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Series on Harmonization of Regulatory Oversight in Biotechnology No. 18

CONSENSUS DOCUMENT ON THE BIOLOGY OF BETA VULGARIS L. (SUGAR BEET)

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Also published in the Series on Harmonization of Regulatory Oversight in Biotechnology:

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Consensus Document on the Biology of Betula pendula ROTH (European White Birch) (in preparation)

Consensus Document on Information Used in the Assessment of Environmental Applications Involving Bacillus (in preparation)

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OECD Environment, Health and Safety Publications

Series on Harmonization of Regulatory Oversight in Biotechnology

No. 18

**Consensus Document on the Biology of
Beta vulgaris L. (Sugar Beet)**

Environment Directorate

Organisation for Economic Co-operation and Development

Paris 2001

About the OECD

The Organisation for Economic Co-operation and Development (OECD) is an intergovernmental organisation in which representatives of 30 industrialised countries in North America, Europe and the Pacific, as well as the European Commission, meet to co-ordinate and harmonise policies, discuss issues of mutual concern, and work together to respond to international problems. Most of the OECD's work is carried out by more than 200 specialised Committees and subsidiary groups composed of Member country delegates. Observers from several countries with special status at the OECD, and from interested international organisations, attend many of the OECD's Workshops and other meetings. Committees and subsidiary groups are served by the OECD Secretariat, located in Paris, France, which is organised into Directorates and Divisions.

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FOREWORD

The OECD's Working¹ Group on Harmonization of Regulatory Oversight in Biotechnology decided at its first session, in June 1995, to focus its work on the development of *consensus documents* which are mutually acceptable among Member countries. These consensus documents contain information for use during the regulatory assessment of a particular product. In the area of plant biosafety, consensus documents are being published on the biology of certain plant species, on selected traits that may be introduced into plant species, and on biosafety issues arising from certain general types of modifications made to plants.

This consensus document addresses the biology of *Beta vulgaris* L. (sugar beet). It contains a general description as a crop plant, taxonomy, centre of origin/diversity, reproductive biology, crosses and weed characteristics. However, its ecology to specific geographic regions is not presented, since this may vary from one geographic region to another. For the intraspecific and interspecific crosses, emphasis has been placed on detailing potential hybridisation between the cultivated species and their close relatives. In this document, only hybridisation events not requiring human intervention are considered, rather than listing all successful crosses, which would be very long and subject to frequent changes.

Switzerland served as lead country in the preparation of this document, and has been revised on a number of occasions based on the input from other Member countries. It is intended for use by regulatory authorities and others who have responsibility for assessments of transgenic plants proposed for commercialisation, and by those who are actively involved with genetic improvement and intensive management of the genus.

¹ In August 1998, following a decision by OECD Council to rationalise the names of Committees and Working Groups across the OECD, the name of the "Expert Group on Harmonization of Regulatory Oversight in Biotechnology" became the "Working Group on Harmonization of Regulatory Oversight in Biotechnology."

TABLE OF CONTENTS

| | |
|-------------|--|
| Preamble | 9 |
| Section I | General Description Including Taxonomy, Morphology, Genetic Characteristics and Use as a Crop Plant 11 |
| | A. Taxonomy 11 |
| | B. Uses 13 |
| | C. Description 13 |
| | D. Genetic characteristics (ploidy number)..... 15 |
| | E. Survival strategies 16 |
| | F. Isolation measures and distances..... 16 |
| Section II | Agronomic Practices..... 17 |
| Section III | Centres of Origin/Diversity, Geographic Distribution, Close Relatives and their Geographical Distribution 18 |
| | A. History of cultivated Beet 18 |
| | B. Origin 19 |
| | C. Close relatives and their geographic distribution 19 |
| Section IV | Reproductive Biology 21 |
| | A. Flower morphology..... 21 |
| | B. Compatibility 21 |
| | C. Formation of reproductive parts..... 21 |
| | D. Pollen 22 |

(continued next page)

| | | |
|-------------|---|----|
| | E. Pollen dispersal | 22 |
| | F. Pollination..... | 23 |
| | G. Seed..... | 23 |
| | H. Seed dispersal | 23 |
| Section V | Crosses | 24 |
| | A. Intraspecific | 24 |
| | B. Interspecific..... | 24 |
| | C. Introgression..... | 25 |
| | D. Interactions with other organisms..... | 25 |
| Section VI | Weed Characteristics and Weediness | 26 |
| Section VII | References..... | 27 |
| Appendix | Interactions: Common Diseases and Pests of <i>Beta vulgaris</i> | 32 |
| | Questionnaire to return to the OECD | 39 |

Preamble

OECD Members are now commercialising and marketing agricultural and industrial products of modern biotechnology. They identified the need for harmonization of regulatory approaches to the assessment of these products, in order to avoid unnecessary trade barriers.

In 1993, **Commercialisation of Agricultural Products Derived through Modern Biotechnology** was instituted as a joint project of the OECD's Environment Policy Committee and Committee on Agriculture. The objective of this project is to assist countries in their regulatory oversight of agricultural products derived through modern biotechnology – specifically in their efforts to ensure safety, to make oversight policies more transparent and efficient, and to facilitate trade. The project is focused on the review of national policies, with respect to regulatory oversight, that will affect the movement of these products into the marketplace.

The first step in this project was to carry out a survey concentrating on national policies with regard to regulatory oversight of these products. Data requirements for products produced through modern biotechnology, and mechanisms for data assessment, were also surveyed. The results were published in *Commercialisation of Agricultural Products Derived through Modern Biotechnology: Survey Results* (OECD, 1995).

Subsequently, an OECD Workshop was held in June 1994 in Washington, D.C. with the aims of improving awareness and understanding of the various systems of regulatory oversight developed for agricultural products of biotechnology; identifying similarities and differences in various approaches; and identifying the most appropriate role for the OECD in further work towards harmonization of these approaches. Approximately 80 experts in the areas of environmental biosafety, food safety and varietal seed certification, representing 16 OECD countries, eight non-member countries, the European Commission and several international organisations, participated in the Workshop. *Report of the OECD Workshop on the Commercialisation of Agricultural Products Derived through Modern Biotechnology* was also published by the OECD in 1995.

As a next step towards harmonization, the Working Group on Harmonization of Regulatory Oversight of Biotechnology instituted the development of *consensus documents*, which are **mutually acceptable** among Member countries. The goal is to identify common elements in the safety assessment of a new plant variety developed through modern biotechnology, to encourage information sharing and prevent duplication effort among countries. These common elements fall into three general categories: the first being the biology of the host species, or crop: the second, the introduced gene and resulting gene product: and the third, environmental biosafety issues arising from certain general types of modification made to plants.

The safety issues identified in the consensus documents on the biology of specific crop plants are intended to address the potential for gene transfer within the crop plant species, and among related species, as well as the potential for weediness. They make no attempt to be definitive in this respect,

however, as the many different environments in which the crop species may be grown are not considered individually.

This consensus document is a “snapshot” of current information that may be relevant in a regulatory risk assessment. It is meant to be useful not only to regulatory officials, as a general guide and reference source, but also to industry and others carrying out research.

In using this document and others related to the biology of crop plants, reference to two OECD publications which have appeared in recent years will prove particularly useful. *Traditional Crop Breeding Practices: An Historical Review to Serve as a Baseline for Assessing the Role of Modern Biotechnology* presents information concerning 17 different crop plants. It includes sections on phytosanitary considerations in the movement of germplasm and on current end uses of the crop plants. There is also a detailed section on current breeding practices. *Safety Considerations for Biotechnology: Scale-Up of Crop Plants* provides a background on plant breeding, discusses scale dependency effects, and identifies various safety issues related to the release of plants with “novel traits.”

To ensure that scientific and technical developments are taken into account, OECD countries have agreed that consensus documents will be updated regularly. Additional areas relevant to the subject of each consensus document will be considered at the time of updating.

Users of this document are therefore invited to provide the OECD with new scientific and technical information, and to make proposals for additional areas to be considered. ***There is a short, pre-addressed questionnaire for that purpose at the end of this document. The completed questionnaire (or a photocopy) should be returned to the OECD’s Environment, Health and Safety Division at the address shown.***

Section I - General Description Including Taxonomy, Morphology, Genetic Characteristics and Use as a Crop Plant

A. Taxonomy

Sugar beet (*Beta vulgaris* L. ssp. *vulgaris* var. *altissima*) belongs to the family *Chenopodiaceae* and the genus. *B. vulgaris* comprises several cultivated forms of *B. vulgaris* subsp. *vulgaris*. Cultivars include leaf beet (var. *cicla*) and beetroot (root beet USA). The genus *Beta* is divided into four sections shown in Table 1 below (Ford-Lloyd and Williams, 1975; Campbell, 1976; Tranzschel, 1927 and Ulbrich, 1934):

Table 1: Classification of the *Beta* species.

| Species name | Chromosome number |
|---|-------------------|
| Section I: <i>Beta</i> Tranzschel | |
| <i>B. vulgaris</i> L. ssp. <i>vulgaris</i> | 18 |
| <i>B. vulgaris</i> L. ssp. <i>maritima</i> (L.) Arcang | 18 |
| <i>B. vulgaris</i> L. ssp. <i>adanensis</i> (Pam.) Ford-Llyod & Williams | 18 |
| <i>B. patula</i> Ait. | 18 |
| <i>B. macrocarpa</i> Guss. | 18, 36 |
| Section II: <i>Corollinae</i> Ulbrich | |
| <i>B. macrorhiza</i> Stev. | 18 |
| <i>B. corolliflora</i> Zoss. | 36 |
| <i>B. lomatogona</i> F. et M. | 18, 36 |
| <i>B. intermedia</i> Bunge | 36, 45 |
| <i>B. trigyna</i> W. et K. | 36, 54 |
| Section III: <i>Nanae</i> Ulbrich | |
| <i>B. nana</i> Boiss. et Heldr. | 18 |
| Section IV: <i>Procumbentes</i> Ulbrich | |
| <i>B. procumbens</i> Chr. Sm. | 18 |
| <i>B. webbiana</i> Moq. | 18 |
| <i>B. patellaris</i> Moq. | 18, 36 |

In Europe, wild sea beet occurs as a wild plant. Wild *B. vulgaris* species are distributed along the border-zones of the Mediterranean from southern Russia, the Near-East, and Syria to the Canary Islands

and Madeira. They are also found along the European Atlantic coasts where they come into contact with the Gulf Stream. *B. vulgaris* has also been introduced into Baltic and Central and South America. In North America, the species has become naturalised, resulting from the introduction of plants for cultivation. Table 3 shows the global distribution of the wild species of *Beta*.

Table 2: Distribution and use of cultivated forms of *Beta vulgaris* ssp. *vulgaris*
(according to Mansfeld 1986).

| Species | Var. | Common name | Distribution | Use |
|----------------------|-------------------|---------------------|---|-----------------------------|
| <i>Beta vulgaris</i> | <i>Cicla</i> | Spinach beet | Central, western and southern Europe Asia | Cooking vegetable |
| <i>Beta vulgaris</i> | <i>Flavescens</i> | Swiss chard | Central, western and southern Europe Asia | Cooking vegetable |
| <i>Beta vulgaris</i> | <i>Vulgaris</i> | Red beet (beetroot) | Central, western and southern Europe; Asia; Western India | Cooking and salad vegetable |
| <i>Beta vulgaris</i> | <i>Lutea</i> | Yellow beet | Central, western and southern Europe; Asia | Salad vegetable |
| <i>Beta vulgaris</i> | <i>Rapacea</i> | Fodder beet | Europe; Commonwealth of independent States (CIS); North America | Fodder plant |
| <i>Beta vulgaris</i> | <i>Altissima</i> | Sugar beet | Europe; CIS; China; Asia; North America; South America | Beet sugar production |

Table 3: Global distribution of the wild species of the genus *Beta* (according to Mansfeld, 1986)

| Species | Subspecies | Distribution |
|--------------------------|------------------|--|
| <i>Beta vulgaris</i> | <i>maritima</i> | Mediterranean, Canary Islands, Near East, Madeira, European Atlantic coast to India, North sea, Middle and South America |
| <i>Beta vulgaris</i> | <i>adanensis</i> | Mediterranean, Canary Islands, Near East, Madeira, European Atlantic coast to India, North sea, Middle and South America |
| <i>Beta macrocarpa</i> | | India |
| <i>Beta patula</i> | | Mediterranean, western Europe, North-west Africa |
| <i>Beta vulgaris</i> | <i>adanensi</i> | Mediterranean, western Europe, North-west Africa |
| <i>Beta intermedia</i> | | Asia Minor to Hungary, Persia |
| <i>Beta corolliflora</i> | | Asia Minor, Caucasus, Black sea coast |
| <i>Beta macrorhiza</i> | | Asia Minor, Caucasus, Black sea coast |
| <i>Beta trygina</i> | | Asia Minor, Caucasus, Black sea coast |
| <i>Beta patellaris</i> | | North-west African coast and Islands, southern Spain |
| <i>Beta procumbens</i> | | Canary and Cape Verde Islands, North-west African coast |
| <i>Beta webbiana</i> | | Canary and Cape Verde Islands, North-west African coast |

Sugar beet is cultivated world-wide, but primarily in warm and temperate climates with little precipitation. There is an increase in cultivation in subtropical regions (Brouwer et al., 1976). The largest areas of cultivated sugar beet are in the U.S.A., C.I.S. (Commonwealth of Independent States, formerly the U.S.S.R. [e.g. Russia]), Europe (FAO Yearbook, 1992) and in China.

B. Uses

Sugar beet is used for the production of sugar. By products of sugar production as pulp, molasses, fibre etc, are used as feed.

When sugar beet is grown in areas of livestock production, leaves of the plant may also be used for fodder. More recently, sugar beet has been used for molasses production. Molasses are used for alcohol production and in other forms of fermentation (penicillin production, etc...).

C. Description

Morphology

A glabrous or slightly, hairy annual, biennial or perennial of very varied habit, from 30 to 120 cm (or even 200 cm) in height. The root is stout, sometimes conspicuously swollen forming a beet together with the hypocotyl, and sometimes forming a branched taproot (as in ssp. *maritima*). Stems are decumbent, ascending or erect, and more or less branched. Leaves are very varied in size, shape and colour, often dark green or reddish and rather shiny, frequently forming a radicle rosette. Inflorescences

are usually large and more or less branched. The flowers are hermaphrodite arranged in small cymes (Clapham et al., 1962; Højland and Pedersen, 1994).

Cultivated forms of sugar beet are essentially biennial and are grown for the swollen roots that develop at the end of the first growing season. Sugar beets is biennial and require a period of vernalisation at the end of the first year before they can flower, although a small proportion of plants flower in their first year and are able to set seeds that persist in the soil. This phenomenon is known as “bolting”. A possible source of annual weed beets is the pollination of seed crops by contaminating pollen from annual wild beets (Longden, 1976; Evans and Weir, 1981). In particular, this may have happened in southern Europe during the production of sugar beet seed of triploid monogerm varieties, when the male-sterile diploids used as mother plants are especially susceptible to pollination by contaminating pollen from diploid wild or weed beet plants, rather than by the intended tetraploids pollen bearing plants (Scott R.K. and Longden P.C., 1970). The other possibility is the variability in vernalisation requirements between varieties, some varieties need less vernalisation than the other and can easily flower during the first year.

In Europe, flowering weed beets in sugar beet production areas have, since the early 1970's, become a serious problem. The weed beet is phenotypically different from volunteer sugar beet in that it produces more seed, and in France, this seed has been shown not to require the usual vernalization period prior to flowering (Harding and Harris, 1994). The weedy form may, in theory, have evolved in parallel with “bolters” *in situ* in sugar beet producing areas, but, molecular evidence suggests that weed beet originated from pollination by wild diploid species in seed producing areas along the Mediterranean (Boudry et al., 1992; 1993).

Beta vulgaris ssp. *vulgaris* is customarily divided into two types: fodder beet and sugar beet. Some authors refer to sugar beet as var. *saccharifera*, however the distinction is not clear. The obvious morphological difference is that the beet in fodder beet is formed primarily by the hypocotyl, whereas in the sugar beet a considerable part of the beet is formed by the root. This results in a higher dry matter content in sugar beet, and also the beet itself is placed deeper in the soil. A variety of beet is, as a rule, only accepted as a sugar beet if the dry content matter is 20% or more and the beet is white (Højland and Pedersen, 1994).

The wild *Beta vulgaris* ssp. *maritima* is hardy, has thin, multi-stemmed roots, and low-lying stalks in a rosette-like array.

Seedlings

Sugar beet seeds contain very little perisperm for germination and early growth. This make seedlings very vulnerable during early growth to competition from weeds and to damage by disease and browsers (Højland and Pedersen, 1994). Weeds emerging within 4 weeks after the sugar beet has reached the two-leaf stage are the most damaging. Weed competition has been estimated to reduce root yields 6 % in Canada and 10% in the USA. Competition from annual grasses also suppress root yields, however, competition from annual grass species is not usually as severe as that from broadleaf weeds because they do not compete for light as effectively as broadleaf weeds (Højland and Pedersen, 1994). Sugar beet seedlings have two, and occasionally three leaves, however, varieties vary in terms of leaf position, leaf number, leaf size, and curling of the leaf edge. Yellow and red pigments are often stored in leaf tissue. After differentiation of the leaves, they become covered with a waxy layer (Gilloly Bystron et al., 1968). Unlike fodder beet, the lower leaves of the sugar beet commonly lie in a rosette-form on the ground (Brouwer et al., 1976). The crown leaves are spirally arranged in 5/13 position. Leaf development is

usually most advanced from the end of July until late August, depending on the area of cultivation. Leaf yellowing and wilting generally begins when temperatures drop below 6°C.

Plant Development

Beta vulgaris is hemocryptophytic, that is it is a plant that develops its buds just above, or below the soil-surface where they are protected from drought or cold experienced during very cold winters (Højland and Pedersen, 1994).

Sugar beets generally only show stem elongation in the second growing season although, as previously noted, this may begin in the first year in some plants (bolting). The gene B located on chromosome 2 (Boudry et al., 1994) cause shoot elongation and early flowering without vernalization. The dominant allele fragmentally occur in *B. maritima* populations. Also quantitative genetic variation for bolting has been observed resulting in stem elongation under specific environmental conditions. The most important of these are low temperatures (+1 to +4°C) in the 4-5 leaf stage, the duration of low temperature, day length, and the effects on the phytochrome system of light quality (Lane et al., 1965; Lexander, 1981; Smit, 1983). Due to successes in breeding programmes, today's cultivated sugar beet varieties show very little stem elongation ("bolting") in the first year.

Roots

The fibrous root system can reach to a depth of 1-2- meters. Numerous secondary roots spread out directly under the soil surface and are highly branched. Secondary roots submerged deeper in the soil are stronger and grow in downward arcs. 70% of the root mass is located in the soil layer from 0-30 cm. The roots of cultivated beets range in colour from white to yellow, orange and red in various shades and intensities. Sugar beets are sometimes "fangy"; this refers to overdeveloped secondary roots alongside the taproot.

D. Genetic characteristics (ploidy number)

The genus *Beta* exists in diploid, tetraploid and hexaploid forms with a chromosome number of $x=9$ (Walter, 1963) (see also table 1). Dense genetic maps based on molecular marker have been published and linkage groups have been allocated to the 9 chromosomes of beet (Barzen et al., 1992; Pillen et al., 1992). also the abundance of repetitive sequence classes has been extensively studied (Schmidt and Heslop-Harrison, 1993). All wild and cultivated *Beta* species are capable of hybridising, and wild beet species represent a valuable gene reservoir and are frequently used in variety breeding programmes.

Most of the sugar beet grown since 1970s has been triploid hybrids, although actually the diploid varieties represent 50 % in France. Triploid plants are produced by crossing a tetraploid male parent, onto a diploid male sterile plant, used as the female parent. The resulting plants are usually doubly sterile because of chromosome imbalance and cytoplasmically inherited male sterility in the same plant. However, small proportions of plants do produce aneuploid pollen, which will give fertile progeny when used to pollinate the diploid male sterile plants.

The development of hybrid sugar beet was made possible by the discovery of cytoplasmic male-sterility (CMS) (OECD, 1993b). As in other plant species, CMS in sugar beet is the result of the interaction between nuclear genes and changes in the mitochondrial genome. To obtain entirely male

sterile offspring, CMS plants must be pollinated with so-called maintainer plants, which carry the normal, unchanged mitochondrial genome (OECD, 1993b).

Truly nuclear male-sterility which depends on a single recessive nuclear gene exist but this system does not allow the production of a population that is 100% male-sterile (OECD, 1993b).

The goal of breeding programmes is to develop sugar beet varieties with higher root yield and higher sugar content, better extraction yield (juice purity), higher seed germination percentages; lower tendency to “bolt”; physical attributes of the root well adapted to mechanical harvesting; higher resistance to leaf diseases; and, higher root dry matter content (especially for fodder beet).

E. Survival strategies

Sugar beet possesses long-lived dormant seeds that can become a volunteer weeds in sugar beet fields (Højland and Pedersen, 1994). They tend to germinate in the field 1-3 days later than planted sugar beet seeds (Højland and Pedersen, 1994). Sugar beet seeds may remain in the soil for ten years or more and still retain some germination capacity (OECD, 1993b; Brouwer et al., 1976; Lysgaard, 1991). It is generally accepted that six year-old multigerm and four year-old monogerm sugar beet seed exhibit the same germination level of 70%. Eight-year-old sugar beet seeds have been shown to germinate at a level of 59% in laboratory conditions. These germination percentages depend of the quality of the seeds and of the conditions of germination. Thus *Beta vulgaris* has the ability to generate a viable seed bank (Højland and Pedersen, 1994). The seed-balls of *Beta* are resistant to salt water, and ocean currents can move propagules over relatively long distances. Above the high water line, strong winds distribute them over the shoreline, and sometimes even inland (Smart, 1992).

Since commercial sugar producing sugar beet is biennial and is harvested during the first year whilst still in the vegetative phase, sexual reproductive organs (floral parts) never develop. Varieties that tend to bolt in the first year of growth pose some problems and much effort has gone into developing currently cultivated varieties that limit bolting. When *Beta vulgaris* is planted for seed production, some seeds may remain on the field after harvesting the seed crop. Agricultural practices tend to limit those shoots.

F. Isolation measures and distances

As pollen is mainly wind-borne, large isolation distances are necessary to prevent pollination from sources other than the desired male parent. For commercial seed production, isolation distances are very variable according to the country. In the literature, it varies from 1 to 3.2 (Campbell and Mast, 1971; Smith, 1980; Højland and Pedersen, 1994).

The OECD developed a scheme in order to homogenise the isolation distances (OECD Council Decision of 10th October 1988 (C [88] 66), appendix II).

Section II - Agronomic Practices

Sugar beets are cultivated all over Europe (including the former USSR) and in the USA (FAO Year book, 1992; Højland and Pedersen, 1994). Various biotypes of beet are found in cultivation throughout Europe (De Bock, 1986) and outside Europe in North Africa, Asia and in North and South America (FAO Yearbook, 1992).

In central Europe sugar beet is usually grown at altitudes below 400m. Climate affects both beet yield and sugar content. To produce high sugar content, sugar beet requires at least 170 growing days and high levels of sunlight (Brouwer et al., 1976) but in Nordic countries this growing period is shorter (only 150 days). The crop also requires high amounts of moisture. Sugar beet crop fields are irrigated in regions with low precipitation. Sugar beet roots are slightly tolerant of acidic conditions, although soils with a pH of 7-8 are suitable.

Genetically monogerm seed is used almost exclusively in sugar beet cultivation except in China. Multigerm varieties are still used in Europe, South Africa, Near East and North America. Calibrated and pelleted seed is available. Calibrated seed has been mechanically separated. This process is relatively crude, resulting in fragments of quite different sizes. The monogerm seed for sugar beet on the market is almost exclusively in pellet form. Pellet seed is encased in a coat containing components used to control diseases and pests. (Geissler, 1988). In terms of form and size, pelleted seed represents an extremely uniform seed type.

Section III - Centres of Origin/Diversity, Geographic Distribution, Close Relatives and their Geographical Distribution

A. History of cultivated Beet

Beet was a well-established vegetable in “classical” ancient Greece and Rome. The earliest documentation comes from eighth century B.C.E. Babylonia. Greek, Roman and Jewish literary sources provide clear information that in the first century BC the crop was represented by several leafy forms (chards). Cultivars with swollen roots appeared later. There are no archaeological records of *Beta vulgaris* from pre-classical times, and it is not known exactly when and where beet was domesticated. The wild forms from which the crop could have been derived are widely distributed over the Mediterranean basin and the Near East (Zohary and Hopf, 1994).

The first known description of beets are of foliage beets (or chards) by Aristotele (c. 350 BC), who described a red chard, and Theophrastus (c. 300 BC) who recognised two different beets, white and black, the colours referring to light and dark green appearance of the leaves. The use of roots of beet are referred to for both culinary and medicinal purposes by Roman writers (Fort-Lloyd and Williams, 1975).

Beet leaves were probably used as potherbs (herbs used in cooking) in prehistoric times. In the sixth to fourth century BC, the first cultivated forms were developed and used as salad vegetables (chards). Red fodder beet has been cultivated since the 15th century, and sugar beets only since the end of the 18th century (Frietema-De Vries, 1996).

Beta vulgaris L. ssp. *maritima*, wild sea beet, is regarded as the mother species of the *Beta* beets (fodder beet, sugar beet, beetroot, yellow beet, Swiss chard). It is indigenous to European coastal regions, particularly the Mediterranean. Beet spinach, convar. *cicla*, has been cultivated in the Mediterranean region since 2000 B.C. In Europe *B. vulgaris* species with distinctly swollen roots were cultivated in the Middle Ages. Central European types are presumed to be descended from those used in Arabian horticulture in Spain. These plants were taken to the Netherlands, where they were cultivated beginning in 1500, and then to the Palatinate region, later spreading throughout Germany as “Burgundy beet”. During the sixteenth and seventeenth centuries, red and yellow beets became increasingly common as salad vegetables. Fodder beet cultivation only began to increase during the course of the eighteenth century. The crop was introduced into the USA in 1800 where it became known as a garden beet. Sugar beet was introduced to North America around 1830 and to South America circa 1850 (Mansfeld, 1986).

In 1747, when the pharmacist Markgraf found that the sweet substance in beets was sucrose, efforts to extract sugar from beets began. At this time the sucrose content was 6.2%. Some forty years later in 1786, the breeder Achard selected from 23 local beet varieties a plant from the Halberstadt area for beet-sugar production. Kopyy and Sohn selected the local variety “white Silesian Sugar beet.” This submerged-root variety became the mother type for all sugar beet varieties. A student of Markgraf built the first factory extracted the sugar from beet in 1801 (Campbell, 1976; OECD, 1993b) and produced the first “variety” White Silesian. In the following 70 years, selection produced a beet variety with sugar

contents of 16%. Today's sugar beet has a sugar content of 18-20%. In 1925, the global production of beet sugar represented 50% of the cane sugar production. By 1982, 30% of all sugar produced was from sugar beets.

B. Origin

Sugar beet originates from the cultivated form of beet around the Mediterranean area; region A1 (Near East) (Pernès J., 1984). It is possible that all cultivated beets originated from *B. maritima* (McFarlane J.S., 1971).

C. Close relatives and their geographic distribution

Beta vulgaris ssp. *maritima* (wild sea beet), is a common seashore plant of the coasts of Europe and Western Asia, and is perhaps a complex of closely related species. Primitive "superior" forms of this plant have been used as a leaf vegetable since prehistoric times and Root Beets, the ancestors of modern varieties, have been cultivated since the first century (De Rougemont, 1989).

Beta vulgaris ssp. *maritima* has spread from the centre of origin (Near East) to the coastal areas along the Mediterranean Sea to the Canary Islands, the Azores and along the Atlantic coast to Ireland and the southern parts of Scotland. It has been found in Belgium. It is rare in Holland and Germany (only known from the island Helgoland) and there is an isolated area of distribution in Denmark and at the Swedish Kattegat coast (Højland and Pedersen, 1994). It is not known in Switzerland. In Eastern Europe, it is found in Bulgaria and Romania. The area of distribution extends eastward to Iran, India, China and other Asian countries (Højland and Pedersen, 1994). Cultivated beet seed production areas are sometimes adjacent to sea beet populations (Bartsch et al., 1999).

Ssp. *maritima* occupies a very narrow coastal niche between high tide level and 10 to 20 meters inland (Doney, 1992). Neither sugar beet nor sea beet is naturalised in habitats away from the coast (Højland and Pedersen, 1994). Ruderal beet from South-western France are very close to Mediterranean *Beta maritima*.

Distribution of the *Beta* species is shown in Table 4:

Table 4: distribution of the five *Beta* species present in Europe.

| | <i>B. vulgaris</i> L. | <i>B. macrocarpa</i> Guss. | <i>B. patellaris</i> Moq. | <i>B. trigyna</i> Waldst. and Kit. | <i>B. nana</i> Boiss. and Heldr. |
|---------------------------|-------------------------------|-------------------------------|------------------------------|--|-------------------------------------|
| Albania | X | | | | |
| Azores | X | | | | |
| Belgium and Luxembourg | X | | | | |
| Baleares | X | | | | |
| Britain | X | | | | |
| Bulgaria | X | | | X | |
| Corsica | X | | | | |
| Crete | X | | | | |
| Former Czechoslovakia | | | | X | |
| Denmark | X | | | | |
| Finland | X | | | | |
| France | X | X | | X | |
| Germany | X | | | | |
| Greece | X | X | | | X |
| Ireland | X | | | | |
| Italy | X | X | | X | |
| Former Yugoslavia | X | | | X | |
| Netherlands | X | | | | |
| Portugal | X | X | | | |
| Romania | | | | X | |
| Former Russia | South western part | | | Crimea | |
| Sardinia | X | | | | |
| Spain | X | X | X | | |
| Sweden | X | | | | |
| Switzerland | X | | | | |
| Turkey | X | | | | |

(See Tables 2 and 3. for the general distribution of *Beta* species)

Legend: the presence of an X indicates the presence of the *Beta* species in the country.

Section IV - Reproductive Biology

A. Flower morphology

Flowers of *Beta vulgaris* ssp *vulgaris* are located on the terminal portions of the main axis and on lateral branches subtended from this. Flowers are sessile and occur singly or in clusters of two to eight (Smith, 1980).

Flowers are perfect and consists of a tricarpellate pistil surrounded by five stamens and a perianth of five narrow sepals (Smith, 1980). The flowers, solitary or in clusters of 2-8, are rarely self-pollinating (Free, 1970). The flower has a raised ovary with three or four secure stigmata. Three leaves are fused together into a single gynoeceium to form the ovary. The seed arrangement is campylotropous.

B. Compatibility

Beet is a strongly self-incompatible plant (the stigma is not fully mature when the flower opens). Plants set few or no seeds at all when isolated (OECD, 1993b; Smith, 1980; Valdeyron, 1984). Self-fertilising plants exist in nearly every beet population (Barocka, 1985). Their frequency is lower among tetraploids than among diploids. Selecting for the diploid characteristic can significantly increase the potential for self-fertilisation.

The incompatibility system is genetically controlled by a complex gametophytic system governed by at least four loci, each with a number of alleles, and is further influenced by modifying genes. The *Beta* populations found on shores around the North Sea are largely self-incompatible (Dale and Ford-Lloyd, 1985). Mediterranean *B. maritima* populations are highly self-fertile due to specific gene for self-fertility (Fédération Internationale du commerce des Semences indication).

Sugar beet and sea beet (*Beta vulgaris* ssp. *maritima*) are both protandrous, self-incompatible. Sugar beet is an allogamous species, pollinated by wind and occasionally by insects, the former being the most important. Some cross-pollinations are also achieved by thrips and syrphids (Free J.B. and al., 1975; Valdeyron, 1984).

C. Formation of reproductive parts

The reproductive phase of sugar beet occurs during the second growing season. During the generative growth phase, following vernalisation, the internodes become extended into shoot bearing leaves that are ellipsoid to shape. Leaf axils have buds out of which the flower bearing shoots, panicles, emerge. Often only a single, very strong, unbranched flower shoot develops, although in some instances many flowering stems grow and form an extensive bush. Flowering stems are upright, up to two meters in height, green and coarsely furrowed. The secondary shoots may stretch upward or may hang down.

Temperatures above 21°C favour vegetative growth and temperatures between 4 and 13°C favour initiation of the reproductive phase. Most commercial cultivars of sugar beet require 90 to 110 days of exposure to inductive temperatures for initiation of reproductive development (Smith, 1980). With cultivars that bolt easily, comparatively short exposure to cool temperatures is adequate to induce plants to flower. Cultivars that do not bolt readily require longer periods of cold temperatures for floral induction (Smith, 1980). Photoperiod (short days) has also a strong effect on the vernalization process.

Flower formation commences on the top shoot and flowers mature from the base upwards, growth of the secondary shoots following afterwards. Individual flowers of the cluster, made up of five thin inwardly curved perianth leaves and five stamens, do not flower synchronously. They are joined by gland-like tissue at the base, and this excretes large amounts of honey. The middle flower of the cluster blooms first followed by the surrounding flowers. Protandry exists at the morphological level. The sugar beet plant flowers for duration of approximately four weeks.

Depending on the cultivar and environmental conditions, mature flowers begin anthesis about 5 to 6 weeks after initiation of reproductive growth and continue for several weeks. Flower opening begins at the base of each stem and continues upward as the stem elongates. Flower open mostly in the morning, but continue throughout the day (Smith, 1980). Stigmas may remain receptive for more than two weeks allowing a good chance for wind blown pollen to effect fertilisation depending on weather conditions (Crane and Walker, 1984). The flowering period for sugar beet in Central European climatic is between June and August (Barocka, 1985).

D. Pollen

Pollen grains are round and have numerous indentations in their wartlike exines. The number of pollen grains per anther is estimated at 17 000. This would correspond to 85 000 grains per flower and, given 10 000 flowers per bush, almost one billion per plant (1 ha sugar beet with circa 25 000 seed plants produced approximately 25 trillion pollen grains) (Schneider, 1942). The pollen ability of survival is limited to maximum 24 hours according to the German experts. This depends on the environmental conditions, especially moisture.

The genus Beta also displays pollen sterility. Nuclear male sterility is under the control nuclear genes restoring male fertility (although cultivated and wild beet may have different [Owen, 1945; Boutin et al., 1988 and 1987]). The mechanism can also be cytoplasmic (Owen, 1945, 1952).

E. Pollen dispersal

Pollen is transported primarily in air currents. Insects (honeybees, bees, thrips) play a lesser role in pollen movement. Honeybees may increase seed yields, but seem to visit plants only if no other pollen is available. A study of insect pollination of sugar beet seed crops revealed that most of the visiting insects (129 species) carried sugar beet pollen grains and probably contributed to cross-pollination (Free et al., 1975). Because tetraploid plants produce fewer and larger pollen grains than diploid plants, and the pollen is less readily released by the anthers, insect pollination is probably more important for hybrids whose pollen donor is tetraploid than for pure seed crops. This is especially so when relative humidity is high, and little pollen is transported by air movement, yet insect activity is unaffected (Free et al., 1975).

Wind-borne pollen can be distributed horizontally at least 4,500 m and has been observed at a height of 5,000 m (Archimowitsch A., 1949). Smith (1980) observed pollen drift of up to 5 km from the

originating field, and Gliddon (in Harding and Harris, 1994) assumed that the airborne pollen movement can occur at distances up to 8 km.

F. Pollination

Tetraploid plants release their pollen somewhat later in the day than diploid plants and there is a period in the morning when the stigmata of the male-sterile plants are receptive, but when the pollen donors are not producing an effective pollen cloud. It is during this period that the male-sterile mother plants are most receptive to contamination from background pollen released by wild and weedy forms of diploid *B. vulgaris*, many of which, in continental Europe, are annuals or near annuals. This leads to the production of weedy forms of beets. This contamination is a potentially serious weed problem (Scott and Longden, 1970; Longden, 1976; Hornsey and Arnold, 1979).

G. Seed

The fruit of the sugar beet is a capsule and seed is imbedded in a hollow that remains closed by a small lid that springs open during germination although the seed remains firmly attached to the pericarp. The seed is circular, approximately 1-2 mm in diameter, and has a kidney shaped indentation caused by a small, beak-shaped root. According to Martin and Leonard (1976) and Benjamin and Bell (1985) flowering sugar beet can produce 200 million seeds per hectare. What is generally referred to, as the beet seed is in fact a cluster-like multiple fruit. Sugar beet seed normally consist of a seed-ball formed by two to four true seeds (OCDE, 1993b). 1000 clusters weigh between 10-40 g.

The ovaries are enclosed by the common receptacle of the flower cluster (Smith, 1980). They form a hard and irregular dry body, the so-called seed ball, which usually contains one to four seeds.

A plant with monogerm seed borne in separate flowers was found in the United States in 1948 (Martin and Leonard, 1976). Before the genetically monogerm seed was found, they were made mechanically by grinding seed clusters (Højland and Pedersen, 1994). The characteristic of monogerm is recessive and determined by one gene. Today most cultivated sugar beet varieties are monogerm and whose seedlings need not be thinned after sowing and germination (Barocka et al., 1968; Winner, 1981).

H. Seed dispersal

In wild beet a large proportion of mature seeds produced by the end of the flowering season are shed in the immediate vicinity of the maternal plant. Some of the seeds, however, may be dispersed over greater distances. The major agent of long distance dispersal of the multigerm seedballs of ssp. *maritima* is believed to be tidal movements of the water (Dale and Ford-Lloyd, 1985).

Sugar beet seed do not shatter as easily as some wild *Beta* species, which may drop their seeds as they ripen. Seeds falling on the ground does not usually germinate in the same season, partly because of the presence of germination inhibitors, partly because of poor seed-soil contact (OECD, 1993b; Letscghert, 1993).

Section V - Crosses

A. Intraspecific

The six *Beta vulgaris* subspecies are interfertile although individually they are self-incompatible. The cultivated species *Beta vulgaris* ssp. *vulgaris* is characterised by a great varietal diversity. In addition to sugar and fodder beets, there also exist leaf spinach beet, Swiss chard, and red beet (see table 2). All varieties may cross with one another, a characteristic that must be taken into account in seed production.

Sugar beet and sea-beet (*Beta vulgaris* ssp. *maritima*) hybridise freely and hybrids are spontaneously formed in the wild and in seed-production fields (Bartsch et al., 1999). Such hybrids are fertile and do not demonstrate incompatibility at the chromosome level (Evans and Weir, 1981). The most important precondition for hybridisation in natural habitats is the existence of spatially overlapping populations and flowering periods. *Beta vulgaris* ssp. *vulgaris* and *Beta vulgaris* ssp. *maritima*, which hybridise the most frequently in nature, share a common flowering period from May to September. They can occur in the same areas, as ssp. *maritima* is distributed along the Atlantic coastal region (Hanf, 1990). As already noted, these hybrids are an important source of so-called weed beets among the cultivated types of West Europe and North America (Hornsey and Arnold, 1979; Evans and Weir, 1981).

B. Interspecific

Beta section

Beta vulgaris belongs to the section *Beta* (syn. *vulgare*) together with *B. maritima*, *B. macrocarpa*, *B. patula* and *B. vulgaris* ssp. *adanensis*, the wild species of the cultivated beet (Valdeyron, 1984; Smart, 1992). All these species are cross compatible (Smith, 1980; Bartsch et al., 1999). The hybrids are vigorous and fertile and do not show incompatibility at the chromosome level (Geyt Van et al., 1990). However, hybrids between beet and *B. macrocarpa* are rare due to differing flowering times of the parental species (Mc Farlane, 1975). Wild species of the section *Vulgares* (*B. vulgare* ssp. *maritima*, *B. orientalis*) have been used in beet breeding (Geyt Van et al., 1990).

Abe et al. (1984) observed that hybridisation between *B. macrocarpa* and *B. vulgaris*, and between *B. maritima* and *B. atripicifolia* result in a certain degree of pollen sterility and seed abortion of the F₁ generation. Lange and De Bock (1989) produced triploid and tetraploid hybrids between tetraploid *B. macrocarpa* and diploid and tetraploid types of *B. vulgaris*. The triploid descendants were sterile although the tetraploid descendants exhibit a better fertility. The F₂ is partially fertile. A number of researchers have reported successful crosses between *B. vulgaris* and species of section *Corollinae* (reference in Geyt et al., 1990).

Corollinae section

Artificial hybrids can be produced with the species of the *Corollinae* section, but such hybrids are mostly sterile and only set a few seeds when backcrossed to sugar beet (OECD, 1993b).

No evidence of interfertility has been found between the cultivated beet and the Caucasian beet (*Beta trigyna*).

Procumbentes section

Artificial hybrids with members of the *Procumbentes* section usually die at the seedling stage. They can be saved by grafting onto sugar beet, and they then develop into vigorous plants. These hybrids are also almost completely sterile and set few seeds upon backcrossing (OECD, 1993b).

The majority of *Beta vulgaris* ssp. can be crossed with wild species of the section *Procumbentes*. Jung and Löptien (1986) achieved crosses between sugar beet and *B. procumbens*, *B. webbiana* and *B. patellares*. The F1 hybrids were backcross with *B. vulgaris* (See also Højland and Pedersen, 1994) to establish a complete set of monosomic addition lines ($2n = 19$).

Nanae section

No hybrids between sugar beet and *B. nana* are known (OCDE, 1993b).

C. Introgression

There is extensive evidence of hybridisation in the wild between, and introgression from wild beet to cultivated sugar beet and vice versa.

D. Interactions with other organisms

The sugar beet leaves contain oxalic acid which can cause problems if fresh, unwilted sugar beet tops are used as cattle feed (OECD, 1993b).

Interactions between *Beta vulgaris* ssp. *vulgaris* with common disease organisms and pests are shown in Appendix I.

Section VI - Weed Characteristics and Weediness

Sugar beet may become a weed through the roots or crowns remaining in the field after harvest. These “volunteer” plants, if left, will flower and produce seed. The offspring of these plants is normally controlled by herbicide treatment or other means in the following crops.

Cultivated beet may possibly run wild but it is difficult to distinguish between cultivated beets and the weed beet. Beet is often found outside cultivation but there is no indication of such plants establishing in the wild (Frietema, 1996).

Sugar beet bolters could produce enough viable seeds to become a weed problem. This “weed beet” is seldom found in winter cereals, sometimes in spring cereals, especially where poor establishment has occurred, but is relatively common in potato and pea crops. This is because of the limited selection of herbicides that can be used, and because of the similar timing of cultivation techniques. It is estimated that one field in four in England will have viable beet seed in the top soil (Højland and Pedersen, 1994).

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Appendix

Interactions: Common Diseases and Pests of *Beta vulgaris*

Viral diseases

Beet yellows (BYV and BMYV)

Beta virus 4 causes beet yellow. The disease is transmitted by aphids (primarily by *Myzus persicae* and *Aphis fabae*). Leaf yellowing is the principle symptom. The disease is of considerable economic importance as it leads to significant reduction in beet and sugar yield, particularly in regions where the transmitting aphids appear early (Brouwer et al., 1976; Geissler, 1988; Heitefuss et al., 1993).

Sugar beet mosaic virus

Beta virus 2 is responsible for this disease which is transmitted by various aphids. Symptoms include whitish or light green mosaic-like patterns on the inner part of young leaves. Sugar beet mosaic virus rarely causes severe economic damage (Brouwer et al., 1976; Geissler, 1988).

Beet-leaf curl

Beet leaf curl is caused by *Beta virus 3*. The disease is transmitted by the beet leaf bug *Piesma quadrata*. Symptoms are leaf curling and the mosaic-like lightening of young leaves. Leaf veins swell. Severe epidemics can lead to yield reduction (Brouwer et al., 1976; Geissler, 1988; Heitefuss et al., 1993).

Rhizomania

Beet necrotic yellow vein virus (BNYVV) is responsible for rhizomania. The soil fungus *Polymyxa betae* transmits BNYVV. Infected plants display stunted growth, the leaves are smaller, light green, and stand straight up. A strong dense, root network is characteristic of the disease. The disease has been observed in Germany since the mid-1970s. BNYVV represents a serious threat to stricken crops (yield reduction of up to 50%) (Brouwer et al., 1976; Barocka, 1985; Geissler, 1988; Heitefuss et al., 1993). But it is spreading and is present all over Europe except Ireland and Denmark.

Bacterial diseases

Beet leaf spot

Pseudomonas syringae is responsible for this bacterial disease known as beet leaf spot. The bacteria enter the beet leaf through the stomata and wounds in the leaf. Brown to black spots of various sizes develop. Infected tissue breaks off. The disease has occurred in central and western Europe with increased frequency in recent years, but has not had significant economic effects (Heitefuss et al., 1993).

Crown gall

The disease is caused by *Agrobacterium tumefaciens*. Crown gall can be identified by abnormal tissue growth on the body of the beet near the soil surface. The bacteria enter the beet through small wounds. Damage from crown gall is negligible from an economic point of view (Brouwer et al., 1976).

Common beet scab

Actinomyces scabies induces the disease. The scab colours the rind of the beet blackish brown. Infected beets lignify severely. Beet scab does not represent a significant economic threat to beet cultivation (Brouwer et al., 1976).

Fungal diseases

Root rot and secondary root rot

The disease is transmitted by fungi contaminating both seeds and soil. *Phoma betae* is transmitted on the beet seed, and infection after cold-weather sowing can cause significant damage during seedling emergence. *Pythium* species and *Aphanomyces* infect the seedling by means of motile zoospores. Damp conditions and cool temperatures increase the likelihood of *Pythium* infection. *Aphanomyces* requires higher temperatures for infection. Symptoms are often discernible on secondary roots. Many fungus-stricken seedlings do not emerge and those that do remain retarded in their development. If the plant survives the disease, growth remains stunted due to secondary root damage and rotting of the root tips. (Brouwer et al., 1976; Geissler, 1988; Heitefuss et al., 1993).

Beet leaf spot diseases

In warmer areas with high rainfall, beet leaf spot is the fungus that causes the most economic damage in sugar beet production. It is induced by a variety of fungi. The disease is caused by *Cercospora beticola*, for instance. The fungi can be transmitted on beet seed, but can also be moved on dead beet leaves or beet tops. The fungus' spores develop at temperatures at or above 17°C (optimum: 27°C) and require high air humidity. Wind and rain carry the spores onto the leaves of the beet plant where they germinate and enter the plant through the stomata. The first spots develop a few days thereafter. The fungus then sporulates once again, leading to renewed infection and the further spread of the disease throughout the crop. Crop damage can be observed in late June with old leaves showing the first symptoms. Initially, 2-3

mm round, reddish spots develop which later turn grey in the centre. As the disease progresses, the spots enlarge and merge and the leaves dry out. If the entire crown dies, the plant responds with new growth.

Beet leaf spot can also be induced by *Phoma betae*. The optimal temperature for development of this disease is 20°C. Diseased sugar beets grown for seed can result in a significant infection of the seed. Symptoms include round leaf spots with lighter centres and concentric dark and light rings. The disease is generally not an economically significant problem.

Ramularia beticola enters the beet through the stomata. Optimal infection temperatures are 18-20°C with a relative humidity of over 95%. After infection, 1 cm leaf grey to brownish spots develop. The disease is primarily of importance in seed beet production.

Powdery mildew

The disease is caused by *Erysiphe betae*. The fungus develops well during dry weather with temperatures around 20°C. Initial infection is induced by spores that may have travelled over long distances. Signs of damage can be observed beginning in mid July. A white, powdery layer develops on the upper side of older leaves and quickly covers the entire leaf. The disease has been identified in central Europe since the early 1970s. Crops infected early can be severely damaged (Brouwer et al., 1976; Geissler, 1988; Heitefuss et al., 1993).

Downy mildew

Peronospora forimosa requires high air humidity and temperatures below 15°C. A grey mildew layer covers upper and lower leaf surfaces. The disease is generally insignificant in central Europe (Brouwer et al., 1976).

Other fungal diseases

Leaf scorch (*Helicobasidium purpureum*), beet rust (*Uromyces betae*), violet root rot (*Helicobasidium purpureum*) and sclerotinia rot (*Sclerotinia sclerotiorum*, *S. fuckeliana*) may infect sugar beet, but generally do not cause significant biological or economic damage in central Europe (Brouwer et al., 1976).

Animal pests

“Finger” beetle

The beetle (*Clivina fossar*) is about 6 mm long and has a small, nearly cylindrical body. Its colouring is reddish brown and it inhabits upper soil layers if sufficient moisture is available. From here the beetle attacks young plants. Occasionally, it causes extensive damage in sugar beet, particularly when fields are sown early and are weed-free after comprehensive herbicide application (Heitefuss et al., 1993).

Pygmy mangold beetle

The beetle (*Atomaria linearis*) grow to a length of 1.2-1.7 mm. It is dark in colour and spends the winter in plant remains on field borders and in the ground. The pygmy beetle migrates into beet fields in the spring. The hypocotyls of afflicted plants reveal dark, pin-head-sized bite marks. Plants may die in instances of extreme beetle damage. Considerable economic damage can result when beet crops are planted in succession (Brouwer et al., 1976; Geissler, 1988; Heitefuss et al., 1993).

Beet cyst nematode

Heterodera schachtii is a “thread worm”. In addition to beets, cruciferous plants are among the beet cyst nematodes primary victims. Also known as the “beet eelworm”, beet cyst nematodes reach a length of 1.5 mm. Approximately 250 eggs per cyst develop into larvae. A portion of the larvae hatch in the summer and migrate into the roots of the beet. Sexually mature nematodes develop after they have absorbed enough nutrients. The swelling of the females causes the root tissue to break open. After mating, the female hardens and develops into a cyst. Eggs and larvae remain viable in this phase for years. Infested crops mature irregularly, wilt, turn yellow, and die. Plants also develop an unusual number of secondary roots and a so-called “root beard” displaying many cysts. Severely infested soil can result in significant yield reduction. Beet cyst nematodes are considered to be partly responsible for beet sickness affecting soil (Brouwer et al., 1976; Loptien, 1984; Barocka, 1985; Geissler, 1988; Heitefuss et al., 1993).

Collembolans

Colembolans (*Onychiurus armatus*) are white, 1-2 mm in length, and live underground, usually using plant detritus in the soil as a food source. Lacking these sources of nutrients, the pest attacks the roots of sugar beet seedlings. Seeds and hypocotyls may be damaged. Plants may die in cases of severe infestation. Colembolans do not account for significant economic losses in sugar beet cultivation (Heitefuss et al., 1993).

Wire worm

The brown beetle (*Agriotes ssp.*) is 6-12 mm long. Eggs are laid in the summer and the larvae develop into adults over the course of 3-5 years. They can cause feeding-related damage beginning in their second year of development. The roots of young beets may be partially or completely eaten. The plants wilt and die. Wire worm infestation can result in considerable yield reductions in years with high precipitation or when new land is cultivated (Brouwer et al., 1976; Heitefuss et al., 1993).

Millipede

Millipedes (*Blaniulus guttulatus*) are light-coloured, approximately 1 mm in diameter, and grow to a length of 20 mm. They have a life span of two years. They occasionally cause feeding-related damage to seeds and seedlings.

Beet-leaf fly

Pegomya betae overwinters as a pupa in the soil. The larvae bore into leaf tissue within 4-10 days after hatching. The larvae exit the leaves after feeding for 2-3 weeks and pupate in the soil. Two to three generations develop each year, but only the first is relevant as a pest. Leaf tissue damaged between the top and bottom sides dries, splits apart, and eventually dies. Crops that are afflicted early in the season may be severely damaged. Damage rarely occurs after the beet has reached the 6-leaf stage. Economic damage due to beet-leaf flies has been on the decline in recent years (Brouwer et al., 1976; Heitefuss et al., 1993).

Green peach aphid

Myzus persicae spends the winter as an egg in peach (*Prunus persica*) and cherry (*Prunus* species) trees. In the spring, the mother aphid hatches and produces wingless aphids. Winged aphids develop beginning in May and these migrate to beet. Here they reproduce asexually for a number of generations. Infested plants can be recognised by their slightly discoloured leaves. The green peach aphid causes significant economic damage as a carrier of viruses responsible for beet yellows (Heitefuss et al., 1993).

Blackfly

Aphis fabae spends the winter in egg form in the European Euonymus and the snowball tree (*Viburnum opulus*). Its development is similar to that of the green peach aphid. Infested plants display rolled leaves; young leaves are strongly curled. Severe damage and yield reduction is caused primarily by the sucking activity of the blackfly, although the pest is also a transmitter of viruses (Brouwer et al., 1976; Geissler, 1988; Heitefuss et al., 1993).

Field slug

Deroceras reticulatum attains a length of 50-65 mm. The slugs have a scale-shaped shell and are yellow-white or red-brown in colour. Field slugs damage almost all cultivated plants. They spend the winter as eggs or slugs. Mild winters allow them to multiply more quickly. They eat away at the leaves until only the more sturdy veins remain. The damage caused by field slugs has increased in recent years, and not only with respect to beet cultivation. Rape cultivation, rotational crops, and fallow fields have led to a general increase in the field slug's impact on agriculture (Heitefuss et al., 1993).

Common wood mouse

The common wood mouse (*Apodemus sylvaticus*) is grey with a brown-grey to brown-red stomach. It has a short tail and large eyes and ears. Field woods, wood borders, fields and gardens are its habitat. The common wood mouse only gained significance as a pest with the introduction of pelleted beet seed. The mouse causes damage by digging up seeds along the drilled rows, cracking them, and eating the seedlings. This pest repeatedly causes severe damage in some areas (Heitefuss et al., 1993).

Some other herbivores attacks the beet:

Agrosetis segetum: roots

Blitophaga linearis: leaves of small plants

Calocoris norvegicus: leaves

Discestra trifolii: leaves

Ditylenchus dipsaci: stems and leaves

Pegonya hyoscyami: leaves

Thrips angusticeps: leaves and stems of small plants.

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