A Manual for the Identification of

PLANT SEEDS AND FRUITS

Groningen Archaeological Studies
Volume 23

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A Manual
for the Identification of
PLANT SEEDS AND FRUITS

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Barkhuis &
University of Groningen Library
Groningen 2013

Book cover design: Nynke Tiekstra, ColtsfootMedia - Noordwolde
Book interior design and typesetting: Nynke Tiekstra, ColtsfootMedia - Noordwolde
Photo's: F. Bottema, R.T.J. Cappers, D. Fennema & J. Jans
Copy editor: Suzanne Needs
Proofreader: Heather Sangster

Cover: Infructesence of Black medick (*Medicago lupulina*; left)
and fruit with seeds of Common whitlowgrass (*Erophila verna*; right).

ISBN: 9789491431265

This volume is part of the Digital Plant Atlas, a joint project of the Groningen Institute of Archaeology (GIA) of the University of Groningen (the Netherlands) and the German Archaeological Institute (DAI, Berlin, Germany)

university of groningen / groningen institute of archaeology

Contents

Seeds and fruits of weed species found in a sample of flax from Argentina.

Introduction

Organization of the manual

To identify plant seeds and fruits, it is important to know to which family of plants they belong. To further identify them to species, one is able to narrow down the possibilities using both the scientific literature and reference collections. Especially in families with many genera, the morphology of fruits and seeds can vary considerably. This variation is a result of the fact that the grouping of genera into families is not only based on characteristics dealing with generative plant parts. In addition, specific adaptations to seed dispersal mechanisms have occurred within more than one family.

To narrow down the identification of fruits and seeds to a particular plant family, it is helpful to have some insight into the way in which the flowers, and in a later stage the fruits, are attached to the plant. It is also important to determine the dispersal unit: a seed, a fruit, or a fruit that has merged with parts of the flower.

This manual illuminates the variation in seeds and fruits belonging to 19 plant families (figure 1). These particular plant families have been included because the fruits and seeds of the wild plant species of these families often occur both in seed mixtures and in archaeological contexts. The emphasis is on the morphology of the wild species, as expressed in the choice of illustrative examples.

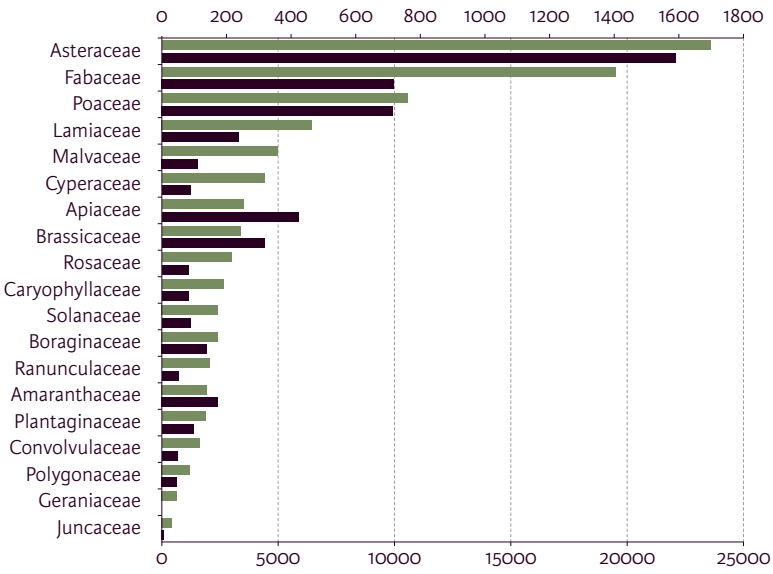

Figure 1 Number of genera (brown, numbers on top axis) and species (green, numbers on bottom axis) per plant family that have been described worldwide (adapted from Mabberley [2008]). →

↑ **Figure 2** Inflorescence (left; 21 June 2009) and infructescence (right; 11 July 2009) of Buckwheat (*Fagopyrum esculentum*). The flowers and fruits are united in panicles.

The introduction to each plant family briefly explains issues of taxonomy. Where applicable, attention is paid to nomenclature, subdivisions within the family, and defining characteristics that distinguish the family from other families. Recent DNA research has provided many new insights into the relationship between genera. Based on this research, some families have recently been split, while others have been combined. For this manual, scientific family names based on the type genus are used. The delineation of the families is based on Mabberley (2008).

This short introduction is followed by a paragraph describing the primary types of inflorescence and infructescence within each family. These terms refer to the way in which the flowers, and in a later stage the fruits, are attached to the stem (figure 2). A solid understanding of this distinction can make it much easier to place fruits and seeds in their correct family. Unfortunately, the way in which plants are grouped in terms of inflorescence and infructescence can be quite complicated and, in addition, can be difficult to determine when the pedicels of the flowers or fruits themselves are very short. Another major distinction, which will be elaborated on in the section 'Fruit and seed', is between species with multiple fruits and those with compound fruits. For more detail about the varies types of inflorescence, the reader is referred to botanical dictionaries and floras.

A paragraph titled 'Fruit and seed' describes the different types of fruits and the variation in seed morphology within the plant family. This manual follows the fruit typology of Spjut (1994). The accompanying photos show fruits and seeds native to various parts of the world whose appearance is representative for the entire family.

The diagnostic features of the fruits and seeds sometimes provide a clue to the plant's dispersal methods, as noted in the paragraph titled 'Diaspore'. This paragraph indicates which dispersal units (that is, diaspores) are most commonly found within that particular family. A diaspore is the seed-containing part of the plant, which eventually detaches to ensure the

creation of offspring in a new location. This dispersal unit can be loose seeds, but it can also be one or more seeds within a fruit or even entire fruits fused to parts of the flower. People often use the term seed dispersal, but what they actually mean is diaspore dispersal, which includes the dispersal of fruits and of fruits fused to parts of the flower.

For plants that are planted and harvested by humans, the dispersal unit can differ from that found in the wild, as determined by the method of harvest and the timing of harvest with respect to the ripening process. This explains why in seed samples we sometimes find dispersal units that deviate from the natural dispersal units (e.g. Cappers & Neef 2012, p. 286). It also explains why we sometimes encounter fragments of the infructescences or vegetative parts such as roots.

The paragraph titled 'Heterocarpy and seed dimorphism' discusses a phenomenon encountered in some families whereby a single plant can form more than one type of fruit (heterocarpy) or seed (seed dimorphism). This variation in fruit and seed morphology often relates to differences in dispersal mechanism and even in germination. For example, some species in the family Asteraceae form, within a single flowering head, fruits with a pappus and fruits without a pappus. The fruits with a pappus are adapted to effectively disperse over longer distances, for example by means of wind and/or water. The fruits without a pappus are often smaller, which allows them to more easily penetrate into the ground and thus contribute to a supply of seeds in a spot that has already been proven to be favourable by the mother plant.

↑ **Figure 3** Photo of Coriander (*Coriandrum sativum*) from the seed atlas. The 1 mm scale pertains to the colour image. The small silhouette represents the actual size of the fruit depicted.

Providing a comprehensive overview of the variation in fruit and seed morphology within the selected plant families is beyond the scope of this manual. Instead, a selection of genera that are representative of the respective families is presented. The selection of fruits and seeds in the concise seed atlas that concludes each chapter is mostly based on the Dutch flora (Van der Meijden, 2005). This concise seed atlas depicts fruits and seeds within a frame, accompanied by a scale. In addition, each image includes a silhouette that is depicted at the same scale for each of the images relating to that family (figure 3). For more extensive images, please refer to the publications of the Digital Plant Atlas project at www.plantatlas.eu.

Family, genus, and species

Plants are categorized in a hierarchical system based on relatedness. In the context of this manual, the most important levels are family, genus, and species. Family names and genus names consist of a single word. Species names consist of two words, namely, the genus name and the species name. Family names often end in -eae or -ae. In contrast, the endings of genus and species names vary.

New insights into relatedness have resulted in changes in the nomenclature and even reorganizations within plant families. The recent

large-scale research into certain loci of plant DNA, in particular, has led to species being reassigned to different families. When a species is reassigned to a different family, this need not necessitate changes to the species name. The species name does change, however, if new insights have led to the reorganization of species within a genus or to a species being assigned to a different genus. In order for researchers to be able to make the link between the new, so-called valid name and the older, so-called invalid name, the author's name is added after the species name.

Some species are subdivided into subspecies or varieties. In that case, a third name is added to the species name, preceded by the abbreviation ssp. (subspecies) or var. (variety). Scientific names for genus, species, subspecies, and variety are set in italics; family names are not. The common names are written with a capital letter on the first word to avoid any confusion between adjectives and words belonging to the proper name of the plant (for example, creeping Cockspur versus Creeping Buttercup). If a plant has no common name, the binomial is given without parentheses. Nomenclature of common English names of plant follows Stace (2010).

Types of seeds and fruits

A seed develops from an ovule and becomes enclosed by a fruit or aril (figure 4). Plants whose seeds are not enclosed by a fruit mostly produce their seeds in cones and are often called gymnosperms (figure 5).

In angiosperms the ovules and thus the developing seeds are enclosed by a fruit. The distinction between seed and fruit presents no problem if the seed does not connate with the fruit (figure 6). Often the seed is an independent dispersal unit.

There are also plants in which the seed and fruit connate. One-seeded fruits in which the fruit is often not much larger than the seed are frequently wrongly called 'seed' (figure 7).

When the fruit is the dispersal unit, other plant parts may also become part of the dispersal unit. This may result in the fruit itself not being visible anymore. An example of plant parts that may partially or completely enclose the fruit are bracts. In cereals, such bracts can be distinguished as separate pieces of chaff (figure 8). In some species, these types of bracts are fused, as is the case with the green husk surrounding the fruit of the Walnut (figure 9). In the latter case, the tissue surrounding the fruit is sometimes referred to as the exocarp.

Some fruits are composed of visibly distinct layers. This is the case for stone fruits. In such fruits the inner layer is firm and is called endocarp. The endocarp is often enclosed by a middle layer, called mesocarp, and an outer layer, called epicarp. An example of a stone fruit with a clear differentiation in layers is the Olive (figure 10). Sometimes the term exocarp is used instead of epicarp. In accordance with Spjut (1994), in this manual we use the term exocarp only for those plant parts that are not part of the fruit, e.g. the husk surrounding the fruit of a Walnut (figure 9).

Figure 4
Seed of the Yew (*Taxus baccata*) surrounded by an aril (longitudinal section).

Figure 5
Cone and seed of the Giant sequoia (*Sequoiadendron giganteum*).

Figure 6
Longitudinal section of the Melon (*Cucumis melo*), a fruit with seeds.

Figure 7
Complete fruit of the Sunflower (*Helianthus annuus*) and a longitudinal section of the fruit containing the seed.

Figure 8
Fruit of the Einkorn (*Triticum monococcum*) covered by chaff (left) and without chaff (right). Cereals have 1-seeded fruit.

Figure 9
Fruit of the Walnut (*Juglans regia*) with part of the exocarp (left), fruit without exocarp (middle), and a longitudinal section of a fruit containing the seed (right).

Figure 10
Complete fruit of the Olive (*Olea europaea*) (left), fruit whose mesocarp and epicarp (shell) were half removed (middle), and a cross-section through the fruit and seed (right). The epicarp and mesocarp are purple in colour, the endocarp is brown, and the seed is white.

Figure 11
Infructescence of the Elderberry (*Sambucus nigra*).

Figure 12
Multiple fruit of the Yellow-flowered strawberry (*Potentilla indica*) (top). A highly magnified fleshy axis contains a large number of small, 1-seeded fruit (bottom).

Figure 13
Exterior (top) and longitudinal section (middle) of the compound fruit of the Fig (*Ficus carica*). The fleshy axis is closed but for a small opening at the bottom. At the receptacle there are several hundred flowers. After pollination by a Fig wasp, a 1-seeded fruit may develop in each of these flowers (bottom).

Flowers are often arranged in a characteristic pattern. This pattern is called inflorescence, and the various types are indicated with specific terms. The term infructescence is used for a characteristic arrangement of fruit (figure 11).

In this manual no specific terms are used for the different ways fruits can be arranged. However, in accordance with Spjut (1994), we distinguish between simple fruits, multiple fruit, and compound fruit. A simple fruit develops from a single flower with a more or less isolated position in the infructescence. A multiple fruit develops from one flower with multiple pistils. In the ovary of each pistil, one or more seeds ripen (figure 12). A compound fruit develops from several flowers, each with its own pistil (figure 13). The transition from compound fruit to infructescence may sometimes be arbitrary.

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PLANT FAMILY

Amaranthaceae Love-lies-bleeding (*Amaranthus caudatus*)

Amaranthaceae

Introduction

The Amaranthaceae family is named after the genus Amaranth (*Amaranthus*). Plants in the Goosefoot family have recently been subsumed under the Amaranth family. Genetic research has proven that the Goosefoot family and the Amaranth family are closely related; distinguishing between them at the taxonomic level of family is therefore no longer desirable. The Amaranth family now contains about 2000 species in 175 genera.

Figure 1 Terminal inflorescence of the Purple Amaranth (*Amaranthus cruentus*). ↓

Inflorescence and infructescence

The flowers are small. Because of their green or brown colour, they are not very noticeable. The flowers and fruits are united in tight clusters distributed over the length of the stem or at the end of the stem (figure 1).

The fruit is sometimes surrounded by a perianth (the collective name for the sepals and petals) and bracteoles. During fruiting, the perianth and bracteoles can become enlarged and partly or completely surround the fruit. In Oraches (*Atriplex*), the fruit is surrounded by two bracteoles that have fused together distally. These bracteoles vary in morphology and size within Oraches and can be toothed and nubbly. Sometimes the perianth is noticeably swollen, as in the Strawberry goosefoot (*Chenopodium foliosum*) (figure 2).

Fruit and seed

In some genera, such as Amaranth (*Amaranthus*), the fruit and seed are not fused together. The fruit of Amaranths is membranous and contains a single seed. This seed is disc-shaped and usually black and shiny. Because the seeds of the different species in this genus are similar in shape, they are usually not identified below the genus level. A species determination is, however, possible based on the characteristics of the fruit and the perianth. In some (sub) species, such as Indehiscent amaranth (*Amaranthus*

Figure 2 Strawberry goosefoot (*Chenopodium foliosum*) with fruits surrounded by red, swollen perianths. →

Figure 3 Infructescence of Short-tepalled pigweed (*Amaranthus graecizans*). The tops of some of the fruits have torn or fallen off. →

hybridus ssp. *bouchonii*), the fruit does not open, whereas in other (sub) species the fruit opens transversely. In the latter case, the surface of the break can be irregular, as in Guernsey pigweed (*A. blitum*), or regular, as in Short-tepalled pigweed (*A. graecizans*) (figure 3).

In many other genera, the fruit and seed are fused together. In some of these genera the fruit wall is thin, fragile, and easily separated from the seed. This kind of fragile fruit wall occurs in Summer-cypress (*Bassia*), Perennial glasswort (*Salicornia*), Spinach (*Spinacia*), Saltworts (*Salsola*), Goosefoots (*Chenopodium*), and Oraches (*Atriplex*). Of those Goosefoots and Oraches that occur in cultivated fields, it is often the seeds rather than

→ **Figure 4** Fruit with perianth (left), fruit without perianth (centre), and seed (right) of Fat-hen (*Chenopodium album*). The perianth consists of five keeled tepals. The top row shows the top, the bottom row shows the underside. The scar on the perianth in the bottom left image marks the location where the flower was once attached to the stem. The scar on the fruit in the bottom centre image marks the location where the fruit was once attached to the receptacle. In the bottom right photo the scar is only faintly visible.

intact fruits that are found, because the fragile fruit is removed during threshing (Berggren, 1981). In the Goosefoots, the outermost layer of the fruit is also referred to as 'exocarp' (Berggren 1981; Cappers *et al*., 2012). Here, both layers are considered part of the fruit (figure 4).

Winged fruits occur in Bugseed (*Corispermum*) and Saltworts (*Salsola*). In Bugseed, the wings are formed by the margins of the fruit, whereas in Saltworts the wing is formed by the perianth that surrounds the fruit. The seed of Glassworts (*Salicornia*) is partly covered with hooked hairs (figure 5).

The orientation of the fruit in the perianth can be horizontal or vertical (figure 6). The fruits of Oraches are all oriented vertically, while within the genus Goosefoots both orientations occur. In the case of horizontal orientation, the fruit is attached to the receptacle along the flattened side. These kinds of fruits have a scar on just one side, in the middle. This scar is often still visible under oblique light on the seed itself, as in Fat-hen (*Chenopodium album*) (figure 4, bottom centre). Fruits oriented vertically on the receptacle lack this scar, as in Clammy goosefoot (*C. pumilio*) (figure 6).

Figure 5 The seed of Common glasswort (*Salicornia europaea*) is partly covered with hooked hairs. →

Figure 6 Fruits of Many-seeded goosefoot (*Chenopodium polyspermum*) (left) are oriented horizontally, whereas those of Clammy goosefoot (*C. pumilio*) (right) are oriented vertically. →

↑ **Figure 7** Ripe fruits of Saltmarsh goosefoot (*Chenopodium chenopodioides*) surrounded by the perianth. Top: A fruit from a terminal cluster with four-five perianths that are joined only at their bases. Bottom: A fruit from a lateral cluster with mostly three completely fused perianths.

Diaspore

The dispersal unit can be the seed; the 1-seeded fruit; or the 1-seeded fruit with perianths, bracteoles, or a swollen receptacle (table 1).

Table 1 Composition of the dispersal unit in several genera of Amaranthaceae.

	Seed	1-Seeded Fruit	1-Seeded Fruit with Perianth	1-Seeded Fruit with Bracteoles	1-Seeded Fruit with Receptacle
Salicornia	•				
Amaranthus	•		•		
Corispermum		•			
Suaeda		•			
Chenopodium		•	•		
Salsola			•		
Bassia			•		
Spinacia				•	
Atriplex				•	
Beta					•

↑ **Figure 8** Fruits of the Spinach (*Spinacia oleracea*) encapsulated by bracteoles, with three long spines (left) and with only the bases of the spines (right).

Heterocarpy and seed dimorphism

Heterocarpy is common in this family. For example, the type of perianth surrounding the fruits of Saltmarsh goosefoot (*Chenopodium chenopodioides*) varies depending on the fruit's location along the stem (figure 7).

The variation in the bracteoles in Oraches (*Atriplex*) relates to the position of the fruit on the plant. In some species the fruit also varies in size and shape. Therefore it is not always possible to obtain a secure species-level identification. The variation is especially great in such species as Common orache (*Atriplex patula*), Spear-leaved orache (*A. prostrata*), and Grass-leaved orache (*A. littoralis*). The fruits of the first two of these species are usually not differentiated; only large fruits (with a diameter of at least 3.2 mm) are identified as Grass-leaved orache. The fruits of Halogeton *Halogeton glomeratus* and Fat-hen (*Chenopodium album*) and the seeds of Common glasswort (*Salicornia europaea*) are also heterocarpic (Imbert, 2002).

The number of fruits in fruit clusters of the Beet (*Beta vulgaris*) varies from (1-)3-5(-7). In the Beet from the eastern Mediterranean, the number of fruits is small.

Variation in the shape of the fruit can also be the result of the selection of seed stock. For example, the bracteoles of Spinach (*Spinacia oleracea*) possess a spine. This spine is absent in fruits used today as seed stock (figure 8).

Seed atlas Amaranthaceae

Amaranthus standleyanus

Amaranthus standleyanus

Atriplex prostrata

Atriplex prostrata

Axyris amaranthoides

Bassia scoparia

Bassia scoparia

Beta vulgaris

Beta vulgaris

Chenopodium rubrum

Chenopodium rubrum

Corispermum intermedium

Polycnemum arvense

Polycnemum arvense

Salicornia europaea

Salsola kali

Salsola kali

Spinacia oleracea

Spinacia oleracea

Suaeda maritima

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