Case Studies for the Use of Infraspecific Classifications in Managing Germplasm Collections of Cultivated Plants

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Abstract
Rational categories of infraspecific diversity are useful for structuring a genebank collection, when discussing gene-erosion and for making management decisions for maintenance of ex-situ germplasm collections. The interrelated history of ex-situ germplasm collections and the concept of infraspecific classifications in cultivated plants are briefly outlined. The diversity of oat (Avena sativa), flax (Linum usitatissimum) and coriander (Coriandrum sativum) are considered for discussing their infraspecific diversity as reflected by taxonomy and nomenclature. Phenotypic diversity as evident from characterization data generated at the national genebanks in Canada and Germany and the most significant taxonomic literature for these species form the basis of this discussion. The rationals for distinguishing three subspecies of Avena sativa, four convarieties of Linum usitatissimum and three subspecies of Coriandrum sativum are discussed. The goal of this paper is to demonstrate the usefulness and the limitations of formal infraspecific groupings from a genebank perspective. It is suggested that infraspecific classifications should be complementary and the highest infraspecific ranks should divide the species into the most relevant groups from an agronomic or horticultural perspective. More elaborated classifications are useful for special investigations into the diversity of a crop.

INTRODUCTION
A rational and standardized terminology for species or infraspecific groups of plants is highly desirable for effective communication of genetic diversity. Therefore, genebanks must be current with recent developments in taxonomy and nomenclature. The importance of appropriate taxonomical and nomenclatural principles for the successful management and use of plant genetic resources was already elaborated and emphasized by Vavilov (1931). Taxonomic concepts for cultivated plants were further developed (Mansfeld, 1953; 1954; Danert, 1962; Harlan and de Wet, 1971). The important role of taxonomy for genetic resources has recently been emphasized by Hazekamp and Guarino (1999), and is also evident from the architecture of modern computerized databases, such as the Genetic Resources Information Network Database (GRIN) of the United States Department of Agriculture (Shands, 1995).

The binomial nomenclature introduced by Linnaeus is generally accepted as the basic unit for communication of genetic diversity, although the species concept is sometimes questioned (Bachmann, 1998). There have been suggestions to replace this classical taxonomic concept with a new, separate nomenclature for cultivated plants (Hetterscheid and Brandenburg, 1995). Genebanks typically deal with large collections for any given species. A common concern is how to structure the diversity observed in a given species, and how to manage and communicate infraspecific diversity (Hazekamp and Guarino, 1999).

Genebanks preserve, to a large extent, historically collected germplasm. Often this material is associated with historic taxonomic information documented in the passport...
part of a database. Taxa, considered at one point of time as species, are now often considered as infraspecific taxa, or not as formal taxonomic groups at all. The historical dimension of genebank work causes these institutions to be conservative in accepting nomenclatural changes. However, new insights into the genetic makeup and composition of germplasm sources, in particular from molecular genetic investigations, require continuous evaluation of existing characterization methods for genetic diversity. Information associated with genebank accessions, from taxonomic revisions or other historic documentations of diversity will be important for detection of changes in biodiversity. An example in this direction is a botanical variety of coriander collected in Ethiopia, taxonomically described and documented in herbaria by Vavilov and his colleagues, which could recently not be found in cultivation. This demonstrates the use of reliable methods to transfer genebank collections and associated information to future generations.

This contribution briefly outlines the origin of infraspecific classifications in cultivated plants and their relevance for ex-situ germplasm collections in genebanks. It considers the diversity of oat (Avena sativa L.), flax (Linum usitatissimum L.) and coriander (Coriandrum sativum L.) for discussing their infraspecific diversity as reflected by taxonomy and nomenclature. Phenotypic diversity as evident from characterization data generated at the national genebanks in Canada and Germany and the more significant taxonomic literature of the species form the basis for this overview. The goal of this paper is to demonstrate the usefulness and the limitations of formal, infraspecific groupings from a genebank perspective. Based on phenotypic data for the above three plant species suggestions for formal infraspecific groupings in cultivated plants are developed.

**INFRASPECIFIC GROUPINGS IN CULTIVATED PLANTS**

The usefulness of infraspecific classifications as a concept for the characterization of diversity is often questioned and sometimes even the usefulness of the species itself as a unit of diversity is questioned (Bachmann, 1998). However, the usage of names which are practical for grouping phenotypic and thus genotypic diversity evolved naturally in human society. Man strives to bring his thoughts about the environment in congruence with his observations. Thus, he develops language and appropriate terminologies for several areas which are the rational complement to the observed facts. In crops, for example, farmers have good reasons to distinguish between wild oat and cultivated oat, or between hulled oat and hull-less oat, and certainly between oat and flax. Obviously, humans create useful terms to communicate their observations on the environment, which are needed to understand their surroundings and also to actively change their environment. Plant taxonomy is born out of this general characteristic of human nature.

Vavilov (1935) introduced the “differential phyto-geographical method” for infraspecific classification of cultivated plants which includes the formal taxonomic approach for naming infraspecific taxa. Vavilov (1931) clearly stated that the study of herbarium material is not sufficient for describing infraspecific groups in cultivated plants, but genebank collections grown and investigated under different environmental conditions yield the data to structure a genepool. Vavilov (1920) also indicated the usefulness of morphological homologies for rationally structuring the diversity of species. The interactions between diversity studies in genebanks and taxonomy of cultivated plants have influenced the research and genebank management at the All Russian Institute of Plant Industry (VIR) at St. Petersburg and at several other places, especially in Europe (Danert, 1962; Hanelt, 1988; 2001).

The differences between wild and cultivated plants have always challenged taxonomists (Hetterscheid et al., 1996). Linnaeus himself considered the wild species as something different from the variations gardeners produced (Stearn, 1986). Several cultivated plant species, and in particular ornamental plants were bred utilizing interspecific or intergeneric hybridization. Modern technologies allow combination of genetic material from different, species, genera, families and even kingdoms. Therefore, the distinctness among species and even more so among infraspecific groups, which may
have been historically closely related to certain geographical areas and morphologically different, are disappearing in many modern crop cultivars. Due to these developments, Hetterscheid and Brandenburg (1995) suggested a completely new approach for grouping cultivated plants by introducing the term culton as a replacement for the well defined term taxon. They mention explicitly that their classification for cultivated plants would not be complementary, that is it does not necessarily cover the entire diversity within the group it refers to. They also indicate that their classification will only include cultivars which have been named. They consider unnamed material as not important enough to give it a proper identity. This clearly shows that the culton concept can not replace the classical concepts of taxonomy as outlined in the International Code for Botanical Nomenclature (Greuter et al., 2000) in cultivated plants from a genebank perspective. Landraces and primitive material without assigned cultivar names need to be respected in infraspecific groupings (Hanelt, 2001). The International Code of Nomenclature for Cultivated Plants (Trehane et al., 1995) partly integrates the culton concept as outlined above and is useful for naming and identifying recent cultivars in a consistent manner, but does not give guidelines for the rational classification of the entire range of diversity in a species as preserved in genebanks.

MATERIAL AND METHODS

Selected Crops

Oat represents a major cereal crop, which was of great importance in industrialized countries before tractors replaced horses. Breeding efforts in these countries decreased, but in areas with short vegetation periods, such as Canada and the Scandinavian countries, oat remained a part of crop rotations and oat breeding is still active. Common oat, Avena sativa, is a hexaploid species. A wide range of Avena species exist at the hexaploid, tetraploid and diploid levels that are related to A. sativa. Flax as an industrial crop is used for fibre and the seed/seed oil is used for human and animal nutrition or industrial purposes. Historically, selection in flax occurred for fibre types vs. seed types. Breeding activities for both uses continue in several countries, but usually one of the usages dominates depending on the economic importance of the use. A well defined taxon of the wild progenitor of cultivated flax exists. Coriander represents a horticultural crop used as a vegetable, or the seeds are used as spice or in medicine. Modern plant breeding has been limited in this crop and a wild progenitor is not known.

Phenotypic Characterization

The phenotypic data used for discussing the infraspecific diversity of oat (about 9,900 accessions) and flax (about 3,100 accessions) were collected at the Canadian genebank, Plant Gene Resources of Canada (PGRC), Saskatoon, Saskatchewan. The data for coriander (330 accessions) were mostly generated at the German genebank, Institut für Pflanzengenetik und Kulturpflanzenforschung, Gatersleben (IPK), and partly at PGRC, Saskatoon. The collections at PGRC and IPK for the species are comprehensive and cover a wide range of geographic origins of the three species. The phenotypic data for the three plant species were collected from field grown plants. Standardized descriptor lists were applied for the agrobotanic characterization. The composition of the collections and the detailed observation data have been published for coriander (Diederichsen, 1996; 1997) and flax (Diederichsen, 2001); the composition of the oat collection is presented in Diederichsen et al. (2001).

In this study, the phenotypic observations are discussed in synopsis with taxonomic literature on the infraspecific diversity of the species. The observations presented are limited to the most important characteristics from an agronomic viewpoint, because these are the aspects of greatest concern for most genebank clients and, therefore, of greatest relevance. This also limits the discussion of the infraspecific taxa to the most relevant aspects, i.e., to the highest ranking infraspecific taxon, which are the subspecies in A. sativa and C. sativum and the convarietas in L. usitatissimum.
RESULTS AND DISCUSSION

Phenotypic Diversity in Cultivated Hexaploid Oat

Within cultivated hexaploid oat (Avena sativa) a wide range of diversity can be observed for quantitative characters such as plant height, which ranged from 30 cm to 200 cm (n = 9,928, standardized data). Phenotypic diversity is very obvious when considering qualitative characters of the generative plant parts such as panicle shape (unilateral vs. equilateral) or lemma colour (black, black and white, black and brown, brown and white, grey, reddish brown, tan, white/amber and yellow), which are under the control of a few genes. A character of great practical importance in agriculture and the food industry is the distinction between hulled and hull-less oat. In the PGRC A. sativa collection 9,660 accessions (97.7%) were found to be hulled and 223 accessions (2.3%) to be hull-less. A phenotypic group of cultivated hexaploid oat which was formerly often distinguished at the species level with the formal name A. byzantina C. Koch, or the informal name “red oat” is often mentioned in oat literature (Stanton, 1961). The morphological distinction is mainly based on the separation of the rachilla segment between the first and second floret within the spikelets. In the A. byzantina group, the separation occurs by basifracture or heterofracture, i.e. the entire rachilla segment or most of it remains attached to the second floret (Stanton, 1961; Rodionova et al., 1994). In common A. sativa, the rachilla segment separates by acrofracture, i.e. the rachilla segment remains with the first floret. In general, the A. byzantina group has characteristics of a more primitive type of oat, as indicated by dark coloured lemmas and loose panicles. However, drought resistance is also a characteristic of this group and in the southern United States several cultivars of the A. byzantina group have been released and are referred to as red oat (Coffman, 1977; Rodionova et al., 1994). Breeding has created intermediate types between A. byzantina and A. sativa, which can make morphological distinction between these two types difficult. Within the hulled oats of the PGRC collection, 17.5% show the A. byzantina and 82.5% the A. sativa floret separation pattern.

The phenotypic differences mentioned above are also reflected in the geographic origin of the accessions. Hull-less, hexaploid oat is frequently described for China and is less common in oat from Europe or other parts of the world (Vavilov, 1926). The evolutionary history of hull-less oat is not clear. The A. byzantina type oat originates from the Mediterranean area.

Infraspecific Groups in Oat

The fundamental phenotypic difference between hulled and hull-less oat gave rise to a formal taxonomical distinction at the subspecies level (Rodionova et al., 1994). Hulled oat is named A. sativa subsp. sativa and hull-less oat A. sativa subsp. nudisativa (Husnot.) Rod. et Sold. (Rodionova et al., 1994). The name A. nuda L. has often been used for hull-less hexaploid oats, but this name refers to the hull-less diploid cultivated oat (Danert, 1972), which should better be classified as a subspecies of the diploid cultivated A. strigosa. A rational grouping of the phenotypic diversity of the genus Avena should reflect cultivated diploid and hexaploid oat showing parallelism in phenotypical diversity (e.g. hulled vs. hull-less kernels on both ploidy levels). It seems inconsistent when oat taxonomists assigned morphotypes a species rank in cultivated diploid oat (which are: A strigosa Schreb., hulled; A. nuda L., hull-less; A. brevis Roth and A. hispanica Ard. ex Saggi, from the Mediterranean area) while the formal distinction of the corresponding morphotypes on the hexaploid level is not conducted or rejected by the same authors (for example: Baum, 1977; Leggett, 1992; Kruse, 2001). Diploid oat is rarely cultivated, occurring often as a weed, and obviously received more recognition by taxonomists than the economically much more important hexaploid oat. However, in monographs describing the diversity in the genus Avena for plant breeding (e.g. Zade, 1918; Coffman, 1977) the mentioned morphotypes of cultivated hexaploid oat are carefully discussed from an agronomic viewpoint and the species rank is frequently used to name these groups. This demonstrates clearly that biologists and agronomists often
have different perspectives and as a result their grouping and nomenclatural treatment of a gene pool can be very different.

Vernacular and scientific names for the main groups of *A. sativa*, and their representation in the national genebanks of Canada, USA, Germany and Russia are presented in Table 1. In contrast to the grouping presented in Table 1, Rodionova et al. (1994) suggested to maintain the species rank for *A. byzantina*. Recently, molecular investigations (Zhou et al., 1999; Jellen and Beard, 1998) showed that *A. sativa* was derived from *A. sterilis* and also supported the earlier hypothesis that *A. byzantina* was derived from *A. sterilis* (Thellung, 1911; Holden, 1976; Scholz, 1991). It seems appropriate to use the taxonomic name combination introduced by Romero Zarco (1996) assigning the subspecies rank to this taxon resulting in the name: *A. sativa* subsp. *byzantina* (C. Koch) Romero Zarco.

In conclusion, a formal distinction of three major groups within the hexaploid cultivated oat is suggested: (1) common oat *A. sativa* subsp. *sativa*, (2) hull-less oat, *A. sativa* subsp. *nudisativa* and (3) red oat, *A. sativa* subsp. *byzantina*. Since these three groups are also associated with distinct geographic areas, it is also appropriate to use the taxonomic rank of subspecies for these taxa. Assigning the rank of subspecies to the three groups of *A. sativa* clearly indicates that these taxa are very closely related and belong to the primary gene pool for oat breeding.

Cultivated hexaploid oat (*A. sativa*) produces fertile offspring when crossed with the other hexaploid species of the genus *Avena*, which are wild or weedy (Loskutov 2001). Baum (1977) lists five species belonging to the primary gene pool of *A. sativa*: *A. sterilis* L., *A. fatua* L., *A. hybrida* Peterm., *A. occidentalis* Durieu and *A. trichophylla* C. Koch. The use of the so called biological species concept in *Avena* as suggested by Ladizinsky and Zohary (1971) would result in including all hexaploid taxa in one species *A. sativa* s.l. This would cause several name recombinations, affecting also the widespread and well studied weed species *A. sterilis* and *A. fatua*, for which several infraspecific taxa are described (Rodionova et al., 1994). The advantage of historical continuity, nomenclatural stability and also the major morphological and evolutionary differences (wild vs. cultivated taxa) support preservation of distinct species names for the wild hexaploid oats.

**Phenotypic Diversity in Flax**

Flax is either cultivated for the stem fibre or for its seed. Therefore, vernacular names in several languages clearly distinguish between fibre flax and linseed. However, phenotypic diversity shows a continuous variation for all characters used to distinguish fibre flax from linseed. Characterization data of about 3,100 accessions grown at Saskatoon, Saskatchewan, demonstrated this continuum. For example, plant height ranged from 20 cm to 130 cm, 1,000 seed weight from 2.8 g to 11.5 g and stem branching was observed from branching on the entire stem length to branching limited to the upper parts of the stem. The characters describing colour of flower parts and seeds show a wide range of diversity and these characters are highly heritable. A qualitative character of great practical relevance is the degree of dehiscence of mature capsules. In certain genotypes the capsules open completely which results in seed shattering. Phenotypes with complete opening of the capsules are not found in cultivation by present day agriculture and are only preserved in genebanks. These flaxes were formerly often classified as a separate species, *Linum crepitans* Dumort. (Kulpa and Danert, 1962).

**Infraspecific Groups in Flax**

A guideline for the taxonomic grouping of cultivated flax into fibre flax, oilseed flax and intermediate flax has been provided by Kulpa and Danert (1962). Their key for determination of these infraspecific group uses a combination of the characters plant height, branching pattern of the stem and seed weight to distinguish fibre flax, oilseed flax and intermediate flax. In addition to that, the authors defined a fourth group with spontaneously opening capsules (dehiscent flax). The representation of these major flax
groups in the PGRC and IPK flax collections is shown in Table 2.

The taxonomic grouping of flax uses the category convarietas (convar.). The taxon convar. was introduced by Alefeld (1866) under the German term “Varietäten-Gruppe” when he worked extensively on infraspecific grouping of cultivated plants (Helm, 1964). Using the taxon convar. implies that the distinction is morphologically obvious, but does not clearly reflect a geographic and phylogenetic difference, as does the taxon subspecies. Furthermore, the application of the category convar. implies that, at a lower taxonomic rank, botanical varieties exist. The distinction of the 28 botanical varieties in flax as suggested by Kulp and Danert (1962) is artificial and of less practical relevance, but is still useful when very specific categories are desired to distinguish the diversity within the species (Diederichsen, 2001).

The wild progenitor of cultivated flax, *L. usitatissimum* subsp. *angustifolium* (Huds.) Thell., is a taxon sometimes considered as a species of its own (*Linum bienne* Mill.) and sometimes referred to as a subspecies. Since there is only this one wild progenitor, nomenclatural changes when integrating this taxon into the species *L. usitatissimum* are relatively minor. The observations by Heer (1872) suggested this and the taxonomic name combination was proposed by Thellung (1912).

**Phenotypic Diversity in Coriander**

Coriander shows a wide range of diversity in characters describing vegetative and generative plant parts. The weight of 1,000 fruits varies from 3.1 g to 18.9 g, plant height from 20 cm to 150 cm and volatile oil content in the mature fruits from 0.01% to 1.73% (Diederichsen, 1997). Very large phenotypic differences occur also in habitus, degree of leafiness, shape of leaves and phenological characters.

**Infraspecific Groups in Coriander**

The fruit size and weight has for a long time been recognized as an important character dividing the species into two subspecies (small-fruited vs. large-fruited), which have different geographical origin and agronomic properties (Alefeld, 1866; Harrod, 1960). De Candolle (1830) was the first to recognize the small-fruited coriander as being considerably different. In addition, the shape of the mature fruits can be used to distinguish a third group within the species, which originated mostly from the Indian subcontinent. This infraspecific group is morphologically distinguished by ovate fruits and chemotypically characterized by a low proportion or complete lack of camphor in the volatile oil in the fruits. The geographically distinct origin of this third group and the great economic importance of the volatile oil composition support the distinction of this infraspecific group as a third subspecies. The three subspecies of coriander, their formal taxonomic names, a corresponding English name and their representation in the collection at IPK are listed in Table 3.

**USEFULNESS OF FORMAL INFRASPECIFIC GROUPINGS**

Infraspecific groups using names assigned according to the rules of the *International Code of Botanical Nomenclature* (ICBN) (Greuter et al., 2000) are useful for international communication because the principles of priority, typification and publication guarantee a clear reference for each name. The names and associated infraspecific groups can be tracked and investigations at different points in time can be interrelated. The detailed infraspecific classifications for oat (Rodionova et al., 1994), flax (Elladi, 1940; Kulpa and Danert, 1962) or coriander (Ivanova and Stoletova, 1990) give an exact picture of the known range of diversity within a species at a given time. This rationalizes communication and the use of the diversity within a species.

Categories for quantification of biological diversity are needed to describe the phenomenon of gene-erosion, the occurrence of which is sometimes questioned due to lack of data (Evenson and Santaniello, 1999). Infraspecific taxa defined according to the rules of the ICBN can be used for such categories and several examples exist. For example, the recent existence of *Coriandrum sativum* var. *vavilovii* Stolet., which was
described for Ethiopia, could not be proven. Hammer et al. (1999) documented gene-erosion in Italian wheat \textit{(Triticum} L.) by comparing the infraspecific taxa in recently cultivated wheats to the number of taxa grown at the beginning of the 19\textsuperscript{th} century. A comparison of the botanical varieties in flax represented in Canadian flax cultivars with the botanical varieties represented in a world collection documented the phenotypic uniformity among the recent cultivars. In his criticism of infraspecific classifications, Mac Key (1981) stated the same for wheat: modern European wheats only fall into a few groups of the widely differentiated wheat classification elaborated by Dorofeev and Korovina (1979). This demonstrates, that the classification is less useful for distinctions among genetically closely related recent wheat cultivars, but shows also the narrow genetic basis in modern cultivars.

For genebanks, the importance of structuring the information about infraspecific variation of cultivated plants is also evidenced from recent discussions about the establishment of core collections in order to enhance the use of large germplasm collections (van Hintum, 1999). In several instances, infraspecific classifications of a crop proved to be useful when selecting genebank accessions for a core collection. Skinner et al. (1999) demonstrated this for the genus \textit{Medicago} L.

Improved comparisons of large genebank collections are possible when using standardized infraspecific groupings as shown for oat, flax and coriander in the Tables 1-3. This is an example for communication of diversity.

Taxa, which were at one point of time distinguished on the species level, are usually morphologically well defined. For practical reasons it may be desirable to maintain a separate name on the infraspecific level. In cultivated plants, the morphological differences among such taxa are often of great practical relevance and may be useful for the management of a collection to clearly distinguish such groups. Appropriately applied, taxonomy can facilitate the rational use of plant genetic resources (Small, 1993). Examples are the distinctions within oat, flax and coriander shown in Tables 1-3, which are of great relevance to farmers and industry.

LIMITATIONS

An argument for rejection of infraspecific classifications is that modern breeding combines characters of traditionally separated phenotypic groups and thus creates phenotypes that merely fit into artificial classifications (Mac Key, 1981). This argument can not be rejected and only in certain cases there will be a way to define intermediate groups, as for example, in flax. The limitation becomes particularly obvious in crops which have been subjected to considerable breeding activity and international germplasm exchange. An example is the problematic distinction of \textit{A. sativa} subsp. \textit{byzantina} in recent breeding material.

Infraspecific classifications which describe many taxa on several hierarchical levels are obviously artificial (Danert, 1962). Such elaborated classifications do rarely reflect the evolutionary relations of the groups within the species. The evolutionary pathways under domestication are different from those in wild plants and the concepts of classical taxonomy are sometimes difficult to apply to cultivated plants.

The formalism connected with the application of the rules outlined in the ICBN (Greuter et al., 2000) causes inflexibility and complicated names or name combinations, which are not easily accepted outside the circle of taxonomists.

CONCLUSIONS

Infraspecific groups in cultivated plants defined and named in accordance to the ICBN (Greuter et al., 2000) can be useful to support management of genebank collections and communication about diversity. Infraspecific classifications have to be complementary and the highest infraspecific ranks should divide the species into the most relevant groups from an agronomic or horticultural perspective. Formal taxonomy should study the reasons farmers and gardeners had, when creating an informal name for an infraspecific group, because this may guide the development of a useful formal system for
grouping and naming. Elaborated and detailed classifications are useful for special investigations into the diversity of a crop. Well assembled genebank collections with comprehensive characterization data are suitable for evaluating the diversity observable within cultivated plant species and for developing rational infraspecific classifications. In addition to the typification method of the ICBN, which prescribes to refer the published name of a taxon to a herbarium specimen, it is suggested to assign reference specimens which are living accession in an existing genebank in publications describing infraspecific taxa of cultivated plants.

Informal names or cultivar names given according to the rules of the International Code of Nomenclature for Cultivated Plants (Trehane et al., 1995) have a different function and cannot replace names, which structure the genepool in a rational way and are assigned to infraspecific groups based on the rules of the ICBN (Greuter et al., 2000). However, in some cases, involving wide crosses or new technologies, it may be impossible to place a given cultivar in a hierarchical classification and the cultivar or cultivar group name in connection with the lowermost applicable formal taxon name is the best way of identification. Temporarily or locally used names and names based on the cultivar group concept should be preserved in the passport data associated with genebank accessions.

ACKNOWLEDGEMENTS

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Literature Cited


Leningrad, Moskva.
### Tables

Table 1. Infraspecific groups of *Avena sativa* L. dividing the species into three major phenotypic groups and their representation in the collections of Plant Gene Resources of Canada (PGRC), United States Department of Agriculture National Germplasm Network (USDA), All-Russian Research Institute for Plant Industry (VIR) and Institut für Pflanzengenetik und Kulturpflanzenforschung (IPK).

<table>
<thead>
<tr>
<th>Formal botanical name</th>
<th>Vernacular name</th>
<th>Differential characteristics and geographical centre of diversity</th>
<th>Accessions in genebanks</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>A. sativa</em> L. subsp. <em>sativa</em></td>
<td>Common oat</td>
<td>Kernels hulled; floret separation by acrofracture; temperate regions of Europe and western Asia</td>
<td>PGRC&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td><em>A. sativa</em> L. subsp. <em>nudisativa</em> (Husn.) Rod. et Sold.</td>
<td>Hull-less oat</td>
<td>Kernels hull-less; China, Central Asia and Central Europe</td>
<td>223</td>
</tr>
<tr>
<td><em>A. sativa</em> L. subsp. <em>byzantina</em> (C. Koch) Romero Zarco</td>
<td>Red oat</td>
<td>Floret separation by basifracture or heterofracture; Mediterranean area</td>
<td>1,689</td>
</tr>
<tr>
<td><strong>Total hexaploid, cultivated oat</strong></td>
<td></td>
<td></td>
<td>9,883</td>
</tr>
</tbody>
</table>

<sup>1</sup> Source: Own characterization data.
<sup>2</sup> Source: USDA website: http://www.ars-grin.gov/
<sup>3</sup> Source: M. Grau, IPK, Gatersleben, pers. communication, and IPK website: http://mansfeld.ipk-gatersleben.de/mansfeld/Query.htm
<sup>4</sup> Source: I.G. Loskutov, VIR, St. Petersburg, pers. communication and VIR website: http://www.vir.nw.ru
Table 2. Infraspecific groups of *Linum usitatissimum* L. subsp. *usitatissimum* dividing cultivated flax into four major phenotypic groups and their representation in the collections of Plant Gene Resources (PGRC) of Canada and Institut für Pflanzengenetik und Kulturpflanzenforschung (IPK).

<table>
<thead>
<tr>
<th>Formal botanical name</th>
<th>Vernacular name</th>
<th>Differential characteristics</th>
<th>Accessions in PGRC collection¹</th>
<th>Accessions in IPK collection²</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>L. usitatissimum</em> L. convar. <em>usitatissimum</em></td>
<td>Intermediate flax</td>
<td>Combines characteristics of fibre flax and the large seeded flax</td>
<td>2,501</td>
<td>827</td>
</tr>
<tr>
<td><em>L. usitatissimum</em> L. convar. <em>elongatum</em> Vav. et Ell.</td>
<td>Fibre flax</td>
<td>Tall plants with branching only in the upper region; small seeds</td>
<td>417</td>
<td>440</td>
</tr>
<tr>
<td><em>L. usitatissimum</em> L. convar. <em>mediterraneum</em> (Vav. ex Ell.) Kulpa et Danert</td>
<td>Large-seeded flax</td>
<td>Short plants with branching all over the stem; large seeds</td>
<td>173</td>
<td>117</td>
</tr>
<tr>
<td><em>L. usitatissimum</em> L. convar. <em>crepitans</em> (Boenningh.) Kulpa et Danert</td>
<td>Dehiscent flax</td>
<td>Mature capsules open completely and shatter seeds</td>
<td>10</td>
<td>27</td>
</tr>
<tr>
<td><strong>Total cultivated flax</strong></td>
<td></td>
<td></td>
<td><strong>3,101</strong></td>
<td><strong>1,411</strong></td>
</tr>
</tbody>
</table>

¹ Source: Own characterization data.
² Source: IPK website: http://mansfeld.ipk-gatersleben.de/mansfeld/Query.htm
Table 3. Infraspecific groups of *Coriandrum sativum* L. dividing the species into three major phenotypic groups and their representation in Institut für Pflanzengenetik und Kulturpflanzenforschung (IPK).

<table>
<thead>
<tr>
<th>Formal botanical name</th>
<th>Vernacular name</th>
<th>Differential characteristics and geographical centre of diversity</th>
<th>Accessions in IPK collection</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. sativum</em> L. subsp. <em>sativum</em></td>
<td>Large-fruited coriander</td>
<td>Fruits of medium size or large, fruits round, plants with intermediate foliation and intermediate length of growing season, volatile oil contains camphor; Near East, Mediterranean area, western Europe</td>
<td>93</td>
</tr>
<tr>
<td><em>C. sativum</em> L. subsp. <em>microcarpum</em> DC.</td>
<td>Small-fruited coriander, slow-bolt coriander</td>
<td>Fruits round and small, plants tall and with many leaves, long growing season, volatile oil with camphor or no volatile oil in fruits; Near East, Asia, eastern Europe</td>
<td>195</td>
</tr>
<tr>
<td><em>C. sativum</em> L. subsp. <em>indicum</em> Stolet.</td>
<td>Indian coriander, ovate-fruited coriander</td>
<td>Fruits ovate, volatile oil with low proportion of camphor; Indian subcontinent, Arabian peninsula</td>
<td>42</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>330</td>
</tr>
</tbody>
</table>