

# The Utilization of Mustards

*The best known usage of members of the mustard group is as the basis for condiment, but some of the species are important as oil seeds. The leaves are widely used as a vegetable, especially in the Far East, while in temperate agriculture mustards are extensively used as green manures, cover crops, and fodder. Oilcake residues after expressing are used as fertilizers.*

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## Introduction

According to Musil (15), *Brassica* species of commercial importance can be divided into rapes, cabbages, and mustards. Musil includes in the group of mustards: (a) turnips and turnip-rapes; (b) black mustard; (c) white mustard; (d) Indian or brown mustard; (e) oriental or Chinese mustard; and (f) charlock. The present paper refers mainly to the utilization of the last five types of mustard, although some account is also given of *Eruca sativa* Lam.

The term "mustard" is believed to be derived from the usage of seeds as condiment; the sweet must of old wine was mixed with crushed seeds to form a paste, "mustum ardens" (hot must), hence "mustard".

The following are the main species of economic importance:

**Black Mustard** (*Brassica nigra* (L.) Koch). The plant is widespread in Central and Southern Europe and most regions with a temperate climate. The original home of the species seems to be unknown, but it has been suggested (25) that the plant belongs to a Mediterranean center with a secondary center in the Near East.

In commerce the seeds of the plant

are utilized for condiment and for oil, while in agriculture, *B. nigra* has occasionally been planted as a cover crop. It has been cultivated for its seed particularly in Holland, England, Italy, Hungary, Austria, Roumania, Bulgaria, France, Greece, Russia, Syria, India, China, North Africa, Chile, Australia, New Zealand, Argentina, and the U.S.A. In England (17) it is grown in deep, rich, fertile soil in the eastern counties, being sown in the spring and harvested in August, when it is cut rather green and allowed to ripen in small carefully made stacks. Well known commercial varieties of the seed are English, Bari, Trieste, and Californian.

**White Mustard** (*Sinapis alba* L.). This mustard is probably a native of the Mediterranean and the Near East but has been introduced into northwestern Europe, Russia, Japan, North and South America, Australia, New Zealand, India, North Africa, and China.

Like black mustard, its seeds provide oil and are used as a condiment. The plant is grown for its seed in various parts of Europe and America, particularly England, Austria, Czechoslovakia, Sweden, Holland, Russia, France, Germany, Australia, Argentina, and California.

White mustard is also used as a salad plant, a green fodder crop, and a green manure.

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**Indian or Brown Mustard** (*Brassica juncea* Coss. and Czern.). Burkill (2) has given an admirable account of the development of nomenclature and extent of this difficult species. He points out that, like *B. nigra*, it is a pungent mustard, but it is more nearly tropical than the *nigra* species, and, consequently, stands heat better and is fairly drought-resistant. He suggests that for backward agricultural communities it offers the advantage over *B. campestris* L. of being disliked, on account of its pungency, by various pests which the communities do not control.

Burkill is of the opinion that *Brassica juncea* is an Old World plant, at home in the rather dry parts of North and Central Africa, the Levant, the North of India and probably the interior of China. It is now to be found in many parts of America, Europe, Asia, and Africa. He believes that human agency has played a large part in this dispersal and has suggested the carrying of *B. juncea* to the West Indies by negro slaves from Africa. The Chinese might well have carried the plant to Malaya, while the appearance of *B. juncea* near European ports indicates a connection with imported grain. Vavilov (24) records the primary center of origin of the species as central Asia (northwest India, including the Punjab and Kashmir) with secondary centers in central and western China, Hindustan (east India and Burma) and Asia Minor through Iran.

The plant has mainly been developed for oil and as a vegetable but in the last decade has become important in the condiment industry as it is an easier crop to grow than *Brassica nigra* (16). It has also been used in some countries as a cover crop. Well known cultivated races of the species are Asl-rai or Indian mustard, Sarepta mustard (*B. besseriana* Andr.), Palai rape (*B. rugosa* Prain), and Abyssinian mustard (*B. carinata* A. Br.).

**Oriental or Chinese Mustards** (*Brassica pekinensis* (Lour.) Rupr., *B. chinensis* L., and *B. perviridis* Bailey). Pestsai (*B. pekinensis*), pak choi (*B. chinensis*), and tendergreen (*B. perviridis*) are salad and vegetable plants with a probable origin in China and Japan. They have been introduced into and appear to be popular in Canada and the U.S.A. The first two species have been cultivated in France and are offered for sale by specialist seed merchants in Great Britain.

**Charlock** (*Sinapis arvensis* L.). Charlock is found in Europe, North Africa, South West Asia, Russia, North and South America, South Africa, Australia, and New Zealand. It is best known as a very persistent weed of arable land in temperate agriculture, with seed viabilities of up to 70 years, but it is cultivated to a small extent for oil seeds in south Russia, France, Hungary, and Roumania. Charlock has also been used as a vegetable, a cover crop, and an adulterant of poor quality table mustard.

**Rocket** (*Eruca sativa* Lam.). This plant seems to be of Mediterranean and East Asian origin but is now found in many other parts of the world. It has been cultivated in France, Spain, Persia, and India, and its cultivation dates back to ancient Greek and Roman times. Rocket has been utilized as a salad plant while its seeds have provided oil and have been used as a condiment.

### Condiment

The types of mustard seed usually utilized in the preparation of fine table mustard at present are *Brassica juncea* and *Sinapis alba*. In the past *B. nigra* was the species of brown mustard used with *S. alba*. *B. juncea* seed was first imported into France from Russia and India about 1860 (18), but little was used in good quality condiment mustard until after the Second World War. Since that time *B. juncea* has gradually replaced

*B. nigra* as it is preferred as a crop by farmers and can be grown more economically.

Mustard condiment has long been of importance, and there are numerous references through the centuries to its usage and properties. Pliny gave an account of its medicinal virtues, while Pythagoras recommends it for scorpion stings and the Romans are believed to have been responsible for the spread of *S. alba* throughout Europe. Nicholas Culpepper, the 17th century English scientist, recorded some of the superstitious beliefs in the efficiency of mustard "for clarifying the blood and for weak stomachs, for strengthening the heart and resisting poisons, and for drawing out splinters of bones". The Greeks used mustard for sauce with fish, and in Chaucer's time it was commonly used with meat dishes. Mustard was among the stores carried by Vasco da Gama on his first voyage around the Cape of Good Hope in 1497.

John Wycliffe, in the 14th century, refers to an early prepared mustard, probably composed of roughly crushed seeds stored in vinegar. The earliest English center for the production of such prepared mustard was Tewkesbury, from whence balls of mustard paste were sent to London during the 17th century. Shakespeare makes Falstaff say, "His wit is as thick as Tewkesbury mustard". The practice of fine grinding and sifting of mustard flour was first started by a Mrs. Clements in Durham (1720), and this lady is said to have had considerable custom from George I. Powder mustard rapidly increased in popularity during the 19th century with the center of production at Norwich in England. The French centers of Dijon, Bordeaux, and Toulouse have specialized in the production of paste mustards.

Nowadays mustard condiment is marketed in two forms. In Great Britain, North America, and most of the British Commonwealth both powder and paste mustards are sold, whereas in France,

the rest of Europe, South America, and other parts of the world the demand is almost exclusively for paste mustards, and very little powder mustard is sold. Powder mustard consists usually of a mixture of mustard flours to which may be added wheat flour. Mustard paste, also known as French or German mustard, is a mixture of flour or ground seed of one or more kinds of mustard with spices, salt, and vinegar. Poor quality mustards are sometimes adulterated with charlock, starchy matter, mustard hulls, gypsum, and other mineral substances, dyes and preservatives (27). Campbell (4) has given a number of recipes for table mustard.

Both black and white mustard seeds contain relatively high proportions of fixed oil, protein, and carbohydrate, but the use of mustard as a condiment is mainly related to the pungent principles of the seed. Black mustard contains the glucoside sinigrin, while in white mustard the glucoside is sinalbin. Both mustards have the enzyme myrosin which is to be found in cells different from those that contain the glucoside, and therefore no reaction takes place unless the seeds are crushed and then moistened. The pungent principle produced as a result of the reaction between myrosin and sinigrin is the volatile allyl isothiocyanate, which in the condiment produces heat in the throat and nose. The amount of allyl isothiocyanate produced varies within the species. Juillet, Susplugas, and Courp (12) have given a whole range of percentage production of the volatile oil from 0.59 in Hungarian seed to 1.26 in Chilean seed. In white mustard the essential principle is parahydroxybenzyl isothiocyanate. This substance is not volatile in steam but gives a "hot" flavor to the palate.

The position in *Brassica juncea* is not clear. It is usually stated (12) that the volatile mustard oil is a mixture of allyl isothiocyanate and crotonyl isothiocyanate. Again, there is variation within the species. The percentage production of

allyl isothiocyanate is said to vary between 0.33 and 0.44 and of crotonyl isothiocyanate between 0.27 and 0.36. However, Schmalfers and Mueller (22) deny the existence of crotonyl isothiocyanate in the volatile mustard oil prepared from a sample of Sarepta mustard. It may well be that the wide variation within the species is attributable to its origin as an amphidiploid hybrid between *B. nigra* and *B. campestris* (9) the pungent principles of which are respectively allyl- and crotonyl-isothiocyanate. Current research programs in France and England are aimed at the selection of strains of *B. juncea* with high contents of allyl isothiocyanate.

Charlock (27) produces practically no volatile principle, while in *Eruca* (12) the percentage production varies between 0.5 and 0.6%. In India Pahadi rape or Palai rape (*B. rugosa*) is crushed and used as condiment (21).

In Great Britain (26) brown mustards are not grown for forage but are widely cultivated for seed in Cambridgeshire, Norfolk, and Lincolnshire and adjoining counties with production chiefly on contract for condiment manufacture. In the past the common variety of *B. nigra* was "English Brown" which yielded some eight or nine cwt. of clean seed per acre; but as the plants shed seed badly when maturing, the crop demanded careful hand harvesting. A variety of *B. juncea* known as "Trowse" is now grown. It yields from seven to twelve cwts. per acre; and as the plants hold their seed well, the crop can be harvested by combine harvester. White mustard is grown for seed in the same areas of Great Britain; the crop is cut and swathed to dry and then either stacked before threshing or picked up and threshed by a combine harvester. The yield of white mustard ranges from seven to ten cwts. per acre.

The total acreages of mustard under cultivation in Great Britain are shown in Table I.

TABLE I  
MUSTARD ACREAGES IN GREAT BRITAIN (29)

Year	Acreage of mustard for seed*	Acreage of mustard for fodder and ploughing in*
1934	16,900	.....
1935	28,447	20,219
1936	31,920	23,820
1937	24,154	22,369
1938	23,703	26,914
1939	23,551	24,292
1940	24,146	29,605
1941	17,285	27,700
1942	21,544	26,520
1943	15,933	29,507
1944	12,518	28,977
1945	18,083	23,944
1946	24,974	21,644
1947	35,847	24,644
1948	16,577	21,292
1949	14,749	21,663
1950		28,186
1951		58,924
1952		42,106
1953		37,968
1954		33,637
1955		39,658
1956		31,518

\* The "acreage of mustard for seed" includes both white and brown mustard (*Brassica nigra* up to 1952 but principally *Brassica juncea* since that year), whereas the "acreage of mustard for fodder and ploughing in" is almost exclusively white mustard.

The annual seed production of white and brown (*B. nigra*) mustard in Great Britain varied from 3,000 to 14,000 tons between 1934 and 1949, with annual values ranging from £276,000 to £700,000 (29).

After the mustard seeds are harvested, it is essential that they are dried at an early stage to prevent the growth of moulds. In Great Britain they are roughly dried on the farm, and the process is completed at the factory. The maximum temperature for drying is 115°F. Large stocks of seed are usually held in order to insure a regular supply for milling.

The milling process is essentially the separation of the bran (testa and aleurone layer) from the flour (embryo and cotyledons). This is effected by variously shaped rollers. The flour is then subjected to careful sifting to separate the fine and coarse fractions. This sifted flour

constitutes, in part, powder mustard, although it is usually possible to pick out a number of testa fragments. In England no fixed oil is removed from the mustard seed prior to milling. This is not the case, however, in the rest of Europe and in America, where the seeds are often partially de-oiled by crushing to aid the milling process.

Apart from its use as a condiment, mustard flour and its by-products have been employed in many other spheres. The utilization of the mustard fixed oils and the seed residues as feeding stuffs or fertilizers is important but will be referred to at a later stage in this article.

Mustard is incorporated in various food products such as salad creams, mayonnaise, sauces, pickles, piccalilli, and curries. It acts as a preservative against the action of yeasts and moulds. The pungent principles are responsible for this action, and mustard is said to be more efficient in this respect than sulphur dioxide and benzoic acid (7). A further quality of mustard in creams and mayonnaise is that it is a very efficient emulsifying agent (6).

Mustard has been used in the wine industry in France and Spain to remove mustiness in wine and wine barrels. It has also been used to prevent secondary fermentation in wine which would lead to bad flavor. A similar preservative action has been suggested for allyl mustard oil, or its equivalent in ground mustard, in fresh apple cider and fruit juices (10). Guenther (10) states that most of the "allyl mustard oil" offered on the market today consists of the synthetic product, the natural oil having lost much of its former importance.

In the field of medicine, mustard has been used to a certain extent. It has been employed as an irritant drug in the form of mustard baths, poultices, and plasters. As far as one can make out, this usage was largely domestic in Great Britain, and the general impression is that it is now very much on the decline. Mustard has also been used as an emetic and as a constituent of cough cures (20).

## Oil

The fixed oils of the seed of various species of mustard are of definite economic importance.

***Brassica nigra.*** The fixed oil of this species, obtained by expression, is brownish yellow and has a mild taste. Its content in the seed varies between about 26% and 37% (27). At one time it appears to have been a by-product of the allyl mustard oil industry. It has been used as a salad oil, for cooking, as a lubricant, a lamp oil, and in soap-making.

In Great Britain today this oil seems to be available only as a by-product of the condiment industry. Under these circumstances, it is generally sold for lubrication purposes.

At the present time, there is little crushing of any mustard for its fixed oil in Great Britain. The oil contents are lower than those of rape seed, and the "hot" nature of the seed residue usually precludes its use as a feeding stuff.

***Sinapis alba.*** The oil is usually of a golden yellow color and has a mild taste. Its content in the seed varies between about 20% and 35%. It has been used as a lubricant and an illuminant.

At the beginning of the Second World War, Sweden became an important producer of oilseed crops (1). White mustard was cultivated because of its rapid growth. In 1951 the manufactured output of oil of this plant was 27% of the tonnage of seed harvested. White mustard oil has been used in Sweden in the production of mayonnaise. Cultivation of *S. alba* has, however, decreased in Sweden in recent years from about 16,000 harvested hectares in 1953 to about 5,000 hectares in 1957. In recent years *S. alba* has been grown on an increasing scale in Canada for oil production.

White mustard oil is also a by-product of the condiment industry in countries where the seed is partially deoiled before milling.

*Brassica juncea*. "Mustard oil" is one of the major edible oils of India, but it is a term that is applied loosely in that country to the fixed oils of Rai (*B. juncea*), Toria (*Brassica napus* L. var. *dichotoma* Prain), and Sarson (*Brassica campestris* L. var. *sarson* Prain). *B. juncea* only will be considered in this article.

Rai is mainly cultivated in Bengal and Bihar (21). Varieties of the plant recognized in India are Laha, Lahi, Lahta, and Desi Rai, but breeding work has produced more uniform strains such as "R.T. 11" and "Raya 2.8" (28). Sowing takes place usually in October or November and harvesting in February or April. In India, *B. juncea* may be cultivated with peas and barley. Under these circumstances three pounds of the mustard seed are sown per acre, whereas for a pure crop four to six pounds of seed are sown per acre. The seed yield is in the region of 11 cwt. per acre.

Rai is mostly grown as a rainfed crop. It is said to be less susceptible to insect pests and diseases than other Indian *Brassicaceae* (28).

The plant is generally harvested before the fruits are completely ripe to preclude "shattering" (21). Night moisture helps to prevent shattering; hence, harvesting is usually carried out in the early hours of the morning. Entire plants are either pulled out by hand or cut a few inches from the ground with sickles. The plants are tied into small sheaves and dried in the sun for four to ten days. Harvesting, threshing, and winnowing are carried out by the cultivator and his family.

The fixed oil content of Rai seed varies between 28.6 and 45.7%. Extraction of this oil is carried out by village "ghanis," rotary mills, expeller and hydraulic processes. It is used mainly for culinary purposes. In the northeastern region of India the oil is used in its crude form as a frying medium for several food preparations. The oil is also utilized for massaging the

body, as a hair oil, an illuminant, and a lubricant.

*Brassica juncea* is being increasingly grown as an oil crop in many other parts of the world. The race of the plant obtained from South Russia and Roumania is generally known as *B. besseriana* Andr. The adoption of this mustard as an oil crop is said to date from the end of the 18th century (2). It is stated that in Russia the oil of *B. besseriana* is used in place of olive oil (28). Two forms of *B. juncea* are cultivated in the U.S.A. and Canada. The brown-seeded type is probably *B. besseriana* (15). The yellow-seeded form, probably of Chinese origin, is known as Oriental or McCormick mustard (15). In the U.S.A. Montana is the largest mustard-producing state (13). The oil is expressed as a preliminary step in the making of food products and has been used as a special lubricant in the place of rape oil (13). Alberta is the principal mustard-growing region of Canada, and in 1956 over 87,000 acres were seeded to *B. juncea*. Most of the crop was exported to Europe, but a small amount was used locally for expressing or condiment manufacture.

*Brassica carinata* is usually regarded as a race of *B. juncea* (23). The seed is now frequently found in European commerce under the name of Ethiopian rapeseed. In Ethiopia the plant is cultivated on small lots, and in 1956 exports of the seed amounted to some 8,000 tons. Analyses of *B. carinata* seed crushed in Great Britain give fixed oil contents of between 35% and 38%.

*Sinapis arvensis*. Charlock seed contains about 26% fixed oil (27) which has been used for soap making, cooking, and lubrication. This seed has been imported into Great Britain and France from Russia and Roumania under the name of Ravison, although the commercial material contained many seed impurities, such as *Brassica campestris*, *Camelina*,

and *Lepidium* (3). Of recent years Ravison has not been crushed in Great Britain.

Charlock seed, separated from cereal crop screenings, has been utilized for its oil in the U.S.A. and Canada (8).

***Eruca sativa*.** The seed of this plant is utilized for its oil mainly in India where it is known as Jamba or Taramira. It is grown extensively in the Punjab. The fixed oil content varies between 32% and 36% (21).

An important commercial aspect of the crushing of any oil seed is the disposal of the seed residue. Mustard meals are comparatively rich in protein, but their pungent principles normally make them unsuitable for stock feed purposes.

*Brassica nigra* and *B. juncea* cake are usually considered unsuitable for feeding cattle (12) because of the production of allyl isothiocyanate in the cake remaining after the oil has been extracted by expelling. Indian rape and mustard cakes are treated with some caution in Europe (3) because of the possible presence of *B. juncea*, although the cake of the yellow-seeded *B. juncea* of Montana (13) has been used in stock feeds there, but its content is kept below 5%. If a solvent extraction of *B. nigra* or *B. juncea* oil has been used, followed by steam treatment, there should be no residue of allyl isothiocyanate, and the cake so prepared is innocuous.

White mustard and charlock (Ravison) seed residues are also considered unsuitable for feeding. The pungent principle of white mustard has been described in a previous paragraph. It is suggested (12) that the toxicity of charlock meal is due to choline and sinapic acid, derivatives of sinalbin.

All the residues described can be used as fertilizers, but the commercial value of a meal used as a fertilizer is very much less than if it is used as a feeding stuff. In Great Britain, at least, this is one important reason for the small amount of mustard seed crushing for oil.

In contrast to other mustards under consideration, *Eruca sativa* cake is well thought of as a feeding material. In India, particularly in the Uttar Pradesh and Punjab provinces, it is given to cattle, camels, and horses (21).

### Other Uses of Mustard

Most of the species of mustard described are used as vegetables, often in the raw state.

*Brassica juncea* is cultivated in many parts of the world as a vegetable and salad plant. *B. juncea* var. *cuneifolia* or Mustard Vegetable is cultivated in North Bengal and Assam as a pot herb, while *B. rugosa* or Cabbage Leaved Mustard is common in Nepal where the leaves are dried in the sun, pickled, and eaten (28). *B. carinata* is grown all over the highlands of Eritrea and Ethiopia in small fields near villages and homesteads. The plant is grown mainly for its tender leaves and sprouts which are boiled and eaten especially during periods of fasting which are numerous among the Coptic people. *B. juncea* is used considerably as a vegetable from wild sources or in the nearly wild condition in certain parts of West Africa (2).

In the U.S.A. and Canada and in Holland *Brassica juncea* seems to be grown to a considerable extent for greens. A large number of horticultural varieties or strains are in existence, and they would appear to be of Japanese or Chinese stock (14, 15). *B. juncea* has been introduced as a vegetable by the Chinese into Malaya and is known as "sawi hitam" (2).

The three oriental mustards (*Brassica pekinensis*, *B. chinensis*, and *B. perviridis*) are of importance in China and Japan but have also been introduced with success into other countries. In the U.S.A. *B. pekinensis* is a fairly common vegetable in the stores, although it is not often grown in the home garden. *B. perviridis* is not often seen for sale in

the northern states, although it is probably grown to some extent in home gardens. It is possibly more common in the South. *B. chinensis* seems to be grown only by Chinese market gardeners in the U.S.A. A similar state of affairs exists in Canada (14).

White mustard seed is sold together with cress (*Lepidium sativum* L.) in Great Britain and America for the production of seedlings used as "mustard and cress" in salads and sandwiches.

Young plants of charlock have been cooked as vegetables (11) while *Eruca* has been used as a salad plant both in southern Europe and the drier parts of the Old World tropics (5).

Because of their rapid growth mustards are widely used as cover crops and green manures. Black, brown, and white mustard are all used in America for this purpose (15), but in Great Britain white mustard is usually preferred. On good land *Sinapis alba* may attain a height of over two feet in less than two months (26) even when sown after an early crop has been removed from the field. The cover crop gives good protection to the soil between an early crop and a late autumn cereal sowing and is also in favor as it provides good cover for game birds on the farm. White mustard cover crops are sometimes grazed off as sheep fodder, but they are not suitable for dairy cattle as the strong flavor may taint the milk and milk products.

White mustard is extensively grown for ploughing in as a green manure when maximum growth has been reached. Apart from the value of the green manure in ameliorating soil structure and as a ready source of nitrogen, there is evidence (19) that white mustard is able to extract more phosphorus from soil minerals than many crop plants and so render it available to succeeding crops. The acreage of white mustard grown in Great Britain for fodder and ploughing in is shown in the foregoing table.

Because of their rapid growth and the ease of handling, mustards are frequently used as subject crops in experiments with herbicides and in soil culture studies on mineral deficiency or toxicity.

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B O O K   R E V I E W S

**Abstract Bibliography of Fruit Breeding and Genetics to 1955.** *Rubus* and *Ribes*—**A Survey.** R. S. Knight and Elizabeth Keep. Tech. Comm. No. 25, Commonwealth Bureau of Horticulture and Plantation Crops, East Malling, Maidstone, Kent, England. January, 1959. 45 shillings.

The survey covers currants, gooseberries, raspberries, blackberries, and hybrid berries, dealing largely with literature published between 1900 and 1955. The breeding, genetics, and cytology of *Rubus* and *Ribes* are summarized in detail, but pomological descriptions, the classification and synonymy of varieties and species, and diseases and pests are also covered. Gene lists and linkage data are given in appendices. Papers solely on the systematic botany of the two genera are given by title only.

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**Nomenclature of Plants.** Harold St. John. The Ronald Press Co., New York. (*Chronica Botanica*. New Series.) 1958. \$2.50.

This is a workbook for students of plant taxonomy. Problems for the application of appropriate scientific names are given, with all the necessary references to decide which name is to be applied. No solutions are given, as the author feels that if "the correct solution of each case is left freely open to each class, with the professor and students acting as judge and jury," there will be more learning of the various rules of nomenclature.

DAVID J. ROGERS