field of research. Thus the frost-hardiness of pomegranate is an integral feature dependent on many factors. Nonetheless, a continuous study of the frost-hardiness of a large variety of cultivars gives us objective information.

Frost sensitivity of the cultivars is listed in Table 1. In those years there were enough winters with sublethal temperatures to differentiate cultivars according to their low-temperature resistance. Relatively frost-hardy cultivars had an average damage index up to 1.5 points, mildly frost-hardy had 1.6-2.5, less frost-hardy had 2.6-3.5 and frost-sensitive had 3.6-4.5 points.

The unique environment for differentiating the pomegranate cultivars according to their frost-hardiness created by nature in Garrygala made it possible to distinguish a group of cultivars characterized by a relatively high frost resistance. There were 2 such ones out of 64 cultivars planted out in 1938-1940 and 1960, and 12 out of 130 planted in 1968: 'Kazake', 'Meykhosh', 'Kunduzsky', 'Melekeshsky' and 'Kzyl UK 12/5'. The cultivars having a number of useful qualities are also relatively frost-hardy.

Among mildly frost-hardy cultivars are such varieties as 'Vashingtongsky (Washington) 5-4-41', 'Zubeida', 'Shakh-nar', clones of 'Kzyl-anor', 'Meykhosh', 'Sochny (Nikitsky 110)', 'Sakerdze', 'VIR-1', 'Al-shirin-nar', 'Krmzy-kabukh', 'Salavatsky', 'Bashkalinsky', 'Nor-alma', 'Kay-achic-anor', 'Veles', 'Bala myursal', 'Meles', 'Nikitsky ranniy', etc. They are undoubtedly of great interest for industry and selection for higher frost resistance.

**Table 1.** Reaction to frost of pomegranate cultivars grown at the Turkmenian Experimental Station of Plant Genetic Resources at Garrygala, Turkmenistan

Frost-sensitive	Less frost-sensitive	Mildly frost-hardy	Frost-hardy
Planted 1938-40			
Kaliforniyskaya Krasavitza; Sladkoplodny	DK-8; Genliksky sladky 4441; Karakalinsky; Koryagynsky 4770; Kyzyl-achi; Shirin-kyzyl	Achik-dona; Achik-nar 4454; Agdamsky 4564; Ak-dona; Bala mjursal; Chinae; DK; DK-4; DK-10; DK-11; DK iz Narli; DK iz Narli N3; DK iz Tiamilja; Genlik-mir; Gjulosha; Gjulosha azerbayjanskaya; Gjulosha rosovaya; Kara-achi; Karakel 6; Karakel 7; Karakel 9; Kay-achi; Kazake; Kazjan 4432; Kok-dona; Krak mushlak; Krmzy-Kabuch; Makhrovoy krasny; Meles; Noukhoursky; Pridzevansky 4446; Shelly 4487; Shirin-nar krasnozerny; Sladky iz Bernau; Takhta-kala; Veles; VIR-1; Zubeida 667	DK iz Shevlana; Zangelansky
Planted 1968			
680a; Ispansky rubin; Kaliforniysky 5-18-8; Kaliforniysky Chiko; Kalin-Kabuch; Kedy-nor; Myagkosemyanny rosoviy; Vkusny; Wanderful Achik-dona 1680; Apsheeronsky;	Apsheeronsky krasny; Bala myursal; Bedona dashnabadskaya; DK-4; Genlick-mir; Gyulosha 4431; Gyulosha krasnaya; Kadan 11; Kaliforniysky 6506; Kalin-kabukh; Kandagarsky; Kara bala myursal; Karakalinsky; Kazake UK 11/4; Krakhuna; Kzyl-dona; Lodzuar; Nazik-kabukh; Paper shell; Sherabadsky kisly; Shoulyansky 871; Shoulyansky 679-5, 666, 158, 77; Veles; Zangelansky	Ak-dona; Al-shirin-nar; Apsheeronsky zelenoplodny 869; Bashkalinsky; Bedona varganzinskaya; Washington 5-4-41; VIR-1; Gey-shirin-nar; Genlinsky sladky 4441; DK; DK-10; DK iz Narly; DK iz Tyamilya; DK iz Shevlana; Zubeyda; Karakalinsky; Karakel 6; Karakel 7; Karakel 9; Kyzyl-kabukh; Kzyl-anor; Kaim-anor; Kay-achik-anor; Krmzy-kabukh; Meykosh 6269; Nikitsky 125; Nikitsky 43; Nikitsky 96; Nikitsky 118; Nor alma; Nukhursky; Safed; Surh-anor; Sslavatsky; Sochny (Nikitsky 110); Sakerdze; Tursh-nar; Cherikarsky; Chinae; Shakh-nar; Shirin; Shoulyansky zheltoplodny 868a; Shaartyzsky 450, 165, 680a, 4446, 450a, 6396	Achik-nar 4454; DK iz Narly 3; DK-11; Kazake; Kitaisky 2a; Kunduzsky; Kzyl UK 12/5; Melekeshsky 176, 491; Meykosh; Washington 6-4-36

## Distribution and use of *Malus* in the Hengduan mountain region, southwest China

Deng Guo Tao, Li Da Fu, Li Yu Tang, Zhang Yan Shu, Wang Qiao Chun, Li Huan Xiu and Fan Li Zhang

Sichuan Agricultural University, Dijiangyan, Sichuan Province 675014, China

### Introduction

Hengduan mountain region is located in the centre of southwest China, extending from 97 to 103°E longitude and south to 33°N latitude. It includes the western part of Sichuan and Yunnan provinces and southeastern Tibet. The region was formed by strong geological forces and is the oldest and most magnificent area of China in terms of geological structure. Mountains and rivers run from south to north, in contrast to those running from east to west in Asia. Each mountain range is higher in the north and lower in the south, alternated with rivers. The rivers have cut deep valleys, which are surrounded by high mountains, thus making the area rugged and rough. Within the boundaries of the region are many peaks above 5000 m, the highest being Gongga mountain (7556 m a.s.l.), which accumulates snow throughout the year. Most of the ridges and valleys are between 1000 and 2000 m, and some are above 3000 m.

The complex terrain in this region results in complex weather patterns. Because most parts of the region are located in the semitropical area of middle latitude, a semitropical climate is its basic characteristic. The northeast part is located in inland China, the southeastern and southwestern parts near the Indian Ocean. The region has three monsoon climates: southwest monsoon, southeast monsoon and plateau monsoon. From south to north it has three climates: hot, warm and cold. Climate also differs greatly from east to west. There are five climate zones from west to east in the whole southern section: south Asian tropics, middle Asian tropics, north Asian tropics, warm temperate zone and temperate zone.

From top to bottom of the mountains, the natural landscape is so variable that one mountain can have four seasons. Owing to the huge vertical difference of weather, a vertical stratification of plant growth is evident, and within an area of little altitudinal range can be found plants of the frigid, temperate and tropical zones.

The soil of the region ranges from brown soil or red (from 23°N latitude to the south), red soil (23-25°N), brown red (24-26°N) and brown forest soil (26-31°N). At 27-28°N latitude, the distribution of soil from east to west is yellow soil → yellow red soil → typical red soil → brown forest soil.

This region, with its complicated natural environment, is rich in plant species, mostly those of the mid-subtropi-

cal broad-leaved evergreen forest zone, where the vegetation is mainly *Cyclobalanopsis glaucooides* and *Quercus semicarpifolia*. The distribution of vegetation by altitude from low to high is: broadleaved evergreen forest → mixed forest of broad-leaved evergreen and deciduous → boreal needle-leaved forest → subalpine bushes and meadow → alpine subice sparse vegetation. In some low-altitude river valleys, a hot and dry climate is formed as the result of foehn effects so the sparse vegetation is mainly mesophytic. Xerophytic grasses, such as *Heteropogon contortus* and *Cymbopogon jwarancusa*, are interspersed with *Gossampinus malabarica*, *Trema orientalis* and *Toona ciliata*.

Owing to the geological structure, the complex weather caused by the topography and the multitudinous plant types, the region is well known as a 'treasure bowl' of genetic resources. In 1979-83 and 1992 six collecting trips were made into the region to investigate and record the distribution of *Malus* plants. The region has three types and twenty kinds of *Malus*; their distribution and utilization are summarized in Table 1.

### Conclusions

Apple is widely planted in the Hengduan mountain district. The areas that are situated in the northern part of the mountains, such as Maowen, Xiaojin, Li and Yanyuan county in the western part of Sichuan province and Lijang, Cayan, Bomi county in the northwestern part of Yunnan province, are optimum places to grow apple. These districts are 1500-2800 m a.s.l. and have the best climatic factors, such as brilliant illumination, low temperature and great difference in temperature between day and night. 'Starking Delicious' and 'Richard Delicious' in these districts grow well with high yields. Their yield on 10-15 year old trees is 500-600 kg/tree. Their fruits are long, with a bright colour, rich perfume and high sugary quality. The largest quantity of soluble solid substance is 20.1%. 'Golden Delicious' fruit shape is long, its surface is gold and bright and the part facing the sun is red with slight fruit rust. Their fruits are of the best quality. The three varieties in Maowen and Yanyuan county are regarded as the first grade apple of China.

However, even breeds of wide adaptation perform differently in different ecological environments of the

region. Under temperate and wet districts of 1500 m a.s.l., the 'Golden Delicious' fruit shape becomes short, the quality declines and powdery mildew and brown spot of apple are serious diseases. High temperature in winter results in no dormancy, leaf drop is difficult, plant diseases and insect pests are serious in summer at Mengla, Menghai, tropical Xishuangbana as well as in northern tropical areas of 1300 m a.s.l. where it generally shows low yields, small fruits, poor qualities, and difficult fruit-setting. Above 3000 m a.s.l., because accumulated temperature is not enough, it is late maturing and produces small fruit with hard pulp, little fruit juice and high acid content. Because of low winter temperatures, serious freezing injury occurs in cultivated 'Golden Proof' apple in Litang county around 4000 m a.s.l.

According to rough statistics, 130 big apple breeds have been introduced from overseas. These apple breeds are preserved largely at Maowern county Sichuan and Nijiang county Yunnan. The main cultivated breeds are 'Golden Proof', 'Yuanshuai', 'Redstar', 'Redproof', 'Fuli Zhuguang', 'Xu', 'Green Banana', 'Guoguang' and 'Xiangyu Jinahong'. Some new breeds were developed in recent years, such as 'Qinguan', 'Fushi', 'New Redstar' and 'Red Star'. Of the newly developed apple breeds, 70% are from 'Golden Proof' and

'Red Star'. Currently, cultivated red 'Fushi' shows good quality, fast development, high yield and good storage qualities.

In addition, since 1960, many apple breeds from America or other parts of the country have been introduced in Batang county. Selection and breeding for 70-80 years have maintained excellent varieties and eliminated inferior breeds. More than 50 varieties of middle grade quality have been preserved.

Representative breeds are 'Bing Tang', 'Dianxin' (extremely early maturity, better quality), 'Mei Gui Xiang' (early maturity, better quality), 'Da Doang Qing' (late maturity, high yield, strong resistance to environment, better quality), 'Da Dong Hong', 'Xiangjiaoang' (big fruit, high yield, good storage, late maturity), 'Xiao Dong Hong' (high yield, good storage, late maturity) and 'Shui Guo Tong' (short branchlet character). These breeds and strains are a valuable source of our country's apple breed wealth. Among them, the varieties 'Da Dong Qing', 'Mei Gui Xing', 'Xiao Dong Hong' and 'Da Dong Hong' have spread to Tibet, Yunnan province and each county of Ganzizhou. Furthermore, 'Da Dong Hong', 'Bing Tong' and 'Shui Guo Tong', which have large fruit and a short brushy growth pattern, have been introduced as important breeding materials in the fruit tree scientific research unit of Heilongjiang, Zheijiang provinces.

Table 1. *Malus* species of the Hengduan mountain region of China

Species	Distribution	Environment	Characteristics	Comments
<i>Malus hupehensis</i> Rehd.	all of Aba, Liangshan prefecture; Baoshan, Yunnan province; concentrated distribution at Tengdong county, Baoshan prefecture	often grows in mixed-tree forest on hillsides or in banks of ditches in gorges at 600-2500 m	fruiting rate is high, seedlings grow in good order and are robust, root system growth is good, affinity with grafting apple breeds is strong, growth of nursery stock is fast	a good apple stock, mostly used in the southwest region of China
<i>Malus rockii</i> Rehd.	Daofu, Luhuo Kangdin, Ludin, Mianling, Muli, Yanyuan, Zougue and Meigu of western plateaux in Sichuan; Deqing, Zhongxun, Nijiang and Weixi of northwest Yunnan; has concentrated distribution at Yanyuan, Muli, Zoujue, Meigu, Zhongxun and Nijiang	brown forest soil of the western area, in shade at 800-3500 m; tolerance for environment is strong	high fruit-setting rate, high yield, easy seed collection; root systems grow strongly, grafting apple breed affinity is strong; does not carry viruses; many variations in appearance	one of the best stocks for breeding virus-free apple nursery stock
<i>M. yunnanensis</i> (Franch) Schneid.	widely distributed in this region, at Baoxin, Tianjuan, Luding, Meigu, Zoujue, Yanyuan and Muli in western parts of Sichuan; Deqing, Zhongxun, Weixi, Nijiang, Gongshan, Baoshan and Linglun in western Yunnan; there is a concentrated distribution of trees more than 200 years old in the upper reaches of the Pula River, Gongshan county	often grows in mixed forests of needle-leaved and broad-leaved species, which are located in the ditches of streams and on hillsides at 2000-3300	brushy growth, but grows well; in Meigu of Sichuan and Lijiang of Yunnan, the breed used as varieties of Golden Proof has a well-developed root system and short brushy growth, but has a large base	

Table 1. *Malus* species of the Hengduan mountain region of China - cont.

Species	Distribution	Environment	Characteristics	Comments
<i>Malus sikkimensis</i> (Hook. f.) Koehne	Deqing, western Yunnan; Daofu, western Sichuan; Zuogong, Mangkang, Bomi; Chaou, Tibet; distribution is concentrated at Deqing, Weixi of Yunnan, and Zuogong, Tibet	mixed needle-leaved and broad-leaved forest at 2800-3550 m	high fruiting rate, easy seed collection, nursery stock growth is short, brushy and strong, tolerance to environment is strong, the root system growth is good; lateral and fibrous roots are abundant and strong	has been used as apple stock because of its good grafting affinity; the best apple stock for acid soil; leaves yellow in alkaline soil; the oldest trees are 200 years or more
<i>Malus micromalus</i> Makino	concentrated in Nijiang county of western Yunnan, is found in Weixi, western Yunnan and Dechang, and has scattered distribution in Huili, western Sichuan	grows in the range of 1800-2500 m	very well-developed main root, and good resistance to drought; grafting affinity is good	long cultivation history at Nijiang of Yunnan; fruits are eaten raw or dried for eating; stock is grown from seedlings; this species is useful for the development of apple in the Nijiang area
<i>Malus toringoides</i> (Rehd.) Hughes	Kangding, Yajiang, Daofu, Luhuo and Batang plateaux of western Sichuan; Changdu, Zhougong and Mangkang, Tibet; concentrated in Yajing, Daofu, Kangding, Batang and Mangkang	riverbanks, valleys or streams and ditches as well as in mixed-tree forest at 2400-3500 m; grows well in subacid and alkaline soils	high fruit-setting rate; fruit is brilliant red, seeds are plump-eared and easily collected; good grafting affinity, strong growth, good resistance to drought, strong adaptation	old trees are more than 100 years
<i>Malus transitoria</i> (Batal) Schneid.	Daofu, Luhuo, Batang and Changdu; concentrated at Daofu, Luhuo and Changdu	often grows on terraces along rivers and banks of streams and ditches as well as in mixed-tree forests; sometimes grows with <i>M. toringoides</i>	fruit is oval, either yellow or red; high fruit-setting rate; has no affinity for grafting; growth is generally poor	until more is known about this species, it is not possible to use it widely
<i>Malus kansuensis</i> (Batal) Schneid.	Kangding, Luding of Northwest Sichuan and Lanpin county	at 1800-3300 m within mixed-tree forests on hillsides or streams and ditches	high fruit-setting rate, good resistance to cold, good adaptability to alkaline soil and good resistance to shading	At present it has only been used for experiments with apple stock in certain areas, and so has not been utilized
<i>Malus prattii</i> (Hemsl.) Schneid	only recorded at Luding, Kangding, Tianqian and Baoxin of western parts of Sichuan; concentrated at Baoxin and Erlang mountain	always distributed within the mixed forest of needle-leaved and broad-leaved species at 1500-2500 m	good resistance to shading and good growth in neutral and subacid soils; high fruit-setting rate, and easily collected	trees are large and perennial with ages of 100 years; studies of this variety have not been made yet
<i>Malus honanensis</i> Rehder	has only been recorded in Lanpin county, Aba prefecture, northwest Sichuan	grows in the mixed-tree forest at 1000-2500 m	fruit-setting rate is high, growth is good in neutral and subacid soils, resistance to drought is good	has not yet been utilized
<i>Malus ombrophila</i> Hand.-Mazz.	Baoxin, Muli, Yanyuan, Zoujue of western Sichuan and Nijiang, Gongshan, Weixi county of western Yunnan	grows within mixed-tree forest in ditches, valleys and hillsides; always occurs with <i>M. yunnanensis</i>	trees are high and large with strong growth, high fruit-setting rate, good plump seeds and good resistance to shading	

Table 1. *Malus* species of the Hengduan mountain region of China - cont.

Species	Distribution	Environment	Characteristics	Comments
<i>Malus prunifolia</i> (Willd.) Borkh.		always used in single planting, for eating and admiring; generally it grows about 2300 m	high fruit-setting rate, good plump seed; fruit has bright colour, ellipse shape; strong growth, good grafting affinity, good resistance to drought; fixed adaptation for damp makes it suitable for producing apple stock	it has been cultivated to view and admire as a potted tree in recent years
<i>Malus sieboldii</i> (Rgl.) Rehd.	Weixi county, western Yunnan and Mowen county, western Sichuan	often grows within mixed-tree forest of hillsides or ditches and valleys	strong growth, good affinity	within the boundaries of Weixi Yunnan, most leaf blades of the new growth have 1-2 shallow splitting, the other leaf blades have no splitting at all, so its character is not very typical; it has been used as apple stock in Yunnan
<i>Malus halliana</i> Koehne, Gatt	wide in Hengduan mountain area, from Laibo of Sichuan to Baoshan Kunming Yunnan of the middle section of Simao in the south	within 600-2300 m	strong adaptation, layered petals, early spring flowering, low fruiting rate, seedlings difficult to start	cultivated to view and admire in parks and tourism places of various areas; has been used as apple stock
<i>Malus asiatica</i> Nakai	wide in Hengduan mountain area; occurs as a large perennial tree of 100 years at Yanyuan, Muli, Leibo, Meigu of plateau in western Sichuan and Lijiang, Weixi in northern Yunnan	always occurs over ploughed land and around farmers' residences at 1000-3000 m	high yield, brilliantly coloured fruit, sweet flavour and thick fragrance	cultivation has a long history in the region; has been liked and consumed for a long time; after the western apple (big fruit, good quality and high yield) was introduced to the region and cultivated in the 1960s, <i>M. asiatica</i> was eliminated gradually because of its small fruit and inconvenience of transport; at present its distribution is wide, but scattered
<i>Malus manshurica</i> (Maxim) Komarov	scattered distribution only in Ebian county of Liangshan mountain range	grows in mixed-tree forests of needle-leaved and broad-leaved species on mountain sides, valleys and ditches or hillsides at 100-2500 m		because there have been few trees, it has not been used and studied at present in the region
<i>Malus spectabilis</i> (Ait.) Borckh.	scattered distribution at Leibo, Meigu of Liangshan mountain range, western Sichuan and Lijiang of northwestern Yunnan	grows on hills of cultivated lands or around residences at 1500-2500 m		although it has been used to be viewed and admired and cultivated in a few places, it has not been used for other purposes

Table 1. *Malus* species of the Hengduan mountain region of China - cont.

Species	Distribution	Environment	Characteristics	Comments
<i>Malus baoshanensis</i> G.T. Deng <i>ser. nov.</i>	western Yunnan, with concentrated distribution in Shiniu River district of Baoshan county, where there is a community of trees 100 years old	in mixed forests of needle-leaved and broad-leaved species at 2500-3200 m	shows good affinity for grafting; nursery stock has strong growth with well-developed root systems; fruiting rate is good	called 'Big Malus' in the locality, and is now used as apple stock; quality has not been tested
<i>Malus xiaojinensis</i> Cheng et Jiang	Xiaojin and Li counties	grows on hillsides or streambanks at 2800-3350 m, together with <i>M. toringoides</i>	strongly growing grafting nursery stock, loose leaf blade, good affinity and varied resistance to drought, waterlogging and cold	has been used as apple stock
<i>Malus pumila</i> Mill.	cultivated variety is widely distributed in the region, north to Yushu Quinghai and south to Xishungbanna of the southern tip	extends across temperate, subtropical and tropical zones; cultivated from 1500-4000 m		

## Collecting germplasm of sheanut (*Vitellaria paradoxa*) in Ghana

Y. Adu-Ampomah, J.D. Amponsah and J.A. Yidana

Cocoa Research Institute, P.O. Box 8, New Tafo-Akim, Ghana

### Introduction

The sheabutter (*Vitellaria paradoxa*) tree is indigenous to the Guinea Savana belt of West Africa extending from Senegal in the west to Sudan in the east (Dalziel 1955). In Ghana it covers about two-thirds of the country, mostly in the wild state in the northern sector of the country (Abiw 1990). It is estimated that about 9.4 million trees are in Ghana with a potential yield of 100 000 tons of shea nuts that can contribute about \$100 million per annum (Abiw 1990).

The pulp around the seed is edible and extensively eaten in the Guinea Savana area, especially during times of food shortage. Sheabutter is obtained from the nuts. The butter is one of the cheapest and most important cooking oils for the people in the sheanut-growing areas in West Africa. It also serves as a pomade and an illuminant. Sheabutter is commercially used in soap, candlemaking and cocoa butter substitutes, and is incorporated into margarine formulations.

In Ghana about 70% of what is collected is processed and used locally (Adomako 1985). The trees are constantly being damaged or killed (especially young trees) by incessant bushfires. Also the trees are constantly being cut and used as fuel-wood for making charcoal and the timber is used for various items. These activities are gradually eroding the genetic stock. In spite of this no attempts are made by farmers to replenish the existing stock. This is mainly due to its poor establishment and long generation time of 9 to 15 years.

In view of its increasing economic importance to Ghana and the Guinea Savana subregion and the potential dangers of reduction in the existing stock, we have started a breeding programme aimed at creating commercially desirable sheanut cultivars. The emphasis is on selection and breeding for types that are easy to establish, high yielding in terms of nut production and high fat content. To be able to achieve these a germplasm collection was made in areas of Ghana where the plant grows extensively. This paper reports on the collections and the variations observed in the collection.

### Collection

Between 1985 and 1986 four collecting missions were launched and samples were collected from 19 sites in the northern sector of Ghana (comprising the Upper East, Upper West and Northern Regions of Ghana) where the

main distribution of sheanuts is found. Figure 1 shows the northern sector of Ghana and where the samples were collected. About 10 individuals were sampled from each collecting site. Collections were carried out mainly in areas with the highest concentration of trees which normally coincided with human population centres where the soils are good and bushfires are well controlled.

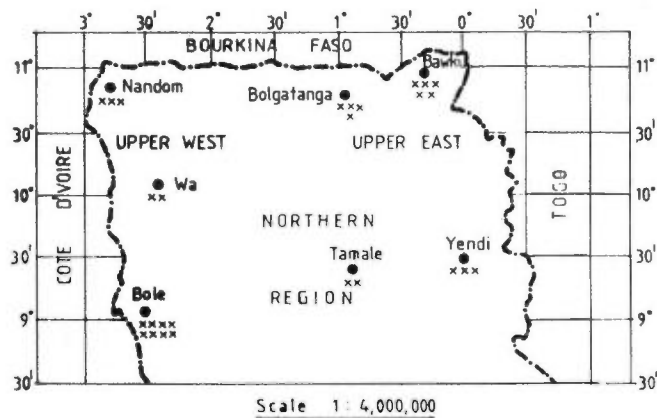


Fig. 1. Collection sites in northern Ghana.

Plants showing the most morphological variations (leaf shape, fruit shape and colour, petiole colour and high fruit numbers) were selected in order to sample a wide genetic spectrum of the populations. Selected trees were conspicuously marked with red paint and given numbers to ease future identification. Seeds were stored in wet black polythene bags and sent to the Cocoa Research Institute of Ghana's substation at Bole in the northern region within a day or two so that some seeds could be germinated for field planting; long storage drastically reduces nut viability.

Each sample was depulped and one-half germinated and planted in the field. The growth rate was measured on half; the other half was used for fat content, fruit and nut size analysis.

### Results and discussions

Extensive variations in fruit and nut sizes, and percentage fat content were observed in the collections (Table 1).

The fruit and nut sizes in the northern region are generally the smallest among the three regions. Fruit size ranged between 12.4 and 17.2 g in the northern region, between 18.1 and 30.2 g in the Upper East and between

20.6 and 28.4 g/fruit in the Upper West. Within localities, variations were also observed in the fruit sizes, but variation of nut sizes within regions was small (5.5 to 7.3 in the north, 10.6 to 13.2 in the Upper East and 9.3 to 10.4 in the Upper West). High nut to fruit ratios were observed in some localities, notably Kpalungu, Binaba, Kukuo and Zang.

Fat content ranged between 45.0 and 62, 43.0 and 58.1, and 45.54 and 54.32% in the Northern, Upper West and Upper East, respectively. Nuts from Kahifehiyili, Songo, Balungu and Kusanaba had well over 55% fat content. There appears to be no correlation between fruit weight and fat content as well as nut weight and fat content. The variations recorded in fruit size, nut size and fat content, if not environmentally induced but genetic, could lead to significant genetic improvement in the crop by way of breeding.

**Table 1.** Fruit weight, nut weight, fruit/nut ratio and fat content variation in sheanut collections

Region	Mean weight		Fruit/nut weight	Fat content (%)
	Fruit	Nut		
<b>North</b>				
Zang	12.8	7.1	0.55	45.90
Sambu	17.2	8.4	0.49	52.57
Yendi	14.3	6.5	0.45	45.00
Kahifehiyili	12.4	5.5	0.44	61.96
Kukuo	12.9	7.3	0.57	46.76
Mean	13.9	7.0	0.50	50.44
<b>Upper East</b>				
Sumburungu	30.0	11.5	0.38	50.98
Binaba	20.0	12.1	0.61	43.00
Songo	22.2	10.6	0.48	56.95
Kpalungu	18.3	10.9	0.60	51.54
Balungu	24.3	11.5	0.47	58.10
Kusanaba	26.4	11.8	0.45	55.60
Ghani	27.8	13.2	0.47	52.00
Koka	25.3	12.5	0.49	54.87
Kokobla	18.1	8.2	0.45	54.14
Mean	23.6	11.4	0.49	53.00
<b>Upper West</b>				
Convent	20.6	9.3	0.45	52.41
Tamapuo	23.8	10.4	0.44	53.56
Funsi	25.3	13.5	0.53	54.32
Fian	28.4	11.7	0.41	45.54
Kon	27.7	11.8	0.43	54.14
Mean	25.2	11.3	0.45	51.99

The progenies of some of the collections have shown easy establishment after one year of planting as shown by their high values in height, girth and leaf area in the first year (Table 2). Notable among these are the collections from Sambu, Kpalungu, Kusanaba, Ghani, Funsi and Kon. However, it is too early to make any reasonable conclusions.

In view of the fast erosion of the genetic stock due to bushfires and human activities, further efforts are being

**Table 2.** Growth measurements for progenies of sheanut collection

Region	Mean at 1 year			Leaf area (cm <sup>2</sup> )
	Height (cm)	Girth (cm)	No. leaves	
<b>North</b>				
Zang	4.0	3.3	6	7.8
Sambu	4.6	3.7	6	9.4
Yendi	4.2	2.3	6	6.8
Kahifehiyili	3.9	3.8	6	7.5
Kukuo	3.8	2.7	6	6.9
Mean	4.1	3.2	6	7.7
<b>Upper East</b>				
Sumburungu	4.3	2.4	7	7.3
Binaba	2.4	2.1	4	4.3
Songo	2.4	2.5	6	8.9
Kpalungu	4.8	3.4	6	9.3
Balungu	3.7	3.1	7	8.3
Kusanaba	3.6	3.9	6	8.8
Ghani	6.1	2.5	6	7.8
Koka	3.8	2.8	7	6.8
Kokobla	3.9	2.7	7	7.3
Mean	3.9	2.8	6.2	7.6
<b>Upper West</b>				
Convent	4.4	3.0	6	7.1
Tamapuo	4.4	3.2	6	7.5
Funsi	5.1	3.3	6	9.1
Fian	4.3	3.1	7	6.4
Kon	4.8	2.8	6	8.1
Mean	4.6	3.1	6.2	7.6

made to collect as much as possible the populations in the wild to be conserved in protected fields in both the northern and southern sectors of the country.

### Acknowledgements

We thank Mr. David Frempong for helping in the germplasm collection and Mr. P.C. Aculey for the fat content analysis. We are also grateful to Mr. J.N. Krofa for the preparation of the manuscript. This paper is published with the permission of the Executive Director of the Cocoa Research Institute of Ghana.

### References

- Abiw, D.K. 1990. Useful plants of Ghana. Intermediate Technology Publications and the Royal Botanic Gardens, Kew, 1990, 66p.
- Adomako, D. 1985. Prospects for the development of the Sheanut Industry in Ghana. Technical bull. No.11, Cocoa Research Institute of Ghana.
- Dalziel, J.M. 1955. The useful plants of Tropical West Africa. 3rd ed. Crown Agents, London.

## Recent information sources on Global Positioning System (GPS) technology

**Luigi Guarino**

IPGRI, Sub-Saharan Africa, PO Box 30677, Nairobi, Kenya

As a result of recent advances in satellite technology, it is now possible to accurately locate one's position on the surface of the Earth by means of small hand-held devices called Global Positioning System (GPS) receivers. Although originally developed by the US Department of Defense for military applications, the GPS is now available for civilian use. It consists of 21 satellites and 3 operational spares, orbiting the Earth twice a day at 11 000 miles (17 600 km). Each satellite constantly transmits its position in space and time. A GPS receiver is capable of computing location fixes anywhere in the world at any time of day on the basis of these data in less than a minute or so, to a precision typically of about 100 m RMS (root mean square, meaning that 63% of fixes will be within 100 m of the true position).

GPS receivers are rapidly becoming less expensive, and are already being used by plant collectors (herbarium botanists as well as germplasm collectors) to record accurate passport data on latitude and longitude in the field on their collecting forms. Prendergast (1993) reviews one of the models currently on the market. However, GPS receiver technology is evolving rapidly, and the prospective user is faced with a wide choice on the market, and an often bewildering terminology. The purpose of this short note is to bring to the attention of plant genetic resources workers three recent publications that should help them decide if they need to invest in a GPS receiver,

how much they are likely to spend and which of the model(s) on the market best fits their needs and resources. For the very interested, there is a periodical entirely devoted to the subject, *GPS World*.

1. Ackroyd, N. and R. Lorimer. 1994. *Global Navigation - A GPS User's Guide*. 2nd ed. 312 pp. Approximately US\$ 80 plus postage. Lloyds of London Press Inc., Book Sales Dept., 611 Broadway, Suite 308, New York, NY 10012 USA. Fax: 1-212-529-9826.

2. Chodota, M.W.L. 1994. Should you acquire a Global Positioning System receiver now? The current GPS status. *Earth Resources Mapping in Africa 1:1-2,4,7*. A Newsletter of the Regional Centre for Services in Surveying, Mapping and Remote Sensing, P.O. Box 18118, Nairobi, Kenya. Fax: 254-2-802767.

3. Dierendonck, A.J. van. 1995. Understanding GPS receiver terminology: A tutorial. *GPS World* 6(1):34,36,38,40,42,44. Editorial Office: 859 Willamette Street, Eugene, Oregon 97401-6808 USA. Fax: 1-503-344-3514.

### Reference

Prendergast, H.D.V. 1993. Product review: the Magellan GPS NAV 5000 PRO. *FAO/IBPGR Plant Genet. Resour. Newsl.* 91/92:60-61.

## Soyabean varieties and their geographical distribution in Iran

N. Mulalic, M.R. Ahmadi and F. Yousefi

Oil Crop Department, Seed and Plant Improvement Institute, Karaj, Iran

### Geographical position and climatic characteristics

Iran, with an area of 1.7 million km<sup>2</sup>, has several geographical zones with completely different climatic, topographical and hydrological characteristics. In northern Iran and along the Caspian Sea, the humid climate provides the best conditions for soyabean production. Both irrigated and nonirrigated crop production occurs within this area. The province of Azarbaijan (35-40°N), in north-west Iran, has a mountainous area which is suitable for irrigated soyabean production. In the central parts of Iran (27-31°N), the Dashte and Lut deserts have dry weather and high temperatures.

The cultivated area in Iran is about 18 million hectares. Water is the most important limiting factor for crop production in the dry area. Most parts of Iran receive less than 200 mm of rain annually; only a small area in northern Iran (Mazandaran and Gillan) receives 1000-2000 mm annual rainfall. The total rainfall in the west and north-west of Iran is nearly 600 mm per year.

### Distribution of maturity groups and varieties

It is difficult to select the best soyabean varieties and specific maturity groups for this large area. From the results of the national research programmes on soyabean and many experimental trials during the past 24 years we have recommended the varietal distribution of soyabean in Iran from 25 to 40°N.

Eight maturity groups from 0 to 8 have been considered. Soyabean distribution is influenced by many factors such as photoperiodic effects, climatic conditions and latitude. Photoperiodic effects distinguish the different zones from south to north (25 to 40°N) but, because of some specific situations, topographical and climatic conditions are more effective factors for determining the best maturity groups for each zone.

The best maturity groups in the provinces of Mazandaran and Gorgan (37 to 38°N) are groups 3, 4 and 5 (Fig. 1), whereas groups 1, 2, 3 and 4 are more suitable for southern Iran (32 to 36°N) because of the influence of deserts in the central part and mountainous area in west-

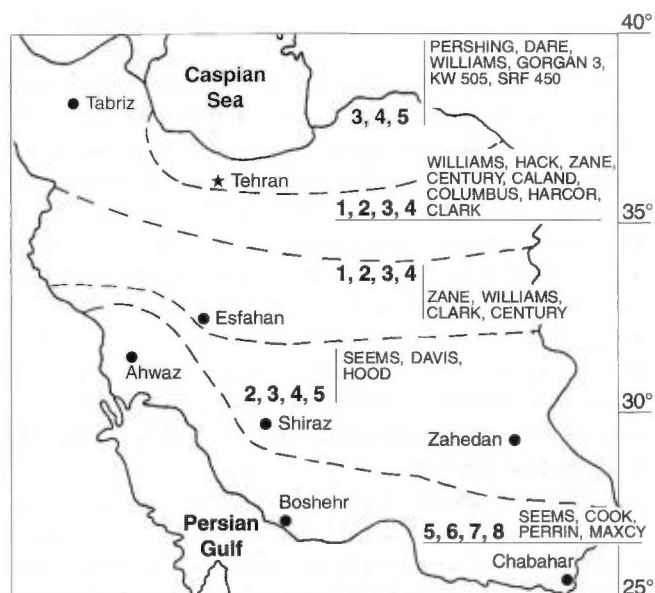


Fig. 1. Recommended distribution of soyabean varieties (groups 1 to 8) in five geographical areas of Iran

ern Iran. These conditions make groups 1 and 2 (which have a shorter vegetative period) more suitable for these zones. The higher maturity groups of 5, 6, 7 and 8 are favourable for the last zone, located along the Persian Gulf (25 to 27°N). This zone has not been a soyabean production area until now, but some experimental programs are being conducted to determine the potential of the area for soyabean production in future.

On the basis of the results of many trials, cultivar 'Williams' has shown the best adaptability in a large part of zones 1, 2 and 3 from 32 to 40°N. Cultivar 'Seems' is the most suitable cultivar for zones 4 and 5. Cultivars 'Cook', 'Perrin' and 'Maxcy' have shown good performance in the last zone in the south (25 to 27°N), but more research is needed to recommend them as the best cultivars.

In addition to the research conducted by the national breeding programme, experimental trials are conducted every year at several research stations in Iran to determine the adaptability of new varieties.

## News and Notes

### First Extraordinary Session of the Commission on Plant Genetic Resources

The FAO intergovernmental Commission on Plant Genetic Resources met in an extraordinary session in Rome, in November 1994, in order to allow countries to begin to negotiate the revision of the International Undertaking on Plant Genetic Resources, in harmony with the Convention on Biological Diversity, by incorporating the three annexes into the main body of the International Undertaking. The annexes contain an agreed interpretation of the text of the Undertaking, that recognizes both Plant Breeders' Rights and Farmers' Rights, and national sovereignty over plant genetic resources). At the same time, negotiated solutions are sought to outstanding issues, namely access on mutually agreed terms to plant genetic resources, including *ex situ* collections not addressed by the Convention, as well as the realization of Farmers' Rights.

In this context, the Commission had in front of it a number of documents prepared by the Secretariat. These documents identified the current state of negotiations and the issues at stake, and analyzed the technical, economic and legal implications, providing the Commission with options and ideas that could facilitate the negotiations<sup>1</sup>.

A progress report on the preparatory process of the Fourth International Conference and Programme for Plant Genetic Resources (ICPPGR) was presented to the Commission. Achievements to date include the establishment of direct contacts with technical experts and policymakers in countries of all developing country regions, as well as in a number of Organizations for Economic Cooperation and Development countries.

Introductory guidelines for country reports had been prepared and the meeting recognized their quality. It was suggested that developed countries be asked to provide information on the impact of their aid programmes on genetic resource conservation and use, with emphasis on agricultural development projects and programmes. The reports on the State of the World's Plant Genetic Resources, and the Global Plan of Action, which were being prepared for the Conference, would cover plant genetic resources for food and agriculture. Some countries felt

that this should not include forestry. It was noted that the Global Plan would move the process from words to action.

The importance of support for the sustainable utilization of plant genetic resources — as a step towards the realization of Farmers' Rights — was identified as a major objective for the Global Plan of Action. Other suggested elements for the Global Plan of Action included conservation, training and the transfer of technology. In all these activities, particular attention should be given to supporting farmers and their communities directly. The primary purpose of increased support should be to 'add value' to genetic resources, particularly in developing countries.

The Commission requested a forward-looking report to the Commission, on technical and scientific matters, especially on the sustainable utilization of plant genetic resources for food and agriculture. The report should include a study of new approaches to plant breeding which draw upon a wider range of genetic material, and allow the maintenance of a wider genetic base in crops.

Germany, Sweden, Norway and the United States are contributing to the Fourth International Technical Conference and its preparatory process. France, Italy and Japan made pledges. Canada is contributing in kind. China and Iran will hold subregional meetings. There is, nevertheless, a shortfall in funding for the preparatory process of about \$US 2 million, as well as a lack of contributions to finance the participation of developing countries in the International Technical Conference itself. The Conference Secretariat will seek resources to allow two representatives from each developing country to participate, and to meet the remaining funding needs. Germany reported that it was initiating a national funding effort with these objectives.

Germany announced that the Fourth International Technical Conference would be held in Leipzig, Germany, from 17 to 23 June 1996 with the hope of high-level participation, and technical excellence in a process that was both political and technical.

The Commission discussed the links between the preparations for the 1996 International Technical Conference and the negotiations, within the Commission, for the revision of the International Undertaking. The Commis-

<sup>1</sup> The following documents are available, on request, from the Secretary of the Commission: **CPGR-EX1/94/3** Revision of the International Undertaking - Mandate, context, background and proposed process; **CPGR-EX1/94/5** Revision of the International Undertaking - Issues for consideration in Stage II: Access to Plant Genetic Resources, and Farmers' Rights; **CPGR-EX1/94/5 Supp.** Revision of the International Undertaking - Analysis of some technical, economic and legal aspects for consideration in Stage II; **CPGR-EX1/94/5 Annex** Survey of existing data on *ex situ* collections of plant genetic resources for food and agriculture; **Background Study - Paper No. 1** The appropriation of the benefits of plant genetic resources for agriculture: An economic analysis of the alternative mechanisms for biodiversity conservation; **Paper No. 2** Sovereign and property rights over plant genetic resources; **Paper No. 3** Providing Farmers' Rights through *in situ* conservation of crop genetic resources; **Paper No. 4** Identifying plant genetic resources and their origin - the capabilities and limitations of modern biochemical and legal systems.

sion considers it desirable that the Undertaking should be revised in time for the 1996 Conference, so that it is available with the report on the State of the World's Plant Genetic Resources and the Global Plan of Action. However, it was also felt that the revision of the Undertaking should be conducted carefully, and should not be rushed in order to meet these targets. The Global Plan of Action has important links with the workplan of the Convention on Biological Diversity, as well as with Agenda 21.

The Commission considered the possible broadening of the mandate of the FAO Commission on Plant Genetic Resources to include all genetic resources of interest for food and agriculture. In 1991, the Commission and the FAO Council had discussed the possible broadening of the mandate but considered the idea, at that time, to be premature. Developments since then — in particular the Convention on Biological Diversity — have strengthened the arguments for broadening the scope of the Commission. The Commission identified several points which may need further clarification, and referred the issue to the FAO Council.

The Commission warmly congratulated FAO and IPGRI, as well as the other CGIAR Centres, for having signed an agreement through which the twelve Centres put their collections under the auspices of FAO. The Commission considered this an important step towards strengthening the FAO Global System, in line with the recommendations of Agenda 21, and agreed that it represented the beginning of a new era of cooperation between FAO, the CGIAR Centres and national institutions. The Commission also recommended that FAO redouble its efforts to have countries put their national collections on plant genetic resources for food and agriculture into the International Network.

### **USAID creates new priorities**

Climate change and biodiversity will be the principal concerns of the US Agency for International Development's newly created Global Environment Center which, according to its first director, David F. Hales, will spend about \$700 million this year in what is "broadly categorized as the environmental area."

"Most of that will be spent at a mission level, focused on a country-by-country basis. Much of that will leverage or influence spending by others and substantial amounts of it will end up, probably 70% or so, back in the US economy in a very direct form, producing jobs," Hales explained, using the figure customarily cited by AID administrators to emphasize the positive aspect of foreign assistance for development.

"What we'll do, if we're good at it, sometimes we are, sometimes we're not, is mobilize a lot more forces than we could ever pay for or should ever pay for with tax dollars. We spend very little on foreign aid in this country. If you take the budget that we appropriate it's less than one-half of 1% of that total budget."

Hales has been on the job for two weeks. In addition

to being the centre's director, Hales is a USAID deputy assistant administrator. Previously, he directed Michigan's Department of Natural Resources, was deputy assistant secretary for Fish and Wildlife at the US Department of the Interior, commissioner of Michigan's Radioactive Waste Management Authority, the Samuel Trask Dana Professor of Natural Resources at the University of Michigan and director of the Lincoln Park Zoological Gardens in Chicago.

The Global Environment Center, with its professional staff of about 50 people, is not housed in AID's headquarters in the State Department. It is located across the Potomac River in Rosslyn, Virginia.

Interviewed in his office there, Hales described the centre's priorities "from the environmental perspective" as climate change, biodiversity, structuring a "healthy resource base" for developing countries, sustainable cities, and energy.

These priorities were set, he said, following debates within AID, the Washington community and Congress. These debates took place during the first year of the term of the AID administrator, J. Brian Atwood.

"For us, climate change is an area of critical concern as it is for congress. We get substantial earmarked funds every year which say 'We really want you to focus on climate change issues.' We have a climate change strategy which focuses on 10 countries that are the primary emitters of greenhouse gases."

Last June AID reported to Congress that the "significant contributors to greenhouse gases" were Brazil, Central Africa (as a region), India, Indonesia, Kazakhstan, Mexico, Poland, the Philippines and the Ukraine. China was also included, AID said, adding, "USAID is not authorized to conduct projects there."

AID's interest in climate change stems from its view that climate changes induced by greenhouse-gases are "a long-term threat to the global environment" with negative consequences for sustainable economic growth."

AID's interest in biodiversity is due, among other things, to "protecting the basis for our pharmaceutical industry in North America," Hales said. Asking and answering a question, Hales said, "Is the money we're spending having an effective impact in protecting the basis for our pharmaceutical industry in North America? The answer is yes. Which is why pharmaceutical companies and other investors are interested in working with us to help protect that biodiversity. Is it protecting the basis for wild genes on which the future of global agriculture is going to depend? You bet. Which is why seed companies, agricultural interests in North America are interested in supporting our investment and working with us in partnerships."

Asked if the argument that drug companies and others were pillaging the rain forests for substances they would patent and profit from, to the detriment of the people who had nurtured the forests for hundreds of years, Hales said "There's a lot of policy debate on what's

right and what's wrong. I'm lucky, I work at a level of programs." But he explained that "nobody is going to get any benefit from it if it doesn't exist. (I don't know how many species we'll lose while you and I are sitting here talking: 10, 12, 15, maybe 50 today, maybe 100 today; you can pick your scientific estimate. We know that we are going to lose some while we're sitting. Nobody is going to get any benefit from those species that go extinct."

"My concern, from the viewpoint of this environmental centre, is to use every tool that I can find to slow down that rate of extinction and maybe in some places reverse it." Then, he continued, "lawyers and countries and others have something to talk about when they want to deal with intellectual property rights issues. I'm not a lawyer and I have some ethical views about all of this but I'm not an ethicist and I'm running an environmental centre. My concern is to focus on that resource base. It's a luxury I have."

Hales believes that the interests of the USA require "that we continue development investment" and AID is best suited to oversee that. That development, he said, is best done by experienced people in the aid field who have, in this country, the ability to call on, for example, 5000 sources in the private business sector, a consortia of environmental groups and university groups, the US Department of the Interior, and the Peace Corps.

There's very little room for pure unilateral action in the area of the environment, Hales said. "We've got to build partnerships and we've got to build friendships. We've got to use persuasion and influence rather than control the way perhaps some thought it was possible 20 or 30 years ago."

AID, he added, "funds the small grants program for UNDP [the UN Development Program] which gives us an additional both listening and response capacity with a number of countries around the world where perhaps the goal is the same, but it's easier to have a relationship in that country with UNDP than it is with AID. Perhaps they're active in a country where we don't have a mission. We all ought not to duplicate each other's capabilities."

AID is beginning to work out "roles with the World Bank and regional development banks," Hales said.

He also explained that AID sometimes helps a country meet its own goals "by building the capacity to develop, for example, an energy system." AID also helps "by writing a proposal which ends up being funded by some of the folks who have a lot more money than USAID, or, even take that proposal, as we may end up doing in the case of Haiti" and make some suggestions on an overall environmental and energy strategy—"clearly, it's going to have to be a Haitian choice," which will be funded on a multilateral basis.

"We can help construct the components of the strategy and we can help bring together the broad community to take a look at it and encourage through small amounts of funding on our part, larger amounts of funding by

others in the donor community." Thus, AID, Hales said, uses its individual strengths in a framework that is strategic rather than just tactical or project oriented.

By C. Gerald Fraser, reprinted from The Earth Times

### Nutrient-enriched food crops

New mineral-enriched varieties of the world's most common food crops could prevent malnutrition and disease in millions of the world's poorest people. A newly launched programme is developing new varieties of crops such as corn, rice and wheat that will be better at absorbing critical minerals directly from the soil. These crops will perform particularly well on mineral-deficient soils, which are widespread in the developing world. Participants in the programme are the Consultative Group on International Agricultural Research (CGIAR), Waite Agricultural Research Institute at the University of Adelaide, Australia, the US Department of Agriculture's Plant, Soil and Nutrition Laboratory at Cornell University and other research institutes in 12 countries.

"This is a low-cost approach to fighting malnutrition that could improve farm productivity and benefit the environment at the same time," said Howarth E. Bouis, director of the CGIAR Micronutrients Project and research fellow at the International Food Policy Research Institute (IFPRI). Washington, DC-based IFPRI coordinates human nutrition research for the 17 centres of the CGIAR. "Crops such as corn, rice, wheat, beans and cassava, which are the primary sources of food for the vast majority of the world's poor, lack sufficient amounts of essential vitamins and minerals that prevent disease. The CGIAR Micronutrients Project could have nutrient-enriched crops ready for commercial production within 6 to 10 years."

Such mineral-enriched crops also have been shown to outyield present crop varieties and to require fewer chemical inputs and less irrigation, thus reducing the costs of growing them and better protecting the environment. These agronomic advantages enhance the chances that they would be adopted by farmers in the developing world. But mineral-enriched crops would also enhance commercial agriculture in the United States and other developed-world countries where mineral-deficient soils are also widespread.

"The research costs for developing mineral-dense varieties can be justified on the basis of the benefits to agricultural productivity alone," said Bouis.

A strategy of breeding for wheat varieties that are efficient in the uptake of zinc from the soil has already been shown to increase wheat yields in Australia, where zinc-deficient soils are widespread. Turkey also has zinc-deficient soils. A CGIAR wheat breeder based there believes that adopting the same zinc-packed wheat varieties from Australia could save farmers in Turkey millions of dollars a year. "Because of Turkey's zinc-deficient soils, farmers have to plant an enormous number of seeds — 250 kg/ha — because so many seedlings don't survive,"

said Bouis. "If Australia's zinc-efficient wheat varieties can be adapted to Turkish growing conditions, only 150 kg of seed may be needed per hectare. This could save farmers approximately \$100 million a year, not including the higher profits expected from higher yields."

Plants are often vulnerable to disease because they are unable to obtain needed minerals from soils. These nutrient deficiencies are caused not just by the absence of zinc and other minerals in the soil, but by the fact that the zinc and other minerals are bound chemically to other elements that make them unavailable to plants. Certain plant genotypes, however, are more efficient than others in the uptake of zinc, iron and other minerals from soils. Their roots emit substances that chemically unbind minerals in the soil, resulting in their becoming available to plants. Plant breeding can select for such efficiency characteristics, including the characteristic of transferring high amounts of iron and other minerals to the plant's seeds. When replanted in mineral-deficient soils, such mineral-dense seeds have been shown to be more vigorous and disease-resistant, which, in turn, leads to higher plant yields, even though fewer chemical inputs and less irrigation are required.

Research for the CGIAR Micronutrients Project began in May 1993 with start-up funding from the Office of Health and Nutrition of the US Agency for International Development. The coordinated programme to breed for micronutrient-dense staple food crops will be conducted by IFPRI, the Colombia-based International Centre for Tropical Agriculture (CIAT), the Mexico-based International Maize and Wheat Improvement Centre (CIMMYT), the Philippines-based International Rice Research Institute (IRRI), Waite Agricultural Research Institute and the USDA Plant, Soil and Nutrition Laboratory.

Countries where research activities are planned include Australia, Bangladesh, Brazil, Colombia, Egypt, India, Mexico, Nepal, the Philippines, Thailand, Turkey and the United States. Scientists in several other countries have expressed an interest in collaboration as well.

### **IRRI redesigns rice plant to yield more grains**

Scientists at the International Rice Research Institute (IRRI) have harvested the first prototype breeding lines of a new rice plant that promise to increase yields by as much as 25%. Yield increases are sometimes met with skepticism. Will they be stable? Will they harm the environment?

"IRRI's goal is clearly defined. Our research must help to improve the well-being of present and future generations of rice-dependent people in rural and urban areas," stresses Dr Klaus Lampe, IRRI's then Director General. "We cannot protect the environment, we cannot promote biodiversity, and we cannot provide sustainability, without ensuring sufficient income-earning opportunities and an adequate food supply."

"Production of food and protection of the environ-

ment are two essential organs of the same body, our globe," emphasizes Lampe. "That's why IRRI is searching for economically, ecologically and socially sound solutions for long-term yield increases."

Rice scientists now have a fairly good idea of how the new rice plant will appear: robust and heavy with many grains, thick and sturdy stems—all of them grain-bearing—and thicker, greener and more erect leaves.

The plant, currently being field-tested at IRRI's experimental plots, is still a prototype and will not be available to farmers for at least five more years. The next step in the development of the new rice plant is for scientists to breed resistance to pests and diseases into it. Further research by scientists in national research institutions will then be required to incorporate other desirable characteristics such as taste to meet specific country requirements.

"Because the next step includes building resistance against pests into the new rice plant, it will definitely not require more pesticide use," says Dr Gurdev S. Khush, IRRI's principal plant breeder. "It will also use the same level of fertilizer needed by current high-yielding varieties. The new rice is likely to be directly sown in the soil, a method which results in significant savings in labour costs compared with transplanting."

When finally available to farmers, and coupled with promising fertilizer management technology currently being tested in farmers' fields in collaboration with PhilRice, the new rice plants will likely produce 25% more grain than current high-yielding varieties on the same amount of land with the same amount of fertilizer and with less water, under ideal conditions.

It is estimated that, on irrigated land, under the best conditions, the new rice variety should yield 12.5 t/ha versus 10 t/ha for present-day rice. IRRI scientists say that the new rice, if widely planted, could produce 100 million more tonnes of rice per year than is currently grown. At the farmer level, it will bring an additional 1.25 t/ha of irrigated land.

Since the average per capita consumption of rice in the rice-consuming countries of Asia is 200 kg/year, Khush says the additional output would feed at least 450 million more people, or about 20% of the population having rice as the staple food.

It takes 100-130 days to plant and harvest the new rice plant, about the same time it takes to produce current high-yielding varieties of rice.

"Under favourable growing conditions, today's high-yielding varieties produce 20-25 tillers, or stems," explains Khush. "But only 14-15 of them produce small panicles, each bearing about 100 rice grains. The other stems remain unproductive and compete with productive ones for nutrients, such as nitrogen, and solar energy. The dense canopy that results from too many stems also creates a humid microenvironment favourable to diseases and insects."

The new rice plant has only 6-10 stems, all of them

productive, which bear large panicles, each with 200-250 grains. Thicker, sturdier stems support the larger panicles and the vigorous roots prevent the plant from falling over. Thicker, dark green and erect leaves catch more sunlight and use it more efficiently. "Single-leaf photosynthesis of the new rice, for example, is 10-15% higher than that of IR72, a modern high-yielding variety," explains Dr Shaobing Peng, IRRI crop physiologist.

Why a new rice plant? "The rate of increase of rice production is slowing down and if the trend is not reversed, severe food shortages will occur in the next century," says Dr Mahabub Hossain, an economist who heads IRRI's Social Sciences Division. "The world's population of 5.5 billion today is likely to reach 6.2 billion in the year 2000, and 8.3 billion in 2025," Hossain points out. "Total demand for rice will probably increase by 70% during the next 35 years, a 55% jump in the number of people who count rice as their staple food plus another 15% from the increase in per capitum consumption among Asia's poor if countries succeed in alleviating poverty. Thus, 350 million more tonnes of rice will have to be produced by 2025. The growing urban population in Asian cities will demand additional rice from farmers at affordable prices."

Major increases in the area planted to rice are unlikely. The area planted to rice worldwide has remained constant since 1980 and is likely to go down because of pressures of urbanization and industrialization on good ricelands. Because of other demands, water available for rice production will also decrease. Rural labour is migrating to towns and cities. Because of environment and health concerns, use of chemicals such as pesticides will be limited. Thus, the increased demand for rice will have to be met from less land, with less water, less labour and less pesticide use.

"We not only need rice varieties with higher yield potential, but also better management practices, to meet the goals of increased production and to reduce the cost of production per ton of output," says Dr Ken Cassman, IRRI systems agronomist. "The success of the Green Revolution of the past 30 years depended on increased use of fertilizer inputs, especially nitrogen fertilizers," he adds. "The rate of increase in fertilizer use, however, was much greater than the rate of increase in rice yields. The challenge of the next 30 years is to increase both yield and input use efficiency to preserve the quality of the environment and increase the profits from farming. Achieving these two goals will require more information-intensive agronomic management strategies to support the higher yields with greater output-input efficiency."

To attempt to raise rice production to meet the increased demand, IRRI scientists started by redesigning the rice plant to produce more grain than straw. A hectare planted to traditional varieties produces about 10 t of biomass, 3 t grain and 7 t straw. Current high-yielding

varieties produce a plant biomass of 20 t/ha: 10 t grain and 10 t straw, a 50-50 ratio.

In comparison, the new rice plant should produce a biomass of 21 t/ha, of which 60% would be grain and 40% straw. Larger panicle size and fewer rice stems are the key to having more grain than straw. Because there are fewer stems, the new rice plants can grow closer together. And instead of transplanting, farmers will broadcast the seeds. The result will be more plants, and thus grain-bearing panicles, per unit area, which should reduce labour and water requirements.

"By planting the new rice closer and establishing a dense canopy, it will be possible to suppress weed growth, which should lead to a reduction in herbicide use," says Dr Keith Moody, IRRI agronomist.

Already, IRRI scientists are looking at ways to minimize pesticide use. Pest problems were exacerbated in the 1960s at a time when rice production was being modernized and intensified. Insect and disease build-up in the 1970s reduced the usefulness of IR8 and IR5, IRRI's first modern varieties. And because these cultivars were susceptible to pests, insecticide use spiralled.

However, scientists now understand pests and their predators—the friendly insects—and can make use of natural systems to reduce dependence on insecticides. And new varieties have built-in natural resistance to pests and diseases.

"The new rice will not necessarily require greater use of pesticides," says Dr K.L. Heong, IRRI entomologist. "IRRI is well aware of pesticide misuse and is conducting research to better understand farmers' decision-making in pest management. The new rice is still in its infancy. A series of ecological studies of the insect communities in various environments will be conducted before the new rice is released. These could lead to the recommendation, if needed, of appropriate pest management methods, not necessarily limited to pesticides alone."

### **IIMI's next Director General**

Dr David Seckler, well known as an international agriculture researcher and scholar, has been appointed as the next Director General of the International Irrigation Management Institute (IIMI). Currently Director for the Center for Economic Policy Studies at Winrock International in Washington, DC, Seckler's career has been diverse and multi-faceted. Positions have included teaching and research posts at US universities (Berkeley and Colorado State), the role of economic advisor at the Ford Foundation, and Senior Policy Advisor at USAID. As the President of a family corporation, Seckler developed technology for which he holds patents in the field of center pivot irrigation. He is the author/editor of five books and over 50 journal articles in the fields of environmental and resource economics, economic development, policy and theory, irrigation economics, social philosophy and private sector development.

In announcing Seckler's appointment in Colombo last week, Dr Leslie Swindale, the Chairman of IIMI's Board of Governors, noted that Seckler's intellectual and research rigour and breadth of vision will contribute significantly to strengthening the quality and focus of the Institute's work. Today, in the 10th year of IIMI's existence, there is a growing awareness that competition for water is becoming a major global issue, and that IIMI must concentrate on helping the world to produce more food with less water while minimizing environmental damage.

## Book reviews

### **Wild wheats: a monograph of *Aegilops* L. and *Amblyopyrum* (Jaub. & Spach) Eig (Poaceae)**

by M.W. van Slageren

1994. Paperback. ISBN 90-6754-377-2. Wageningen Agricultural University Papers 94-7. Dfl 200. 512 pages. Wageningen Agricultural University, the Netherlands, and the International Center for Agricultural Research in the Dry Areas, Aleppo, Syria.

A comprehensive account of the species belonging to the wider genepool of wheat, this monograph offers the state-of-the-art knowledge of taxonomy and geography. The author collected in most areas of occurrence and consulted a large range of herbarium collections, on a scale never attempted previously. The genus *Aegilops* is now delimited to 22 species and 5 varieties, the genus *Amblyopyrum* with only one species has been reinstated.

The hybrid genus *X Aegilotriticum*, with seven species, is defined in line with the author's conviction that *Aegilops* and *Triticum*, albeit closely related, merit a separate status. All species are treated with detailed descriptions, line drawings, distribution maps, literature and distribution references, notes on ecology, uses and vernacular names when available. The classification of cultivated wheats is treated as a kind of precursor, presenting accepted and not-accepted classifications. It indicates the need for taxonomical follow-up of the *Triticum* species. The keys provide the readers with entries to identify not only *Aegilops* and *Amblyopyrum*, but also the wild taxa of *Triticum*.

This monograph is a must for applied as well as fundamental scientists, such as wheat breeders and geneticists, pathologists and entomologists, and students of the Southwest Asian and Mediterranean floras. The indices to names and conserved plant specimens, and the extensive bibliography, complete this work of great usefulness on the wild relatives of wheat.

Prof. Dr Ir L.J.G. van der Maesen  
Department of Plant Taxonomy  
Wageningen Agricultural University  
Wageningen, the Netherlands

## Help for Authors and Editors

### Scientific style and format

#### **The CBE Manual for Authors, Editors, and Publishers. Sixth Edition**

by Style Manual Committee, Council of Biology Editors  
1995. Hardback ISBN 0 521 47154 0. £19.95, US\$34.95. 841 pages. Council of Biology Editors/Cambridge University Press, Cambridge CB2 2RU, UK.

For more than three decades, the Style Manuals produced by the Council of Biology Editors have been a standard reference for authors and editors of scientific reports. The scope, aims and organization of the manual are clearly outlined in the first chapter of the Sixth Edition. This is a considerably expanded manual which covers all scientific disciplines, and thus is of greater value to those who work in sciences such as agriculture. The emphasis in this version is on terminology and scientific style, with less material on writing style and preparation of scientific reports. Five major sections of the book contain an Introduction, Style Conventions (general), Scientific Conventions (specific), Journal/Book Styles and Formats, and the Publishing Process. A detailed list of contents at the beginning of each chapter, and generous use of cross-references to other text sections and tables are welcome features of this edition. As in previous editions, an Annotated Bibliography is a good source of references for other styles and authorities. And, as is necessary in a book of this size and scope, an Index is also provided.

Users of the 'Chicago Manual of Style' will feel comfortable using the CBE Manual, as the format of both is similar. Bold-face section headings followed by numbers in the left margin make it easier to find relevant text. More white space between paragraphs, compared with pages of solid text in the previous edition, and extensive use of tables also contribute to faster searching and comprehension. The tabular presentation of style conventions and symbols is particularly useful for the reader. Perhaps future editions will include an index of tables, to make it even easier to find the required material.

This book is recommended for all authors and editors of scientific material written in English, including those who may already own the Fifth or previous editions of the CBE Style Manual. With an international flavour, the preferences of English speakers in the USA, Canada, the UK, Australia and elsewhere are included, but one aim of this book is to work toward standardization of scientific English. References in the book are in the 'microbiology' style: Author-Year-Title-Publisher, rather than the Author-Title-Publisher-Year style of the previous edition. Anyone who has edited a report with an extensive alphabetical reference list can appreciate how much easier it is to have the year near the beginning of the entry when checking to see that a cited reference is listed, and I for one would be pleased to see this type of 'user-friendly' or

at least 'editor-friendly' style adopted widely.

The Style Manual Committee has done an excellent job on the Sixth Edition. It is comprehensive (but therefore not as portable as previous editions), well designed and reasonably priced.

Linda Sears, IPGRI, Rome, Italy

### **Editing fact and fiction. A concise guide to book editing**

by Leslie T. Sharpe and Irene Gunther

1994. Paperback ISBN 0-521-45693-2. US\$14.95. Hardback ISBN 0-521-45080-2. US\$39.95. 227 pages. Cambridge University Press, Cambridge, UK.

A book for anyone interested in editing although mainly aimed at those considering a career as an editor in a publishing house or freelance. The authors are well qualified to write the book as they both have years of experience in editing and writing as well as training editors. The book explains the differences, and overlap, between the acquisitions editor, managing editor, copyeditor and proofreader. It then goes on to deal with the qualities needed of an editor, how to treat authors and gives important guidelines such as "Don't adjust an author's style, or language, simply for the sake of changing it." However, if you are looking for a book on how to edit, this is not for you, as it does not go into grammar and style.

It should be borne in mind when reading the book that it was published in America for an American audience and that there are slight differences between English and American editing styles. This also means that the useful list of reference books given at the back are American titles. However, the basic principles of good editing given in the book are the same in any language.

The best way to learn how to edit is by experience and as it is not the most highly paid career, a love of words and their use is essential. However, it is this love of words that can, taken to extremes, turn a good editor into a bad one as a quotation in the book says: "The intellectual challenge is always there, but more than anything else, editing is fun — so much fun that it's easy to get carried away." [Mary Stoughton]

Diana Dixon, Rome, Italy

### **Note to authors:**

The IPGRI Style Guide was issued in December 1994 by the IPGRI Publications Committee to assist staff in preparing scientific reports. It contains useful information on writing style, technical matters (punctuation, nomenclature, units of measurement, references) and a checklist of report writing. Readers interested in obtaining a copy should send their request to the Publications Manager, IPGRI, Via delle Sette Chiese 142, 00145 Rome, Italy.

## **Recent publications**

### **Crop Production Science in Horticulture Series**

by J. Atherton and A. Rees (series editors)

CAB International, Wallingford, Oxon OX10 8DE, UK.

This series examines economically important horticultural crops selected from the major production systems in temperate, subtropical and tropical climatic areas. Systems represented range from open field and plantation sites to protected plastic and glasshouses, growing rooms and laboratories. Emphasis is placed on the scientific principles underlying crop production practices rather than on providing empirical recipes for uncritical acceptance. Scientific understanding provides the key to both reasoned choice of practice and the solution of future problems. Students and staff at universities and colleges throughout the world involved in courses in horticulture, as well as in agriculture, plant science, food science and applied biology, will welcome this series as a succinct and readable source of information. The books will also be invaluable to anyone requiring an authoritative but brief scientific introduction to particular crops or systems.

All the authors are internationally renowned experts with extensive experience in their subjects. Each volume follows a common format covering aspects of production, from background physiology and breeding to propagation and planting, through husbandry and crop protection, to harvesting, handling and storage. Selective references are included to direct the reader to further information on specific topics.

The first three titles in the series are now available (see below). Titles in preparation include Cucurbits; Tomatoes; Ornamental Bedding Plants; Carrots and Related Vegetable Umbelliferae; Coffee, Cocoa and Tea; Bananas and Plantains, and Horticultural Food Legumes.

### **Ornamental Bulbs, Corms and Tubers**

#### **Crop Production Science in Horticulture Series, No. 1**

by A.R. Rees

1992. Paperback ISBN 0 85198 656 0. £15.95 (US\$30 [Americas only]). 224 pages. CAB International, Wallingford, Oxon OX10 8DE, UK.

This volume covers ornamental bulb plants, including those with the related storage organs of corms and tubers. An immense amount of research literature has been distilled so that general principles are stressed, but common examples are also considered in some detail. The contents include horticultural uses; origins, breeding and selection; morphology; physiology; propagation; bulb, corm and tuber production; flower production; pests, diseases and disorders, and future prospects.

**Citrus****Crop Production Science in Horticulture Series, No. 2**

by F.S. Davies and L.G. Albrigo

1994. Paperback ISBN 0 85198 867 9. £19.95 (US\$33 [Americas only]). 272 pages. CAB International, Wallingford, Oxon OX10 8DE, UK.

The major types of edible citrus include sweet and sour oranges, lemons, limes, mandarins and grapefruit. These are grown extensively around the world, with major producers being Brazil, countries bordering the Mediterranean, and the USA. This book adopts an international perspective on citrus, including its biology and cultivation as well as consideration of the citrus industry. It describes the scientific basis of production practices and is aimed at professionals in the industry as well as advanced students of horticulture and allied disciplines within plant and food sciences. Chapters deal with: history, distribution and uses of citrus fruits; taxonomy, cultivars and breeding; environmental constraints on growth, development and physiology of citrus; rootstocks; plant husbandry; pests and diseases, and fruit quality, harvesting and postharvest technology.

**Onions and Other Vegetable Alliums****Crop Production Science in Horticulture Series, No. 3**

by J.L. Brewster

1994. Paperback ISBN 0 85198 753 2. £17.95 (US\$30 [Americas only]). 256 pages. CAB International, Wallingford, Oxon OX10 8DE, UK.

This book introduces the scientific principles that underlie production practices of the edible alliums. These are some of the most ancient cultivated crops and include onions, leeks, shallots, garlic and chives. They are grown in most regions of the world, from the subarctic to the humid tropics, although bulb onions are best adapted to production in subtropical and temperate areas. The contents include: classification, origins, distribution and economic importance of the major food crops; the structure of edible Alliums; genetics and breeding of Allium crops; physiology of crop growth, development and yield; crop production; flowering and seed production; crop storage and dormancy; interactions with other organisms — weeds, pests, diseases and symbionts; the biochemistry and food science of Alliums. The book is written at a level suitable for students of horticulture, crop science and food science, as well as for growers and crop consultants interested in the scientific principles that form the basis of their practice. It also provides a valuable example of how the different disciplines within plant sciences interrelate when applied to particular crops.

**Catalogue of the Potato Genebank, Groß Lüsewitz [Kartoffelgenbank Groß Lüsewitz]**

by Monika Vandrey, Dietrich Rothacker and Konrad Schüler (Curator)

1994. Paperback. 145 pages. Institut für Pflanzengenetik und Kulturpflanzenforschung Gatersleben - Genbank Außenstelle Nord, D 18190, Groß Lüsewitz, Germany.

Catalogue containing a list of the complete genebank material of the Potato Genebank in Groß Lüsewitz, a substation of the Genebank of the Institute of Plant Genetics and Crop Plant Research in Gatersleben. Parts A and B list the collection of wild and cultivated potato (*Solanum*) species from Middle and South America, and potato varieties, respectively.

**Agriculture and Rural Development**

Published by DLG-Verlags-GmbH, Eschborner Landstraße 122, 60489 Frankfurt am Main, Germany. Two issues per year.

Four agricultural research organizations are partners in producing this publication, which focuses on tropical agriculture and rural development. The Technical Centre for Agricultural and Rural Cooperation (CTA) attempts to facilitate access to scientific and technical information by translating and publishing material relevant to its readership. In collaboration with the German Foundation for International Development/Food and Agriculture Development Centre (DSE/ZEL), the German Agency for Technical Cooperation (GTZ) and the German Agriculture Society (DLG), this publication presents reports translated from German. The publication is bilingual, in English and French. Contributions to Volume 1, No. 1 include topical articles on the status of aid to agricultural research, essays on rural development projects and approaches to ensuring food security, research on aspects of animal production, and a report of the introduction of new technology to rural communities. **Agriculture and Rural Development** is intended to be a platform for exchanging experiences and imparting knowledge and expertise to partner countries in order to fight poverty and realize development of the agricultural sector.

**Bibliography on local crop development**

The Centre for Genetic Resources, the Netherlands (part of the centre for Plant Breeding and Reproductive Research — CPRO-DLO), the International Plant Genetic Resources Institute, Italy (IPGRI) and the Overseas Development Institute (ODI) are working together to produce an annotated bibliography on local crop development.

Farmers often grow a mixture of diverse varieties, in part to ensure that some of the crop survives to harvest in spite of bad weather, pests or diseases. Social and cultural factors also influence the need for a range of different varieties. Most farmers continually modify the genetic characteristics of their crops. The term 'local crop development' is used for this in preference to 'local crop improvement' since in many cases the objective is not to achieve specific improvements but to gradually adapt and change their varieties.

The literature on local crop development is scattered throughout the literature of social sciences and plant sciences. The bibliography draws this literature together and provides an indication of the range of research carried out on local crop development.

The bibliography is organized in four thematic sections, each listing key references: (i) descriptive studies on local crop development, local seed systems and related local knowledge systems; (ii) biological studies on local crop development; (iii) social, economic and policy aspects; (iv) research methodologies relevant to local crop development. All entries include an abstract and the bibliography is indexed by crop, country and subject.

The bibliography will be published toward the end of 1995 and distributed to institutional libraries. To be included on the mailing list for this publication, librarians should send a request to J. Dearing, Library & Information Services Officer, IPGRI, Via delle Sette Chiese 142, 00145 Rome, Italy. Fax (39-6) 5750309. Email J.DEARING@CGNET.COM. Please quote reference PGRN/LCDB. Requests from individuals will only be considered on a case-by-case basis.

### **Corrigendum**

The following changes apply to the article 'Genetic resources of ginger (*Zingiber officinale* Rosc.) and its conservation in India' by P.N. Ravindran *et al.*, which appeared in *Plant Genetic Resources Newsletter* No. 98, on pages 1-4.

#### Introduction (p. 1)

India's export of ginger during 1991-92 was **14,259 tonnes**, not 1,560,000 tonnes.

#### Results and discussion (p. 3)

In many cases the major production centres are far from the areas of origin of the crop concerned. This **does not seem to be true of ginger**.

Table 3. Mean, range and coefficient of variation (CV) for yield, yield attributes and quality traits in ginger germplasm

Character	Mean	Range	CV (%)
Plant height (cm)	59.20	23.13 - 88.60	19.0
Leaf number/plant	37.14	17.00 - 52.00	18.17
Tiller number/plant	16.81	2.75 - 35.50	45.92
Leaf length (cm)	23.79	17.01 - 36.50	10.90
Leaf width (cm)	2.65	1.95 - 3.75	10.82
Days to maturity	225.92	214.00 - 235.50	13.53
Dry recovery (%)	21.70	14.00 - 28.50	14.30
Rhizome yield/plant (g)	363.12	55.00 - 770.00	39.33
Crude fibre (%)	4.31	2.10 - 7.00	23.34
Oleoresin (%)	6.12	3.20 - 9.50	21.70
Gingerol (%)	19.95	14.00 - 27.00	15.16
Shogaol (%)	4.12	2.70 - 7.50	24.35



## Conseils aux auteurs

Les textes dactylographiés seront préparés en anglais, en espagnol ou en français et envoyés en deux exemplaires au directeur de rédaction. Ils seront présentés en double interligne, avec de grandes marges (3 à 5 cm). Toutes les pages (y compris les tableaux, figures, légendes et références) seront numérotées à la suite.

### Titre

Le titre sera le plus court possible et devra contenir le nom commun de toutes les espèces dont il est question dans le document, et le nom des principaux pays visités durant, par exemple, un voyage de collecte de matériel.

### Nom et adresse des auteurs

Mentionnez le nom complet de tous les auteurs du document, ainsi que leur adresse à l'époque de l'étude. Indiquez leur adresse actuelle et leur adresse de contact en bas de page sur la première page du document; indiquez également l'auteur auquel doivent être adressées la correspondance et les épreuves.

### Résumés

Articles et études doivent être accompagnés d'un résumé en anglais, en espagnol et en français. Envoyez un résumé de 200 à 250 mots au maximum dans la même langue que le texte dactylographié, ainsi que la traduction (y compris le titre) dans les deux autres langues, si possible. Placez-les à la fin de votre texte, après les références et avant les tableaux. Les résumés d'articles devraient mentionner l'objectif de l'étude (hypothèse et buts), le matériel et/ou les méthodes utilisés pour l'expérience, un résumé des résultats et les conclusions tirées de ces résultats.

### Mots-clés

Indiquez au maximum six mots-clés qui serviront pour un index, par ordre alphabétique, au-dessous du résumé dans la langue de rédaction au début du texte dactylographié.

### Texte principal

Faites bien ressortir les titres et les sous-titres, mais évitez les titres de plus de trois lignes. Ne numérotez pas les titres ou les paragraphes, qui devraient être mis en retrait.

Utilisez un langage simple. Il serait préférable qu'avant d'être soumis, le document soit mis en forme par une personne dont la langue maternelle est celle de la langue de rédaction.

### Remerciements

Ceux-ci (de même que les dons ou l'aide, etc. éventuellement reçus) devraient figurer à la fin du texte et avant les références.

### Références

Les références seront présentées par ordre alphabétique, dactylographiées en double interligne et indiqueront:

auteur et année de la publication, par exemple (Dawsib, 1987). On évitera les citations de communications personnelles ou de données inédites. Ces citations ne devraient figurer que dans le texte, comme (E.D. Smith, communication personnelle) et non dans la liste des références. Abrégez les titres des périodiques comme il est indiqué dans le *Bibliographic Guide for Editors and Authors* (Biosis, Chemical Abstract Service and Engineering Index, Inc., 1974). Adoptez la présentation ci-dessous:

#### Périodiques

Molina-Cano, J.L., P. Fra-Mon, G. Salcedo, C. Aragoncillo, F. Roca de Togores et F. Gardia-Olmedo. 1987. Morocco as a possible domestication center for barley: biochemical and agromorphological evidence. *Theor. Appl. Genet.* 73:531-536.

#### Livres (édités par quelqu'un d'autre que l'auteur de l'article)

Hanelt, P. 1986. Cruciferae (Brassicaceae). Pp. 272-332 in *Rudolf Mansfelds Verzeichnis landwirtschaftlicher und gärtnerischer Kulturpflanzen (ohne Zierpflanzen)*, Vol. 2. (H. Schultze-Motel, ed.) Akademie-Verlag, Berlin, Allemagne.

#### Livres (même auteur et même éditeur)

Chapman, C. 1985. *Genetic Resources of Wheat. A Survey and Strategy for Collecting*, IBPGR, Rome, Italie.

#### Nomenclature

*Taxinomique*: suivre l'*Index Kewensis*. *Génétique*: les applications des termes phénotype et génotype devraient être conformes à Demerec *et al.* (*Genetics* 54:61-74, 1966); pour des résumés des abréviations génétiques, consultez le *Journal of Bacteriology* qui contient des conseils aux auteurs.

*Unités*: exprimez toutes les quantités en unités du système international. Si une unité traditionnelle ou locale est utilisée, ou une unité qui pourrait être connue dans un pays seulement, indiquez toujours l'équivalent en unités du système international afin que d'autres chercheurs puissent comprendre les quantités indiquées.

#### Préparation des figures et des tableaux

Figures et tableaux servent à étayer le texte et doivent être organisés logiquement, apparaissant là où ils sont mentionnés. S'il y a une grande quantité d'informations dans un tableau, il vaudrait mieux l'inclure dans une annexe à la fin de l'article. Les figures et les tableaux doivent être clairs et simples. Il s'agit de présenter un matériel complexe sous une forme facile à comprendre. Présentez les données dans le texte, dans une figure ou dans un tableau mais jamais dans les trois à la fois.



## Instrucciones para los Autores

Los textos deben redactarse en inglés, francés o español y entregarse por duplicado al director de redacción. Deben presentarse mecanografiados a doble espacio, con amplios márgenes (3-5 cm). Todas las páginas (incluidos los cuadros, figuras, leyendas y obras consultadas) se deben enumerar consecutivamente.

### Título

El título ha de ser lo más corto posible y debe incluir los nombres común y genérico completos de las especies descritas en el documento, así como los principales países visitados, por ejemplo, durante el viaje de colección.

### Autores/direcciones

Incluir los nombres completos de los autores del documento, junto con las direcciones de los autores en el momento de la realización del trabajo presentado. Indicar las direcciones actuales o postales como nota al pie de la primera página del documento. Indicar también el autor designado para recibir la correspondencia y las pruebas.

### Resúmenes

Los artículos y reseñas se publicarán acompañados de resúmenes en inglés, francés y español. Entregar un resumen que no exceda las 200-250 palabras en el mismo idioma empleado en el texto mecanografiado, así como, de ser posible, las traducciones (incluido el título) a los otros dos idiomas. Incluir estas traducciones al final del documento, después de la bibliografía y antes de los cuadros. En los resúmenes de los artículos se debe mencionar el propósito de la investigación (hipótesis y objetivos), el material y/o los métodos experimentales, un resumen de los resultados y las conclusiones.

### Palabras claves

Para facilitar la inclusión del documento en el índice, deberá incluirse un máximo de seis palabras claves, en orden alfabético, después del resumen en el idioma original y antes del texto mecanografiado.

### Texto principal

La importancia relativa de los títulos y subtítulos debe distinguirse claramente, pero hay que evitar el empleo de más de tres niveles de encabezamiento. No enumere títulos o párrafos que se han de sangrar.

Utilizar un lenguaje sencillo y claro en el texto. Se aconseja que una persona cuyo lenguaje materno sea el empleado en el documento, revise el trabajo antes de presentarlo.

### Reconocimientos

Los reconocimientos (al igual que las subvenciones, ayudas etc.) deberán incluirse después del texto y antes de la bibliografía.

### Bibliografía

Las referencias bibliográficas deben presentarse en orden alfabético, mecanografiadas a doble espacio, e indicar autor y año de publicación, por ejemplo (Dawsib, 1987). Se deben evitar las citas de comunicaciones personales y datos no publicados. Estas citaciones han de aparecer sólo en el texto (E.D. Smith, comunicación personal), y no en la bibliografía. Abreviar los títulos de revistas de conformidad con el estilo de la Bibliographic Guide for Editors and Authors (Biosis, Chemical Abstract Service and Engineering Index, Inc., 1974). Seguir el modelo siguiente:

#### Revistas y periódicos

Molina-Cano, J.L., P. Fra-Mon, G. Salcedo, C. Aragoncillo, F. Roca de Togores y F. Gardia-Olmedo. 1987. Morocco as a possible domestication center for barley: biochemical and agromorphological evidence. *Theor. Appl. Genet.* 73:531-536.

#### Libros (editados por alguien que no es el autor del artículo)

Hanelt, P. 1986. Cruciferae (Brassicaceae). Pág. 272-332 en Rudolf Mansfelds Verzeichnis landwirtschaftlicher und gärtnerischer Kulturpflanzen (ohne Zierpflanzen), Vol. 2. (H. Schultze-Motel, ed.). Akademie-Verlag, Berlin, Germany.

#### Libros (del mismo autor y editor)

Chapman, C 1985. Genetic Resources of Wheat. A survey and Strategy for Collecting. IBPGR, Rome, Italy.

### Nomenclatura

*Taxonomía:* de conformidad con el *Index Kewensis*. *Genética:* los términos fenotipo y genotipo se deben aplicar de acuerdo con Demerice *et al.* (*Genetics* 54:61-74, 1966); para los resúmenes de las abreviaturas genéticas, consultar las Instrucciones para los Autores contenidas en el *Journal of Bacteriology*.

*Unidades:* expresar todas las cantidades con arreglo al sistema internacional. Si se emplea una unidad tradicional o local, o una unidad que tal vez se conozca sólo en un país, incluir siempre el equivalente en el sistema internacional para que los demás puedan entender perfectamente las cantidades.

### Preparación de figuras y cuadros

Los cuadros y las figuras complementan el texto y deben presentarse de modo lógico, apareciendo cuando se mencionan. Si un cuadro contiene una gran cantidad de información, tal vez sea mejor incluirlo como apéndice al final del documento. Las figuras y los cuadros deben ser sencillos y claros. Su propósito principal es presentar información compleja en un modo fácilmente comprensible. Presentar los datos ya sea en el texto, en un cuadro o en una figura, pero nunca en las tres formas a la vez.



# Instructionstoauthors

Typescripts should be prepared in English, French or Spanish and submitted in duplicate to the Managing Editor. Typescripts should be double-spaced throughout, with generous (3-5 cm) margins. All pages (including tables, figures, legends and references) should be numbered consecutively.

## Title

The title should be as short as possible and should contain the common and full generic name of any species featured in the paper, as well as the main countries visited during, for example, collecting trips.

## Authors/addresses

Include the full names of all authors of the paper, together with the addresses of the authors at the time of the work reported in the paper. Indicate current or postal addresses as a footnote on the first page of the paper; indicate also the author nominated to receive correspondence and proofs.

## Abstracts

Articles and reviews will be published with abstracts in English, French and Spanish. Supply an abstract not exceeding 200-250 words in the same language as the typescript, as well as translations (including the title) into the other two languages, if this is possible. Include these at the end of the paper, after the references and before the tables. The abstracts of articles should mention the objective of the investigation (hypothesis and aims), the experimental material and/or methods, a summary of the results and the conclusions drawn from the results.

## Key words

Provide a maximum of six key words for use in indexing purposes, in alphabetical order, below the native-language abstract at the start of the typescript.

## Main text

The relative importance of headings and subheadings should be clear, but avoid using more than three levels of headings. Do not number headings or paragraphs, which should be indented.

Use simple clear language in the text. A native speaker of the language should preferably edit the paper before submission.

## Acknowledgements

These (also grants, support, etc. if any) should follow the text and precede the references.

## References

The references to the literature should be arranged alphabetically, typed double-spaced and in text referred to as: author and year of publication, e.g. (Dawsib, 1987). Citations of personal communications and unpublished data

should be avoided. Such citations should in text appear in the text only, as (E.D. Smith, personal communication), and not in the reference list. Abbreviate titles of periodicals according to the style of the Bibliographic Guide for Editors and Authors (Biosis, Chemical Abstract Service and Engineering Index, Inc., 1974). Follow the style shown below:

## Periodicals

Molina-Cano, J.L., P. Fra-Mon, G. Salcedo, C. Aragoncillo, F. Roca de Togores and F. Gardia-Olmedo. 1987. Morocco as a possible domestication center for barley: biochemical and agromorphological evidence. *Theor. Appl. Genet.* 73:531-536.

## Books (edited by someone other than the author of the article)

Hanelt, P. 1986. Cruciferae (Brassicaceae). Pp. 272-332 in Rudolf Mansfelds Verzeichnis landwirtschaftlicher und gärtnerischer Kulturpflanzen (ohne Zierpflanzen), Vol. 2. (H. Schultze-Motel, ed.). Akademie-Verlag, Berlin, Germany.

## Books (identical author and editor)

Chapman, C. 1985. Genetic Resources of Wheat. A Survey and Strategy for Collecting. IBPGR, Rome, Italy.

## Nomenclature

*Taxonomical*: in line with *Index Kewensis*. *Genetic*: applications of the terms phenotype and genotype should be in accordance with Demerec *et al.* (*Genetics* 54:61-74, 1966); for summaries of genetic abbreviations, consult the *Journal of Bacteriology* Instructions to Authors.

*Units*: express all quantities in terms of SI. If a traditional or local unit is used, or a unit that may be well known in one country only, always include an SI equivalent so that other workers can fully understand the amounts.

## Preparing figures and tables

Tables and figures support the text and must be organized logically, appearing where they are mentioned. If there is a large amount of information in a table, it may be better to include it as an appendix at the end of the paper. Figures and tables should be clear and simple. Their major purpose is to present complex material in a form that is easily understood. Present data in the text, or as a figure, or a table, but never in more than one of these ways.

*La version française des Conseils aux auteurs se trouve à la page 50.*

*La versión española de las Instrucciones para los autores se encuentra en la página 51.*

# Plant Genetic Resources Newsletter

No. 102, June 1995

## Contents

### REVIEW

- Translating genetic resource rights into sustainable development:  
gene cooperatives, the biotrade and lessons from the Philippines  
Walter V. Reid, Charles V. Barber and Antonio La Vina 1

### ARTICLES

- X-ray analysis of empty and insect-damaged seeds in an  
*ex situ* wild species collection 18  
S. Linington, J. Terry and J. Parsons
- Accession regeneration in genebanks: seed production environment and the  
potential longevity of seed accessions 26  
R.H. Ellis and M.T. Jackson

### SHORT COMMUNICATIONS

- Aspects of pomegranate culture in Turkmenistan 29  
Gregory M. Levin
- Distribution and use of *Malus* in the Hengduan mountain region, southwest China 32  
Deng Guo Tao, Li Da Fu, Li Yu Tang, Zhang Yan Shu, Wang Qiao Chun,  
Li Huan Xiu and Fan Li Zhang
- Collecting germplasm of sheanut (*Vitellaria paradoxa*) in Ghana 37  
Y. Adu-Ampomah, J.D. Amponsah and J.A. Yidana
- Recent information sources on Global Positioning System (GPS) technology 39  
Luigi Guarino
- Soyabean varieties and their geographical distribution in Iran 40  
N. Mulalic, M.R. Ahmadi and F. Yousefi

### NEWS AND NOTES

- First Extraordinary Session of the Commission on Plant Genetic Resources 41
- USAID creates new priorities 42
- Nutrient-enriched food crops 43
- IRRI redesigns rice plant to yield more grains 44
- IIMI's next Director General 45

BOOK REVIEWS 46

RECENT PUBLICATIONS 47

Corrigendum 49

Conseils aux auteurs 51

Instrucciones para los autores 53

Instructions to authors Inside back cover