Seed certification, provenance nomenclature and genetic history in forestry

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Introduction

The establishment of forest plantations throughout the world demands annually increasing amounts of seed. Seeds are often transferred between countries, or between areas within countries, accompanied by inadequate information about their source and history. Many countries have established seed zone systems for their indigenous species and various schemes of seed certification have been or are being designed in which better and essential information on seed is provided both nationally and in relation to international trade.

Most existing schemes relate to European and North American countries; the purpose of the present paper is to bring them to the attention of other countries, particularly those tropical and subtropical countries that are currently establishing large industrial plantations of both exotic and indigenous species. The development of local certification schemes based on an international system is recommended. There are, however, limitations in the existing systems for tree breeding programmes which are noted and some amendments suggested.

Seed certification

Certification is defined in English usage as the authoritative attestation of facts or statements and it usually implies documentation by a formal written certificate. Seed certification is an official statement that a seed lot conforms to certain standards which may include specific identity, origin, genetic characters and seed purity. These include the 'genetic' and 'somatic' values described by Rohmeder (1960). As used by plant breeders, after many years of development, seed certification implies genetic improvement and it aims to facilitate the provision of high quality seed from superior crop plants with similar genetic identity and purity. In this case, strictly, the term certified should be reserved to describe seed of improved (and uniform genetic) quality; it should not be used to identify seed origin. Complete genetic uniformity and predictability are generally obtained only after several generations of selective breeding and in forestry they have been rarely obtained or required. For forestry, therefore, seed certification systems have developed largely to provide labels and records that give officially authenticated details of identity and origin; a summary of early European work was given by Commonwealth Forestry Bureau (1941). However, as tree breeding Progresses and particularly as improved seeds are exchanged between countries, it will become increasingly important to know more of their genetic history and quality.

According to Banks (1968) forestry has been slow to follow agriculture's lead in seed certification for three main reasons: — (i) the lack of appreciation of the importance of seed origin, (ii) seed certification is based on breeding, and tree breeding is slower than agricultural breeding, and (iii) the volume of forest tree seed traded is small. Also tree seed is commonly collected by unsupervised and unskilled labour. However, as tree breeding programmes become productive, seed certification is becoming more urgent, particularly in tropical regions with their fast growth, early flowering and short commercial and breeding rotations.

A detailed review of progress towards seed certification in 30 countries was provided by Matthews (1964). There were at that time 12 comprehensive national certification schemes; with the exception of Japan and U.S.A. these were all for European countries. Since then Canada has progressed towards the development of a national scheme which is currently applicable in Alberta, British Columbia, and parts of Northwest Territory and the Yukon (Wang and Sziklai, 1969; Anon., 1971, 1973; Piesch and Phelps, 1971). (Source-identified seeds with a value approaching a quarter of a million Canadian dollars are now exported annually from Canada under this scheme.) In Australia the principles of seed certification have been discussed (e. g. Banks, 1968, 1970) but there are no state or national systems operating. The State Forest Services have usually maintained records of the origin of seed lots on a voluntary basis (Turnbull, 1973; pers. comm.[3]).

Matthews (1964) outlined the principles of a national seed certification scheme and a good example of the details of such a scheme was given by Schoenike (1969) for the state of South Carolina, U.S.A. Minimum standards for certification, particularly for the provenance and progeny testing necessary, have been described by the Georgia Crop Improvement Association (1959), Wakeley et al. (1960), Barber (1964), Schoenike (1969) and Stern (1969).

Despite the cooperation of foresters, seed collectors, seed dealers and local or national legislators, it is obviously difficult do develop national schemes that are acceptable to all those concerned with tree seed. (See, for example, the earlier controversy in the United States recorded in Society of Arnerican Foresters Seed Certification Subcommittee, 1961, 1963 a, 1963 b; Western Forest Tree Seed Committee, 1961; Cech, Barber and Zobel, 1962).

Clearly it is important, even though difficult, to create internationally acceptable systems of seed certification. As more countries become involved in seed exchange, plantation work and tree improvement, such a system can be considered essential. In fact an international scheme does now exist. This is the scheme which sets minimum standards for the control of forest reproductive material moving in international trade, prepared by the Organization for Economic Cooperation and Development (O.E.C.D., 1971; see also Barner in F.A.O., 1971). First accepted in 1967 after several years' preparatory work and meetings, this latest version is still subject to discussion and amendment. O.E.C.D. covers 23 countries, 17 of which are interested in the scheme while 11 have already named their designated authorities for the issue of certificates and for making the necessary checks.

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The F.A.O. Panel of Experts on Forest Gene Resources recommended that countries should model their own national seed certification schemes on that of the O.E.C.D., even though varying conditions from country to country will make complete standardisation impossible (F.A.O., 1971). The O.E.C.D. scheme is also compatible with that of the European Economic Community (E. E. C., 1966).

The O.E.C.D. scheme

The O.E.C.D. scheme has not been widely publicised outside Europe and North America although it is open, on a voluntary basis, to all member countries of the Organization and to member countries of the United Nations or its specialised agencies. Although participation is voluntary, it entails complete acceptance of the rules of the scheme, including the designation of competent authorities to issue the relevant certificates. The scheme refers to all reproductive parts of plants, not just seed. The following terms are defined: — stand, indigenous stand, selected stand, seed orchard, clone, cultivar, provenance (location of seed source), origin, region of provenance, and designated authority. Barner (1972), who is the forestry consultant to the O.E.C.D. scheme, has considered in detail the implications of the scheme for seed orchard classification and certification.

In essence the O.E.C.D. (1971) scheme recognised three categories of reproductive material: source-identified, selected and certified.

The two requirements for *source-identified* reproductive material are (a) the region of provenance where the reproductive material is collected and the nature of the origin of the reproductive material (which may be indigenous or non-indigenous) shall be defined and registered by a Designated Authority; (b) the seed shall be collected, processed and stored or plants shall be raised under the control of a Designated Authority. For *selected reproductive* material the same requirements apply but in addition the scheme outlines special criteria for the isolation, uniformity, population size and properties of selected stands. For *certified* reproductive material there is the additional requirement of genetic superiority, demonstrated by provenance or progeny tests.

As indicated earlier, this latter term '*certified*' is unfortunate because in English it simply means the provision of a certificate; the other two categories are also provided with certificates. The term '*tested*' is currently being considered although, again in English, this does not imply superiority. Terms such as '*passed*', '*qualified*', '*certified superior*', '*proved*' might be better although any one would be acceptable if an adequate definition is given.

However, results of tests in one environment must be interpreted with caution when applied to another because of the interactions of the genotype with the new environment. At its meeting in March, 1973, the O.E.C.D. proposed the inclusion of a fourth category "Reproductive material from untested seed orchards". This category additionally requires approval by the Designated Authority of the objectives, design, components, isolation, location and management of the seed orchard.

Other schemes

Some countries recognised subclassifications of their local seed sources, before progeny testing showed their genetic value, *e. g.* the plus, almost plus, normal and minus categories of Great Britain (Larsen, 1960, 1961); or the plus, normal and minus stands of Sweden (The Royal Board of Private Forestry of Sweden, 1950); or the standard plus, standard superior, and standard grades suggested for Western American conifers by Isaac (1960).

However, none of these systems offers adequate information on the genetic history and probable variability of the material. It has long been known that, for most tree species, the source and parentage of a seed sample influence the survival, adaptability, variability, productivity and value of the resultant plantation. The number of potential parents varies with species from densities of one to several hundred trees per acre. To determine the optimum seed source for a given site type or region, comparative experiments are necessary, commonly termed seed source trials or provenance trials. Various definitions of provenance (provenience) and seed source are available.

Current definitions of provenance

Published definitions

Probably the earliest widely accepted English definitions have been:

(i) *"The geographical source or place of origin from which a given lot of seed or plants was collected; the material from such a source or origin; often restricted to imply material from a specified race."* (Empire Forestry Association, 1953).

(ii) *"The original geographic source of a lot of seed (or pollen)."* (Wright, 1962).

These definitions were commonly associated with studies of variation in naturally widespread species that demonstrated ecotypic, clinal or random variation between populations; thus, although they did not specifically exclude nonnative populations (*i. e.* exotic plantations) they were often taken as referring to natural populations. This is specifically stated in the first of two definitions of provenance given in the Terminology of Forest Science (Society of American Foresters, 1971):

Provenance (i) = *provenience*
The geographical area and environment to which the parent trees, etc. are native, and within which their genetic constitution has been developed through natural selection.

Provenance (ii) = *source, origin, provenience*
The geographical source, i. e. place of origin, of a given seed lot or pollen.

However, the S.A.F. Terminology defines seed source as:

Seed source = *seed origin*
The locality where a seed lot was collected.
Note: *If the stand from which collections were made was exotic, the place where its seed originated is the original seed source.*

However, these do not coincide exactly with the Southern Forest Experiment Station's revision of a Society of American Foresters' Glossary for Forest Tree Improvement Workers (Snyder, 1972):

Provenance.
The original geographic source of seed, pollen or propagules.

Seed source.
The locality where a seed lot was collected; also the seed itself. If the stand from which the collections were made was in turn from nonnative ancestors, the original seed source should also be recorded and designated as the provenance.

The Organization for Economic Cooperation and Development, in its scheme discussed above, defined the following:

Provenance = *The area on which any stand of trees is growing. The stand may be indigenous or non-indigenous.* (At its meeting in 1972 the O.E.C.D. proposed a slight amendment: *The place in which any stand of trees is growing. The stand may be indigenous or non-indigenous.*)[4])

Origin = *For an indigenous stand of trees the origin is the place in which the trees are growing; for a non-indigenous stand the origin is the place from which the seed or plants were originally introduced.*

Which ever definition of provenance is used, it is desirable to compare different seed lots in designed experiments called provenance tests. Indeed the '*certified*' category in the O.E.C.D. scheme requires proof of superiority to be shown by provenance or progeny tests. Currently proposed amendments for the O.E.C.D. scheme may include one or other of the following definitions:

Progeny.

Offspring of a particular mating, or of a particular mate, or of a particular individual in the case of apomictic reproduction (RIEGER, MICHAELIS and GREEN, 1968).

Progeny test.

Evaluation of parents by comparing the performance of their offspring. Accuracy is usually gained because several to many offspring per parent are evaluated under more controlled conditions than exist for the parent (SNYDER, 1972).

Progeny test.

Evaluation of parents by the performance of their sexual progeny. Includes 1-parent progeny test, in which only the female parent is known, and 2-parent progeny test, in which both the seed and pollen parents are known (WRIGHT, 1962).

Limitations of existing definitions

All the definitions of provenance quoted above have limitations. The object of any definition is to provide as many people as possible with as much unequivocal information as possible about the object described. With careful and combined use of one or more of the above definitions, the geographic history of a seed lot could be described, *i. e.* where the seed itself was collected and where the seed that produced its parent trees had originated, and so on.

Consider, for example, the provenance nomenclature applicable to a sample of seed of *Pinus patula* collected in Kenyan plantations; these plantations were raised from seed collected in South African plantations and these were themselves raised from seed collected in natural stands in Los Reyes, Hidalgo, Mexico. The source, origin or provenance could variously and reasonably be named Kenya, or Kenya ex Mexico, or Kenya ex South Africa ex Mexico, or Mexico (Los Reyes, Hidalgo). In practice all available information should be sought and given, particularly in international transfers of seeds.

However, none of these possible names would give any indication of the history of natural and artificial selection to which the natural stand and subsequent plantations had been subjected, and which could influence the genetic constitution of the seed sample. (Additionally, and quite correctly, none of these names gives any indication of the pattern of natural variability in a species.) None of the classificatory and nomenclatural systems discussed above can impart all the information that is desirable about the antecedents of a given seed lot; they relate only to the geographical history not to genetic history.

All genetically based tree improvement programmes essentially follow classical plant breeding procedures. The value of the end product is recognised and cultural techniques are developed to produce an acceptable yield. Certain highly productive or better adapted populations are identified and intensive breeding is based on these. The genetic variability is high in early populations; as the amount of parental stock is decreased by selective breeding, the genetic variability will be reduced which in turn reduces the genetic gains possible by further selection.

To maximise genetic gains it is essential to know the genetic composition of the initial population used for breeding. In the next section we consider some of the possible alternative histories of natural and artificial selection that could have a bearing on the planning of programmes of selection and breeding. It is not suggested that a formal system of nomenclature or classification be developed for these; rather we would wish only to emphasise the need to obtain as much relevant information as possible on each seed lot.

Genetic history

A sample of reproductive material may comprise fruits, seeds, pollen, scions for vegetative propagation, or tissue for aseptic culture, but the following discussion will be restricted to seeds because these form the major component of commercial forest reproduction, particularly seeds of naturally outcrossing species.

A sample of seed from one population of parent trees may be collected from one, a few, or many parents. The amount of genetic variability represented generally increases with increasing number of parents particularly if they were randomly selected to represent the population. However, genetic variability may be reduced even with larger numbers of parents if the parents were located close together in a natural stand, or if they occur in a plantation which itself was derived from a small number of parents, or if they were selected to meet special criteria. In the latter case, their phenotypes are similar and there is an increased chance that their genotypes will be similar; in the other two cases there is a greater chance of common descent (coancestry).

There are three important consequences of reduced genetic variability in a seed sample. Firstly, in the commercial plantation there is a risk of increased susceptibility to damage by pathogens and climate factors, and to a change in marketability of produce; this risk, common to all types of monoculture, increases as genetic variability decreases, although it may be offset to some extent by increased predictability of performance and ease of management. Secondly, the amount of additive genetic variance available for future use by selection in the plantations is decreased, reducing the further gains possible through breeding. Thirdly, the risk of inbreeding depression in a breeding programme increases with increasing degree of relationship between selected individuals.

The number of parents represented, and their degree of relationship are thus important considerations when a crop is raised from seed. Seed may be obtained in bulk commercial collections or as small research lots; the latter may

[4]) Personal communication, H. BARNER 4th July, 1972.

be taken from commercial collections or purposely collected for research. In most commercial collections many parents are represented although unfortunately there is still a tendency in some areas to collect from easily climbed, accessible trees with poor phenotype and, presumably, frequently poor genotype. (The O.E.C.D. *source-identified* category allows this; the category *selected* is applied to seed from stands that are superior to the accepted mean for the prevailing ecological conditions. Inferior phenotypes must be removed from selected stands.) The number of parents represented in small research lots clearly influences the deductions that can be made from a comparative trial or the use that can be made of the material for further selective breeding.

The year of seed collection is also important. Annual changes in the environmental factors that influence flowering and seed production cause different trees to be represented as the male or female parents in different years. Although little can be done to influence this, the year of collection may have some effect on the use of the resultant trees for further breeding. The genetic constitution of a plantation changes with age as thinnings are carried out.

Classification of genetic histories

In a classification of genetic histories *(Table 1)* the main division is between seed collected in a natural stand ("natural provenance") and in a plantation ("derived provenance"). Even if the plantation is within the natural range of the species there are sufficient differences between natural or artificial selection in natural forests and plantations to merit separate discussion.

For both gregarious and non-gregarious species, natural provenances may be classified dichotomously by the degree of human interference *(Table 1A)*. Both dysgenic and eugenic treatment may reduce genetic variability, and both of these may have caused the development of new local races. Similarly a forest population invading or reinvading a deforested area may develop new genetic structure.

Seed collected from trees in a plantation (derived provenance) may be classified according to whether or not the provenance of the parents of the plantation trees is known; the provenance of the parents may itself be natural or derived *(Table 1A)*.

Seed collected in natural forests:

In the case of natural provenances *(Table 1B)* the poorest category is the bulked commercial collection made over a wide area with imprecise information on seed source and without any check on the collection. The lowest category to which an O.E.C.D. certificate could be applied is the *source-identified* class in which seeds are collected from representatives of a well defined region of provenance. The region of provenance is defined as the area or group of areas subject to sufficiently uniform ecological conditions on which are found stands showing similar genetic or phenotypic characters. However, it would be better to obtain information on a stand basis.

A higher category would require bulked collection from random representatives of a well defined stand sufficiently uniform in composition and arrangement to be distinct from adjacent populations. The next category in the O.E.C.D. system *(selected)* is the bulked collection from random representatives of a selected stand which is superior to the accepted local mean. In these three classes random checks should be made on the seed collection process and on the extraction data. (The O.E.C.D. *selected* category also includes seed from untested seed orchards based on superior individual trees — see below.)

A further important category in this group is the completely supervised collection of seed from specially selected representatives, usually superior phenotypes, with the seeds from each parent kept separate. This category is often termed 'plus tree seed' in indigenous forest; it is intended for research and is not referred to in the O.E.C.D. scheme for seed certification. Nevertheless it would be important to have this information about a seed lot if further selection were planned in the resultant plantation.

When the genetic superiority of any of these seed lots over some standard has been proved by properly conducted provenance tests the O.E.C.D. category *certified* (or *tested)* is applicable.

Seed collected in plantations:

If seed is collected in existing plantations there are again several categories that influence the genetic uniformity and value of resulting plantations *(Table 1C)*. The lowest category, which is frequently used, is seed from small plots such as arboreta or introduction trials. Here the numbers of trees represented as male and female parents are low and there is a possibility of deleterious self-pollination or of unwanted hybridization with other provenances or species.

Seed is commonly collected in commercial plantations that have received degrees of silvicultural treatment, hopefully eugenic. These range from virtually untreated stands (which suffer only local natural selection) to seed stands and seed production areas (which receive heavy silvicultural selection and special cultural treatment).

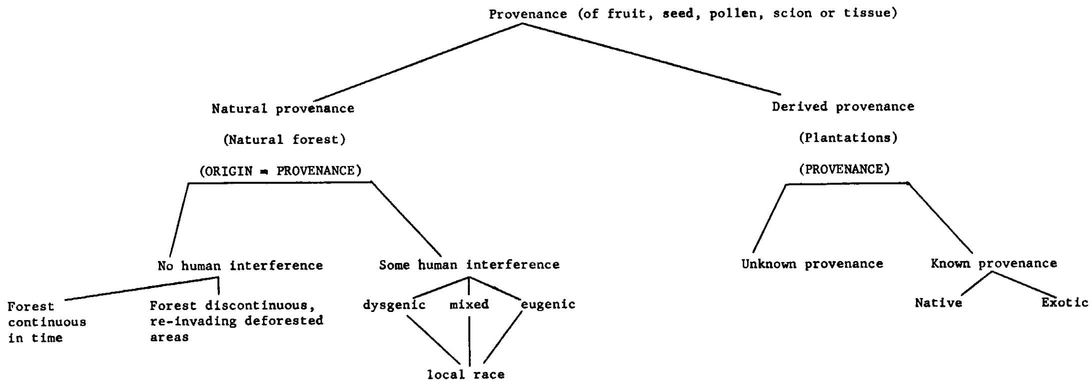
The ultimate step in the production of improved seed is the creation of seed orchards. These may comprise seedlings or vegetative propagules from superior individual phenotypes and may be untested (O.E.C.D. *select* grade) or tested; (see Barner, 1972). If found genetically superior to an acceptable standard sample they are graded *certified* (or *tested)*. The use of such material over several generations in a commercial plantation programme may produce land races (see de Vecchi Pellati, 1969). Seed orchards may be based on parents with good general combining ability or good specific combining ability or they may be intended for hybridization between species or provenances.

Few tropical and subtropical countries, apart from some in the Pacific, Mediterranean and central American regions, will establish major industrial plantations from indigenous species. Therefore the development of national seed zone systems may not be urgent. Nevertheless such a system is desirable. It is absolutely essential that all countries insist on some form of seed source identification and control for all seeds used, particularly imported seed. It is recommended that control is based on the O.E.C.D. system.

As all countries progress from seed source experiments to selection of individual phenotypes and tree breeding, it will become necessary to adopt more informative categories than *source-identified*. The indiscriminate use of seed of allegedly 'correct' species and provenance may be dangerous. The *selected* and *certified* categories of the O.E.C.D. scheme are valuable but more details of the genetic history of a given seed lot should be obtained; in particular the provenance (natural or derived) and the potential number of parent trees must be known.

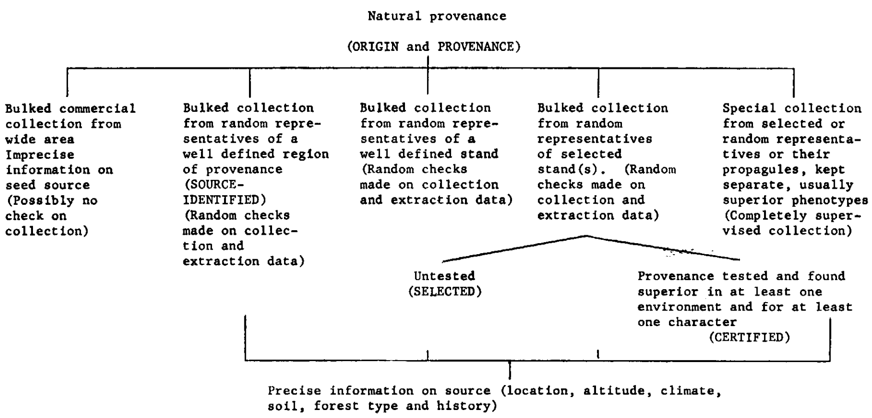
Table 1. A stylised classification of genetic history

A. Classification into natural and derived provenances



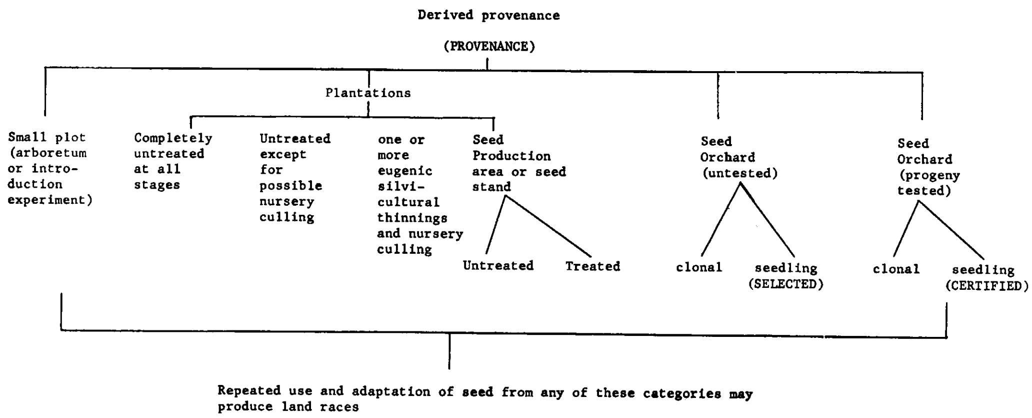
N.B. The entire system or any level of it could be repeated for parentages of 1 parent tree, 2-10 parent trees, or more than 10 parent trees; similarly by year of collection. Equivalent terms from the O.E.C.D. system are given in capital letters in brackets.

B. Sub-classification of natural provenance



N.B. Information, value and uniformity increase from left to right.

C. Sub-classification of derived provenance



N.B. Information, value and uniformity increase from left to right.

Abstract

Demands for forest tree seed are continually increasing throughout the world. Improvement programmes have revealed a paucity of information on the parentage of seed. Seed certification schemes have been developed in some countries to control the quality of seed and provide some of the required information. The Organization for Economic Cooperation and Development has proposed a scheme to control reproductive material moving internationally. This scheme is compatible with the scheme accepted by the European Economic Community, Various definitions of provenance exist. However, these definitions and schemes have limitations particularly for tree improvement programmes. This paper draws attention to additional information required for rational tree improvement. A classification of genetic histories is tabulated which emphasizes the potential parental differences between seed collections made in natural forests and those made in plantations.

Key words: Provenance, origin, seed source, seed certification, nomenclature, selection, seed trade.

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