

# Chapter 1

## Oat Morphology and Taxonomy

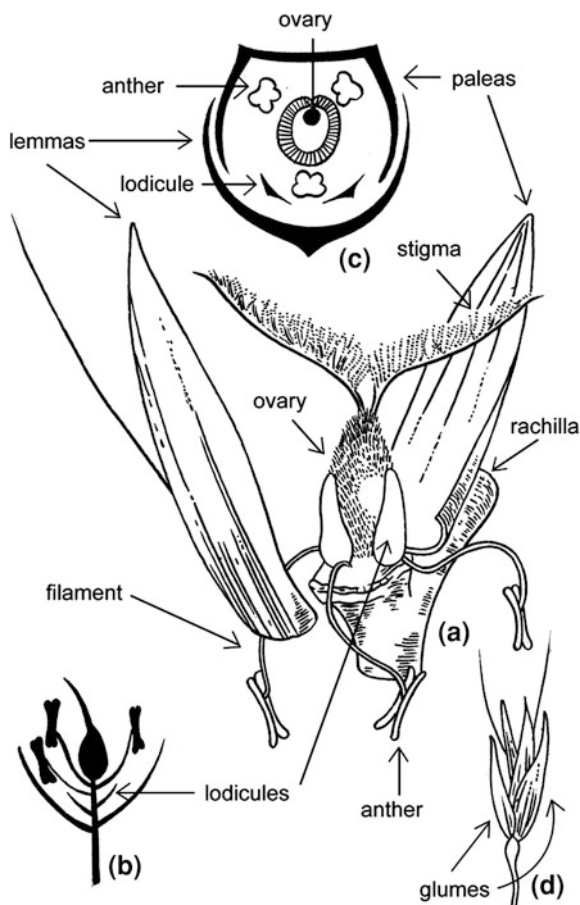
**Abstract** The morphological characters used for classification and identification are those of the spikelet. Additional characters that may be critical for accurate identification are chromosome number and potential for hybridization with other species. The taxonomy of the genus *Avena* in this book is based on that of Malzew, with a number of important changes such as omission of the taxon *A. macrostachya* from the genus. Determination of the *Avena* species is based on the biological species concept, which reflects mainly evolutionary and genetic features together with morphological and ecological uniqueness. Accordingly, a key to the various species is presented, and this is followed by a description of each species.

**Keywords** Oat morphology • Taxonomy • Morphological species • Biological species • Gene pool system • Identification key • Description

### 1.1 Oat Morphology

Oats are annual grasses with flat leaf blades; inflorescences open, effuse, or contracted or one-sided panicles with peduncles of pedicellate spikelets. Peduncles at the lower part of the panicle are usually longer bearing several spikelets. Spikelets are large, one to several flowered, and hermaphrodite. The rachilla is fragile, at least below the lowest floret in the wild species but tough in cultivated oats. Glumes, lower and upper, equal to one another or markedly unequal, chaffy, and remain attached to the panicle after seed dispersal. Lemmas are coriaceous to crustaceous, hairy or naked, seven-nerved, two-lobed, or entire with a stout geniculate awn issuing from the dorsal surface. The callous of the disarticulated florets have vertical or oblique scars. The palea is two-keeled, bearing hairs on the keels. There are three stamens, ovary is villous, and there are two lodicules, ovate to lanceolate, acuminate, fleshy below (Fig. 1.1). Grains are oblong, hairy, adherent to the lemma

**Fig. 1.1** Schematic diagram of the oat flower, **a** partly dissected oat flower at anthesis, **b** longitudinal, and **c** transverse diagrams of the flower, **d** spikelet



and palea, or free in some cultivated oats. Embryos are about one-eighth the length of the grain with basal hillum.

Of the oat morphological characters, those of the spikelet have been mainly used for species delimitation and classification and can be regarded as diagnostic characters.

They are as follows:

- Glumes shape.
- The structure of the lemma tips.
- Size and shape of the disarticulation scar.
- Shape of the callus at the bottom of the dispersal unit.
- Point of insertion of the awn into the lemma.
- The mode of the spikelet disarticulation at maturity.

In most oat species, the two glumes of the spikelet are equal in length or nearly so. Exceptions are *A. clauda* in which the lower glume is about half as long as of

**Fig. 1.2** Variation of glumes shape. **a** Markedly unequal, *A. clauda*, **b** moderately unequal, *A. ventricosa*, **c** equal or nearly so, *A. longiglumis*



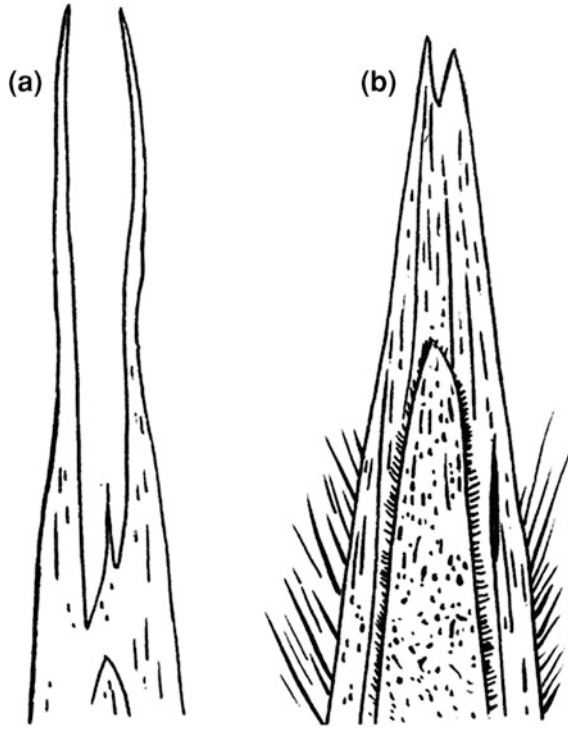
the upper glume, and *A. ventricosa* in which the lower glume is about three-quarters of the length of the upper glume (Fig. 1.2).

Lemma tips have two basic structural forms, the lobes each terminate in a bristle whose length differs. It may have a side tooth, but its appearance is not consistent among plants or even among different spikelets of the same plant, and is thus of little or no taxonomic value. Aristulate lemma tips are typical of *A. clauda*, *A. strigosa*, *A. prostrate*, *A. damascena*, *A. longiglumis*, and *A. barbata*, but in *A. ventricosa* they are subulate (Fig. 1.3). In the other species, the two lobes terminate in denticulate membranous structure. This is seen in *A. canariensis*, *A. agadiriana*, *A. magna*, *A. murphyi*, *A. insularis*, and *A. sativa*.

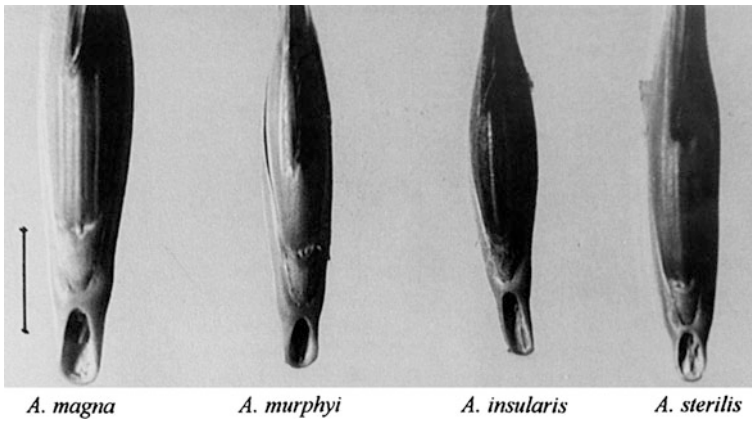
The size of the disarticulation scar and the callus at the bottom of the dispersal unit is usually interrelated. They are narrow in *A. clauda*, longer in *A. longiglumis*, and the longest in *A. ventricosa*, but in the last species the disarticulation scar, although very long, is remarkably narrow. In *A. strigosa*, *A. barbata* and their allied species the callus is shorter and the disarticulation scar is more elliptical. The largest disarticulation scar is found in *A. magna* and somewhat smaller in *A. murphyi* and the *sterilis* form of *A. sativa*. *A. insularis* can be distinguished from them by its oblong disarticulation scar (Fig. 1.4).

In most oat species the awn is inserted at a point between one-third and one-half of the length of the lemma. *A. murphyi* is unique in that its awn is inserted at a point in the lowest quarter of the lemma, and in *A. ventricosa* the insertion point is in the uppermost quarter of the lemma. (Fig. 1.5).

At maturity wild oat species present one or two modes of spikelet disarticulation; either at the base of the lower floret only, or at each floret (Fig. 1.6). In the first type the dispersal unit contains two or more florets (seeds) and in the second one the dispersal unit is single seeded. This character has been widely used by oat taxonomists because of the ease with which the two modes can be distinguished. The disarticulation mode may be the main or even the only difference between closely related species as in the case *A. clauda* and *A. eriantha* (in which the

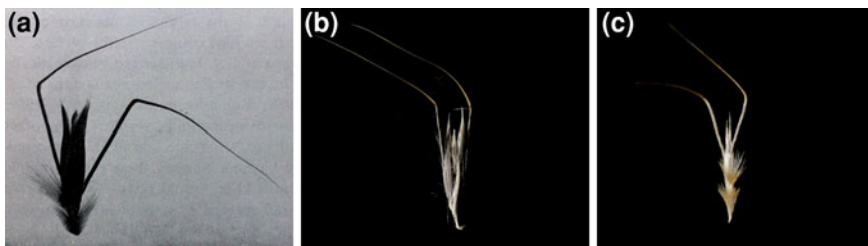


**Fig. 1.3** The two basic forms of lemma tips in *Avena*

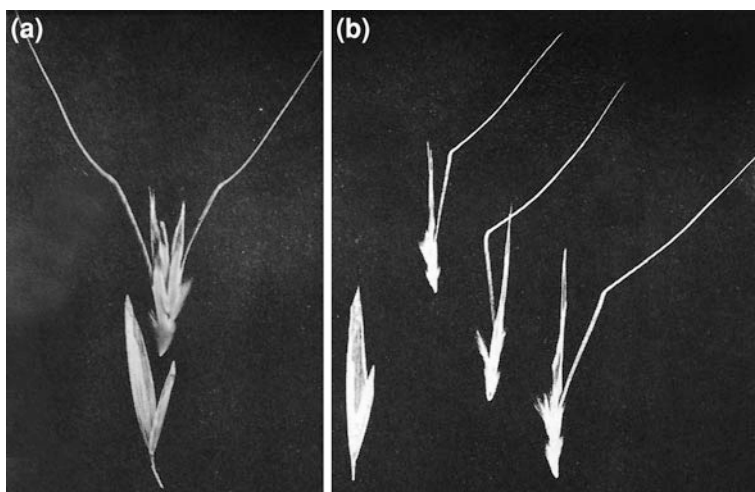


**Fig. 1.4** Disarticulation scar of *A. magna*, *A. murphyi*, *A. insularis*, and *A. sativa* ssp. *sterilis*

dispersal unit is the floret and spikelet, respectively), or of *A. fatua* and *A. sterilis*. In both cases the mode of spikelet disarticulation is governed by a single gene (Rajhathy and Thomas 1967; Coffman 1961) and in each case the two species are



**Fig. 1.5** Variation in awn insertion into the lemma, **a** lowest quarter, *A. murphyi*, **b** middle, *A. magna* (hairs removed), **c** upper quarter, *A. ventricosa*



**Fig. 1.6** The mode of spikelet disarticulation in *A. clauda*, **a** ssp. *eriantha*, **b** ssp. *clauda*

fully interfertile, casting doubt on the validity of their classification as different species.

In addition to the characters mentioned above, Baum (1977) also employed lodicule and epiblast (supposedly a rudimentary cotyledon) shape in his classification. I tried to examine these microscopic characters but found them difficult to handle and more important, not reliable. I am not aware of anyone other than Baum who uses these traits for oat identification and classification.

A great value for oat classification is the chromosome number. This is  $2n = 14$  in the diploid species,  $2n = 28$  in the tetraploids, and  $2n = 42$  in the hexaploids. The polyploid oats are allopolyploids which are believed to have evolved from interspecific hybridization of species with lower chromosome numbers followed by duplication of the chromosome number of the sterile interspecific hybrid.

In certain cases oat plants may have the same chromosome number and the morphological difference between them is inconclusive. Therefore, the only way to

resolve their identity in such cases is to cross them with one another or with tester lines. This was done to distinguish *A. prostrata* and *A. damascena* from each other and from the wild forms of *A. strigosa*.

## 1.2 Oat Taxonomy

The purpose of plant taxonomy is to arrange the plants of the world in forms of species, genera, families, etc. The basic unit of taxonomy is the species but what constitutes a species is far from clear. Nevertheless, it is commonly accepted that individuals of a certain species represent not only morphological coherence but also evolutionary ties (more about this in [Sect. 1.3](#)). In classical taxonomy the basis for species delimitation is according to morphological characters. Appropriate selection of the diagnostic characters for intraspecific, and intrageneric, classification would determine the quality of the classification and the validity of the resulting taxa. Species are usually differentiated from one another by definitive characters (not intermediate) or combination of characters.

A species name is composed of two words, the genus name and the species epithet like, *Avena sativa*. The species name stands for all the peculiarities of a particular species and is of immense value for communication between botanists and scientists.

Within a genus the species may be grouped in sections, subsections, and series. Here too, the grouping is usually according to morphological resemblance. Similarly, intraspecific classification might be based on morphological characters or geographic distribution. The most common taxon here is the subspecies.

During the last 80 years two taxonomic treatments of the genus *Avena* were published by Malzew (1930) and Baum (1977). Malzew was an oat specialist of Vavilov's team who published a series of monographs on several crop plants and their wild relatives. Obviously, Malzew did not have the botanical and cytogenetical knowledge of oats that is available now, but his attitude toward oat classification is interesting.

Malzew arranged the genus *Avena* in two sections: *Avenastrum* with a single perennial species *A. macrostachya* and *Euavena* where he placed all the annual oat species. In fact his taxonomical treatment deals only with the *Euavena* section. In addition to its perennial growth habit, *A. macrostachya* differs from other oat species in being autotetraploid, outcrosser, and self-incompatible, and under normal circumstances it is reproductively isolated from the annual species, although hybridization between them may be achieved by the aid of embryo rescue techniques. To my mind it would be more appropriate to transfer this taxon to the genus *Helicotrichon* as was suggested by a number of botanists in the past. There is no doubt that transfer of *A. macrostachya* to the genus *Helicotrichon* would make the *Avena* genus more uniform and coherent.

Section *Euavena* was further divided by Malzew into two subsections: *Aristulatae* which was further divided into three series, *Inaequaliglumes*, *Stipitatae*,

and Eubarbatae and the other subsection, Denticulate, which was not divided into series.

Except for series Eubarbatae, each of the other series and subsection Denticulatae are composed of two species each. Disarticulation of the dispersal unit is at the base of the lower floret in one species and at the base of each floret in the other. While that grouping seems natural in series Inaequaliglumes and subsection Denticulatae (because the two members are interfertile and grow in the same habitats), it is not natural in series Stipitatae. The two species in that series, *A. longiglumis* and *A. ventricosa*, are cross incompatible and occur in different habitats. On the other hand, the former species is cross compatible with members of series Eubarbatae and the latter with members of series Inaequaliglumes. It would thus be appropriate to transfer them to these respective series and to delete series Stipitatae.

While Malzew's attitude toward oat classification is reasonable, some changes should be made in order to make it compatible, as much as possible, with present botanical and genetic knowledge and are as follows:

1. As already mentioned the genus *Avena* will include only the annual species.
2. The two sub sections, Aristulatae and Denticulatae, should become sections.
3. Section Aristulatae should be divided into two Series, Inaequaliglumes and Eubarbatae.

This grouping will be used from here on in this book.

During the 47 years between the publications of the two taxonomic treatments of the genus *Avena* several new oat species were discovered and a considerable amount of genetic and cytogenetic data have been accumulated on species relations in this genus. Therefore, the expectation from Baum's treatment was that a new overall treatment would bring a more logical approach to oat classification and adequate synthesis between morphological evidence and the growing amount of genetic data on species relationships in the genus *Avena*. However, this has not materialized. As T. Rajhathy commented to me after Baum's monograph was published, "this is not the baby I was hoping for".

Baum arranged the genus *Avena* in six sections and 27 species. Unlike Malzew he correctly placed *A. ventricosa* in the same section with *A. clauda* and *A. eriantha*, and *A. longiglumis* in the same Section that includes members of Malzew's series Eubarbatae.

Baum's classification was based almost entirely on morphological characters, and so some new species were described for the first time in his monograph. When he used data of more genetic nature, they often contradicted the morphological evidence. He ignored the fact that *A. clauda* and *A. eriantha* are interfertile as are *A. sativa*, *A. sterilis*, and *A. fatua* and that the different fruiting morphs are due to single genes (Rajhathy and Thomas 1967, Coffman 1961). The genome labeling of the various species in the monograph is also a good example of the contradiction between the morphological attributes Baum used for describing various species and the genomes he assigned to them.

A genome relates to the chromosome characteristics of the gamete in terms of number, size, shape, and linear arrangement. By definition, two individuals share the same genome if their hybrid develops normally, exhibits normal chromosome pairing at meiosis, is fertile, and no breakdown occurs in the segregating generations. According to Baum *A. clauda* and *A. eriantha* have different genomes. On the other hand some of the Baum's species share the same genome and are interfertile. So why are they are classified as different species?

The confusion in Baum's monograph is even greater among the diploids classified under the A genome, original or modified. The species *A. brevis*, *A. hispanica*, and *A. nuda* are interfertile were labeled by Baum as sharing the A genome, but *A. canariensis* which is intersterile with them and with other species of the A genome like *A. strigosa* and *A. wiestii* has also been labeled as having A genome.

The tetraploid species *A. barbata*, *A. abyssinica*, and *A. vaviloviana* are interfertile and were regarded by Baum as separate species, but they all share the same AB genome.

The greatest confusion of species with different names but sharing the same genome is in the hexaploid oats. All the hexaploid oats are interfertile and according to Baum (1977) share the same ACD genome. So among the hexaploid oats he recognized only one cultivated species, *A. sativa* but six wild hexaploid species.

As already mentioned, Baum (1977) employed lodicules and epiblast shape in his classification. I found these microscopic characters difficult to handle and often unreliable. More important, from Baum's data (1977) it appears that among the cultivated diploid species *A. hispanica*, *A. brevis*, *A. strigosa*, and *A. nuda*, which are all apparently interfertile, there are two lodicule types; fatua-type for the former species and strigosa-type for the latter two which suggests intraspecific variation.

The same is for the tetraploid species (*sensu* Baum) *A. barbata*, *A. abyssinica*, and *A. vaviloviana*. These three oat types are interfertile but the former and the latter ones have fatua lodicule-type while the middle one a sativa-type.

All the hexaploid oat species listed by Baum are interfertile, yet their lodicules and epiblast are of several types, indicating, again, intraspecific variation.

It seems, therefore, that variation in lodicules and epiblast shape among taxa which are interfertile indicates that they cannot be used as diagnostic characters.

### 1.3 The Species Concept in *Avena*

My experience with the taxonomy of *Avena* and the genetic properties of the various species led me to reconsider the species concept in general and particularly in *Avena*. Specifically in genera of economic importance, classical taxonomy is redundant if it does not reflect the evolutionary and genetic ties among the various taxa. The reason is that the wild members of such genera are potential source of



genetic diversity for the improvement of the domesticated species and the genetic relations between them is an indication for the possibility of their exploitation for that purpose. Therefore, delimiting of species boundaries is not taxonomic game but represents a reasonable effort to combine morphological and genetic characteristics which express evolutionary ties. Such approach would satisfy both botanists and plant geneticists and breeders.

The species is a basic unit in plant and animal classification and a corner stone in biology and evolution. However, strange though it may seem, there is no single and common definition of the term species.

The naïve approach to the term species is that it is something real that scientists merely described. The truth is that this term is an invention by scientists. It is a subjective concept and some biologists may deny the validity of certain species that are accepted by others. In addition, there are several types of species. The most common are the morphological species and the biological species.

### ***1.3.1 The Morphological Species***

The morphological species is determined almost exclusively by morphological characters. Accordingly, a species is a group of individuals that share the same key characters known as diagnostic characters. The diagnostic characters which are used to separate species within a genus are of discontinuous nature with no intermediate state. However, some variations do exist in many such characters. Differentiation between closely related species in terms of a single character or combination of characters can be done, or at least has been attempted in the past.

Historically and currently, this is the first kind of species that was employed for the purpose of taxonomy. Most of the known species are in fact morphological species, and in many cases their legitimacy stands even when more rigorous measures of identification and classification, such hybridization experiments, are applied. The main advantage of utilizing the morphology for species identification is that no experimental procedure is involved or required.

The main disadvantage of the morphological species is that the genetic properties are hardly used or taken into consideration. The discontinuous nature of a particular trait, though an important diagnostic character, might indicate that it is governed by a single gene. This is the case with *A. clauda* and *A. eriantha* as already mentioned. These two are distinguished from one another by their dispersal units, the floret in the former and spikelet in the latter. However, they grow in mixed stands in most of their distribution area, are interfertile, and the difference in the mode of seed dispersal is governed by a single gene. It follows that these two are legitimate species by their morphology, but not by their evolutionary ties.

Another drawback of the morphological species becomes apparent in what is called “sibling species”. These are species with the same, or nearly the same morphology but are isolated from one another by various mechanisms such as cross-incompatibility, hybrid sterility, or hybrid breakdown in segregating

generations. In series Eubarbatae, the diploid forms, *A. damascena* and *A. prostrata* form a group of sibling species. Morphologically it is difficult to distinguish between them but they are reproductively isolated from each other. Therefore, the safest way to distinguish between them is to cross the two.

### 1.3.2 The Biological Species

The biological species has been proposed in order to give more meaning to the genetic properties of the species concept. Accordingly, a biological species is a group of individuals which actually or potentially interbreed and form common gene pool which is isolated from other gene pools by means of reproductive barriers (not geographic barriers). This definition also provides the testing tool for determining if two individuals are members of the same species or are of different species, namely, hybridization. The two extreme cases in such an experiment are that the hybrids between the two individuals are either fertile or sterile. Obviously, when hybrids between two morphological species are sterile they automatically can be regarded as members of different biological species. However, if the hybrids are fully fertile, the two morphological species can be regarded as members of the same biological species. The difficulty is when these hybrids are only partially fertile. In those cases more criteria must be taken into account in order to determine their taxonomic status. A major consideration is to what extent the partial fertility is in the range accepted for intraspecific variation or exceeds it.

Chromosome variation is common in *A. barbata*. It can be detected in hybrids among populations or even among plants of the same population that exhibit multivalent association in meiosis. These multivalent are the result of reciprocal translocations between non-homologous chromosomes in the parents. Usually such multivalent association causes reduction of fertility. Despite that, these plants are regarded as members of the same species. Hybrids between *A. barbata* and *A. abyssinica* or *A. vaviloviana* also show 1–2 multivalent associations at meiosis and their fertility is only slightly reduced. Thus, these forms cannot be regarded as separate species even though they are morphologically distinct from *A. barbata* by a character that evolved under human influence and is governed by four genes.

The biological species concept has been widely used in crop plants and their wild relatives. This becomes possible because many hybridization experiments carried out by plant geneticists and plant breeders revealed genetic affinities between morphological species and clearly indicated the taxa from which gene transfer to the cultigen could be made. In many crop plants this has entailed drastic reduction in the number of species. In wheat, for example, Jakubziner (1958) recognized ten cultivated tetraploid and seven hexaploid species while Morris and Sears (1967) reduced the numbers to two tetraploids and a single hexaploid species.

Although interfertility is the most critical characteristic of a biological species, morphology and ecological preferences are also relevant properties of this entity.

After all, most of the biological species are recognized by their morphological characters but alone are not always sufficient to delimit species boundaries. Thus, for example, the diploid forms of series Eubarbatae, wild and cultivated, are all members of the same species. They include the taxa *A. brevis*, *A. hispanica*, *A. nuda*, *A. strigosa* (cultivate forms) and the wild *A. hirtula*, and *A. wiestii*. They are all interfertile and separating them to different species is like considering black-eyed and blue-eyed individuals as members of separate species. Why should something that is an obvious absurdity for mankind is legitimate for plants? I regard all these diploid forms collectively as members of *A. strigosa*.

To this group of taxa one should also add the taxon *A. atlantica* from southern Morocco which was described about 25 years ago. It grows mainly on sandy soil and its main characteristic is the dispersal unit which comprises the entire spikelets (glumes excluded). It was collected independently by G. Fedak, M. Leggett, and P. Hagberg, but was described by the former together with B.R. Baum.

I crossed *A. atlantica* with members of *A. strigosa*. The hybrids were normal and fertile and segregation regarding the kind of the dispersal unit in F<sub>2</sub> indicated the involvement of two genes.

The rare occurrence of forms with morphological characteristic which is not typical of series Eubarbatae, but are found in other oat species, in *A. clauda*, *A. magna*, *A. murphyi*, *A. insularis* and in the hexaploid oats, is a reminder of Vavilov's law of homologous series. According to this law a character which is common in one species may spontaneously occur in a related species or even in a closely related genus. Another example of this law in oats is the seed-retaining property of cultivated oats, diploids, and hexaploids. Furthermore, the occurrence of the two modes of seed dispersal in the taxa *A. clauda*, and *A. eriantha* and among members of *A. sativa* indicate the polyphyletic origin of the spikelet disarticulation mode in the genus *Avena*.

### 1.3.3 The Gene Pool System

Plant breeders and plant geneticists are usually interested in crop wild relatives as sources of genetic variability which does not exist in the crop plants. For the sake of exploring this kind of diversity and transferring it to cultivated background they must be familiar with genetic affinity between the particular wild species and the cultigen. This information is not automatically provided by the morphological species concept. On the contrary, the existence of a large number of morphological species may discourage plant breeders from seeking genetic diversity in them because they are not sure about the feasibility of gene transfer from them to the cultivated material. To overcome this difficulty Harlan and de Wet (1971) proposed the gene pool system in which crop plants and their relatives, cultivated and wild, are arranged in three gene pools (GPs).

The first is GP1, in which all the members are interfertile. These members include the various forms of the crop plant, regardless of their taxonomic status

and also its wild progenitor which may also be classified by taxonomists to several species.

GP2 includes taxa from which some gene can be transferred to the cultigens despite some hybrid lethality or sterility. Even when some seeds are set in the interspecific hybrid, transferral of a specific character is not automatically guaranteed because it might be located on non-homologous chromosome segments.

GP3 includes all other related taxa from which gene transfer to the cultigens is not possible. However, these taxa are the target of exploring and employing new techniques that would eventually enable gene transfer.

All the members of *A. strigosa*, wild and cultivated, are included in the cultigen's GP1 of this species. Similarly, all the hexaploid oats are members of the common oat *A. sativa* GP1.

GP2 of *A. strigosa* includes *A. barbata* and its related tetraploid forms. Gene transfer from them can be made through a triploid bridge. Using such a bridge, I transferred to var. Saia of *A. strigosa* resistance to the herbicide Atrazine from *A. barbata*. This resistance was detected in Israel by B. Rubin and his associates along a road that had been routinely sprayed by atrazine for many years. It is a maternally inherited character and I used *A. barbata* as the female parent. The triploid hybrids produced only a few seeds and from these I selected a diploid plant which was similar to var. Saia and also atrazine resistant.

All other oat species are in GP3 of *A. strigosa* because of various obstacles for hybridization.

Gp2 of the common oat includes mainly the tetraploid species *A. magna*, *A. murphyi*, and *A. insularis*.

It is my belief and conviction that utilization of the biological species concept for oat classification is the most appropriate and reasonable approach for botanists as well as geneticists and plant breeders. Below is the list of the biological species of the genus *Avena*. Names of some of the morphological species have been omitted or retained as subspecies.

## 1.4 The Biological Species of *Avena* and Their Main Sub Species

For reasons already indicated above, it seems to me that adopting the biological species concept for oat classification is much more beneficial to botanists and plant breeders alike. Below is the list of the *Avena* species known at present, and their main sub-species (Table 1.1).

While lowering the taxonomic status of a number of *Avena* taxa from species to subspecies is logical, they are occasionally written as species in this book. Particularly in events described prior to this publication.

**Table 1.1** The biological species of *Avena* and their main sub species

Species name	Sub species	Chromosome no.
<i>A. clauda</i>	<i>clauda</i> <i>eriantha</i>	14
<i>A. ventricosa</i>		14
<i>A. longiglumis</i>		14
<i>A. prostrata</i>		14
<i>A. damascena</i>		14
<i>A. strigosa</i>	<i>strigosa</i> <i>wiestii</i> <i>hirtula</i> <i>atlantica</i>	14
<i>A. barbata</i>	<i>barbata</i> <i>abyssinica</i> <i>vaviloviana</i>	28
<i>A. canariensis</i>		14
<i>A. agadiriana</i>		28
<i>A. insularis</i>		28
<i>A. murphyi</i>		28
<i>A. magna</i>	<i>magna</i>	28
<i>A. sativa</i>	<i>sativa</i> <i>sterilis</i> <i>fatua</i>	42

### 1.4.1 Key to the *Avena* Species

The key is based on several morphological characters, chromosome number, ecological preferences, and the place of origin of the oat material. The morphological traits used in the key are shape of the glumes, shape of the spikelet, structure of the callus at the lower part of the dispersal unit, shape of the disarticulation scar, point of awn insertion into the lemma, and structure of the lemma tip. Differentiation to subspecies is made mainly according to the mode of spikelet disarticulation.

Note: (1) Counting of chromosome numbers may be necessary for separating *A. barbata*, *A. prostrate* and *A. damascene* from one another. (2) Confirming the identity of the latter two species may require hybridization with known accessions of these species.

#### 1.4.1.1 Key:

1. Glumes markedly unequal in size (2)
- \_ Glumes equal or almost equal in size (4).

2. Lower glume about half the length of the upper glume (3)
  - \_ Lower glume about two-third to three-fourth of the upper one, callus at the bottom of the spikelet sharp, 4–6 mm long, *A. ventricosa*.
3. Each floret disarticulates at maturity, *A. clauda*, *ssp. clauda*
  - \_ Disarticulation occurs only in the lower floret, *A. clauda*, *ssp. eriantha*.
4. Lemma tips biaristulate (5)
  - \_ Lemma tips bidentulate (9).
5. Panicle mostly flag-shaped, glumes 25–40 mm, individual florets disarticulate, 2–3 mm awl-shaped callus at the base of the dispersal unit, bristles at the lemma tips 8–12 mm, *A. longiglumis*
  - \_ Callus blunt, glumes shorter (6).
6. Lemma's bristles 2–5 mm, plants 100–150 cm,  $2n = 28$ , *A. barbata*, *ssp. barbata*
  - \_ Lemmas glabrous, florets disarticulate, found in Ethiopia, *ssp. vaviloviana*
  - \_ Florets do not disarticulate, found in Ethiopia, *ssp. abyssinica*
  - \_ Plant shorter than 80 cm,  $2n = 14$  (7).
7. Occurring in southeast Spain and Morocco, *A. prostrata*
  - \_ Occurring in Syria and Morocco, *A. damascena*
  - \_ Lemma's bristles 5–12 mm (8).
8. Cultivated form, *A. strigosa*, *ssp. strigosa*
  - \_ Desert and steppe type, *ssp. wiestii*
  - \_ Mediterranean type, plants 80–100 cm in height, *ssp. hirtula*
  - \_ Disarticulation occurs only at the lower floret, found in Morocco, *ssp. atlantica*.
9. Spikelets small, 1–1.5 cm, known from the Canary Islands,  $2n = 14$ , *A. canariensis*
  - \_ Spikelets of similar size, known from littoral southwest Morocco,  $2n = 28$ , *A. agadiriana*
  - \_ Spikelets larger (10).
10. Awn insertion at the lowest quarter of the lemma,  $2n = 28$ , *A. murphyi*. Awn insertion at the lower one-third to one-half of the lemma (11)-
11. Spikelets considerably hairy, lemmas of the two lower florets close to each other at their upper part and are nearly parallel, *A. magna*
  - \_ Lemmas of the two lower florets more distant from one another at their top forming V-shaped spikelet (12).
12. Disarticulation scar elliptical oblong, its length about twice the width.  $2n = 28$ , *A. insularis*
  - \_ disarticulation scar elliptical ovate or domesticated form,  $2n = 42$ , *A. sativa*.
  - \_ Only the lower floret disarticulates, *ssp. sterilis*
  - \_ Each floret disarticulating, *ssp. fatua*
  - \_ Domesticated form, *ssp. sativa*.

### 1.4.1.2 Description:

#### Section 1. Aristulatae

##### Series 1. Inaequaliglumes

###### *A. clauda*

Plants are short-medium culms 20–70 cm long occasionally masked by taller oat species. Panicle slightly flagged. Glumes unequal, the lower being about half the length of the upper one,  $2n = 14$ .

###### ssp. *clauda*

3–5 florets per spikelet, disarticulates at each floret.

###### ssp. *eriantha*

Two florets per spikelet, disarticulates at the lower floret only.

###### *A. ventricosa*

Plants short-medium 25–65 cm. in height, panicle semi-flagged. Glumes unequal in length, the lower one being two-thirds to three-quarters of the upper glume. Spikelet without awns 1.5–2.5 cm, two florets per spikelet only the lower one disarticulates. The callus at the base of the dispersal unit is long, 4–6 mm, and sharp. Awn inserted at the upper two-thirds to three-quarters of the lemma. Lemma tips subulate  $2n = 14$ .

##### Series 2. Eubarbatae

###### *A. longiglumis*

Plants medium to tall, 40–180 cm in height. Panicle flagged, glumes large and equal. Spikelets made of 2–3 florets, each disarticulates at maturity. Lemma tips aristulate, 8–12 mm long. The callus at the base of the dispersal unit is typically awl-shaped.  $2n = 14$ . Restricted to sandy and sandy loam soils in desert and mesic habitats in the Mediterranean region.

###### *A. prostrata*

Plants short to medium, culms 20–80 cm in height. Panicle is rather dense. Glumes equal or nearly so, spikelet without awns 1.3–3 cm. 2–3 florets per spikelet all disarticulate at maturity. Lemma tips aristulate bristles 3–5 mm long.  $2n = 14$ . Known from south east Spain and a number of locations in Morocco. Reliable identification of this species may require hybridization with known accessions of this species and cytological examination of the hybrids.

###### *A. damascene*

Plants short-medium to tall, culms 20–120 cm in height. Panicles rather dense, glumes equal or nearly so, spikelet small 2–2.6 cm long with three florets disarticulates at maturity, lemma tips aristulate, bristles 3–5 mm long.  $2n = 14$ , known from one locality in Syria and several locations in Morocco. Reliable identification of this species may require hybridization with known accessions of this species and cytological examination of the hybrids.

###### *A. strigosa*

This species has been divided by some taxonomists to several independent species some cultivated and others wild. However, they all are interfertile and are treated

here as one polymorphic species, with four main subspecies, ssp. *strigosa* the domesticated form, ssp. *hirtula* Mediterranean wild type, desert and steppe wild type ssp. *wiestii*, and ssp. *atlantica*,  $2n = 14$ .

#### Subspecies *strigosa*

Plants are medium to tall 80–200 cm in height. Panicle rather dense, equilateral, glumes equal or nearly so, spikelets without awns 2–2.5 cm. 1–3 florets per spikelet none disarticulate. Lemma tips aristulate, bristles 6–8 mm long.

#### Subspecies *hirtula*

Plants are medium to tall, 80–180 cm in height. Panicle is rather dense, equilateral. Glumes equal, or nearly so. Spikelet without awns 2–3 cm, 2–3 florets per spikelet, all disarticulate at maturity. Lemma tips aristulate, bristles 6–10 mm long. It grows on a wide range of soils in the Mediterranean region.

#### Subspecies *wiestii*

Plants short to medium 40–100 cm in height. Panicle is dense. 2–3 florets per spikelet, bristles 5–8 mm long. Occurs on a wide range of soils in steppe and desert habitats bordering the Mediterranean zone.

#### Subspecies *atlantica*

This is a recently discovered taxon which was described as an independent species but later appeared to be interfertile with members of *A. strigosa* and accordingly is regarded here as additional ssp. of *A. strigosa*.

Plants short to medium, 40–80 cm. in length. Panicle is rather dense, equilateral. Spikelets, 1.4–2 cm long, 2–3 florets per spikelet, only the lower one disarticulates. Lemma tips aristulate bristles 5–6 mm long. Known from south west Morocco.

#### *A. barbata*

This species is similar to the wild forms of *A. strigosa* ssp. *wiestii* and ssp. *hirtula* but can be distinguished from them by its broader panicle with longer internodes and shorter bristles at the lemma tip, and its chromosome number  $2n = 28$ . It comprises of three main sub species, *barbata*, *vaviloviana* and *abyssinica*.

#### Sub species *barbata*

Plant medium to tall, 80–180 cm. in length. Spikelets without awns, 2–2.5 cm long, 2–3 florets per spikelet all disarticulate at maturity. Glumes equal or nearly so, lemma tip aristulate bristles 3–5 mm long. Is an aggressive weed in cultivation and in other man-made habitats. Its similarity to *A. strigosa* ssp. *hirtula* and ssp. *wiestii* has caused confusion between them resulting in considering ssp. *barbata* as having diploid and tetraploid forms and the same for ssp. *wiestii*.

Subspecies *barbata* can easily be distinguished from *A. strigosa* ssp. *hirtula* and *wiestii* by its broader panicle and shorter bristles at the lemma tip, 3–5 mm in ssp. *barbata* and 6–10 in ssp. *hirtula* and *wiestii*. This distinction is sometimes difficult when they grow in mixed populations, because gene flow between them creates intermediate bristle length in up to 10% of the plants or even more.

#### Subspecies *vaviloviana*

This subspecies is restricted to Ethiopia where it occurs mainly in abandoned fields. It differs from ssp. *barbata* by its glabrous lemmas and occasionally only the upper floret disarticulates.



### Subspecies *abyssinica*

This subspecies also confined to Ethiopia where it grows as tolerated weed in barley fields. It does not shatter its seeds at maturity and in that sense can be regarded a domesticated form, but it is never purposely planted. It endures because the Ethiopian farmers cannot select them out by their threshing-winnowing methods. Therefore, this oat is planted, harvested, and consumed together with barley.

## Section 2. Denticulatae

### *A. canariensis*

Plants are short to medium, culms 10–80 cm in length. Panicle equilateral, glumes are equal or nearly so. Spikelet of two florets without awns 1.2–1.6 cm long, awn inserted at the middle of the lemma. Disarticulation occurs at the lowest floret only.  $2n = 14$ , known from the Canary Islands, mainly Fuerteventura and Lanzarote.

### *A. agadiriana*

Plant short to medium 30–150 cm in height, panicle equilateral. Spikelets without awns 1–1.8 cm, with two florets, only the lowest one disarticulates. Lemma tips denticulate.  $2n = 28$ . This species is known from southwest Morocco. The genetic relations between this species and other oat species have not yet been fully established.

### *A. insularis*

Plants small to medium, 40–90 cm in height. Panicle equilateral. Spikelets v-shaped 1.8–2.5 cm without awns, with 2–3 florets, only the lowest one disarticulates. Lemma tips denticulate. Disarticulation scar elliptical oblong, its length is more than twice its width.  $2n = 28$ . Known from Sicily and Tunisia.

### *A. magna*

Plants medium to tall 60–120 cm in height. Panicle equilateral, glumes are equal or nearly so. Spikelet without awns 2–3 cm with 2–4 florets only the lowest one disarticulates. Lemma tip dentate, lemmas of the two lower florets are exceptionally hairy and almost touch each other at their upper part. Disarticulation scar is large and elliptic. Known from Morocco on heavy crumbling soil.  $2n = 28$ .

Lately a domesticated form of this species has been developed by transferring the domestication syndrome of the common oat to the wild *A. magna* (see Sect. 2.5.2). Accordingly, the wild form may be regarded as ssp. *magna* and the domesticated type as ssp. *domestica*.

### *A. murphyi*

Plant medium to tall, 60–100 cm in height. Panicle equilateral, slightly flagged. Glumes are equal or nearly so. Spikelet without awns 2–3 cm with 2–4 florets, only the lowest one disarticulates. Awn inserted to the lower quarter of the lemma. Lemmas can be yellow, brown or black, glabrous or hairy. Lemma tips denticulate.  $2n = 28$ . Known from southern Spain and northern Morocco on heavy crumbling soil.

*A. sativa*

This is a variable species containing three main subspecies *sativa*, *sterilis*, and *fatua*. They include domesticated, wild, and weed forms. All are interfertile and share dentate lemma tips and the same chromosome number,  $2n = 42$ .

Subspecies *sativa*

A domesticated form, extremely variable as result of human selection and breeding. It has been separated to several species by some taxonomists but these are all interfertile. Spikelets with 2–3 florets none disarticulates at maturity. Lemmas are usually yellow and awns may be present, reduced in size or absent.

Sub-species *sterilis*

The most widespread and variable oat type. It is an aggressive weed and common in man-made habitats far from its natural place of origin which is the warm parts of the Mediterranean basin. Plant medium to tall 50–140 cm in height. Panicle equilateral. Spikelet 1.5–4 cm with 2–5 florets, only the lowest disarticulates. Lemma tips denticulate. This subspecies has been divided into a number of species by various taxonomists despite being interfertile.

Subspecies *fatua*

This is mainly a weed form in cultivation and other man-made habitats. Occurs only rarely in primary habitats and usually for a short period. It differs from ssp. *sterilis* mainly by the mode of spikelet disarticulation, which occurs at each floret. It also differs by its geographic distribution which is mainly Europe and North America. This subspecies has also been divided into a number of species by various taxonomists but these are all interfertile.

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