Ghana J. Sci. **47** (2007), 59-67

STRATEGIES FOR SUSTAINABLE CONSERVATION AND USE OF LEGUME GENETIC RESOURCES IN GHANA

L. M. Aboagye
CSIR-Plant Genetic Resources Research Institute, P. O. Box 7, Bunso, Ghana

Abstract

Strategic development of conservation technologies in plant genetic resources (PGR) is the backbone for agricultural development, food security and sustainable livelihood, now and for the future. In this paper, strategies for conservation of legumes pertaining to the collection, characterization, evaluation and conservation are presented. An integrated approach to legume PGR management in germplasm collection, characterization and evaluation, together with genetic conservation strategies both *in situ* and *ex situ*, for effective utilization is stressed. Emerging approaches such as diversity block, community biodiversity register and biodiversity fairs for genetic advancement of legumes are discussed. Collaborative efforts of farmers, scientists and policy makers in networking, capacity building, information sharing on legume PGR, and policy formulation on seed laws, quality, financing, and private-public sector partnership in legume seed development would enhance the sustainable utilization of legume genetic resources for food and agriculture.

Résumé

Aboagye, L. M.: *Les stratégies pour la conservation durable et l'utilisation de resources génétiques de légumineuse au Ghana.* Le développement stratégique de technologies de conservation en resources génétiques de la plante (RGP) est l'épine dorsale pour le développement agricole, la sécurité alimentaire et le moyen d'existence durable, actuellement et pour l'avenir. Dans cet article, les stratégies pour la conservation de légumineuses se rapportant à la collection, la caractérisation, l'évaluation et la conservation sont présentées. Une approche intégrée à la gestion de RGP légumineuse en la collection, la caractérisation et l'évaluation de germeplasme considérée conjointement avec les stratégies de conservation génétique *in situ* et *ex situ* pour l'utilisation efficace est soulignée. Les approches émergeantes telles que le bloc de diversité, le registre de la biodiversité communautaire et les foires de biodiversité pour le progrès génétique de légumineuse sont discutés. Les efforts fait en collaboration avec les agriculteurs, les scientifiques, les décideurs, pour le travail en réseau, le renforcement de capacité, le partage d'information sur RGP légumineuse, ainsi que l'élaboration de principes sur les législations de graine, la qualité, le financement, l'association entre le secteur privé-public dans le développement de graine légumineuse, amélioréraient l'utilisation durable de resources génétiques de légumineuse pour l'alimentation et l'agriculture.

Introduction

The development of strategies for conservation and use of plant genetic resources (PGR) is of great importance in the development of crop varieties of high yield per unit area, that would increase the income of farmers, reduce poverty and enhance sustainable food security. In Ghana, a number of indigenous and exotic legumes are cultivated and consumed. Depending on the area under cultivation and quantity consumed, they are termed major or minor. The major legumes are cowpea (*Vigna unguiculata* (L.) Walp.), groundnut (*Arachis hypogaea*) and soybean (*Glycine max*). The minor ones are African yam bean (*Sphenostylis sternocarpa*), bambara groundnut (*Vigna subterranea*), French beans

(*Phaseolus vulgaris*), Jack bean (*Canavalia ensiformis*), Kertings groundnut (*Kertingsgiella geocarpa*), Lima bean (*Phaseolus lunatus*), pigeon pea (*Cajanus cajan*), sword bean (*Canavalia radiata*), velvet bean (*Mucuna prueriens*) and winged bean (*Psophopcarpus tetragonolobus*) (Aboagye, 2005).

Out of the 13 legumes, seven are of African origin and, thus, have become adapted to the African environment (Aboagye, 2003ab). Wild relatives of these crops include cowpea, e.g. *Vigna reticulata,* and velvet bean. Some of the local pulses are endemic in certain areas of the country, e.g. *Kerstinsgiella geocarpa* (*Macrotyloma geocarpa*), in the Northern Region and African yam bean (*Sphenostylis sternocarpa*) in the Volta Region. These species are in danger of being extinct due to rampant bush fires, land clearing, road construction, human settlement and over grazing (Amoatey *et al*., 2000ab). Some of the wild species have been collected and conserved, and it would be appropriate to collect such useful, or potentially useful, species for conservation and use. The objectives of this paper were to review strategies pertaining to germplasm collection, characterization and conservation of legumes genetic resources that would provide a holistic approach for effective conservation and utilization.

Experimental

Collection of germplasm

Plant genetic resources (PGR) collection is aimed at collecting germplasm variability of different plants, their wild relatives and related species. The variability is revealed by different species, within species, cultigens and also their agro-ecological/ phyto-geographical distribution (Arora, 1996). Principally, there are two kinds of collecting missions. These are specific and broad based. Specific mission is aimed at collecting variability in a particular crop, cultigens or materials of special attributes, as well as collecting specific wild relatives, weedy types and related taxa. Broad based mission is aimed at tapping maximum diversity in different crops, occurring in the region to be explored (multi crop collection). Plant genetic resources organisations undertake both missions depending on the priorities, specific needs, salvaging endangered/endemic resources, land races and wild types (Williams, 1978).

Germplasm collecting involves the application of both theoretical knowledge on population sample and practical know-how in the understanding of the overall plant diversity and environmental control, including socio-economic and the culture of the farming societies. Efficient planning is essential so as to capture the widest variability as much as possible. Exploration planning involves deciding the route of expedition and site for collection, the gene pool sampling strategy and equipment to be used (Chan, 1985). The team composition and the duration of the collection should be determined, as well as other logistics, e.g. survey/collecting items, published materials and medicine for use by the collectors. Collectors should be accompanied by a guide and must approach the chiefs and opinion leaders who may have the indigenous knowledge of the crops (Arora, 1981).

Germplasm collection and exploration has been undertaken primarily by trekking from place to place to obtain the materials. There have been some inefficiencies in the collection. Though farmers may be cultivating these crops, they may not have the scientific knowledge associated with them. Time of the collection may not coincide with the time of harvesting or cultivation, when the crops can be seen in the field and variations observed. Essentially, a good knowledge of the area and the types of crops to be surveyed and documented is essential before embarking on collection expeditions.

Characterization, preliminary evaluation and further evaluation

Germplasm has little or no practical use until its attributes are evaluated and made known to breeders and stakeholders. Germplasm evaluation and characterization is the description of the materials in collection. It involves the receipt of the materials, growing for seed increase, characterization, evaluation (involving the study of the morphology, physiology and development, and resistant or tolerance to diseases and pests of the germplasm). The basic steps to follow are preparation of descriptor list, seed increase, data collection and management (Chapman, 1989; Gupta *et al*., 1995). It should be noted that since evaluation and characterization needs may change in response to changes in agricultural practices, farm economics, breeding strategies, pests and diseases, aspects of detail evaluation work should always be open ended and need not be confined to characters in the descriptor list. Further characterization and evaluation is the recording of potential agronomic characters that will determine the usefulness of an accession for a specific purpose and circumstance. These include stress tolerance, disease, pests and quality evaluation.

Genetic conservation

Conservation is the management of human use of the biosphere so that it may yield the greatest sustainable benefit to current generations while maintaining its potential to meet the needs and aspirations of future generations (IUCN-UNEP-WWF, 1980). Thus, conservation embraces preservation, maintenance, sustainable utilization, restoration and enhancement of natural environment. Conservation of materials is to ensure stability, through proper conservation methods, aimed at reducing to minimum the genetic variation and availability of the materials (Bretting & Duvic, 1997).

In situ *conservation.* This is the conservation of the ecosystem and natural habitats and the maintenance and recovery of viable populations of species in their surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties. *In situ* conservation of agricultural biodiversity is the maintenance of the diversity present in and among populations of the many species used directly in agriculture or used as source of genes in the habitats, where such diversity arose and continued to grow (Altieri & Merrick, 1987; Brush, 1991).

Ex situ *conservation.* This includes the conservation of species outside their natural habitats and man-made conditions pertaining to their survival. The principal aim in PGR conservation in gene banks for the conservation of seed, as an *ex-situ* conservation practice, is to provide ideal storage conditions so that the viability of the materials are extended as much as possible. Successful seed storage depends on effective control of temperature, seed moisture and humidity (Powel, 1977). Seeds of cowpea, groundnut, bambara groundnut and lima bean show orthodox behaviour and can withstand dehydration to a moisture level of 3-7 per cent or less without damage and kept at the desired temperature (Bennett-Lartey, 1991).

Improving the longevity of seeds. In order to ensure the quality and long life span of the seeds, four steps must be taken. These are 1. Seeds must be dried, devoid of inflorescence materials and floral, structures; 2. An accession should be at least 12,000 seeds for long term storage, especially for heterogeneous materials in order to represent the variation in the original sample, and sufficient seeds should be available for viability monitoring and regeneration; 3. Seeds must be dried to the required moisture content, and duplicate samples must be kept at an alternate centre.

Loss of viability results in genetic change and must be regenerated when the viability falls below 85 per cent. In view of the above, maintenance of seeds under good storage conditions is the important conservation aspect and must be specified and used for retention and prolongation of viability (Gene Bank Standards,1994).

Development of core collection. Gene banks consist of repositories of a large number of accessions that have been accumulated to prevent their disappearance due to genetic erosion, genetic vulnerability and genetic wipe out (Harlan, 1975). For proper utilization of legume genetic resources with the greatest diversity, the core collection concept was suggested (Brown, 1989). A core collection can be defined as a limited set of accessions of a plant species and its wild relatives which represent the minimum of repetitiveness, the diversity of a plant species and its wild relatives. This subset of a whole collection provides potential users with a greater amount of available genetic variation of a crop in a workable number of accessions. Several methods for establishing a core collection have been proposed (Bisht, Mahajan & Petel, 1998; Mahajan et al., 1996; Noirot, Hammon & Anthony, 1996).

The main purpose of core collection is to provide efficient access to the whole collection which would be representative of the diversity at hand. It would be useful to users, seeking new characters which require screening techniques not possible with a large collection. Core collection may also have a role to play in gene bank management from the view point of distribution of representative materials. A core collection can also serve as a logical and efficient starting point of projects involving screening of a large germplasm collection for sources of desirable alleles. The effectiveness of core collection as a tool for understanding and utilization of plant germplasm will depend on extensive evaluation of the core collection. It will also depend on the range and representativeness of the genetic diversity of the core, compared to the reserve collection (Bisht, Mahajan & Petel, 1998; Skroch *et al*., 1998). Core collection can be developed using different kinds of information: passport data, characterization and evaluation data, either alone or in combination of these data (Basigalup, Barnes & Stucker, 1995; Diwan, Bauchan & Mcintosh, 1994, 1995; Taba *et al*., 1998; Hollbrook, Anderson & Pitmann, 1993).

The geographic origin of the accessions provides indirect evidence of diversity, since adaptation to difficult environmental conditions can be inferred, and accessions from the same origin can be assumed to share a larger portion of their gene pool (Peters & Martinelly, 1989). Evaluation and characterization data based on strongly inherited characters of importance to the breeder can further improve the identification of the phenotypic clusters within broad geographic groups. For the maximization of diversity and to reduce redundancy of identical genotypes, the frequencies of entries in the most represented class should be reduced while increasing the frequencies of the most rare types. Proper understanding of genetic diversity among the constituents of germplasm collection and their proper documentation is essential for developing representative sets.

Strategies for sampling for core collection. In developing core collections there are several strategies that can be used to sample a representation of the materials. These include (a) random sampling without replacement and (b) random-systematic by chronology. In this method, the whole collection is listed and planted in the field in numerical sequence by their accession numbers. This represents the order in which the accessions were accepted in the gene bank. The accessions may appear in groups by place of collection; (c) random-stratified by geographic origin and frequency. This strategy is by fixing the total number of selected accessions and selecting at random a fixed number of accessions from each area of origin in proportion to the number of accessions from each area (Basigalup, Barnes & Stucker, 1995); (d) random-stratified by log frequency of accessions by geographic origin – the logarithm of the frequency of accessions from each area is used to establish the number of accessions from each area (Diwan, Bauchan & Mcintosh, 1994); and (e) random-stratified by canonical variables. This strategy is based on the concept of the pre-existing information about the collection, and it is used to stratify the accessions on phenotypic as well as geographic basis (Diwan, Mcintosh & Bauchan, 1995).

Molecular characterization. This is the identification of plants using molecular techniques to detect the presence of specific deoxy-ribonucleac acid (DNA) sequence or combinations of sequences, and it is based on nucleic acid hybridization or polymerase chain reaction (PCR) (Susan, 1993). Plant identification using molecular techniques can be used in plant varietal protection, where new varieties can be distinguished from old or closely related types. It can be used for verification, identification, purity and stability studies. Analyses of DNA allow direct assessment of variation (Tao *et al*., 1993).

In molecular characterization, markers are used and these include the restricted fragment length polymorphism (RFLP) which involves the digestion, by restricting endonuclease of total genomic DNA followed by hybridization with a radioactive labelled probe. Other methods include the randomly amplified polymorphism, DNA (RAPDs) which is used to detect DNA sequence polymorphism, and provides the estimation of genetic diversity in plants and to construct genetic maps, as well as the amplified fragment length polymorphism (AFLP), which is a random PCR based marker system and involves the digestion of genomic DNA and ligation of double stranded adapters (Chalmers *et al*., 1992; Lin *et al*., 1996; Sharma, Knox & Ellis, 1996; Kearsey, 1997).

Genetic advancement

Advancing the use of germplasm includes the creation of awareness about the importance of agro-biodiversity, improving seed flows within and between the communities and the characterization of land races *in situ* through activities such as diversity fair, diversity theatre, community biodiversity register and diversity block (Brush, 1991).

Diversity fair. Traditionally, local seed markets and fairs constitute important seed exchange system in villages and provide the opportunities for the exchange of seeds and indigenous knowledge. Commercialisation of private sector seed production and distribution is threatening informal sector, leading to the erosion of indigenous knowledge and the management of PGR (Lonnette, 1996). This can be circumvented by the organization of fairs on only indigenous landraces. One area where variability can be observed and relevant information obtained is during agricultural shows, where farmers exhibit products and exchange information (Sthapit, 2001a).

In Ghana, national farmers' days are held to honour some selected farmers and to exhibit their produce. Invariably, these selected farmers produce crops of high yield per unit area (improved types). However, these farmers may possess other forms of the various crops for several reasons. The concept of PGR encompasses collecting and studying the variability of obsolete and modern cultivars. Some farmers may have obsolete materials or landraces. Organization of diversity fairs raises the awareness and encourages farmers to maintain maximum genetic diversity and to promote access to diversity. Diversity fairs are organised to: (i) recognize farmers who possess good knowledge and act as sources of information for others, (ii) locate areas of high diversity, (iii) identify and locate the most endangered landraces, (iv) identify key custodians who maintain high diversity and reasons of doing so in terms of use, economic, cultural, religious, breeding and ecological values, (v) prepare an inventory of crop genetic resources, and (vi) empower local communities to have control over their genetic resources and develop a sense of ownership using the concept of the community gene banks to link formal and informal seed supply system, in a public-private partnership approach.

Diversity theatre. Drama raises the awareness about the importance of local crop diversity while celebrating local culture and art forms. The drama may be based on traditional stories and myths that relate to local crops, and organised and performed by local actors and community groups. These include village workshops, rural poetry journey, folk song competition and local food fairs.

Participatory breeding. Participatory breeding is based on the theory that diversity may be both conserved and improved between farmers and researchers (Amanda, 2000). Farmers shape the diversity of their crops through decisions affecting the selection and maintenance of crops with specific agro-morphological traits and adaptive characteristics (Chang, 1985). Participatory breeding strengthens the ability of researchers to locate diversity, to identify uses for different crops, and to characterise the traits that farmers perceive as valuable (Sperling & Berkowitz, 1994). Participatory breeding allows communities and individuals to establish a degree of ownership over research, which is important in improving the equity of research relationships and the sustainability of the resulting conservation strategies. Participatory plant breeding and participatory varietal selection are used to develop varieties with farmers according to their preferences but with access to germplasm and technologies from the gene bank. In this process, the formal plant breeding sector acknowledges the farmer's role in plant breeding and PGR management (Sthapit, 2001b).

Diversity block. This is a participatory research technique to characterise local landraces under typical farmer management conditions. The germplasm characterized under diversity block may be selected from crops displayed in diversity fairs or from the community members' seed stock. Farmers use traditional practices to manage the crops while scientists observe and record agro-morphological characteristics.

Community biodiversity register (CBR). In this register, records are kept by community members about local crop biodiversity and associated knowledge. The register is designed to meet the farmers' priorities, and easily maintained and accessed by farmers or local institutions to act as sustainable tool for biodiversity conservation (Sthapit, 2001b). It functions as a decentralized community gene bank. Information in the register includes landrace names, name of donors, associated local knowledge and uses, the traditional and non-traditional passport data like agro-morphological characteristics, agro-ecological characteristics and the cultural significance. The information is contributed by farmers and maintained centrally, while the seeds are stored by individual households with access open to all community members. Community biodiversity registers and community gene banks are mechanisms for linking rural communities to formal seed supply and conservation systems, and should be encouraged. The register allows communities to monitor the level of genetic diversity and prevent extinction of rare varieties, which may then be preserved in collaboration with *ex situ* conservation programmes (gene banks).

Conclusion

The sustenance of collection, characterization and conservation of crop species need a holistic approach involving farmers, scientists, policy makers and the general public. In Ghana, a lot of legume germplasm has been collected, with cowpea, groundnut, and bambara groundnut topping the list. Pigeon pea and sword bean had the lowest accessions (Aboagye, 2003a). Agro-morphological characterization and evaluation information had been obtained. However, they are insufficient in elucidating the genetic diversity in the accessions for immediate use. Molecular characterization information should be used as a complement or a supplement to agromorphological data for effective utilization of legume germplasm.

Recommendations

The above activities pertaining to the effective conservation and utilization would require capacity building in terms of training and upgrading of skills of scientists and technicians. The establishment of national, sub-regional and regional networks would strengthen information sharing, through the Internet, organization of problem solving fora, regular publication of findings through conferences and newspaper publications. The establishment of a centre of excellence with advance facilities for PGR conservation, through the development of infrastructure and acquisition of equipment would enhance the utilization of the legume genetic resources under conservation.

A policy must be formulated for the integration of formal PGR systems (gene banks) with the informal system, i.e. local farmers. The local farmers are mainly resource poor but they provide most of the seeds in gene banks. They have the indigenous knowledge about legumes and possess greater diversity of crops. Farmers must, therefore, be linked to national gene banks and research institutes in developing crop varieties with desirable characteristics that would enhance their processing, storage and utilization.

Genetic advancement in the breeding of legumes could be achieved through conventional breeding with the support of participatory varietal selection involving farmers. The establishment of a systematic utilization of legume PGR should be of utmost importance, since the modalities of utilization are evolving, as breeders have more and more access to new tools for diversity studies with the level of utilization becoming closer to the gene, rather than the genotype. Finally, all stake-holders and the general public should be sensitized on the conservation and use of legume genetic resources to ensure perpetual use for the sustenance of food security.

References

ABOAGYE, L. M. (2003a) Evaluation of information on genetic resources activities of some legumes in Ghana. *Ghana Jnl agric. Sci.* **36**, 31-40.

ABOAGYE, L. M. (2003b) Evaluation of genetic resources enhancement in some legume genetic resources in Ghana. *J. Ghana Sci. Ass.* **5**, 123-131.

ABOAGYE, L. M. (2005) Genetic resources of some legumes species in Ghana: Origin, characteristics and conservation. *Technical Report of the Plant Genetic Resources Institute 2005,* Bunso, Ghana. 12 pp.

ALTIERI, M. A. & MERRICK, L. (1987) *In situ* conservation of crop genetic resources through maintenance of traditional farming systems. *Econ. Bot.* **41**, 86-96.

AMANDA, B. K. (2000) Tools for participatory research on crop and tree diversity. In *Participatory approaches to the conservation and use of plant genetic resources.* (E. Friss-Hans and B. Sthapit, ed.) Rome, Italy.

AMOATEY, H. M., KLU, G. Y. P., BANSA, D., KUMAGA, F. K., ABOAGYE, L. M., BENNET-LARTEY, S. O. & GAMEDOAGBAO, D. K. (2000) The African yam bean (*Sphenostylis sternocarpa*): A neglected crop in Ghana. *West Afr. J. appl. Ecol.* **1**, 53-60.

AMOATEY, H. M., KLU, G. Y. P., BANSA, D. & KUMAGA, F. K. (2000) Cultivation and use of African yam bean (*Sphenostylis sternocarpa*) in Volta Region of Ghana. *Pl. Genet. Resour. Newsl*. **124**, 13-16.

ARORA, R. K. (1996) Plant exploration and germplasm collection. In *Proceedings of the 4th MAFF workshop on genetic resources – Plant genetic resources and conservation and management. pp. 55-93*. Tsukuba Ibaraki, Japan.

ARORA, R. K. (1981) Plant genetic resources exploration and collection: Planning and logistics. In *Plant exploration and collection.* (K. L. Mehra, R. K. Arora and S. B. Wadhi, ed.), pp. 46-54. NBPGR Sc. Monograph 3. NBPGR, New Delhi.

BASIGALUP, D. H., BARNES, D. K. & STUCKER, R. E. (1995) Development of core collection for perennial Medicago plant introduction. *Crop Sci.* **35**, 1163-1168.

BENNET-LARTEY, S. O. (1991) The longevity of pea, sunflower and groundnut seeds under controlled temperature and moisture conditions. *Trop. Sci.* **31**, 9-19.

BISHT, I. S., MAHAJAN, R. K. & PATEL, D. P. (1998) The use of characterization data to establish Indian Mungbean core collection and assessment of genetic diversity. *Genet. Resour. Crop Evolut.* **45**, 127-133.

BRETTING, P. K. & DUVICK, D. N. (1997) Dynamic conservation of plant genetic resources. *Adv. Agron.* **61**: 1-51.

Brown, A. H. D. (1989) Core collection: a practical approach to genetic resources management. *Genome* **31**, 818-824.

Brush, S. B. (1991) A farmer based approach to conserving crop germplasm. *Econ. Bot.* **45**, 153-165.

Chalmers, K. J., Sprent, J. I., Simonds, A. J., Waugh, R. & Powell, J. (1992) Patterns of genetic diversity in tropical tree legume *Gliricidia* sp. revealed by RAPD markers. *Heredity* **69**, 465-472.

Chang, T. T. (1985) Germplasm enhancement and utilization. In Collection of germplasm. *Iowa St. J. Res.* **54**, 399-424.

Chapman, C. (1989) Principles of germplasm evaluation In *Scientific management of germplasm – characterization, evaluation and enhancement* (H. T. Stalker and C. Chapman, ed.) IBPGR, Rome, Italy.

Diwan, N., Bauchan, G. R. & Mcintosh, M. S. (1994) A core collection for the U.S. annual Medicago species. *Crop Sci.* **34**, 279-285.

Diwan, N., Mcintosh, M. S. & Bauchan, G. R. (1995) Methods of developing a core collection of annual Medicago species. *Theoret. appl. Genet.* **90**, 755-761.

Gene bank Standards (1994) FAO, IPGRI, Rome.

Gupta, P. N., Mathura, Rai & Kochlar, S. (1995) Characterization and evaluation of descriptors and descriptor states for vegetables. In *Genetic resources of vegetable crops management, conservation and utilization.* (P. N. Gupta, Rai. Mathura and S. Kochlar, ed.) NBPGR, New Delhi.

Harlan, J. R. (1975) Our vanishing genetic resources. *Science* **188**, 618-621.

Hollbrook, C. C., Anderson, W. F. & Pitmann, R. N. (1993) Selection of core collection from U. S. germplasm collection of peanut. *Crop Sci.* **33**, 475-483.

Iucn-Unep-Wwf (1980) *World conservation strategy*. IUCN, Gland, Switzerland.

Kearsey, M. J. (1997) Genetic resources and plant breeding – identification, mapping, manipulation of simple and complex traits. In *Biotechnology and plant genetic resources conservation and use* (J. A Callow, B. V. Ford-Lloyd, B. V. and H. J. Newbury, ed.), pp. 175-202. CAB International.

Lin, J. J., Kuo, J., Ma, J., Saunders, J. A., Beard, H. S., Macdonald, M. H., Kenworth, W., Ude. G. N. & Matthews, B. F. (1996) Identification of molecular markers in soybean comparing RFLP, RAPD, AFLDP DNA. *Pl. Molec. Biol. Reptr* **14**, 156-169.

Lonette, D. & Small, M. (1996) Genetic diversity in maize seed in a Mexican community: Implications for *in situ* conservation of maize. *NGR* Paper **96/03.** CMMYT, Mexico.

Mahajan, R. K., Bisht, I. S., Agrawal, R. C. & Rana, R. S. (1996) Studies on South Asian okra collection: Methodology for establishing a representative set using characterization data. *Genet. Resour. Crop Evolut.* **43**, 249-255.

Noirot, M., Hammon, S. & Anthony F. (1996) The principal component scoring: A method for constituting a core collection using qualitative data. *Genet. Resour.Crop Evolut.* **43**, 1-6.

Peeters, J. P. & Martinelly, J. A**.** (1989) Hierachical cluster analysis as a tool to manage variation in germplasm collection. *Theoret. appl. Genet*. **78**, 42-48.

Powell, A. A. & Mtathews, S. (1977) Deterioration changes in pea seed (*Pisium sativum*) stored in humid or dry conditions. *J. exp. Bot.* **28**, 225-234.

Sharma, S. K., Knox, M. R. & Ellis, T. N. H. (1996) AFLP analysis of the biodiversity and phyllogens of lens and its comparison with RAPD analysis. *Theoret. appl. Genet.* **93**, 751-758.

Skroch, P. W., Nienhuis, J., Beede, S., Tohme, J. & Pedraza, F. (1998) Comparison of Mexican common bean (*Phaseolus vulgaris*) core and reserve collection. *Crop Sci.* **38**, 488-496.

Sperling, L. & Berkowitz, P. (1994) *Partners in selection: Bean breeders and women bean experts in Rwanda.* CGIAR Washington, D. C. .

Sthapit**,** B. (2001a) *Diversity fair and in-situ conservation on-farm.* In situ *Conservation Methods and Concepts.* Flier No. **1.**

Sthapit, B. (2001b) Options of enhancing benefits of local crop diversity through public awareness, market and non-market incentives and grass root strengthening. In-situ *Conservation Methods and Concepts.* Fliers. No. **11**. IPGRI.

Susan, E. W., Isaac, P. G. & Slater, R. J**.** (1993) Random amplified polymorphic DNA (RAPD) markers for genetic analysis in *Allium*. *Theoret. appl. Genet.* **86**, 497-504.

Taba, S., Diaz., France, J. & Crossa, J**.** (1998) Evaluation of Caribbean maize accessions to

develop a core subset. *Crop Sci.* **38**, 1378-1386.
TAO, Y., MANNERS, J. M., LUDLOW, M. M., & HANZEL, R. G. (1993) DNA polymorphism in grain sorghum (*Sorghum bicolour* L. Moench). *Theoret. appl.Genet.* **86**, 679-688.
WILLIAMS, J. T. (1978) Plant exploration: Capturing genetic variability. In *Conservation of plant genetic resources*, pp. 14-24. *Proceedings of British Association for Adv. of Science Univ. of Ashton Birmingham.*

Received 18 Jul 05; revised 28 Nov 06.