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The Collection, Maintenance, and Environmental Importance, of the Genetic Resources of Wild Plants

by

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INTRODUCTION

Conservation of environments depends to a large extent on the conservation of existing plants and their communities and hierarchies—whether these be successional, altitudinal, or zonal. Interference in the balance of any of these may produce radical changes that lead to progressive deviations from the original situation. These deviations in turn may alter irrevocably the conditions for plant growth, the existing flora, and the composition of its dependent fauna—leading ultimately to significant changes or degradation of fundamental edaphic and even climatic features of the environment.

Conservation is involved basically with the responses of individuals within the plant community, although in practice conservation measures may be applied on a much larger scale to groups of plants or to large communities. The individuals introduce the genetic variability on which depends the communities' resilience to changing circumstances and to the natural or man-imposed hazards of their environment. This genetic heterogeneity represents a resource that is of vital significance both in the maintenance of natural communities and in the development of artificial ones at any level of management. It also represents a vast potential for mankind—employed, amongst other uses, in the development of crop plants, for range improvement, for forestry, or for amenity purposes. A portion of this store has already been used during the domestication of crop plants and the introduction to cultivation of various species and races. However, the greater part still remains undiscovered or unused in natural plant communities, many of which are increasingly threatened with drastic reduction or total loss.

There is accordingly an inevitable interdependence between the conservation of plant communities in their natural environments and mankind's use of the plant resources within these communities. Evaluation of these resources, and a better understanding of the conditions under which they can best be maintained, very often depends on opportunities for studies of component taxa in the field and in the laboratory. Laboratory experiments, and other comparative studies under artificial conditions—including physiology, cytology, breeding systems, biochemistry, etc.—depend on the availability of suitable documented collections of natural origin.

National programmes of plant introduction organized by such countries as the U.S.A. (Burgess, 1971) and the U.S.S.R. (Budin, 1973), and internationally coordinated programmes of plant conservation and distribution organized through the International Biological Programme and the Food and Agriculture Organization of the United Nations, produce an enormous flow of plants of all kinds from one country to another. In many countries, although there may be no centrally coordinated organization responsible for plant introductions, botanical gardens, research institutes, and university departments of botany, maintain considerable volumes of plant introductions either through taking part in collecting expeditions or by correspondence and exchange.

Yet it is a common experience that the collections of living plants maintained by established institutions, some of which may receive thousands of items a year, do not increase, or do so only at a fraction of the rate at which the collections are added to. This paradox results from the rate at which collections are lost, and it may almost be stated as a matter of common experience that, in an established institution with a stable staff-structure, one plant collection is lost for every one which is added. It might be hoped that this would produce an evolutionary situation in which continuous selection would occur for the more useful, the more valuable, or in some other way the more desirable, plants, and that, in the process, collections of lesser merit would be weeded out and discarded. Unfortunately, this is by no means the case; most often selection is on a much more arbitrary basis, and in the

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process much valuable material may be lost—some of it irretrievably.

PRESERVATION OF RESOURCES

Surveys of genetic resources in the U.S.A. (Burgess, 1971) and in the U.K. (Williams, 1974), have demonstrated the wide range of plant genetic resources that may exist at any one time amongst introduced plants of economic importance. Experience has shown, however, that collections assembled for particular purposes in support of breeding programmes or research projects, are often totally lost after a few years—e.g. when the individual mainly concerned retires or moves or transfers his interest to another crop. This situation results from an individualistic view of plant material as the personal resource of a plant breeder or experimenter in pursuit of a particular objective, rather than as part of the national germ-plasm resources of a country. Such a view is reinforced by the normal criteria of success of a breeding programme being based only on the product in the shape, for example, of a new variety or type of disease resistance—without implying any responsibility for the maintenance or distribution of the original germ-plasm which contributed to the successful new variety. Although no surveys similar to those of Burgess and Williams have been attempted for introductions of plants of lesser or no apparent economic value, there is certainly no reason to expect that the latter would provide more effective examples of conservation or planned effort.

The plant collections in any country provide the reservoir of germ-plasm on which future plant breeding progress will depend and scientific investigation will be based, and as such constitute national resources of great economic importance. Viewed in this way it is quite clear that all too often their organization, conservation, and means of distribution, are haphazard or frequently inadequate, and inevitably fail to make full use of the resources available. In many cases these failures may be attributed to the lack of any overall organization charged with responsibility for maintaining a check on existing reserves, or for safeguarding them and adding to them for future use — such as exists in a few countries, including the U.S.S.R., Japan, and the U.S.A. However, a considerable part of the failure is also attributable to the methods used in the collection, storage, and documentation, of existing living collections. These frequently fail to describe the material adequately by any standard; more often than not they provide no safeguard against loss during or even as a result of cultivation, and the lack of any standard form of documentation makes it extremely difficult to circulate details or enquire into existing, widely-dispersed genetic reserves.

A great deal could be done, relatively easily and cheaply, to improve standards of collection, conservation, and documentation. In some cases this could be done by simply ensuring that known information does get recorded and related to particular collections while in other cases much could be accomplished through the application of principles of conservation or methods of documentation which are now widely accepted and understood but still frequently neglected.

Plants may be collected in a great variety of ways ranging from expeditions set up with specific aims in view to exchanges of seed with other institutions. It is usually extremely simple to assemble large collections of taxa when this is done unselectively, and in many cases the documentation attached to such collections is meagre, and insufficient to support most types of scientific investigation. It may be difficult, or impossible, to reach general agreement on what constitutes adequate documentation, since this will vary with the viewpoint of different individuals and the use intended for the material. At one extreme a plant intended for use in amenity horticulture may be valued simply on account of its appearance and performance in the garden, and its antecedents may be of no more than historical interest. On the other hand a collection intended for use in a biosystematic study will be of little or no value unless it is accompanied by detailed documentation relating to the locality of its collection, the nature of its habitat, and other plant associates, etc.

DOCUMENTATION OF COLLECTIONS

Konzak & Dietz (1969), and Konzak (1973), have produced recommendations for standard data-files in connection with collections of crop germ-plasm, and these provide a foundation for data requirements with collections of wild species. Recently, attempts to co-ordinate records of crop-plant genetic resources internationally have been organized through the Food and Agriculture Organization of the United Nations. One result of this activity has been the production of a series of thesauri to provide a basis for the international standardization of gene-bank data, an example being the publication of Seidewitz (1974) concerning cereal crops; other parts of the same series deal with forage crops (including lawn-grasses) and root and tuber crops. A summary of the range of information which may be broadly described as 'collection data' is shown diagrammatically in Fig. 1. Some types of information are of greater, some of lesser, importance at this stage—apart from routine data including the collector's name, the serial number, and the date of collection. For example one might argue that, so far as populations of wild plants are concerned, correct field identification is not of major importance, as it can be verified at a later stage and in the meantime provides a convenient 'handle' for the collection; on the other hand, details of location are vitally important, as these

would be lost for ever if not recorded by the collector. A record of latitude and longitude, to whatever level of accuracy is possible, is particularly valuable, as it avoids the problems that may arise from the diversity of systems used in different survey grids, and provides a globally applicable method of defining geographical localities.

Descriptions of the material collected should always include some guide to the size of the population sampled and, in broad terms, the natural abundance of the species in the locality—otherwise it is impossible, later, to form any opinion as to the breadth of genetic variability represented by the collection.

The most controversial of the sub-headings in Fig. 1 is 'Ecology', because it is very difficult to define limits to what should be recorded as possibly valuable. Thus it is valuable to know at what altitude the collection was made, and in some cases the aspect of a slope may be significant. A general description of the habitat, in such terms as 'deciduous woodland' or 'grassland', and of the topography in such terms as 'hilly', 'flat', etc., is likely to provide useful and easily recorded information on the collection. More detailed descriptions may contribute relatively little vital additional information, and may be difficult to incorporate satisfactorily in documentation systems. Special features should probably only be included when they are unusually noteworthy, as in the cases of plants growing under intensely saline conditions, or in situations that are heavily contaminated with industrial waste. Information on the local plant community can be particularly valuable, especially if it is possible to use a generally-accepted descriptive term rather than merely list other species occurring within the community. Recent publications of methods of classifying vegetation, by Fosberg (1967) and Ellenberg & Mueller-Dombois (1967), provide concise descriptions of vegetational types which may be of great value for recording purposes. Their use in relation to the classification of vegetation for conservation has been compared by Goldsmith (1974).

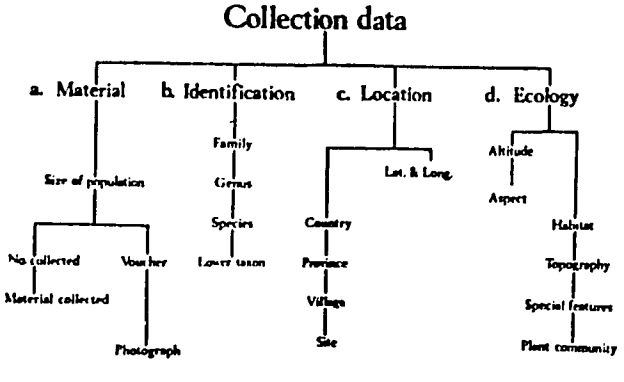

FIG. 1. *Collection data.*

There is much to be said in favour of supporting each collection with a herbarium specimen, however inadequate in quality the latter may appear to be. At the very least this provides a separate record that may be used as a check against the possibility of accidental substitution of the records of one collection for another. Whenever possible a specimen should be sufficiently complete to permit early and full identification or verification of the collection and also to provide an example of the natural growth-form of the plant in the field.

MAINTAINING COLLECTIONS

Methods of maintaining collections, and a brief summary of the major attendant problems, are indicated in Fig. 2. In the vast majority of situations, the choice lies between keeping a collection of living plants or holding seed in store; it is possible that, in future, *in vitro* cultures will play a significant part as a means of conservation, but at present the technology of the method is too immature to provide sound guidelines for practical use.

Maintenance and Storage

(a) As living plants:

problems of regeneration; restrictions on size of populations; hazards of cultivation.

(b) As seeds:

problems of maintaining viability.

(c) As in vitro cultures:

problems of genetic change; technical problems.

FIG. 2. *Maintenance and storage.*

There can be no absolute preference between the alternatives of keeping living plants or seeds; in each case the choice will depend on particular properties of the species involved. A great many seeds store well, and seed storage techniques have advanced to the point at which seed stores for both cultivated crops and wild species may be set up with a high degree of confidence. The majority of small dry seeds can be stored for periods measured in years or decades (*see* Barton, 1961; Roberts, 1972), and the risks of loss or failure can be reduced to the point where they are not decisive arguments against using this method for the conservation even of rare species or threatened populations.

Long-term storage may be used to simplify and rationalize some of the problems associated with distribution of seed between botanical gardens (Thompson, 1970), and as a positive aid in maintaining col-

lections within a botanical garden (Thompson & Brown, 1972). Nevertheless, there are many seeds which cannot be stored satisfactorily. These include most large, moist seeds such as nuts and acorns, and the seeds and fruits of a great many tropical tree species. Seeds of certain small-seeded species, including poplars and willows, are notoriously short-lived, and those of many other tree or shrub genera, such as *Acer* and *Viburnum*, are difficult to store for protracted periods.

It is sometimes suggested that collections of annuals and short-lived perennials are best maintained as seeds in a seed-bank, and that long-lived species such as trees and shrubs are better kept as collections of living plants. There is a certain plausibility in this approach, as by and large the seeds of herbaceous species present few storage problems whereas those of trees and shrubs present many.

However, collections of living plants, even long-lived ones, do not always serve well as a means of conserving plant germ-plasm. In the first place, particularly with species that grow to a very large size, it may be difficult to accommodate more than a few individual plants. This involves intensive selection for the individuals retained, which is seldom done at random; indeed, it must be very rare to find a collection of trees in an arboretum or botanical garden which could justifiably be considered as representative of a mixed population growing under natural conditions, or, more seriously, which would be likely to contain amongst its individuals more than a fraction of the genetic spectrum that is characteristic of the wild population from which it originated.

Some of the problems associated with the establishment of gene-banks based on growing plants are discussed by Sayers & Gaman (1972) with reference to relatively small herbaceous species from Teesdale. In practice, collections of species of large trees, and also of the larger shrubs, are more often than not limited to a very few individuals, which have frequently been deliberately selected because of overt horticultural qualities. There can be little doubt that a very good case can be made out for more research on storage techniques applicable to the seed of tree species and other difficult subjects, in order to make it possible to maintain really representative collections of these species in seed-banks.

REGENERATION PROBLEMS

Whatever the methods used to maintain collections, there comes a time, as plants grow senile or seeds lose their viability, when a new generation must be raised to replace the old. Regeneration is one of the most difficult and least studied problems of maintaining a collection of plant germ-plasm, and aspects of the process are set out for comparison in Fig. 3. It must be assumed that genetic change, either qualitative or

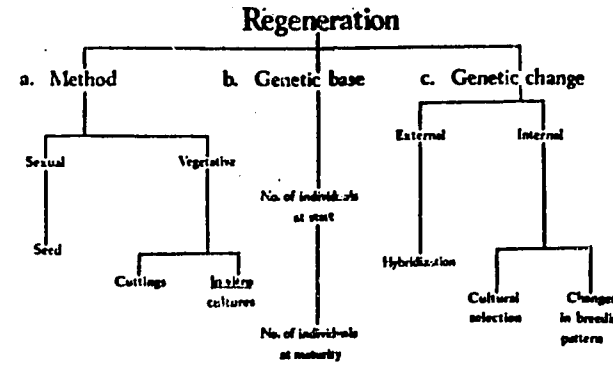

FIG. 3. Regeneration.

quantitative, will occur each time a new generation of a collection is raised. Therefore, during regeneration, two things are necessary; one is to provide detailed records of the method used and the genetic base from which the new generation was derived, while the other is to reduce as far as possible the probability of genetic change by hybridization with closely related species or other populations of the same species, or by selection within the collection itself.

Most frequently regeneration is by seed, and very often it involves sowing a sample of seed that has been obtained from a wild population of the species concerned. Drastic selection may occur at this stage if the seed sample contains a high proportion of dormant individuals, in which case those which germinate may amount to only a few per cent of the number sown. It is therefore most important, whenever possible, to ensure that methods are used which ensure high, preferably 100%, germination rates, and if these are impossible to achieve, that records are kept which identify the level of selection at this stage. Similarly, as the plants are grown on to maturity, every effort should be made to use cultural techniques which avoid reducing the number of individuals either deliberately by manual thinning or, accidentally, by predation.

Precautions to be taken against genetic change during regeneration will depend on the reasons for which a collection is being kept or the ways in which it is intended to be used. If it is required as a gene-bank to retain particular genetic qualities, for example for plant breeding, it may be sufficient simply to aim to maintain a very high proportion of the total genetic constitution of the stock from one generation to another. The number of plants required to do this will depend on the homogeneity or heterogeneity of the collection, but provided selection is avoided, the numbers involved need not be great. If, however, the intention is to retain gene combinations or quantitative differences between gene occurrences that are characteristic of natural populations, the requirements of the process become much more stringent and may

4

even not be attainable. Apart from any other consideration, a sample of seed may not be representative of the genetic constitution of a mature population, as under natural conditions the latter will have been produced as the result of more or less severe selective pressures. It is seldom practicable to attempt to mimic these pressures under artificial conditions, and in biosystematic studies the possibility of crucial differences occurring between original wild collections and regenerated collections must be duly recognized.

IMPORTANCE OF EVALUATION

A collection of plants that has been assembled to represent particular taxonomic groupings or to serve particular agronomic functions, has a much greater value than the sum of its individuals. This is because the opportunities for comparisons which such collections offer, will permit a broader and more balanced appraisal to be made of the relative significance of different qualities than is possible with single populations or limited examples of a species. As time goes on and the collection becomes more fully evaluated or more comprehensive, its value increases correspondingly—provided that methods of documenting evaluation in a retrievable form are practised. Evaluation is by far the most open-ended function of any involved in the conservation of genetic resources, and the one in which practicalities are determined most decidedly by the use to which the collections are to be put. It is therefore quite impossible to detail or even to outline desirable objectives in this field; but the range which may be covered is indicated diagrammatically in Fig. 4.

One aspect of evaluation is, however, of incontrovertible importance, and that is identification. The minimum information attached to any collection should be a valid name, or if this is not possible a proper taxonomic determination to a stated level, backed by a herbarium voucher specimen. Inevitably at the outset a proportion of any collection will be unverified;

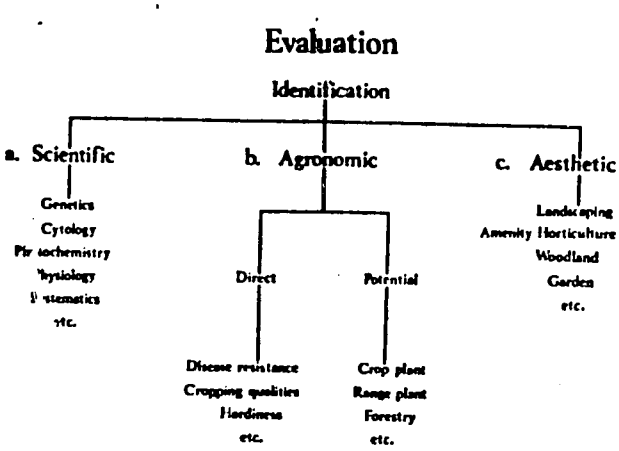

FIG. 4. *Evaluation.*

but the value of unverified material for exchange, for scientific study, or even for agronomic use, is very low indeed, and certainly does not justify the expenses of collection and maintenance.

The range of topics illustrated in Fig. 4 demonstrates the difficulty of maintaining documentation which will ensure that information, obtained about collections during cultivation or research, can be made available on request to others who may be interested in using the same material. Clearly, effective use of collections is greatly facilitated by such information, and data-processing systems based on computers are now being developed with this aim. Although systems can be developed that are capable of including any variety of plant or range of attributes (e.g. Seidewitz, 1974), their function and value are restricted by the time that can be spent inputting and updating data, and, in the absence of unlimited time or expenditure, it is certain that this will always remain the major factor limiting their use.

Ostensibly one of the more important functions of a botanical garden is the assembly and maintenance of genetic resources in the form of plant collections. However, experience has shown that in many cases such collections are used relatively little as a genetic resource but play a predominant part in other functions of a botanical garden—including the provision of plants for teaching and display. In fact, as a genetic resource many such collections comprise too few individuals of each taxon or population to be representative, and are inadequately documented both at the time of collection and during their subsequent cultural history in a garden. Consequently they may be of little value as source material for most scientific studies, and so widely scattered and unevaluated as to be of restricted interest to plant breeders. Adequately curated and moderately comprehensive collections, which would play a part on an international scale as germ-plasm reserves, depend not only on a considerable revolution taking place in accepted and standardized methods of documentation, but also on the development of some system of continuing responsibility for the maintenance and development of germ-plasm resources.

In particular, coordinated policies would have to be developed to allocate responsibilities for the maintenance of particular groups of taxa or regional floras, followed by decisions on the most appropriate means of conservation. Whether by the creation of natural reserves and the maintenance of existing communities, or by inclusion in the living plant collections of botanical gardens either as seeds in seed-banks or as groups of individuals constituting small populations growing under artificial conditions, this can be done only with considerable and lasting expenditure of effort.

Maintenance of the genetic resources of wild species on a comprehensive scale is a function beyond the

means of any single existing institution, and would continue to depend, as it always has done, on the totality of effort of botanical institutions throughout the world. Up till now there has been no overall responsibility for maintaining such collections, and conservation has depended on the narrow interests of particular institutions. Clearly it is now necessary to develop some means by which collections are maintained and continue to be available after the immediate objectives for which they were assembled have been realized. This can be done, and is already being attempted in some countries—particularly for the germ-plasm of crop plants. The means, the objectives, and the funding, of such an enterprise devoted to wild species as well, are subjects of urgent importance for world-wide consideration amongst botanical gardens, university departments, and research institutes.

SUMMARY

Plants are major factors conditioning an environment, and conservation of particular environments depends fundamentally on the maintenance of existing plant communities. In many parts of the world, the destruction of such communities is occurring so rapidly and so completely that entire natural systems are subject to, or threatened with, total destruction. In such cases artificial methods of conserving plant germ-plasm for ultimate regeneration, for supplementing natural populations, for study, or for use by Man as an economic resource, may be of great significance as one possible means of averting total loss. Under less extreme pressures, the availability of representative propagules of significant taxa or populations may be of crucial assistance as an aid to research directed towards a better understanding of factors affecting survival or competitive advantage in the wild, or as a means of providing stocks for assessment of the potential economic value of existing reserves of wild species.

This paper discusses methods of recording, maintaining, and evaluating, collections of populations of wild species. Plant resources of this kind are extremely vulnerable when maintained under artificial conditions, and a very high proportion of collections are lost within a few years, remain unavailable for general use, or fail to be used owing to inadequate documentation. Conservation of plant germ-plasm as an international resource, in a usable form, depends on a wide acceptance and practice of greatly improved methods of documentation, and requires the creation of effective organizations for surveying, maintaining, and coordinating, plant resources on an international scale.

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