Enrico Biancardi · Leonard W. Panella
Robert T. Lewellen

Beta maritima

The Origin of Beets

Springer

Beta maritima

"Unico successo realmente conseguito, ma senza confronti meschino ed irrisorio in relazione alle giovanili speranze, fu quello risalente ad un'epoca ormai lontana coll'utilizzare la *Beta maritima* vegetante allo stato spontaneo lungo la costa adriatica, dal cui incrocio fu a noi possibile separare genealogie offerenti una effettiva resistenza alla cercospora"

(The only achieved success, but without doubt petty and insignificant if compared to the j-uvenile hopes, dates back to bygone years, when it was utilized the *Beta maritima* collected in the wild along the Adriatic coast, from whose crosses it was possible for us to identify some genealogies endowed with an actual resistance to cercospora leaf spot).

Ottavio Munerati (1946)

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The Origin of Beets

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Enrico Biancardi
Rovigo Station
Consiglio per la Ricerca e la
Sperimentazione in Agricoltura (CRA)
Rome, Italy
enrico.biancardi@alice.it

Robert T. Lewellen, Ph.D.
Crop Improvement & Protection
Research Unit, USDA-ARS
Salinas, CA, USA
rtlewellen@hotmail.com

Leonard W. Panella, Ph.D.
Crop Research Laboratory
USDA-ARS
Fort Collins, CO, USA
Lee.Panella@ars.usda.gov

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Foreword

It might be tempting to ask "why a book about sea beet?": a wild plant with no immediately obvious attraction or significance, a somewhat limited geographical distribution, and for a scientist an underlying genetics that doesn't lend itself to easy experimentation. This book provides counterarguments to allay such misapprehensions, detailing its journey through prehistory, its contribution to one of the world's most recently evolved crop plants, and its significance in terms of modern biodiversity conservation.

While sea beet is commonly thought to be an inhabitant of Europe, North Africa, and the Near East, closely related leaf forms of beet were undoubtedly used as a medicinal plant and as a herb or vegetable in Chinese cuisine as far back as the first millennium BC. In 1976, I received correspondence from William Gardener, who was an obsessive collector of plant data and who spent a part of his life in China, fluent in both spoken and written Chinese language. He had recorded that the leaves of "t'ien ts'ai" or cultivated beet, along with some fish, could be used in the preparation of a preserve called "cha." Cha is a preparation originating from the Yangtze valley, and Gardener's research led him to believe that t'ien ts'ai, when brought into culinary use, was a coastal plant from anywhere south of Shantung, and perhaps a riparian plant from along the lower Yangtze. However, there are now no records of wild beets growing anywhere in China, so Gardener's assumption that wild as well as cultivated beets existed in China in these times represents an enigma.

Considering geographical range and moving to a different continent, it has long intrigued me as to how wild forms of beet, closely related to *Beta maritima*, come to exist in California. The fact that genetic evidence suggests that there are two distinct forms living in the Imperial Valley, both having European origins, only partly clarifies the situation. One form is likely to be a naturalized or de-domesticated cultivated beet, while the other closely resembles the wild *Beta macrocarpa* (a sister species to *maritima*). So a second enigma exists as to precisely how both forms of wild beets reached California.

What else is intriguing about *B. maritima*? For me, it is its place in the history of genetic resources conservation. I believe that it could comprise one of the first crop genetic resources to have been actively conserved. As a student, I was first introduced to the needs of "genetic conservation" by my mentor Professor Jack Hawkes in Birmingham and by other key figures who passed through Birmingham at the time such as Jack Harlan, Erna Bennett, and Sir Otto Frankel. Jack Hawkes, in particular, had met the great Russian geneticist Nikolai Ivanovič Vavilov in the Soviet Union and acknowledged him to be the "father" of plant genetic resources. Vavilov had proposed in the 1920s that crop improvement should draw from wide genetic variation and on this premise collected cultivated plants and their wild relatives from most parts of the world. The germplasm that he collected was for immediate use for the development of new crop varieties, and none of it was conserved for future use. George H. Coons, on the other hand, was a US scientist, sugar beet breeder, and germplasm collector, who also influenced my early thoughts and activities ahead of my germplasm collecting missions to Turkey back in the 1970s. Remarkable for me, some of Coons's material was actually conserved and still survives within the USDA-ARS system in Salinas, California. In many ways, Coons was no different to Vavilov; expeditions to Europe in 1925 and 1935 allowed him to collect and then evaluate diverse germplasm and put it to good use in sugar beet improvement programs. The difference is that some of Coons's material still survives but Vavilov's doesn't! Just as significant was the work of Munerati over a century ago, who was one of the first to recognize the value of crop wild relatives for crop improvement, using *Beta maritima* to improve the sugar beet crop. Germplasm he developed still survives in the sugar beet varieties we grow today.

Maybe as a plant scientist one could easily be put off working on beet. But really its basic genetics is what makes it fascinating. *B. maritima* and its relatives range from being short lived annuals where flowering and seed set can be as short as 6–8 weeks, to long lived perennials that are known to survive for as much as 8 years. They can be strongly inbreeding on the one hand, but exhibit genetic incompatibility and obligate out-crossing on the other. If the most recent taxonomy is accepted that *B. maritima* is really a subspecies of *Beta vulgaris*, then this wide range of habits and genetic tendencies are all to be found within a single species. Again, because the wild and cultivated are so close genetically, this is a benefit if genes from wild populations need to be used in crop improvement. By contrast, this represents a serious problem in terms of breeding strategies where hybrids can easily occur and contaminate sugar beet seed crops. This also leaves wild beets vulnerable to contamination from GM sugar beet crops.

These features of beet, particularly related to the life cycle, are what make it worthwhile to consider the value of sequencing its genome. In addition, being a member of the *Caryophyllales*, it is not closely related to any of the plant species whose genomes have already been sequenced such as *Arabidopsis*, poplar, or rice. The newly produced draft sequence for sugar beet suggests that it has around 28,000 genes and a genome size of 758 Mb. This much we now know because of the availability of next-generation sequencing. With this reference genome, and by way of new technologies such as massively parallel resequencing, maybe we will soon be able to answer some of the intriguing questions surrounding this enigmatic species, many of which are covered in this valuable book.

Birmingham, UK Brian V. Ford-Lloyd

Preface

Publication of a book dealing only with a plant without any direct commercial interest is a task requiring some additional explanation. Given that *Beta maritima* is believed to be the common ancestor of all cultivated beets, the collection in a single publication of the countless references concerning the species is useful for biologists, agronomists, and researchers who have the task of preserving, studying, and utilizing the wild gene pool. Indeed, *B. maritima* is necessary to ensure a sustainable future for the beet crops. This very important reason is the easiest but not fully satisfactory to explain a book dedicated to any single plant species. Among other reasons, increasing attention must be paid to wild germplasm for useful traits. Indeed, genetic resistances are a crucial argument, due to the urgent need to minimize both production costs and the use of chemicals especially for sugar beet. The crop is considered among the top ten of the world in economic importance, growing on about 5.2 Mha in 38 countries, and supplying around 20% of the 167 Mt sugar produced annually, with sugar cane (*Saccharum officinarum* L.) supplying most of the remainder.

In compiling the book, particular attention was paid to the history of the use, recognition, and knowledge of *B. maritima*. This was done because little has been collectively recorded and also for the reason that science evolves on the foundations of the past. This interpretation of the flow, distillation, and accumulation of knowledge that lead forward is another task of the book. The information was collected from literature dealing in medical and food plants in general, and, to a lesser extent, with cultivated beets. This part required reading publications written in different languages over almost two millennia. The search allowed information to be found that was mostly unknown even to insiders. This knowledge should be useful for people exclusively interested in beet crops and biotechnology.

Recently, scientific papers related to *B. maritima* have been written, based on the developments and applications of molecular biology. Several doctoral theses concerning particular aspects of the species have been written as well. In fact, sea beet germplasm currently is used as a model for gene flow experiments, owing to the frequent coexistence of different and interfertile genotypes belonging to the genus *Beta*. Being a littoral species distributed in populations more extended in length than in width, *B. maritima* fits very well to research concerning genetics of populations, natural breeding systems, colonization, speciation, etc. In these fields of research, *B. maritima* is surely one of the more studied plants. Modern breeding techniques have moved largely to the greenhouse and laboratory. This movement has resulted in researchers having less and less contact with their crop and its background. A further task of the book is to try to provide them an updated, comprehensive summary on everything that involves the species.

The future of *B. maritima* germplasm is covered in detail. DNA of sea beet has been studied, and this line of research is developing very rapidly. Recent papers have been briefly summarized; the reader can find a comprehensive list of references and additional information sources at the end of the book. Listed are the researchers and organizations presently involved in *B. maritima*. Useful Web sites are listed as well.

Writing of this book would not have been possible, or at least the documentation would have been less, without the opportunity to read on-line part of the literature. Old, often fragile books, surviving in few specimens or conserved in libraries on the other side of the world, were easily examined in PDF format and without copyright infringement. Through the Internet, these scanned books have reached one of the goals always advocated by their respective editors, namely to reach the greatest number of readers possible. Books, journals, proceedings, reports, etc. coming out from their shelves, perhaps after years of hibernation, are acquiring a second and much more dynamic life, along with a potential diffusion that they never had. Something similar began with the invention of printing. The traditional system of bibliographic research has retained its importance not only for the large amount of not digitized books (and therefore named "analogic" by some), but also for old collections of scientific journals no longer in print, such as the "Österreiche-Ungarische Zeitung für Zuckerindustrie und Landwirtschaft," where important articles on sea beet were published at the end of 1800s. Part of this rare literature was found in the library of the former "Stazione Sperimentale di Bieticoltura" (now CRA—Centro per le Colture Industriali) at Rome, Italy. Notwithstanding the large quantity of references, the authors apologize to the reader and research community for possible omissions.

Rome, Italy — Enrico Biancardi
Fort Collins, CO, USA — Leonard W. Panella
Salinas, CA, USA — Robert T. Lewellen

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For their help in historical researches, the authors wish to express their appreciation to the staff of the following libraries: "Nazionale Marciana" and "Accademia Veneta di Scienze, Lettere ed Arti" (Venice); "Apostolica Vaticana" and "Nazionale" (Rome); "Aldrovandi," "Goidanich," and "Centrale Universitaria" (Bologna); "Ariostea" (Ferrara); "Accademia dei Concordi" (Rovigo); "Orto Botanico" and "Abbazia Benedettina di Praglia" (Padua); "Sopraintendnza per i Beni Culturali" (Naples and Pompeii); "Nazionale Vittorio Emanuele III" (Naples); and the mentioned library of ISCI-CRA (Rovigo). Special gratitude is given to the countless Web sites consulted. Some of these are mentioned in Appendix E. Other sources of illustrations are reported in the captions.

Lee Panella would like to thank the members of my USDA-ARS research group, who all accepted the extra work while I was in Italy for two months with Enrico Biancardi, finishing the book. Special thanks go to Delana Disner who entered the hundreds of references into my database. A am very grateful to the Beet Sugar Development Foundation who funded that trip. Most of all, my thanks go to my wife, Ann, and my children, Christopher and Claire, who were most patient in encouraging me to take the time necessary on evenings and weekends to finish this project.

Summary of the Book

Along the undisturbed shores, especially of the Mediterranean Sea and the European North Atlantic Ocean, is a widespread plant called *Beta maritima* by the botanists, or more commonly sea beet. Nothing, for the inexperienced observer's eye, distinguishes it from surrounding wild vegetation. Despite its inconspicuous and the nearly invisible flowers, the plant has had and will have invaluable economic and scientific importance. Indeed, according to Linnè, it is considered "the progenitor of the beet crops possibly born from *B. maritima* in some foreign country." Recent molecular research confirmed the lineage. Something similar to mass selection applied after domestication has created many cultivated types with different destinations. Also the wild plant has always been harvested and used both for food and as a drug. Sea beet crosses easily with the cultivated types. This facilitates the transmission of genetic traits partly lost during domestication, because the selection process aimed only at increasing the features useful to farmers and consumers. Indeed, as with several crop wild relatives, *B. maritima* has been successfully used to improve the genetic resistances against diseases and pests. In fact, beet cultivation would be currently impossible in many countries without the recovery of traits preserved in the wild germplasm.

Contents

Abbreviations

ASSBT	American Society of Sugar Beet Technologists
IIRB	International Institute for Sugar Beet Research
IRBAB	Institut Royal Belge pour l'Amèlioration de la Betterave
IPGRI	International Plant Genetic Resources Institute
OECD	Organization for Economic Co-Operation and Development
USDA-ARS	United States Department of Agriculture, Agricultural Research Service

Chapter 1
History and Current Importance

Abstract Sea beet is known from prehistory for food and above all for medicinal uses. After domestication, beet became more and more important, especially after its most recent use as a sugar crop. But also the cultivation for leaves and root to be used as vegetables and cattle feed retains its economic value. *Beta maritima* has become crucial as source of useful traits, which disappeared in the crop during domestication. This research, which has led to important results, especially in the field of resistances to severe diseases, continues today. The activity of some involved scientists is recounted. An increasing amount of publications are dedicated to sea beet because the species also fits well into studies concerning population genetics, natural breeding systems, colonization, speciation, gene flow, etc.

Keywords History of sea beet • Crop evolution • *Beta maritima* history • Domestication • Origins of sea beet • Researchers involved

Beta maritima[1] is a very hardy plant and tolerates both high concentrations of salt in the soil and severe drought conditions (Shaw et al. 2002). Thus, it can grow in extreme situations almost in contact with saltwater (Figs. 1.1 and 1.2), "frequently between the

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[1] *Beta maritima*, now classified *Beta vulgaris* L. subsp. *maritima* (L.) Arcang (see Chap. 4), is called for the sake of brevity "*Beta maritima*" or "sea beet" in the text. The term "wild beet," improperly utilized by some authors, is used to indicate the species and subspecies belonging to *Beta* Tournef. not including *Beta vulgaris* subsp. *vulgaris* (domesticated beet), and not employed for cultivation. In the text, *Beta maritima* is considered species (spp.) or subspecies (subsp.) according to the bibliographic and/or taxonomic sources. For uniformity, the initial of the word *Beta* is always capitalized, even though this was not compulsory until after Linnè. In the text, Latin phrases, words, and botanical names are written in Italic. Latin or Latinized names of the authors are typed in Italic or in Roman characters if Anglicized. The common or vulgar names of plants are also typed in Roman characters. Words and phrases in other languages are written between brackets, whereas the respective English translation is written between parentheses. With few exceptions, both in text and references, only books including information on *Beta maritima* and synonyms are cited.

E. Biancardi et al., *Beta maritima: The Origin of Beets*,
DOI 10.1007/978-1-4614-0842-0_1,

Fig. 1.1 The picture shows sea beets on a stone bank at the mouth of Po di Levante, Italy. The plants grew on a few grams of sea debris and were able to flower and set seeds notwithstanding being surrounded only by salty water. For this reason, the picture already has been used as a metaphor of the crop's willingness to survive (Biancardi 1984)

high tide zone and the start of the vegetation, or where the wastage of the sea is deposited" (Doney 1992). Saltwater plays an important role in the dispersal of the species (Dale et al. 1985; Fievet et al. 2007). Along seashores, *B. maritima* is sensitive to competition from native plants (Coons 1954; de Bock 1986), especially under conditions of water and nutritional deficiency (Fig. 1.3). Indeed, sea beet seems to utilize its salt and drought tolerance to reduce competitor plants in the neighborhood (Coons 1954; Biancardi and de Biaggi 1979). Salty soils, caused by the seawater spray, tidal flows in estuaries, and storms may also induce relatively low pathogen pressure, and, thus, possibly be advantageous to the species. Von Proskowetz (1910) referred to having never

Fig. 1.2 *Beta maritima* growing near seawater, Kalundborg Fjord, Denmark, 2008 (courtesy Frese)

Fig. 1.3 *Beta maritima* competing against weeds Torcello, Italy

seen cysts of nematodes on sea beet roots likely also due to their "enorme Verholzung" (extreme woodiness). Conversely, Munerati et al. (1913) observed severe attacks of *Cercospora beticola* Sacc, *Uromyces betae* Kickx, *Peronospora schachtii* Fuck, *Lixus junci* Boh, etc. along the Italian–Adriatic seashores. Bartsch and Brand (1998) referred to the absence of *Beet necrotic yellow vein virus* (BNYVV), the causal agent of rhizomania, as likely related to the high salt content in the sandy soils.

Less frequently, sea beet populations are localized in interior areas, in the presence or absence of beet crops in the vicinity. In the first case, the wild populations are likely to be feral or ruderal[2] or more or less old offspring of crosses between sea and cultivated beets (Bartsch et al. 2003; Ford-Lloyd and Hawkes 1986).

Note: To make them more comprehensible, fragmentary references concerning *B. maritima* were ordered chronologically and placed in their historical framework. Therefore, it has been necessary to briefly review information on the evolution of scientific thought. Some references regarding the beet crops have been required because of the direct parentage of *B. maritima*, similarity of the plants' anatomy, and continual interrelationships of the two taxa after domestication.

1.1 Origin

The first use of *B. maritima* goes back to prehistory, when the leaves were harvested and used as raw vegetable or pot herb (von Boguslawski 1984). The leaves, shiny and emerald green even in winter (Fuchs 1551), were unlikely to be confused with those of other plants, a feature that was very important for the first harvesters. Because the separation of the subfamily *Betoideae* from the ancestral family *Chenopodiaceae* is estimated to have occurred between 38 and 27 million years ago (Hohmann et al. 2006), it is quite possible that sea beet (or one of its earlier relatives) already was known to our ancestors in their remote African dawn. Further confirmation of sea beet's ancient and widespread use are remains of desiccated seed stalks, carbonized seeds, and fragment of root parenchyma that have been found in the sites of Tybrind Vig and Hallskow, Denmark, dated from the late Mesolithic (5600–4000 BC) (Kubiak-Martens 2002, 1999; Robinson and Harild 2002). Pals (1984) reported on the discovery of similar remains in the Neolithic site (around 3000 BC) at Aartswoud, Holland. In agreement with Kubiak-Martens (1999),

[2] Feral beets originate by a "dedomestication" of the crop. This process starts with the early flowering (bolting) of some of the cultivated beets (Sect. 3.8) before harvest, which could be due to a number of causes. The plant could be an F_1 cross with *Beta maritima* bearing the annual trait or could result from annual beet seeds released in the field from an earlier crop. In the first case, the bolting beets were planted together with the variety and are therefore called "in-row bolters"; in the second, they are sparsely distributed and defined as "out-of-row bolters." Both types of beets also are called "weed beets" because they grow within the crop and damage it as do any weeds. In the following generations, weed beets assume a particular morphology that is selected for early seed production, i.e., small leaves, small and fanged roots, multiple and prostrate stalks, very early flowering, etc. If located outside the crop, they are called "feral" or "ruderal" (Arnaud 2008). Weed or feral beets reproduce receiving pollen from different sources, including sea beets. Therefore, they are characterized by very large genetic variability, much more than the beet varieties (Arnaud 2008). Bolting beets may appear inside normal varieties drilled too early in the season or subjected to strong flowering induction (long periods of cool weather) after emergence.

Fig. 1.4 Painting of Atlantic *Beta maritima* with regular and swollen root [Smith JE (1803) British plants. Vol. 4. Printed by the Author, London, UK]

evidence of harvest and use of *B. maritima* also is present at the Neolithic site at Dabki, Poland. Pollen of *Beta* wild plants was recognized in sediments sampled at Lake Urmia (Iran), Lake Jues (Germany), and Adabag (Turkey) dated around 16000, 10000, and 8000 BC, respectively (Bottema 2010; Voigt et al. 2008).

The presence of fragments of root suggests that this part was used as frequently as the leaves. It is important to remember that in northern regions the roots of sea beet are much more regular and developed than in southern environments. Therefore, the root better lends itself to harvesting (Fig. 1.4), most likely beginning in August, whereas the leaves were collected mainly in winter through spring (Kubiak-Martens 1999). After the discovery of fire, the roots probably were eaten after cooking (Turner 1995). The frequent presence of remains of other wild plant species in these sites suggests the key role that vegetables played in the hunter-gatherer's diet even in pre-agrarian times (Kubiak-Martens 2002).

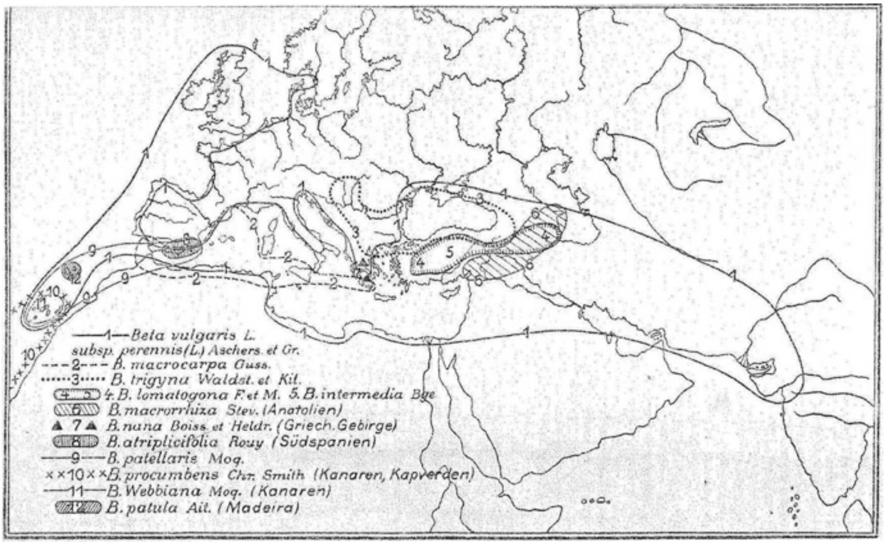

Fig. 1.5 Distribution of the species and subspecies of the genus *Beta* according to Ulbrich (1934)

Charred remains of sea beet seeds were identified in late Mesolithic sites located in the northern region of the Netherlands, demonstrating the ancient presence of the species along the north Atlantic seashores (Perry 1999). This presence was further confirmed by the remains of *B. maritima* found at the site of Peins, the Netherlands, dated to the first century BC (Nieuwhof 2006). Collecting data from 61 archeological sites in different parts of Egypt dated from Pre-dynastic to Greco–Roman times (4000 BC–395 AD), Fahmy (1997) recognized 112 weed species. Macro-remains of sea beet (seeds, leaves, stalks, etc.) were preserved by desiccation in sites dated from 3100 BC until the middle of the Pharaonic period (2400 BC).

As to the area of origin of the species, de Candolle (1885) wrote “la betterave ne pourrait etre originarie que du midi de l’Europe ou des régions tres voisinés” (beets originated from Central Europe or from nearby regions) due to the large amount of wild species of the genus *Beta* present throughout the area. Some years later, de Candolle (1884) asserted that the beet crop was derived from the species classified at that time as *Beta cicla*, very similar (if not identical) to *B. maritima.* He asserted also that *B. cicla* expanded from the Canary Islands along the North Atlantic coasts to the Mediterranean coasts, up to the countries around the Caspian Sea, Persia, and Mesopotamia. This hypothesis of de Candolle, perhaps reasonable because of the numerous *Beta* species present today on Canary Islands, has not been confirmed by later authors (Francisco-Ortega et al. 2000; Meyer 1849; Pitard and Proust 1909). According to Coons (1954), the origin of sea beet could be localized to the areas delimited by Ulbrich (1934) (Fig. 1.5). Southwest Asia could be the area of origin not only of *B. maritima* and many other important crops (wheat, barley etc.), but also of the family *Chenopodiacee* to which the genus *Beta* belongs[3] (Ulbrich 1934). Avagyan (2008) suggested that the species could have originated in Armenia. Other authors (Honaker, Koch, Boissier, Bunge, Radde, reviewed by von Lippmann (1925)) agree in locating the origin of the genus *Beta* in the area comprising the shores of the Caspian Sea, Transcaucasia, the East and South coasts of the Black Sea, Armenia, Asia Minor, the shores of the Red Sea, Persia, and India.

1.2 Domestication

Based on the rudimentary tools found in Neolithic age settlements, the first farming of wheat (*Triticum* spp.) and barley (*Hordeum* spp.) is thought to have arisen in the Near East, perhaps earlier than 8500 BC (Zohary and Hopf 2000). Early agricultural practices then would have spread into the Mediterranean basin through the ship routes of that time, and more slowly toward Central Europe. At least three millennia were necessary for agriculture to arrive in the British Islands, Scandinavia, and Portugal (Zohary and Hopf 1973; Zohary and Hopf 2000): that is, spreading at a rate of about one kilometer per year (Cavalli-Sforza and Edwards 1967).

Beet cultivation may have begun in Mesopotamia around 8000 BC (Simmonds 1976). According to Krasochkin (1959), the first beet cultivation occurred in Asia Minor, mostly in localities at a high altitude with a cool growing season. Subsequently, the practice spread to Mediterranean areas, developing a great diversity of primitive forms of beet still existing today. The wild ancestor may have resembled types currently present in western Anatolia and Afghanistan, characterized by a very short life span, large seed balls, elongated and fangy roots, and the tendency to flower very early (Krasochkin 1959, 1960). Using analyses of mitochondrial DNA, Santoni and Bervillè (1992) confirmed this hypothesis, i.e., that cultivated beets likely originated from a unique ancestor quite different from the current *B. maritima*. Also after domestication, sea beet has continued to be harvested in wild sites and used as a vegetable, a custom still widespread today in many coastal areas (Thornton 1812). According to Magnol (1636), "*Nihil in culinis Beta frequentius est*" (nothing is more used in the kitchen than beet). Rivera et al. (2006) consider the sea beet among the most gathered of wild plants for food (GWPs) in the Mediterranean and Caucasian regions. In the mentioned paper, the local names of sea beet are listed in 25 languages (Appendix C).

Van Zeist and de Roller (1993) argued that beet farming had spread throughout much of Egypt by the time of construction of the pyramids of Giza (around 2700 BC). This hypothesis was supported by Herodotus (von Lippmann 1925). Because of the large quantity of beet that would have been required, the vegetable must have been domesticated. According to Buschan (1895), some wall paintings (Fig. 1.6) inside the tombs of Beni Hassan, near Thebes, and dating to the 12th Dynasty (2000–1788 BC),

[3] In the APG II (2003) classification, the genus *Beta* has been classified in the family *Amaranthaceae*.

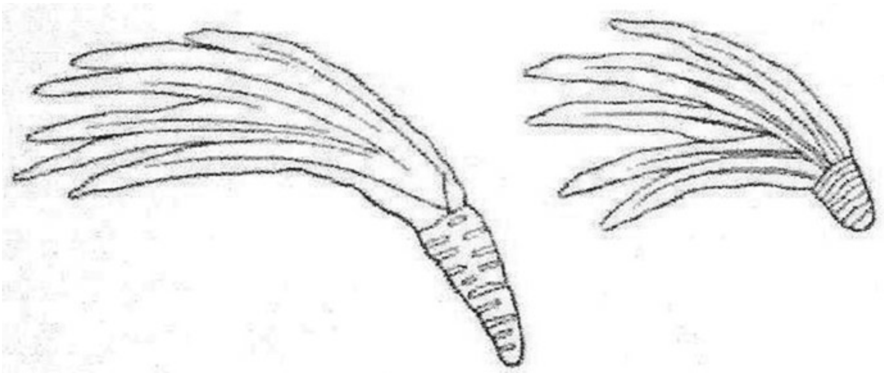

Fig. 1.6 *Beta* (likely) painting at Beni Hassan, Egypt (Buschan 1895)

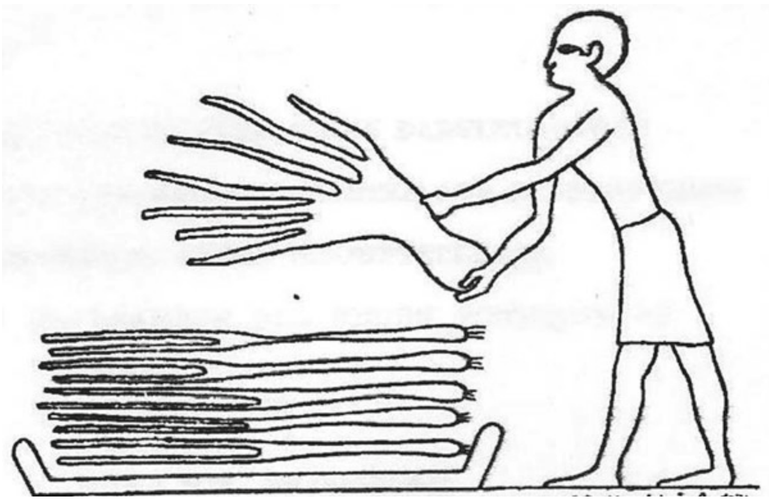

Fig. 1.7 *Beta* (likely) in the hands of the farmer. Painting at Beni Hassan, Egypt (Woenig 1866)

represent beet and not horseradish (*Cochlearia armoracia* L.) as speculated by others. In a second painting inside the same tomb (Fig. 1.7), the farmer seems to have a beet in his hand while the plants on the ground most likely are garlic (*Allium sativum* L.) (Woenig 1866). In both paintings, the regular shape of the root suggests that it is a cultivated variety of beet. The large size is probably to better highlight the subject. Given the extensive spread of sea beet along the northern Egyptian coasts, Buschan (1895) proposed that its cultivation in the region had begun much earlier. In Fig. 1.8, the word for "beet" is written in ancient Egyptian (Kircher 1643; Veyssiere de la Croze 1755). Other findings dating from the third Dynasty (2700–2680 BC) have been made at Memphis, Egypt (Zohary and Hopf 2000). The lack of morphological differentiation often does not allow positive determination of whether remains

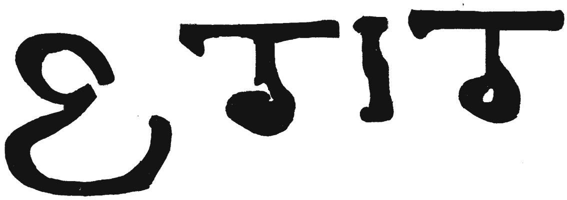

Fig. 1.8 The word meaning beet written in old Egyptian alphabet (Veyssiere de la Croze 1755)

are from wild or cultivated beets. In general, if the beet plant remains are found far from the sea and after the spread of agriculture in the area, it may be assumed that they are derived from cultivated beets. This is the case of beet seeds found in central Germany in sites dating to the Roman Empire (Zohary and Hopf 2000).

The cultivated sea beet has adapted in response to selective pressures imposed by growers, who instinctively selected for reproduction of the plants with the best expression of the traits of interest. The domestication process was hastened by utilizing plants with mutations as well, but only if the new trait enhanced yield and quality (Fehr 1987). This early selection, according to Ford-Lloyd et al. (1975), gave rise to a taxa he classified as *Beta vulgaris* subsp. *provulgaris*, an ancestral form from which beets were derived selected both for root and leaf production. This ancestral plant type is believed still existent in Turkey.

Some traits necessary for survival in the wild became superfluous in cultivated beet (Zohary 2004). For example, cultivation by the farmer reduced beet's already poor competitive ability against weeds, a trait which is not necessary or of reduced need in artificial monoculture. The annual cycle, necessary for increased seed production and thus essential for survival in the wild (Biancardi et al. 2005), slowly became biennial. In this way, as with other vegetables, the duration over which leaves remained edible was increased (Harlan 1992). As a consequence of the selection process, genetic diversity decreased rapidly (Bartsch et al. 1999). Santoni and Bervillè (1995) observed in cultivated beets the lack of the rDNA unit V-10.4-3.3, common in *B. maritima*. Because *B. maritima* has been used in the last century as a source of resistances, the authors suspected the elimination of this DNA unit occurred through the selection processes. Recently, Li et al. (2010) confirmed the key role of genetic variation for the trait of interest in the first phase of sugar beet breeding (Ober and Luterbacher 2002).

The first written record mention of beet farming goes back to an Assyrian text of the eighth century BC, which described the hanging gardens of Babylon (Körber-Grohne 1987; Mabberley 1997; Meissner 1891, see Ulbrich 1934; Zohary and Hopf 2000). As has happened with the most important crops, the cultivated beet left its first domestication sites (Kleiner and Hacker 2010). Some centuries later, the leaf beet was called "selga" or "silga," words that, according to Winner (1993), would have the same origin as the Latin adjective "*sicula*" (Sicilian). Around 400 BC, the cultivated leaf beet returned to Asia Minor (whence the sea beet had spread some millennia earlier) from Sicily, whose population of Greek origin had extensive trade relations with Mycenae and the eastern Mediterranean harbors (Becker-Dillingen 1928; Ulbrich 1934). Older European people, such as the Arians, did not cultivate beet (De Candolle 1885; Geschwind and Sellier 1902).

1.3 Athens and Rome

The first unambiguous written reference to beet cultivation dates back to Aristophanes,[4] who mentions beet, at the time called τευτλον (*seutlon* or *teutlon*), in the plays "The Acharners," "The Frogs," and "Friends" (Winner 1993). According to von Lippmann (1925), in an old edition of "War between Frogs and Mice," a comedy written by Homer, there are some words resembling τευτλον, but their meaning is still uncertain. Again, according to von Lippmann (1925), the first written reference positively alluding to *B. maritima* dates back to Diocles from Carystos (end of fourth century), a pupil of Aristotle, who included its dried leaves in a medicinal mixture with other herbs. Diocles stated that the wild beet (τευτλον άγςια or άγριον) was very common along the coasts of Greece and its islands, and was rather different when compared to the cultivated plant (Jaeger 1952). The cultivated beets were of two types: white (λενχόυ) and black (μελαν). For sea beet, Diocles used also the terms "βλιτος (*blitos*)" and "λειμωνιον (*leimonium*)" and these words certainly can be attributed to the plant. Diocles is believed to be the author of the first illustrated herbal, which was the model for several later authors (Collins 2000).

In "*Historia plantarum*" (295 BC?), the philosopher Theophrastus, student of Plato and then of Aristotle, confirmed the existence of two varieties of cultivated beets: the black "τευτλον μελαν (*nigra*)" and the white "τευτλον λενχόυ (*candida*)" also called "*cicla.*" Both display a long and narrow root similar to horseradish and have a sweet and satisfying taste. This description coincides with the shape of the plants painted, as mentioned above, at Beni Hassan. Both Diocles and Theophrastus described a beet, similar to the black one, and grown at the time for its roots. According to Sturtevant (1919), Aristotle himself cited the existence of a third cultivated type: the red beet. Theophrastus also listed the medicinal properties of sea beet (Sect. 5.1). Since that time, the plant has taken on the dual nature of a food crop and of medicinal herb against various human diseases.

As for other types of beet, with rare exceptions, the therapeutic use was the most prevalent in books written until at least the end of the twelfth century (Jackson 1881; Lamarck 1810). The medicinal properties of sea beet were best described by the physician Hippocrates,[5] who is recognized as the founder of medicine based on a protoscientific basis (Dalby 2003). Von Lippmann (1925) argued that the

[4] The chronology of the ancient authors and, if the case, the complete Latin name or surname is given in Appendix D.

[5] According to Gray (1821), Hippocrates, the "lineal descendant of Esculapius", stated: "The theory must be confirmed by the observation of the reality and by the experience".

dark-leaved variety (*nigra*) was cultivated extensively in the Grecian world also for the root. At that time, in addition to the above-listed uses, it was customary to offer beets to Apollo in his temple at Delphos (Taylor 1875).

In "*De Re Rustica*" (274 BC), the Roman writer and politician Cato, surnamed "*Censorius*" (the Censor), used the word "*Beta*" for the first time without giving indication of its source (Schneider 1794). The term appears in the following phrase, which describes the composition of a laxative mixture: "*Si ungulam non habebis, adde . . . betae coliculos cum radice sua*" (if the nail of jam is not available, use . . . the beet stalk and its root). According to Columella (80 AD?) and several later writers, the name seems to derive from the second letter of the Greek alphabet, i.e., a letter whose form looks like the embryo of the seed in the early stages of germination (Berti-Pichat 1866). De Lobel (1576) stated "*Betam etenim a litera graeca β sic dictam vocant*" (it is believed that *Beta* is so-called from the Greek letter *β*). Whitering, cited by Baxter (1837), believed that the name is derived from the form of its seed vessel, which, when swollen with seed, resembles the letter *β*. The hypothesis that "*Beta*" was derived from the Celtic "bett" (red) or from the Irish "biatas" (red beet) (Baxter 1837) does not seem to be supported due to the infrequent contact that Rome had at the time with the British Islands (Poiret 1827; von Lippmann 1925). People of Celtic origin began to grow beets in Central Europe only around the fourth century AD Geschwind and Sellier (1902). According to Strabo (cited by von Lippmann 1925), the use in the North Sea area of "wildwachsene Gemüse" (wild vegetables) including beet was dated earlier. An original hypothesis was given by Pabst (1887): in his opinion, the word "*beta*" derived from the Latin "*meta*," which means, among other things, "conic heap of stones," similar to the spindle form of the beet root. Because the germinating seed resembles α more than *β* (Fig. 1.9), the assonance of the Greek word "βλιτος" cannot be missed. The etymological evolution of the word may be as follows: βλιτος → *Blitos* → *Blitum* → *Bleta* → *Beta* (Becker-Dillingen 1928).

The beet crop was mentioned several times by Latin writers, including Plautus, Cicero, Catullus, Virgil, and Varro. Martial (80 AD?) listed the beet "among the abundance of the rich countries," and defined it as "unserviceable to a sluggish stomach" (Feemster-Jashemsky and Meyer 2002). Beet also was cited in two epigrams:

> "*Pigroque ventris non inutiles betas*" (Beet is useful for lazy bowel).
> "*Ut sapiant fatua fabrorum prandia betae, o quam saepe petet vina, piperque cocuus*"
> (Insipid beet may bid a tradesman dine, but asks abundant pepper and wine)[6]

Suetonius wrote that the emperor Caesar Augustus invented the verb "*betizare*" to indicate effeminate behavior because of the beet's sweetness (Tanara 1674). Pliny the Elder (75 AD?) provided important information on the crop in "*Historia naturalis*," mentioning both agricultural methods of cultivation and medicinal properties. The treatise, consisting of 37 volumes, represented an encyclopedia of the scientific knowledge of Imperial Rome. Like Hippocrates and Theophrastus, Pliny mentioned the existence of varieties with white roots (*candida*) and dark green

[6] Translated by Ray (1738).