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The Value of Biodiversity to Food & Agriculture

Journal OBJECTIVE

To contribute to the understanding, protection and restoration of the diversity of living things



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Front cover illustration. This image, used on the poster for the International Day for Biological Diversity 2008, has been designed from a traditional Gabba embroidered tapestry from Pakistan that was donated to the CBD Museum of Nature and Culture in 2006 by Pakistan's Minister for Environment. Measuring some two meters across and two meters high, the intricately stitched and brightly coloured Gabba depicts scenes of everyday life and the rich heritage of biodiversity and agriculture in a farming landscape of Pakistan.

SPECIAL ISSUE The Value of Biodiversity to Food and Agriculture

To those who farm the living earth and nurture our livestock- may they reap a rich and full harvest as they continue to respect the diversity of life.

CONTENTS

ARTICIES

Global biodiversity - The source of new crops. E. Small and P.M. Catling
The value of taxonomy to biodiversity and agriculture. Chris Lyal, Paul Kirk, David Smith and Richard Smith8
Sustaining livestock biodiversity – From assessment to action. Dafydd Pilling, David Boerma, Beate Scherf and Irene Hoffmann
Ecosystems and the value of adjacent protected areas to agriculture. Waltraud Kugler and Elli Broxham Stahl
The maintenance of crop genetic diversity on farm: Supporting the Convention on Biological Diversity's Programme of Work on agricultural biodiversity. Devra I. Jarvis and Toby Hodgkin
Benefits of sward diversity for agricultural grasslands. A. Lüscher, J.A. Finn, J. Connolly, M.T. Sebastià, R. Collins, M. Fothergill, C. Porqueddu, C. Brophy, O. Huguenin-Elie, L. Kirwan, D. Nyfeler and A. Helgadóttir
Organic agriculture enhances agrobiodiversity. Cristina Grandi
The effectiveness of participatory plant breeding as a tool to capitalize on agrobiodiversity in developing countries. C.J.M. Almekinders, S. Humphries and A. von Lossau
Opportunity for conserving and utilizing agrobiodiversity through agroforestry in Southern Africa. Paxie W. Chirwa, Festus K. Akinnifesi, Gudeta Sileshi, Stephen Syampungani, Fiix K Jalaba and Oluvede C. Aiavi 45
Diversity in local rice germplasm and rice farming: A case study of Thailand, Benjavan Rerkasem 49
Ecoregions with crop wild relatives are less well protected. Sue Stolton, Tim Boucher, Nigel Dudley, Jonathan Hoekstra, Nigel Maxted and Shelagh Kell
Reconciling genetic resources and local knowledge conservation and livelihoods enhancement in research and development: Experiences of Bioversity International in Sub-Saharan Africa. P. Maundu and Y. Morimoto
Arbuscular mycorrhizal fungi - An underground resource for sustainable upland agriculture. N. Yimyam, S. Youpensuk, J. Wongmo, A. Kongpan, B. Rerkasem and K. Rerkasem
Towards sustainable management of soil biodiversity in agricultural landscapes in Africa. Gudeta Sileshi, Festus K. Akinnifesi, Oluyede C. Ajayi, Sebastian Chakeredza, Simon Mng'omba and Betserai Isaac Nyoka
Genebanks in the post-genomic age: Emerging roles and anticipated uses. Christina Walters, Gayle M. Volk and Christopher M. Richards
Domestication and conservation of indigenous Miombo fruit trees for improving rural livelihoods in southern Africa. Festus K. Akinnifesi, Gudeta Sileshi, Oluyede C. Ajayi, Paxie W. Chirwa, Simon Mng'omba, Sebastian Chakeredza and Betserai I. Nyoka
Towards protecting soil biodiversity in Europe: The EU thematic strategy for soil protection. Luca Montanarella
Agrodiversity in the traditional agrosystems of the Rif mountains (north of Morocco). Younes Hmimsa and Mohammed Ater
Benefits of biodiversity conservation to agriculture and rural livelihoods. Katrina Brandon, Will R. Turner, Götz Schroth, and Mohamed Bakarr
Pollinating Flies (Diptera): A major contribution to plant diversity and agricultural production. Axel Ssymank, C.A. Keams, Thomas Pape & F. Christian Thompson
Developing result-orientated payment schemes for environmental services in grasslands: Results from two case studies in North-western Germany. Elke Berke, Sebastian Klimek and Burghard Wittig
A predictive model of local agricultural biodiversity management in Southern Cameroon. A.W. Mala. Geldenhuvs. R. Prabhu 96
Pacific Island agrobiodiversity and ethnobiodiversity: A foundation for sustainable Pacific Island life. R. R. Thaman
EDITOR 5 CORNER
Increasing the company line of autourule and plouversity. E. Sillal

SPECIES BY SPECIES

BLOSSOMING TREASURES OF BIODIVERSITY

14. Grass Pea (Lathyrus sativus) - Can a last resort food become a first choice? E. Small & P.M. Catling 111

BIODIVERSITY NEWS

2008 – The International Year of the Potato; Functional Diversity May Give Resilience to Stresses from Global Warming; World Livestock Production Perilously Dependent on a Few High-Yielding Breeds; Intense Crossbreeding Threatens Uganda's Ankole Cow with Extinction; Unknown Disease Threatens Several Species of Bats with Extinction; Invasive Species: a Global Problem with Local Consequences; Eutrophication and Hypoxia Choking Coastal Waters; Sovbean Boom Forcing Paraguay to Examine Pesticide Use; Manifestos on the Future of Food and Seed; Svalbard Seed Vault Opens; Are Rising Global Food Costs Driven by Increased Biofuel Production?; Biotech Companies withdraw from International Avriantive Science and Technelant Meanement Independent Technelant the Village Lovel. 417 Agriculture Science and Technology Assessment; Indonesia; Tree Conservation at the Village Level ...117

BOOK REVIEWS



Volume 9 Numbers 1 & 2

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Back Cover: Rice, Oryza sativa L., see caption page 35. Inside Front Cover Art: The Diversity of Life by Roelof Idema

The value of taxonomy to biodiversity and agriculture

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Richard Smith, Director, BIONET-INTERNATIONAL Secretariat, Bakeham Lane, Egham, Surrey, TW20 9TY, UK **Abstract.** Globally, agriculture faces biotic, abiotic and legislative challenges. Impacting on all is the increasing number of species and strains of animals, plants, fungi and microorganisms that must be managed. Planning and implementing appropriate farm- and country-level actions requires accurate identification of organisms to access information although, in developing countries, many important species are neither named scientifically nor their local taxonomies and uses well documented. Improvement and adaptation of crops and livestock to changing environment and needs has long depended on genes from wild relatives. Implementing adequate biosecurity for agriculture at national and local levels may involve information on biota globally. Agricultural and neighbouring ecosystems provide poorly-characterised reservoirs for pests, natural enemies, pollinators and other organisms detrimental, beneficial or essential to productive and resilient agro-ecosystems, and the latter must be assessed and monitored for agricultural impacts under the ecosystem approach. To support these actions taxonomy must deliver timely and appropriate information to those who can use it most effectively. This is hindered by poor funding, lack of clarity on resources required and responsibility for action, and poor delivery systems. The needs of agriculture are inadequately met. Policies developed globally to address this issue are not always simple to implement, or to integrate with other agriculture, research and policy, and provision of appropriate infrastructure and human capacity.

INTRODUCTION

Taxonomic information underpins the success of agriculture. The taxonomist founder of CAB International (CABI) described hundreds of species to meet the needs of agriculture: knowledge of what is managed underpins successful management. Thousands of species, genetic strains and genotypes are significant to agriculture, a number growing rapidly as the agricultural environment alters through climate change, chemical application, salinity, ground-water shifts and expansion of agriculture into new areas. Production must be maximised sustainably and crop losses minimised. Farmers respond to new opportunities to sell produce globally; agriculture trade now encompasses traditional and novel food crops, textiles, biofuels and medicinal plants.

Agricultural management and development may impact adjacent biodiversity (and its goods and services) negatively, so policies and implementation require a thorough understanding of the impact of management practices on both systems.

Biosecurity and quarantine are growing concerns, both demanding confidence in what is being shipped, and an ability to detect pests, pathogens or potential Invasive Alien Species (IAS). At the country level, effective implementation of trade-related controls requires considerable knowledge of native and exotic biota.

All these elements of modern agriculture require knowledge of the identity of organisms, be they products, pests, parasites or pollinators. This enables agriculturalists and government bodies to select appropriate strains and species, predict the impact of changes and how to respond to them, and deal with regulatory issues related to transborder transport. The tools to produce and access this knowledge are taxonomic – products of the science of discovering, naming and classifying organisms. Taxonomic information is used, if unknowingly, by millions of people in farming, extension, research, biosecurity, quarantine, plant protection, pest-control, environmental management and pesticide development and application. This paper reviews where taxonomic tools and information are needed for agriculture and agricultural biodiversity, whether current provision is sufficient and how gaps may be filled.

AGRICULTURE AND BIODIVERSITY – WHERE TAXONOMY IS NECESSARY

Identifications are fundamental to all other biological applications, and the key to access the accumulated knowledge of any organism. While this knowledge increasingly appears on the internet, a bottleneck limiting access to it is often obtaining the identification. Identifications may be to species, level above species (e.g. if this is sufficient to rule out a suspect organism being of importance), or within species (e.g. strain or pathovar).

At a local level, farmers and other practitioners may base actions on their own identifications, using informal, local "taxonomic knowledge". This is commonly supplemented by diagnoses from extension services. Local or national identification specialists may be used, who in turn may call upon extra-national resources (Figure 1). Most internationally-competent institutions now charge for identification services, potentially a problem for developing countries (Naumann *et al.* 2002). Moreover, advice sought from another country may take additional time.

Taxonomic research causes names to change over time, so different names may be used for the same thing and the same name for different species. However, farmers, extension workers and biodiversity monitoring programmes can only communicate effectively if all use the same name for an entity. IAS and SPS (Sanitary and Phytosanitary) legislation need names interpretable by interception and biosecurity staff (Smith & Lyal 2008), and validity of names applied to germplasm materials is essential to avoid disputes where Material Transfer Agreements are used under the International Treaty on Plant Genetic Resources for Food and Agriculture or other instruments.

PESTS, PARASITES, PATHOGENS AND PROBLEMS

Agricultural production and post-harvest storage is subject to a vast range of pests, pathogens and weeds (PPW). Prompt and appropriate actions to protect agricultural productivity and trade require correct diagnosis of the problem, and identification



Figure 1. Obtaining an identification of a specimen. The downward arrow indicates increasing time requirement. Note that the identification tools are themselves products of taxonomic research, and more work may be needed to create such tools where none exist.

of the causative organism (e.g., broad-spectrum insecticide might cause more harm than the original problem; biocontrol programmes require accurately-identified target organisms). While some pests are easily recognized from the damage, others can be confused with species of neutral or positive impact.

In addition to problems of recognising 'traditional' pests, crop diversification and the introduction of alien pests mean that producers increasingly face organisms unknown to them. Problems caused by IAS are set to worsen with the exponential increase in global trade (Carpenter *et al.* 2005: 378).

Although key taxonomic action for PPW is frequently the identification and provision of the correct name to solve local problems (Figure 1), larger scale responses may be needed. Monitoring programmes may be necessary, supported by taxonomic expertise, identification guides and survey protocols (Figure 2). Predicting possible PPW ranges outside

their original distribution, or under different climate change scenarios, is now possible using data of where specimens were collected, and the climatic conditions of those sites. Such a system, drawing extensively on taxonomic information and collections, has been used effectively in Mexico for prediction of IAS potentially harmful to agriculture, and enabled government to assess the safety of Living Modified Organism introductions. Growing recognition that taxonomy – enabled by informatics – can provide such predictions may increasingly drive provision of appropriate taxonomic information.

Access to international agricultural markets requires compliance with international and national regulations. Quarantine officials must be able to identify intercepted organisms, and compare identities against legislated lists of scientific and colloquial names. The Sanitary and Phytosanitary (SPS) Agreement of the World Trade Organisation uses international standards of the International Plant Protection Convention (IPPC) that include criteria for taxonomic scrutiny. The SPS Agreement requires scientific evidence from prospective exporting countries and target markets to substantiate claims regarding the presence or absence of controlled species. Assertions that a species is present must be supported by evidence of diseased host specimens, culture or other biological collections. If an exporting country is able to provide accurate records to validate statements of pest status and occurrence, bids for access to international agricultural markets can be processed rapidly. In contrast, when these data are unavailable, resulting delays lead to lost trade opportunities (Evans et al. 2002; Naumann et al. 2002).

TAXONOMY, THE KEY TO INFORMATION ABOUT HELPFUL ORGANISMS

Agriculturalists have benefitted from biodiversity since the first domestications. Genes from wild relatives are used to increase resistance to PPW and abiotic factors (e.g. water shortage and increased salinity), to improve taste, appearance and storage time, and increase protein and vitamin content (Anon 2003). Strategies proposed for wild relatives include national, regional or global inventories (Kell et al. 2005; Brehm et al. 2007; Heywood et al. 2007) of species and genotypes. This necessitates taxonomic input: identification, checking names, reconciling differences between datasets, and establishing distributions using collections and literature. Brehm et al. (2007) noted their inventory compilation was hindered by taxonomic 'misalignments' between different sources, and the dispersed nature of biological literature. Sharing information requires accepted standards; for Crop Wild Relatives these include Euro+Med PlantBase and the Germplasm Resources Information Network, both built by or with taxonomists.

Natural enemies of PPW can be encouraged by the use of appropriate environments or plants within the agroecosystem (e.g. ICIPE 'push-pull' system: http://www.push-pull.net/), or inclusion of natural or semi-natural reservoir landscapes, such as hedgerows bordering UK fields. Management of peri-

agricultural ecosystems requires monitoring for both natural enemies and other species important to ecosystem functioning; monitoring systems require taxonomic input (Figure 2).

Biocontrol targets pests with a selected suite of enemies. It may require detailed taxonomic work to establish pest identity and, from that, its native range (often accessible only from specimens in collections). Inference from enemies of related species may suggest natural enemies (e.g., Loiácono *et al.*); these may require detailed taxonomic study to establish their identity and host range before introduction (e.g., Lyal 2003). Because pests are permanently suppressed, benefits include savings arising from reduced production losses and removal of the need for recurrent control; when set against the one-off costs of finding, screening and introducing biological control agents, biocontrol has impressive benefit to cost ratios. The importance of taxonomy for biocontrol and the economic value of obtaining the correct identification of both pest and control agent is clear (e.g. Knapp and Haas 2007).

Crop pollinators are in global decline, particularly bees (Klein *et al.* 2007). Pollination success increases for some species if wild bees are present (Kremen *et al.* 2002). Many pollinators are reliant on non-agricultural plants or environments, crops being only a fraction of their activity. To reverse pollinator decline, assess the importance of particular pollinators for given crops, and understand their needs, accurate identification is vital (APIS 2003; Kwapong 2003).

Microorganisms are an integral component of agricultural biodiversity, involved in breaking down plant and animal remains, nitrogen fixation, animal digestion and plant nutrition, as well as providing a major source of important genetic information. Mycorrhizas are a symbiotic association of a fungus and plant roots, found in perhaps 85% of plant species, including those agriculturally important. Without specific mycorrhiza a newly intoduced crop may suffer poor yields. Discovering whether beneficial mycorrhizas are present or need to be introduced calls for the application of taxonomic knowledge.

LIMITATIONS AND IMPROVEMENTS IN TAXONOMIC SERVICE

Although approximately 1.78 million species of animals, plants, fungi and micro-organisms worldwide are formally named many more are not; mostly small organisms possibly including key species for agriculture (e.g., ca. 95% of microbial diversity is undiscovered (Hawksworth 2001)). This issue is most pressing in tropical developing countries where the biodiversity is highest and least documented. If a pest taxon is unknown to science it cannot be identified until a description is written and published.

Even for known species, identification is not always possible: the information provided may be inadequate, the specimen may be fragmented or of an unrecognised life-stage, or there may be no specialist available.

Extra-national taxonomic expertise is often necessary because local expertise and infrastructure is lacking, particularly in the



Figure 2. Taxonomic component of surveys and monitoring biodiversity.

tropics (Naumann *et al.* 2002; Evans *et al.* 2002; Wilson *et al.* 2003) (Figure 1). Problems include a paucity of trained staff in secure employment, a lack of securely-funded taxonomic institutions, poor or absent national and regional reference collections, and inadequate literature resources (SCBD 2002; Naumann *et al.* 2002; Evans *et al.* 2002; SCBD 2007; Smith & Lyal 2008).

Greater accessibility of user-friendly identification tools is needed. Paper publications are most commonly used, but increasingly image-rich identification keys and other resources on CD-ROMs and the internet are available. However, although the internet may provide solutions, finding them is problematic and generating content in forms understandable to non-taxonomist users takes time and expertise. (Resources for Africa can be found at http:// taxonomy.icipe.org/id.html).

BARRIERS AND SOLUTIONS

The need to integrate taxonomic output and the needs of agricultural biodiversity has been recognised by Parties to the Convention on Biological Diversity (CBD) in the Global Taxonomy Initiative Programme of Work (SCBD 2002, 2007). However, CBD policy statements tend to be broad, not always clear on responsibility to ensure implementation, nor provide mechanisms to assess progress.

Biological collections serve as a source of data and information, and also as a necessary reference tool for taxonomists and others in the "North" and, critically, in developing countries. The CBD has called for increased support for national biological collections (SCBD 1998, 2000, 2002); similar recommendations are in Southeast Asian needs assessments on plant pathogens and pests (Evans *et al.* 2002; Naumann *et al.* 2002) and by the OECD regarding *ex situ* conservation in appropriate Biological Resource Centres (BRCs) (OECD 2001). National policies must support the living and dead biotic collections held by museums, herbaria, culture collections, botanical gardens etc.

The information available in collections world-wide is enormous, but is only as good as the taxonomic work that provides the foundation for using it. Over 140,000,000 digitised records are currently available through the Global Biodiversity Information Facility (GBIF: http://www.gbif. org/). More digitisation of data associated with agriculturallyimportant organisms would provide a massive increase in analytical potential so that systems such as Ecological Niche Modelling (Peterson 2001) could be used in the management of both native and invasive species. Collection-holding institutes need to be made aware of the value of these holdings for agriculture and assisted in prioritising and undertaking specimen digitisation.

The core issue of identification is associated with a series of trade-offs and risks. Risk of misidentification can be reduced by expert attention, but this increases risks of financial or crop health penalties due to delay. Risk mitigation requires expertise and problem to be brought closer together. Three strands to this solution are capacity building, providing identification tools, and facilitating communication with distant experts.

Taxonomic capacity worldwide is currently insufficient to meet needs and, in many countries, is declining (SCBD 2007); it must be increased and sustained. Capacity needs include training of personnel and provision of necessary tools: microscopes, libraries, reference collections, computers. Capacity is most effectively built through cooperation and pooling of resources using committed technical cooperation partnerships of national or regional institutions (King 2001; SCBD 2002; OECD 2007), perhaps ultimately linked with establishment of a global, virtual BRC. Probably the most comprehensive existing global taxonomy network is that of BioNET-INTERNATIONAL (http://www.bionet-intl.org/opencms/opencms/index1.jsp), with partner institutions spanning over 100 countries and a strong record in developing taxonomic capacity relevant to agricultural biodiversity.

Networks make best use of limited resources by facilitating communication, increasing the pool of expertise, avoiding duplication of effort, and coordinating ongoing efforts in training, collections development and technology use. Communication between network members will include exchange of images and access to digitised literature via the internet, requiring appropriate hardware, software and bandwidth. However, many networked institutions could have a greater impact on agricultural challenges if mandated to engage with farmers and respond to their needs. Policies and legislation must also facilitate cross-border transfer of biological specimens. To be effective, identification tools should be tailored to enable users to rapidly identify organisms of highest interest within their context (e.g. soil biota, pests of a single crop, IAS, damage type). However, academic taxonomic research agendas tend to focus on taxa rather than functional groups; species descriptions and identification keys are more likely to appear in scholarly journals than field guides. To change requires altering institutional performance indicators and research criteria, perhaps through incentive measures and policy changes. It may also require a 'new' layer of people to produce such tools. A helpful target at policy level might be for time schedules for revising public taxonomic information on agriculturally-important taxa (in the manner of the CABI pest maps), as well as for proportions of these so covered.

DNA sequence data are increasingly used for identification. A section of the CO1 gene - a 'DNA barcode' – is increasingly used to identify animal species (http://barcoding.si.edu/). However, DNA barcoding does not yet work adequately for all species, and the majority of species for which it might work are not yet characterised by a barcode. Although promising, this solution is not in place and implementation will require significant development costs and taxonomic work. As barcodes are collected, vouchers need to be both authoritatively identified and retained, noting possible linkage of loss of traditional taxonomic expertise with misidentification of source material (Bridge *et al.* 2004).

With insufficient local capacity come charges for identifications. These cannot easily be eliminated; economic pressures can demand charges, since providing identifications costs money to someone. Some institutions have had to stop such provision because of the absence of a sustainable economic model. New financial models are needed, perhaps incorporating the bilateral aid model of the market-place Plant Clinics pioneered by the Global Plant Clinic or the no-charge Pacific internet network 'Pestnet', which has received over 5000 e-mail queries and answers over 7 years. However, some questions to Pestnet should arguably have been covered in the funding of the projects of which they were part, and some respondents are employed by institutions that would normally charge.

A compilation of species names is being made available by initiatives such as the Catalogue of Life (a partnership of Species 2000 and ITIS) and GBIF, which draw upon the work of taxonomists worldwide. Key challenges remain e.g., mapping between different taxonomic opinions, and between scientific names and vernacular names from different languages and representing different local taxonomies.

Dissemination of information has to be improved and targeted (Lyal 2004). The internet will inevitably form a major pathway, although constraints of hardware expense, technical expertise, and low bandwidth in many agriculturally centred developing country economies limit the penetration of the user sector. Quality control is needed

searches using standard commercial search engines can return results pertaining to the wrong organism, or nonbiotic objects with the same name. Nevertheless, current work on standards and interoperability will lead to a fully digitized biodiversity data 'digital corpus', which will enable knowledge brokers to 'cut and slice the data warehouse' to deliver information just as use of keywords associated with bibliographic data (from a well structured thesaurus such as the CABI Thesaurus) can relatively easily generate subsets focussed on specific topics. The traditional 'user' and 'provider' dichotomy will disappear so that farmers will contribute as well as acquire information. To realise this vision, however, the corpus must be populated with information, taxonomists and others must start creating output in the appropriate format rather than as plain text, and agricultural users and taxonomists must work together to ensure that the full range of taxonomic benefits can be enjoyed by agriculture.

Meeting the needs expressed above requires changes in institutional and individual priorities, capacity development, and building and populating novel resources for information provision. These in turn demand clarity on the needs, a roadmap to meeting them, and policy creation and promotion. Collaboration between the CBD (GTI), IPPC, FAO and others is important, and policy statements at global level must be mirrored nationally. Implementation will require economic will on the part of governments and donors. An overarching need is for awareness-raising activities to assist understanding by senior managers and plant health scientists of the extent of the needs of agriculture for taxonomic involvement (Naumann *et al.* 2002; Evans *et al.* 2002; SCBD 2003).

Taxonomy is essential for agriculture. With appropriate policies backed by detailed understanding of what is needed, and the will to work across sectors and make a difference, the needs will be met.

REFERENCES

- Anon. 2003. Editorial. Why are crop wild relatives important? Crop Wild Relative 1: 5.
- APIS. 2003. Plan of Action of the African Pollinator Initiative. http:// www.fao.org/ag/AGP/AGPS/C-CAB/Castudies/pdf/apipoa.pdf (Accessed 1/1/2008)
- Brehm, J. M., N. Maxted, B. V. Ford-Lloyd, and M. A. Martins-Loução. 2007. National inventories of crop wild relatives and wild harvested plants: case-study for Portugal. *Crop Resources and Crop Evolution* Published Online at http://www.springerlink.com/content/ a56v59k4q5632324/(Accessed 12/12/2007)
- Bridge, P.D., B.M. Spooner, and P. J. Roberts. 2004. Reliability and use of published sequence data. *New Phytologist* 161: 15.
- Carpenter, S.R., P.L. Pingali, E.M. Bennett, and M.B. Zurek, (Eds.). 2005. Ecosystems and human well-being: scenarios: findings of the Scenarios Working Group, Millennium Ecosystem Assessment. Millennium Ecosystem Assessment Series, 2. Island press.
- Evans, G., K.Y. Lum, and L. Murdoch. 2002. Needs assessment in taxonomy and biosystematics for plant pathogenic organisms in countries of South East Asia. A report for AusAID. (available from the Office of the Chief Plant Protection Officer, Department of Agriculture, Fisheries and Forestry Australia, Canberra, Australia). 67 pp.
- Hawksworth D.L. 2001. The magnitude of fungal diversity: the 1.5 million species estimate revisited. *Mycological Research* 105: 1422-1432.
- Heywood, V., A. Casas, B. Ford-Lloyd, S. Kell, and N. Maxted. 2007. Conservation and sustainable use of crop wild relatives. Agriculture.

Ecosystems & Environment 121 (3): 245-255.

- Kell, S., V. Heywood, and N. Maxted. 2005. Towards a Global Strategy for Crop Wild Relative Conservation and Use. Crop Wild Relative 5: 11.
- King, N. 2001. Overcoming the taxonomic impediment to sustainable development – BioNET-INTERNATIONAL, the Global Network for Taxonomy. *Strelitzia*, 12, 63-75.
- Klein, A.-M., B. E. Vaissière, J. H. Cane, I. Steffan-Dewenter, S. A. Cunningham, C. Kremen and T. Tscharntke. 2006. Importance of pollinators in changing landscapes for world crops. Proc. R. Soc. B (2007) 274, 303–313 doi:10.1098/rspb.2006.3721
- Knapp, M. and F. Haas. 2007. Protecting African tomatoes from the spider mite. Correct species identification - correct control strategy: Molecular tools help identify an invasive alien pest species in Africa. Case Study 40 in: R. Smith, H. Davies and N. King (Eds.), *Why Taxonomy Matters*. BioNET-INTERNATIONAL, Egham, UK. http://www.bionet-intl.org/ opencms/opencms/caseStudies/caseStudies/case_0040.html(Accessed 12/12/2007)
- Kremen, C., N. M. Williams, and R. W. Thorp. 2002 Crop pollination from native bees at risk from agricultural intensification. Proc. Natl Acad. Sci. USA 99, 16 812–16 816. (doi:10.1073/pnas.262413599)
- Kwapong, P. 2003. Case studies on conservation of pollination services as a component of agricultural biological diversity title: African Pollinators Initiative – Ghana. http://www.fao.org/ag/agp/agps/c-cab/castudies/ pdf/6-012.pdf (Accessed 13/12/2007)
- Loiácono, M.S., P. Neuenschwander, and G.W. Watson. Description of a new mealybug species saves US\$ billions across Africa. Case Study 2 in: R. Smith, H. Davies and N. King (Eds.), *Why Taxonomy Matters*. BioNET-INTERNATIONAL, Egham, UK. (Accessed 30/12/2007)
- Lyal, C.H.C. 2003. Major biocontrol agent nearly missed. Case Study 22 in: R. Smith, H. Davies and N. King (Eds.), *Why Taxonomy Matters*. BioNET-INTERNATIONAL, Egham, UK. (Accessed 30/12/2007)
- Lyal, C.H.C. 2004. Strategy and symbioses: Building capacity for the GTI in Asia. pp. 80-88 in Shimura, J., Ed., *Building Capacity in Biodiversity Information Sharing* 2003, NIES, Japan, 254pp.
 Naumann, I.D. & Jusoh Md. Mamat. 2002. Needs assessment in
- Naumann, I.D. & Jusoh Md. Mamat. 2002. Needs assessment in taxonomy of arthropod pests of plants in countries of South East Asia: Biosystematics, collection and information management. A report for AusAID (available from the Office of the Chief Plant Protection Officer, Department of Agriculture, Fisheries and Forestry Australia, Canberra, Australia). 118 pp.
- **OECD. 2001.** Biological Resource Centres Underpinning the Future of Life Sciences and Biotechnology. Paris, ISBN 92-64-18690-5 http://oecdpublications.gfi-nb.com/cgi-bin/oecdbookshop.storefront. (Accessed 1/12/2007).
- OECD. 2007. OECD Best Practice Guidelines for Biological Resource Centres, http://www.oecd.org/dataoecd/6/27/38778261.pdf. (Accessed 1/12/2007)
- Peterson, A. T. 2001. Predicting species' geographic distributions based on ecological niche modeling. *The Condor*, 103, 599–605.
- SCBD. 1998. COP decision IV/1: Report and recommendations of the third meeting of the Subsidiary Body on Scientific, Technical and Technological Advice, and instructions by the Conference of the Parties to the Subsidiary Body on Scientific, Technical and Technological Advice. D.Global Taxonomy Initiative. http://www.biodiv.org/decisions/default. aspx?m=COP-04&id=7124&lg=0 (Accessed 3/1/2008)
- SCBD. 2000. COP decision V/9: Global Taxonomy Initiative: Implementation and further advance for the Suggestions for Action. http://www.biodiv. org/decisions/default.aspx?m=COP-05&id=7151&lg=0 (Accessed 3/1/2008)
- SCBD. 2002. COP decision VI/8: Global Taxonomy Initiative.http://www. biodiv.org/decisions/default.aspx?m=COP-06&id=7182&lg=0(Accessed 3/1/2008)
- SCBD. 2003. UNEP/CBD/SBSTTA/9/INF/16. Global Taxonomy Initiative: Progress and implementation of the programme of work. http://www. biodiv.org/doc/meetings/sbstta/s bstta-09/information/sbstta-09-inf-16en.pdf (Accessed 3/1/2008)
- SCBD. 2007. Guide To The Global Taxonomy Initiative. CBD Technical Series, 30, pp. viii + 195. http://www.cbd.int/doc/publications/cbd-ts-30.pdf (accessed 14/12/2007)
- Smith, R. S. and C.H.C. Lyal. 2008. Taxonomy for Invasive Alien Species management. Part I: a global assessment of needs – what taxonomic support is necessary for IAS management? Unpublished report to Defra, UK.
- Wilson, K., J. Shimura, C.H.C. Lyal, and I. Cresswell, (Eds). 2003. Building Capacity: Bangladesh to Bali and Beyond. Report of First Global Taxonomy Initiative Workshop in Asia. 75pp NIES, Tsukuba.