

1.1 Species Origin and Economic Importance of *Brassica*

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1 Introduction

The genus *Brassica* is one of 51 genera in the tribe Brassiceae belonging to the crucifer family, and is the economically most important genus within this tribe, containing 37 different species (Gomez-Campo 1980). Many crop species are included in the *Brassica* genus, which provide edible roots, leaves, stems, buds, flowers and seed. Next in agronomic importance are the genera *Raphanus*, cultivated for its edible roots and *Sinapis* as a source of condiments. There are many wild relatives that have potential as sources for oil, condiments and other products. Wild relatives could serve as sources for cytoplasmic male sterility (androsterility) for the development of hybrid seed production systems in *Brassica* crop plants and provide nuclear genes for resistance to different diseases and pests. Certain visible characters are informative in the Brassiceae. Mucilage is a very common phenomenon in seed of plants of the tribe Brassiceae, and is therefore of taxonomic value. For instance, seeds of the 9 chromosome species of the genus *Sinapis* such as *S. arvensis* contain no mucilage, while the 12 chromosome species such as *S. alba* contain mucilage. Some species of *Sinapis* and *Crambe* have hairy cotyledons, which is an exception. Drought-adapted genera such as *Moricandia* tend to be glabrous, but they are more sensitive to aphids than hairy species. There is a wide variation in flower shape and colour from yellow to white to violet (*Moricandia*), and the colour of mature seeds varies from yellow to black.

2 Origin, Taxonomy and Distribution of *Brassica* Species

2.1 *Brassica nigra* (L.) Koch

The elementary species *B. nigra* (L.) Koch ($n = 8$) is found growing wild as a weed in cultivated fields in the Mediterranean region (Tsunoda 1980). It has been found on road sides and fields near Tangiers, Morocco, and under

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semi-cultivated conditions in Rhodes, Crete, Sicily, Turkey and Ethiopia. Plants of *B. nigra* can reach a height of up to 2 m and require no vernalization for flower induction.

2.2 *Brassica oleracea* L.

The wild species of the *B. oleracea* group ($n = 9$) are found in small isolated areas and form very distinct phenotypes (Snogerup 1980). *Brassica cretica* Lam. occurs in the Aegean area, on Kriti, southern Greece, and in southwestern Turkey. It is a woody plant with glabrous, fleshy leaves. It is a perennial and persists for 5 to 8 years when established. There are two subspecies: *nivea* with small white or creamy petals and ssp. *cretica*. The *B. rupestris-incana* complex contains many distinct regional variants found in Sicily, southern and central Italy and western Yugoslavia. Several species may be recognized within this group, including *B. villosa* and others. *Brassica macrocarpa* Guss. is found on the Isole Egadi, west of Italy, and is a restricted local endemic form; it could possibly be included as a subordinate within the *B. rupestris-incana* complex. *Brassica insularis* Moris. is found in Corsica, Sardinia and Tunisia. The Tunisian populations have been described earlier as a separate species with the name *B. atlantica*. Plants have large white petals, but the flower colour is genetically different from the white small petals of *B. cretica* ssp. *nivea*. *Brassica montana* Pourr. is found in coastal areas of northern Spain, in southern France and northern Italy. It has a perennial growth habit and is sometimes included in the *B. oleracea* group. *Brassica oleracea* L. is found on the coasts of northern Spain, western France and southern and southwestern Britain. It is a perennial species with a strong vegetative stock which develops over several years before it starts flowering. It has glabrous leaves which have a grayish surface. *Brassica hilarionis* Holmb. is a narrow, endemic population of the Kyrenia Mountains with large pink flowers and is certainly a different species.

The cultivated forms of *B. oleracea* can be subdivided into six groups (Snogerup 1980). These are kales (var. *acephala*) including green kale, marrow stem kale, collards mainly used for edible forage; cabbages (var. *capitata*, var. *sabauda*, var. *bullata*) including headed cabbages, brussel sprouts, savoy cabbage, and others; kohlrabi (var. *gongylodes*); inflorescence kales (var. *botrytis*, var. *italica*) including cauliflower, broccoli, sprouting broccoli, and others; branching bush kales (var. *fruticosa*); and Chinese kale (*B. alboglabra*), used as a leaf vegetable. It is generally believed that all six cultivated groups originated from west European wild *B. oleracea*. However, a few authors presented different theories, suggesting *B. montana* as the progenitor for headed cabbages and kales, *B. rupestris* as the progenitor of kohlrabi, and *B. cretica* as the progenitor of cauliflower and broccoli (Snogerup 1980). However, more research is needed to confirm these theories. All $n = 9$ chromosome *Brassica* species can easily be crossed, producing vital hybrids with some combinations resulting in fertile offspring, which is a clear indication of their close genetic relationship.

2.3 *Brassica rapa* L.

It is generally believed that *B. rapa* L. (synonymous with *B. campestris* L., $n = 10$) originated from the highlands near the Mediterranean Sea rather than from the Mediterranean coastal areas (Tsunoda 1980). The climate in these mountainous regions is very cold, and *B. rapa* exhibits rapid vegetative growth under low-temperature conditions. From here, it spread northward into Scandinavia and westward to eastern Europe and Germany (Nishi 1980). It is believed that *B. rapa* was introduced into China through western Asia or Mongolia as an agricultural species. The introduction into Japan could have occurred via China or Siberia. *Brassica rapa* is cultivated in India as an oilseed, but no wild forms are known in India. It is also cultivated as an oilseed crop in Sweden and Finland, and in Canada. Seven groups of vegetable *B. rapa* types are known, and these are: var. *campestris*, var. *pekinensis*, var. *chinensis*, var. *para-chinensis*, var. *narinosa*, var. *japonica* and var. *rapa*. Until recently, these groups were considered as separate species because of the wide range of variability they represent and the fact that they evolved in isolation from each other.

Headed Chinese cabbage (var. *pekinensis*) has its centre of diversity in northern China and has some relationship to the oilseed type that is grown there. It is adapted to a somewhat cooler climate. The var. *chinensis* is a leaf vegetable which differentiated from oilseed rape types of middle China, var. *para-chinensis* is a derivative of the var. *chinensis*, and var. *campestris* is the most primitive leaf vegetable. The var. *narinosa* has high cold tolerance and is similar to var. *chinensis* in its adaptation. The var. *japonica* is a leaf vegetable of Japan. The var. *rapa* (turnip) is cultivated all over the world as a vegetable and as fodder for animals.

2.4 *Brassica carinata* A. Braun

Brassica carinata ($n = 17$) is an amphidiploid species derived from interspecific crosses between *B. nigra* ($n = 8$) and *B. oleracea* ($n = 9$). No wild forms of *B. carinata* have been reported. Its cultivation is restricted to the Ethiopian plateau, where it might have originated from hybrids between kale, which has been grown in the plateau since ancient times, and wild or cultivated *B. nigra*. *Brassica carinata* grows slowly, a trait which it might have inherited from its *B. oleracea* parent, and its seed contains mustard oil comparable to *B. nigra*. Farmers in Ethiopia grow *B. carinata* as a leafy vegetable in their gardens and also harvest seed for oil.

2.5 *Brassica juncea* (L.) Czern & Coss

Brassica juncea ($n = 18$) is an amphidiploid species derived from interspecific crosses between *B. nigra* ($n = 9$) and *B. rapa* ($n = 10$). Wild forms of *B. juncea*

have been found in the Near East and in southern Iran. It is grown as an oilseed in India (brown or Indian mustard), and as a leaf vegetable in China where leaf mustards have their greatest differentiation. Also, root type (turnip-like) forms var. *napiformis* are cultivated in China. However, China cannot be considered as a centre of origin for *B. juncea* because the two parent species, *B. nigra* and *B. rapa*, were never found as wild species in that country. The Chinese *B. juncea* forms are yellow-seeded, in contrast to the brown-seeded Indian types which also have a larger seed size. The yellow-seeded *B. juncea* types are grown as an oilseed in the Ukraine. Indian oilseed types contain primarily 3-butenyl glucosinolate in their seeds and vegetative tissue, while *B. juncea* from China contains only 2-propenyl (allyl) glucosinolate, and only trace amounts of 3-butenyl glucosinolate. *Brassica juncea* mustard is also grown for the production of condiment mustard in western countries with major production in western Canada (brown and oriental mustard).

2.6 *Brassica napus* L.

Brassica napus ($n = 19$) is an amphidiploid species derived from interspecific crosses between *B. oleracea* ($n = 9$) and *B. rapa* ($n = 10$). Wild forms of *B. napus* have been reported to occur on the beaches of Gothland, Sweden, the Netherlands and Britain. There are also reports that naturalized forms of *B. napus*, which are very distinct from any cultivated *B. napus*, were found on coastal cliffs of New Zealand, where *B. oleracea* and *B. rapa* grow wild. It is thought that *B. napus* was formed on the coast of northern Europe where both *B. oleracea* and *B. rapa* grow wild; other researchers believe that *B. napus* originated in the Mediterranean region or in western or in northern Europe (Tsunoda 1980). It is possible that *B. napus* could have formed at different places from crosses between different forms of *B. oleracea* and *B. rapa*. Both winter and summer annual forms of *B. napus* are grown as oilseeds in many countries of the world, and it is the most productive *Brassica* oilseed species under cultivation. Its high yield potential might be related to the high photosynthetic rate per unit leaf area which is positively related to chloroplast number per unit leaf area and to chloroplast volume. Similar associations have been reported for high-yielding rice and wheat. There are also root-forming *B. napus* types, known as rutabaga, grown as vegetables and fodder for animals.

3 Economic Importance of *Brassica* Species

3.1 *Brassica* Vegetables

Brassica vegetables are of great economic importance throughout the world and different species are utilized. The principal *Brassica* vegetable species is *B. oleracea*, which provides a large range of unique cole and cabbage types that

include headed cabbages, brussel sprouts, cauliflower, broccoli, and others. Much of the production is locally consumed; however, there are production centres in certain countries, such as southern California, from where produce is shipped in specialized trucks to other states and into Canada year-round. Brittany in France is the European centre for production and research on *Brassica* vegetables.

The breeding of *B. oleracea* vegetables is conducted in government institutions and universities and by private breeding firms. There are very specific breeding objectives for the different types with crop uniformity being of utmost importance for marketing. The development of disease- and pest-resistant germplasm and varieties is next in importance. More recently, breeding programs have been started to develop F_1 hybrid varieties to improve crop uniformity and productivity.

Brassica rapa var. *pekinensis* or Chinese cabbage and var. *chinensis* (leaf cabbage) are extensively grown as vegetables in China. *Brassica alboglabra* or Chinese kale is among the 10 most important market garden vegetables in some Southeast Asian countries, such as Thailand, and is also grown in China. Most of the production is locally consumed and there is a concentration of production in home and market gardens around cities.

Leaf mustards (*B. juncea*) are consumed in great quantities in China and other Asian countries. There is a range of different leaf types grown: var. *japonica*, var. *integrifolia*, and others. The greatest differentiation in plant types is found in the Sichuan province of China. The leaf mustards are local vegetable crops and there is very little trade.

3.2 *Brassica* Oilseeds

3.2.1 World Production and Trade

Brassica oilseed production has increased over the last 40 years and has become one of the most important world sources of vegetable oil after soybean and cotton seed. The average total area, yield and production of rapeseed in major producing countries for the period 1991/1992–2000/2001 are shown in Table 1. The largest acreage of *Brassica* oilseeds is found in India, followed by China and Canada. Because of low seed yields, total production in India is lower than China and Canada. Highest seed yields are obtained in Europe (France, Germany and the UK) with average yields of about 3.0 tonnes/ha, more than twice the seed yields obtained in Canada and Australia. This is due to the fact that, in Europe, the winter annual forms of *B. napus* are grown under favourable growing conditions, which are much more productive than summer annual *B. napus* forms grown in Canada. Canada and Australia are major rapeseed-exporting countries while Japan and China are major importers (Kimber and McGregor 1995). More than half of the rapeseed oil marketed internationally is refined in the European Union. The production in India, China and other countries is locally consumed.

Brassica

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