Classifications of intraspecific variation in crop plants

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Introduction

Germplasm collectors must be thoroughly familiar with what is known of the variation present within their target taxon if they are to sample it efficiently. In crops this can be many times greater than in wild plants, especially for species which were domesticated early and have been widely spread around the world. Such variation is the result of both natural and artificial selection pressures. The latter may be conscious or unconscious, and result from the application of diverse agricultural practices and from the disparate and changing demands of growers for specific agronomic and other properties. Variation may be in morphological, anatomical, karyological, physiological, biochemical and molecular characters. Exploratory genetic diversity surveys using biochemical or molecular markers may be useful preliminaries to germplasm collecting (Chapter 6). Most relevant for the collector in the field, however, will be variation in morphological traits and in ecological adaptation. Making use of a scheme for the classification of the morphological variation within a crop can help collectors keep track of what they are finding and compare the diversity of different areas (Chapter 19).

The term ‘intraspecific’ is used here to refer to variation within a cultivated taxon, but it should be pointed out that the crop in a wild–weedy-crop complex is often given subspecific rank (e.g. Harlan and de Wet, 1971). Morphological intraspecific variation has been studied in many crops, though often for only a limited part of their geographic range or for a restricted set of characters. From 1978 to 1993 the literature on crop taxonomy (and evolution) has been reviewed in a series of publications by staff at the Institute of Plant Genetics and Crop Plant Research (IPK), Gatersleben. A full list of these reviews is given by Hanelt et al. (1993b). This series has now been discontinued, its task
taken over by the new *Plant Genetic Resources Abstracts* (Chapter 13). Zeven and de Wet (1982) and Schultze-Motel (1987) summarize information on the taxonomy and evolution of different crops. Floras sometimes consider variation within crop plants, though never in much detail. However, there are also specialized Floras dealing only with cultivated plants (see below).

There is general agreement about the necessity and importance of such studies (Mansfeld, 1963; Baum, 1981) in both applied and theoretical applications, ranging from the investigation of the history of the domestication of plants and their subsequent evolution to the characterization of germplasm. However, the procedures used to develop the classifications and the resulting schemes themselves are extremely diverse and a generally agreed approach has not yet emerged (Hanelt, 1986). Two extreme types of schemes may be recognized:

- complex hierarchical taxonomic subdivisions of a cultivated plant taxon, with many infraspecific taxa at several taxonomic ranks between the species and cultivar level (e.g. Dorofeev and Korovina, 1979; Nechansky and Jirasek, 1967);
- relatively simple, non-structured, special-purpose schemes with a few main groups (e.g. de Wet, 1978).

Because selfing results in the splitting up of variation within a crop into distinct homozygous lines, autogamous species tend to be relatively easier to classify in detail into many groups than allogamous species. In the past, this has led to over splitting, a trend that has been somewhat reversed by genetic studies.

The different methods of approaching the infraspecific taxonomy of crops are discussed in this chapter in so far as they may be relevant to the needs of collectors. For further details, see Hanelt (1986) and Hanelt *et al.* (1993a). The focus is on the literature in languages other than English, which tends to be somewhat overlooked.

Classifications

A classification scheme for classifications of the infraspecific variation of crop plants has been proposed by Hanelt (1986):

1. Formal taxonomic classifications:
   (a) diagnostic–morphological;
   (b) phenetic–numerical;
   (c) ecogeographic.
2. Informal taxonomic classifications:
   (a) diagnostic–morphological;
   (b) phenetic–numerical;
   (c) genetic.
Two principal types of approaches are distinguished, formal taxonomic and informal classifications. Whereas in the former formally recognized categories are used (more or less) according to the rules of the International Code of Botanical Nomenclature (ICBN) and the International Code of Nomenclature of Cultivated Plants (ICNCP), informal classifications use non-standard categories. In informal classifications, therefore, nomenclatural problems resulting from the use of the ICBN and the ICNCP (and the fact that the two codes are not always compatible (e.g. Brandenburg and Schneider, 1988)) are avoided. However, a broadly accepted designation of a group is not guaranteed and, therefore, communication of information on the material under study is more difficult.

**Formal taxonomic classifications**

**Diagnostic-morphological classifications**

Usually these classifications are based on a few, easily recognizable morphological characters and allow a rapid overview of variation within a crop. Several major publication projects have been based on this type of infraspecific classification, e.g. the *Flora of Cultivated Plants of the Soviet Union* and *The Cultivated Plants of Hungary* (Máthé and Priszter, 1982). R. Mansfeld, the founder of the Gatersleben school of taxonomy, which has studied the infraspecific classification of several important cereal, legume and vegetable crops, provides a typical example with his morphological system of *Triticum aestivum* (Mansfeld, 1951). He considers 12 characters and organizes infraspecific variation into more than 400 varieties, each differing from related ones in only one character. Mansfeld's (1950) scheme for *Hordeum vulgare* is another example. Below the species level he applied the category of convarietity (defined by Alefeld, 1866; cited by Helm, 1964) and accepted five, defined by major spike characters: convar. *vulgare* (convar. *hexastichon*), convar. *intermedium*, convar. *distichon*, convar. *deficiens* and convar. *labile*. Formerly, some of these convarieties had even been described as separate species (not least, by Linnaeus). There are some differences in geographic distribution and even some barriers among them which may indicate that this category has some biological significance. Varieties, of which 191 are described, are purely artificial entities, however. In fact, such classifications are as a rule rather artificial, especially at lower taxonomic levels.

The same principles have been applied to *Papaver somniferum*. Based on the classification of Danert (1958), Hammer (1981) developed a system containing three subspecies. Ssp. *setigerum* is the wild ancestor; ssp. *somniferum* and ssp. *songaricum* are both cultivated. The cultivated subspecies differ in having sulcate lobes of the stigmatic disc with dentate margins vs. flat lobes with entire margins. These characters have been considered as very important by *Papaver*
taxonomists and also show clear geographic differentiation. The con-
variety level is defined by indehiscent vs. dehiscent capsules, another
important character indicating different stages of domestication (Hanelt
and Hammer, 1987). The variety level is based on seed colour, resulting
from selection pressure under domestication, and other characters.
Such classifications can be very useful to the plant collector. Since
the morphological entities they define can be recognized relatively
easily, they can be used as the basis of field checklists. Rapid comparison
of different areas with regard to the variation found there is possible and
gaps in collections can be identified. Assessments of variation at dif-
ferent times based on such classifications have been used to estimate
genetic erosion, for example in Sicily (Prestianni, 1926; Perrino and
Hammer, 1983).
In some cases, the classifications are of restricted applicability
because they deal with the cultivated flora of a rather restricted area
(e.g. Máthé and Priszt, 1982). However, even country Floras of
cultivated plants may employ a comprehensive concept of taxa, allowing
them to be used for even a worldwide survey. The *Flora of Cultivated
Plants of the Soviet Union* is perhaps the best example. Important
recent contributions, in addition to the already mentioned *Triticum*
volume are: Kazakova (1978), Makaseva (1979), Fursa and Filov (1982),
Smaraev and Korovina (1982), Girenko and Korovina (1988), Kobyljans-
skij (1989), Kobyljanskij and Lukjanova (1990). The morphological
classifications from the Gatersleben school are listed by Hammer (1981).
In addition to the already mentioned *Hordeum vulgare, Papaver som-
niferum* and *Triticum aestivum* studies, there are works on *Beta
vulgaris, Brassica oleracea, Glycine max, Linum usitatissimum,
Lycopersicon esculentum, Nicotiana rustica, N. tabacum* and *Pisum
sativum*.
A potential problem with such schemes is that the availability of the
publications describing them may be limited. Many are not available in
English and may be difficult to obtain. As a result, some older classifica-
tions, such as that of Percival (1921) on *Triticum*, are sometimes used
even today in the English-language literature.

**Phenetic-numerical classifications**
These classifications consider a large number of characters. Various
multivariate mathematical methods are used to calculate similarities
among types and identify groupings. There are several examples
(reviewed by Schultze-Motel, 1987) but none is particularly convincing
in the context of formal taxonomy.

**Ecogeographic classifications**
Such classifications have been developed by the Vavilov school based on
the hypothesis that, in an area where selection pressures by environ-
mental factors, cultivation practices, propagation methods, etc. are relatively homogeneous, a crop will tend to have a certain genetic integrity (Vavilov, 1940). An example of ecogeographic classification is that proposed by Flaksberger (1935) for *Triticum aestivum*, which includes two subspecies, 15 proles and six subproles.

New taxonomic categories have often been introduced. Groups are largely defined by their geographic origin and by characters which reflect the agricultural and ecological conditions to which they are adapted (e.g. reproductive phenology, pest and disease resistance, growth characters, etc.). In general, field experiments are necessary to verify the results and to incorporate new accessions into such a classification. Therefore, they may not be directly applicable during the collector’s fieldwork. However, they may be very useful for the characterization of collections, facilitating use of the material by breeders. There is still no bridge between formal ecogeographic classifications and the use of an ecogeographic approach in fieldwork (Chapter 14).

**Informal taxonomic classifications**

**Diagnostic–morphological classifications**

There is no example of this kind of approach describing the full extent of variation within a crop. There are, however, some regional studies. The classification of French bush bean cultivars is one. They have been arranged into three categories, i.e. groups, sections and classes (Anon., 1983). Pod characters (11 character states) are used for the differentiation of groups and sections, and leaf colour, pod length, colour of unripe pods and length of bracts (12 character states) for the differentiation of classes. The resulting system comprises five groups, 14 sections and many classes. Another example, also from *Phaseolus vulgaris*, shows that the input of biochemical methods (in this case, phaseoline types) can lead to phylogenetically more relevant groupings within an informal classification of the diagnostic–morphological type (Hammer, 1992).

**Phenetic–numerical classifications**

One of the best examples of this type of classification is the study of the South American cultivars of cassava (*Manihot esculenta*) by Rogers and Fleming (1973). They used 55 character states and defined 19 groups of cultivars. Within these groups there is a high degree of phenotypic similarity, and evidently also considerable genetic similarity. New material can be easily incorporated into the proposed classification scheme. However, the evaluation of the basic data for this type of study is very time-consuming.
Genetic classifications
This type of classification is only possible in crops whose genetics have been well studied, such as *Pisum sativum* (Blixt, 1979), where the genes responsible for the expression of many different characters are known. In peas there has also been an attempt to combine a formal diagnostic and a genetic classification (Lehmann and Blixt, 1984). It is difficult to incorporate new material into such classifications. Test crosses are necessary and multifactorial characters cannot be included at all. Somewhat different are classifications based on genomic composition. An example is that of Simmonds for the edible fruit-bearing bananas (Simmonds, 1966; Simmonds and Weatherup, 1990). These are classified by reference to ploidy (2×, 3×, 4×) and the genomic contribution made by two diploid wild species (AA *Musa acuminata* and BB *Musa balbisiana*). Some 15 characters are used to distinguish among cultivar groups.

Mixed classifications
There is no single classification approach suitable for all possible demands. Different aims can be achieved with different types of classifications. A combination of classifications has been proposed by Hanelt (1972) for *Vicia faba*. A formal diagnostic classification into two subspecies, three varieties and six subvarieties, based mainly on seed size, form and structure of pods, was combined with an informal classification into 14 races, based mainly on ecogeographic data. A similar approach has been used for *Citrullus lanatus* (Fursa, 1981).

Conclusions
It is well known that most of the more important and widespread crop species are characterized by an enormous amount of intraspecific variation. Familiarity with this is essential for the effective collecting of plant genetic resources. There are many publications on the intraspecific taxonomy of crop plants, but many have been written in languages other than English, in particular the papers of the Vavilov school. A variety of methods have been proposed for the classification of crop plants. Most appropriate for collectors seem to be ones based on easily recognizable characters of the gross morphology. Variation in such characters can be used to establish taxonomically formal or informal diagnostic classifications. These will be no less useful for the later management of collections than for the collector in the field.

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