Plant genetic resources management in Ghana: Some challenges in legumes

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ABSTRACT

Legume genetic resources play a very significant role in supplying food for man and livestock, and in improving soil fertility. With this recognition, efforts toward its sustainable use should be the ultimate goal in its conservation. The Plant Genetic Resources Research Institute, serving as the national gene bank of Ghana, together with other stakeholders, had made strenuous efforts in managing the legume genetic resources in the country, which constitute the basic 'building blocks' for crop improvement. However, several challenges hamper effective and sustainable management and use. This paper outlines problems confronting legume genetic resources in the area of germplasm collection, characterization, evaluation, regeneration, multiplication, distribution, utilization and conservation, together with suggested solutions that would ensure the effective and efficient management of legume genetic resources in Ghana.

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RÉSUMÉ

ABOAGYE, L. M.: *La gestion des resources génétiques de plant au Ghana: Quelques défis en légumineuses.* Les resources génétiques de légumineuses jouent un rôle très significatif dans la provision de vivres pour l'homme, l'élevage et dans l'amélioration de la fertilité du sol. En reconnaissance de ce rôle, des efforts envers son utilisation durable devraient être l'objectif final en sa conservation. L'Institut de Recherche des Resources Génétiques de la Plante, servant comme un bagage génétique national du Ghana, ainsi que d'autres parties prenantes, avaient fait des efforts acharnés pour la gestion des resources génétiques de légumineuse dans le pays, qui constituent les 'composantes' de base pour l'amélioraton des cultures. Toutefois, il y a beaucoup de défi gênant la gestion et l'utilisation efficace et durable. Quelques problèmes de resources génétiques de légumineuse auxquels nous sommes confrontés dans le domaine de la collection de germeplasme, la caractérisation, l'évaluation, la régénération, la multiplication, la distribution, l'utilisation et la conservation sont exposées en grandes lignes, avec des solutions suggérées qui assureraient la gestion effective et efficace des resources génétiques de légumineuse au Ghana.

Introduction

Plant genetic resources (PGR) are the germplasm of plants containing useful characters of actual or potential values. They are the basic raw materials for improving crops today and for the future. Genetic resources of plants could be found in wild and weedy relatives, landraces of plants of pre-scientific agriculture, bred varieties which are no longer being used, and advanced varieties in use now, as well as genetic stocks obtained through mutation or DNA transformation (Creech & Reits, 1971; Dodds & Watanabe, 1995). The PGR activities include collection, characterization, evaluation, conservation, regeneration, documentation, distribution, and use.

Managing orthodox seeds (which include legumes) in gene banks seems to be the most convenient and economical method for conserving seeds. The seeds are dried to the appropriate moisture content and stored at

-20 °C. However, depending on the moisture and oil contents, they must be stored at different conditions (Genebank Standards, 1994; Verucci, Ross & Cranne, 1994).

Worldwide, about six million accessions of various plants are being conserved (Hammer, 1998). In Ghana, 13 species of legumes have been collected, characterized, evaluated, distributed, documented, and conserved (Aboagye, 2003a). The following legumes are now under conservation: African yam bean (*Sphenostylis sternocarpa*), bambara groundnut (*Vigna subterranea*), cowpea (*Vigna unguiculata*), French beans (*Phaseolus vulgaris*), groundnut (*Arachis hypogaea*), Jack bean (*Canavalia ensiformis*), Kerstings groundnut (*Kerstingiella geocarpa*), lima bean (*Phaseolus lunatus*), pigeon pea (*Cajanus cajan*), soybean (*Glycine max*), sword bean (*Canavalia radiata*), velvet bean (*Mucuna pruriens*), and winged bean (*Psophocarpus tetragonolobus*).

In Ghana, several institutions are managing legume germplasm in an uncoordinated manner compared to what pertains to the gene banks at the Consultative Group on International Agriculture Research (CGIAR) centres. The general management of PGR in Ghana is not the 'best', and this poses a great challenge to the way forward in legume genetic resources conservation and use.

The objective of this paper was to review some challenges facing legume genetic resources management in Ghana as a step toward the effective conservation and use of legume genetic resources.

Collection of germplasm

The collection of germplasm is the assembling of a wide range of plant species. It is normally undertaken when field surveys show that the plant is being threatened with extinction, when genetic stock needs to be increased, and when users have expressed interest in particular traits. Collection missions are undertaken within and outside the country, particularly to places of origin where broader diversity is envisaged. Collection also includes introducing materials from elsewhere to augment the genetic stock. During collection, passport data are used to collect information on the plant's agronomy, ecology, local name and usage as well as associated indigenous knowledge (Hawkes, 1981).

The challenges in germplasm collection in Ghana include lack of information on extent and distribution of diversity in existing collections under conservation, insufficient knowledge on genetic diversity of the materials at hand due to lack of detailed characterization and evaluation database. These are the results of not involving specialized staff in PGR in planning and collecting the germplasm (independent collecting expeditions by institutions in Ghana). Generally, statistical tools are unavailable for data analyses and validation of PGR work (Aboagye, 2005). Furthermore, in Ghana, some areas are inaccessible owing to the nature of the terrain and hostilities among some communities. To circumvent the above problems, the need is to define national policies considering facilities, expertise for collection, prioritization of the species, extent of genetic erosion, assessment of the collection and analyses of the existing collection to identify the gaps, among others.

Characterization and evaluation

Agro-morphological characterization and evaluation

Agro-morphological characterization and evaluation is the systematic study of the morphological, agronomic and developmental characteristics of the plant that describe the diversity in the materials collected. Characterization descriptors are used. The features used for germplasm characterization are highly heritable, easily observed, and can be expressed over a range of environmental conditions. The characters are used in identifying an accession and monitoring its identity over several generations (Arora, 1996). Some of the characters are leaf colour, leaf shape, stem pigmentation, growth habit, seed colour, leaf length, leaf width, number of branches, and plant height.

Evaluation assesses the agronomic and economic significance of the various characters of the plant in a defined environment (Kresovich & McFerson, 1992; Seychuk, 1973). Evaluation descriptors are susceptible to environmental influences. They are quantitative characters and several tests must be applied in several environments to describe the accessions fully. Observable or qualitative characters are identified in single plants; non-observable or quantitative traits are recorded in at least five plants.

Natural crossing must be minimized to maintain genetic purity by using barrier crop or isolating the flowers for controlled pollination. Fields for evaluation must be rectangular, of uniform fertility with adequate water supply. However, these are hardly possible (Burton, Ellis & Davies, 1984; Frankel, 1986).

The challenges facing characterization and evaluation in Ghana include the need to study the systematics and taxonomy of many species for simple classification relevant to the gene bank and the lack of experts in taxonomy (Sano & Le-Viet Dung, 1996). Some crops lack descriptors, especially the neglected and less used species (e.g. *S. sternocarpa*, *K. geocarpa* and *M. pruriens)*. Out of the 13 legumes under conservation in Ghana, only five have descriptors (Aboagye, 2003a). Analyses in characterization and evaluation have been limited to simple statistical variables, namely range, mean, standard deviation and coefficient of variation (CV) (Table 1)(Aboagye, 2003d). These analyses lead to inefficient exploitation of data collected. Techniques are lacking for eliminating environmental conditions which could be avoided by characterizing and evaluating under controlled environment (e.g. glasshouse). The use of the augmented block design, replication of germplasm evaluation over space and time, would give greater confidence in the results recorded; thus, enhancing the use of materials. Table 2 shows the diversity explained by qualitative traits in groundnuts (Aboagye, 2003d). Invariably, to some extent, qualitative traits are not subjected to environmental influence and could be used succinctly to describe diversity.

Molecular characterization

Molecular characterization in plants show the genetic diversity in population, taxa or species. It has been used to show the relationship between physiological and morphological characteristics and identification of genetic loci associated with agronomic traits. Molecular analyses of genetic diversity in PGR collections allow better management of the germplasm. Molecular characterization enables the identification of suspected duplicates which may be eliminated, and accessions with many unique genes may be targeted for special protection. Molecular analyses may suggest the need for further collections from particular locations of specific

TABLE 1

Evaluation of Pod and Seed Characteristics of Groundnut Germplasm

Trait	*Range*	*Mean*	*STD*	*CV (%)*
Number of pods per plant	5.8-85	29.4	15.4	52.38
Pod length (mm)	18.4-40.6	27.23	4.81	17.66
Pod width (mm)	8.4-16.9	12.69	1.46	11.51
Number of seeds per pod	1 - 3	1.26	0.63	50.0
Seed length (mm)	9.5-18.3	13.06	1.52	11.64
Seed width (mm)	5.9-10.9	8.24	0.90	10.92

TABLE 2

Shannon Diversity Indices in Some Qualitative Traits of Groundnut Accessions

Trait	*SDI*
Pod beak	0.577
Pod constriction	0.438
Stem surface	0.321
Stem branching	0.285
Leaf colour	0.273
Leaf shape	0.267
Stem pigmentation	0.243
Number of branches	0.204
Growth habit	0.190
Seed colour	0.111

genotypes. For genetic resources to be used efficiently in plant improvement programmes, it is first necessary to determine whether the useful genetic variation exists in the material (Kresovich & Westman, 1996; Kearsey, 1997). Marker-assisted selection offers a great opportunity for improved efficiency and effectiveness in selecting genotypes with the desired combination of traits.

Problems confronting molecular characterization are lack of well-equipped laboratories (mainly located at the universities and a few research institutes). With the rising cost of equipment and laboratory supplies coupled with lack of expertise, the need is to establish one or two well-equipped laboratories in Ghana for molecular characterization.

Some challenges in characterization and evaluation

During collection of germplasm, few seeds are received from donors. Therefore, the need is to multiply the material to obtain substantial amount for characterization, evaluation, conservation, distribution and storage. Extreme care must be taken not to lose the materials because of poor adaptation, disease and pest damage, contamination and alteration of the genetic composition. Strategically, a proportion should be saved against any eventuality and also to serve as a reference sample. The multiplication site should be as close as possible to that of its original collecting site to avoid the effect of natural selection (Brown, 1989; Brown, Brubaker & Grace, 1997). For example, localization of African yam bean in southern part of the Volta Region and *K. geocarpa* in the Northern Region of Ghana.

Loss of genetic variation or change in genetic structure may occur when plants in gene banks are being regenerated. To prevent such variation, many plants must be grown at a time and enough crossings made to obtain large quantities of seeds of high genetic purity for preservation (Erskine & Williams, 1980).

The challenges confronting agro-morphological characterization and evaluation include high cost of regeneration especially with cross-pollination plants, lack of knowledge about the reproductive biology in some underused crops, the suitability of the environment as in some legumes that are adapted to a particular environment (*V. subterranea* in the savanna and transition zones), lack of regeneration standards, effective population size, and potential of some species to become weeds (e.g. *M. pruriens*) (Bennett-Lartey, 1998).

Conservation

The principal objective in PGR conservation in gene banks is to provide ideal storage conditions so that the viability of the materials is extended as much as possible (Genebank Standards, 1994). This is done by reducing life processes to a low moisture level. Successful seed storage depends on effective control of temperature, seed moisture, oil content, and humidity (Verucci, Ross & Cranne, 1994).

Seeds under cold storage are mainly of the orthodox types that can be dried to low moisture content of about 3-7 per cent without losing viability. Processing of seeds includes seed extraction, drying, counting, packaging, sealing and conserving at 5 °C or at –20 °C, depending on the usage either as active or base collection. Viability is monitored while in storage, and seeds are regenerated when the viability falls below 85 per cent. The main objective of conservation is to safeguard and make available genetic diversity to improve agricultural productivity (Berthand, 1997).

The challenges in conservation include the following: cost of operations (electricity, equipment problems and appropriate storage strategy [base or active]), optimum conditions for long-term storage have not been developed in some crops, the greater variability in seed size would affect the quantity of seeds that could be stored (Table 3), and not using user-friendly management conservation systems. In improving conservation, there must be less dependence on electricity, and alternative energy sources must be used (e.g. solar). Preventive maintenance should be used to reduce cost, rationalization of collections, identification and bulking of duplicates, and safety duplication to ensure security.

TABLE 3

Variability in the 100-seed Weight of Six Legumes

Species	*100-seed weight (g)*	*Source*
Vigna unguiculata	12.4	Aboagye, 2003b
Sphenostylis sternocarpa	26.5	Aboagye *et al.*, 2002
Arachis hypogaea	54.1	Aboagye *et al.*, 1994
Phaseolus lunatus	79.9	Aboagye, 2002 (unpublished)
Mucuna pruriens	81.6	Bennett-Lartey, 1998

Documentation

Managing and manipulating information is the pivot of all PGR activities. Proper documentation of data on collection, characterization, evaluation, conservation methods, distribution and utilization is indispensable for the ultimate use of germplasm (Yndaard, 1982; Konopka & Hanson, 1985; Beuselinck & Steiner, 1992). Proper documentation can be used to plan future collection, maintaining a reasonable number of materials by eliminating duplicates, and to develop core collections to reflect the entire collection. It will also help users to quickly identify valuable types and traits for crop improvement.

The use of germplasm collection depends on quality passport, characterization and evaluation of data as well as its documentation in an easy retrievable form to enable users select their germplasm (Hersh & Rogers, 1975).

Some challenges in information management are what primary and secondary information are required to characterize and evaluate the lesser-known legumes (e.g. *C. ensiformis),* and easy storage and retrieval. In Ghana, with inadequate computers coupled with frequent power outages, the need is to develop hard copies in the form of catalogues that could be backed up by computers, if available, to enable the information to be accessed always.

Distribution

The usage of germplasm depends on the objectives of the user. Request for seeds must, therefore, include the objectives of the user to enable the curator supply the needed materials based on information documented on the material. The user must also supply the curator with relevant data on the material collected as supplementary or complementary information on the material after the trial.

The challenges in seed distribution include more diverse users (researchers, farmers and students), the unit of distribution, gaps in information concerning characterization and evaluation to select appropriate methods, seed health and quarantine procedures, limited exploitation of existing collection, cumbersome material transfer agreements, and lack of detailed information from requesters. These problems could be solved by eliminating seed-borne pathogens, clear guidelines on sample size, less cumbersome transfer agreements, user-friendly information on germplasm, and by developing core samples (Hollbrook, Anderson & Pitman, 1993; Diwan, Bauchan & McIntosh, 1994; Diwan, McIntosh & Bauchan, 1995; Simond & Hannan, 1995).

Utilization

Although plant gene banks are repositories of PGR to prevent their extinction, efforts must be made to ensure their use through publishing the data assembled on collection, characterization, evaluation, conservation and distribution (Aboagye, 2003a, b). A recent study has shown that the universities and research institutions are the major users of legume germplasm, and the farmers from whom most materials are collected are the least (Aboagye, 2004 unpublished). The challenge in effective use, therefore, lies in publishing and distributing catalogues, preparing extension leaflets and bulletins, and organizing open days not only for displaying commodities, but also documented information. With the formal recognition of property rights of all key players, namely the farmer, the curator and the plant scientist, all must work hand in hand through all aspects of plant genetic resources activities to remove the barriers associated with cumbersome material transfer agreements.

Conclusion

Gene bank management is confronted with several problems, and its resultant challenges must be resolved for effective supply of genetic resources for legume improvement. For effective management, networking and capacity building (infrastructure and personnel) must be pursued vigorously. Effective information-sharing mechanism must be developed and put in place to enhance the use of information in gene banks. Finally, policy makers and stakeholders in plant genetic resources management should be sensitized on their specific roles in germplasm conservation that would ensure sustainable food security through conserving germplasm.

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