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Botanical Characteristics, Nutritional Value, and Economic Importance of the *Brassica* Genus

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Abstract

Brassica species are utilized for various purposes, including human and animal nutrition, oil and spice production, by employing different plant tissues. These plants play a crucial role as oilseed crops globally, contributing significantly to vegetable oil production. *Brassica* species are also rich in vitamins, minerals, and phytochemicals, offering numerous health benefits. Additionally, they are used in the biofuel and petrochemical industries. The self-incompatibility of many *Brassica* species necessitates cross-pollination, which enhances genetic diversity and benefits breeding programs. This review comprehensively examines the botanical characteristics, nutritional value, and economic importance of the *Brassica* genus. The information presented in this study holds significant importance for advancing more efficient agricultural practices, promoting healthy nutrition, guiding sustainability efforts, and introducing innovative approaches to breeding programs.

Keywords: brassica; botanical character; nutritional value;

1. Introduction

Brassica plants are utilized for various purposes depending on their plant tissues. They play a significant role in human nutrition, in addition to being used for oil, spice, and forage. While oil and spices are obtained from their seeds, the buds, flowers, leaves, stems, and roots are used in the diets of humans and animals [1,2]. This study will discuss the botanical characteristics, nutritional value, and economic importance of *Brassica* species.

2. Botanical Characteristics

The *Brassica* genus belongs to the *Brassica*ceae family, also known as *Cruciferae*. The taxonomy of *Brassica* plants, which are represented by approximately 40 species worldwide, is quite complex [2,3]. In 1999, Gomez-Campo classified the *Brassica* genus into subgenera, sections, species, and subspecies [4]. According to

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information from the United States Department of Agriculture [5], Table 1 shows the taxonomy of *Brassica* species. In addition to being biennial or perennial herbaceous plants, they can also take on shrubby forms [3]. *Brassica* species, which grow in temperate regions with a cool climate, can be found in agricultural fields, gardens, greenhouses, or natural areas

Tablo 1. Taxonomy of *Brassica* species [5].

Kingdom	Plantae (Plants)
Subkingdom	*Tracheobionta (Vascular plants)*
Superdivision	*Spermatophyta (Seed plants)*
Division	*Magnoliophyta (Flowering plants)*
Class	*Magnoliopsida (Dicotyledons)*
Subclass	*Dilleniidae*
Order	*Capparales*
Family	*Brassicaceae (Mustard family)*
Tribe	*Brassiceae*
Genus	*Brassica L.*
Species	*B. rapa, B. nigra, B. carinata…*

Most species of *Brassica* have broad, lobed or rosette-shaped leaves and are deciduous. In addition to green leaves, there are also varieties with purple or red leaves. The stems are generally upright and sturdy. Some species have tall, branched stems, while others are short. The roots are deep and spreading. In some species like radish and turnip, the roots thicken and serve as storage organs. This genus typically flowers in the spring and summer, with small flowers arranged in clusters, usually yellow or white in color. The number of petals is four. The fruits are long, slender capsules called silique, which contain small seeds within two compartments. When the fruit matures, the capsules open, releasing the seeds. *Brassica* seeds, which are small, round, and brown or black, have high oil content and are economically valuable for oil production and significant in human nutrition [3,6,7,8].

Although some Brassica species are self-pollinating, most are self-incompatible and reproduce through cross-pollination. In Brassica, self-incompatibility is influenced by pollen and stigma and is controlled by S alleles. Wild diploid species (B. rapa, B. nigra, B. oleracea) are self-incompatible and require cross-pollination. However, some species, such as broccoli, certain cabbage varieties, and B. rapa yellow sarson, can be self-compatible. Tetraploids (B. napus, B. juncea, B. carinata) and older domesticated species are self-compatible, though cross-pollination can still occur during seed production. It is also possible to find self-incompatible species among tetraploids. The self-incompatibility system, which prevents the plant from being fertilized by its own pollen, is important for increasing genetic diversity. By increasing the level of heterozygosity, it results in healthier and more resilient plants. Due to the strong self-incompatibility system, obtaining hybrid varieties is advantageous for breeders [9].

3. Some Species in the *Brassica* Genus

The *Brassica* genus includes many species in both wild and cultivated forms. These species possess either diploid or amphidiploid genomes. *B. rapa*, *B. nigra*, and *B. oleracea* are diploid species with genomes AA (2n=20), BB (2n=16), and CC (2n=18), respectively. In contrast, *B. juncea*, *B. napus*, and *B. carinata* are amphidiploid species with genomes AABB (2n=36), AACC (2n=38), and BBCC (2n=34), respectively. The amphidiploid species are the result of hybridizations among the three diploid species, leading to the formation of the other three amphidiploid species. This relationship is described by U’s triangle model, established by Nagarahu in 1935 (Figure 1) [10].

Amphidiploid species can be synthetically produced through techniques such as embryo rescue and are currently used as model plants for studying polyploidy in crop plants. These six species have significant economic value [11,12]. Some species in the *Brassica* genus are listed in Table 2. Additionally, species like *B. spinescens* and *B. maurorum* are known to be endemic [8].

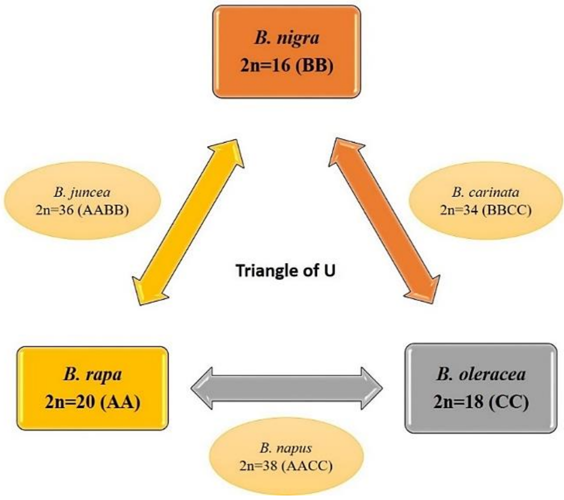

Figure 1. Triangle of U. Species in circle is obtained from the hybridization.

Table 2. Some *Brassica* Species.

Species				
B. rapa	*B. perviridis*	*B. montana*	*B. drepanensis*	*B. amplexicaulis*
B. nigra	*B. rupestris*	*B. spinescens*	*B. kaber*	*B. oxyrrhina*
B. oleracea	*B. septiceps*	*B. taurica*	*B. macrocarpa*	*B. repanda*
B. carinata	*B.tournefortii*	*B. villosa*	*B. maderensis*	*B. sativus*
B. napus	*B. gravinae*	*B. balearica*	*B. oxyrrhina*	*B. napoleracea*
B. juncea	*B. hliarionis*	*B. bourgeaui*	*B. procumbens*	*B. deflexa*
B. elongata	*B. incana*	*B. botteri*	*B. adpressa*	
B. fruticulose	*B. insularis*	*B. cretica*	*B. aucheri*	
B. narinosa	*B. maurorum*	*B. deflexa*	*B. cazorlensis*	

4. Economic Importance and Nutritional Contents

Brassica species are cultivated in millions of tons worldwide and are a major source of nutrition. They include economically important species such as cabbage, broccoli, kale, Brussels sprouts, and cauliflower. While dietary habits vary, carbohydrates, proteins, and fats are primary metabolites forming the basis of nutrition, with fats providing the essential energy required by the body [13]. *Brassica* species are among the world's most important oilseed crops. *Brassica* juncea, *B. carinata*, *B. rapa*, and *B. napus* species, which have oil-rich seeds, account for approximately 12% of global vegetable oil production [13,14,15]. In addition to being used in human nutrition, the oil produced is also used as a renewable resource in the biofuel and petrochemical industries [15]. Besides oil production, *Brassica* species are significant for their high fiber, vitamins (A, C, and E), minerals (potassium), and numerous phytochemicals (phenolics) [14,15].

The fatty acid composition is crucial in determining the applications of these oils, and the fatty acid contents of oil-producing plants vary due to environmental and genetic factors [13]. *B. olerácea*, for example, has a substantial nutrient storage capacity [15]. Fresh and cooked *Brassica* species typically fall into this category. Additionally, *B. rapa*, also known as Chinese cabbage, rapini, or turnip, is used in human nutrition, oil production, and as forage. Its leaves, roots, and seeds are utilized. Studies suggest that *B. carinata*, which includes cabbage varieties, can be used for oilseed and vegetable purposes and as biodiesel [15]. *B. nigra*, known as black mustard, has seeds used as spices. *B. oleracea* var. acephala is also thought to be resistant to boron toxicity, a toxic heavy metal [16]. Thus, it has significant potential for the remediation of heavy metal-contaminated soils [3]. Table 3 summarizes the usage areas and tissues used for other species.

Brassica species are also rich in secondary metabolites with antibacterial, antioxidant, and antiviral effects, playing a regulatory role in the immune system [17]. Especially in the species consumed as vegetables, flavonoids and flavonols like kaempferol and quercetin and their derivatives are present [3]. *Brassica* species also produce biochemical compounds called glucosinolates. These compounds are converted into isothiocyanates, which have tumor-reducing properties and protective effects against cancer and heart diseases. Plants with high glucosinolate content are considered potential genetic resources in breeding programs [12].

*Brassica*s are also valued in bioremediation, as ornamentals, sources of medicines, soil conditioners, green manures, composting crops and many species are important in the production of edible and industrial oils such as liquid fuels and lubricants in diesel engines [18].

Table 3. Commonly Used *Brassica* Species, Their Applications, Used Tissues, and Growing Regions [6,7,8,9,18,19].

Species	Name	Using	Tissue	Region
B. rapa	Chinese cabbage Broccoli rabe Turnip	Human food Vegetable oil Animal feed	Leaves Root Seed	Asia Europe China Japan
B. nigra	Black mustard	Spice	Seed	Mediterranean Asia America
B. oleracea	Kale Cabbage Broccoli Cauliflower Brussel sprouts Kohlrabi	Food crops Animal feed	Leaves Stem Seed	Europe Middle-East
B. carinata	Ethiopian mustard	Oilseed Biodiesel Leaves Vegetable	Seed	Ethiopia India
B. napus	Canola	Vegetable oil Biodiesel Animal feed	Seed	Northern Europe Coasts Iran-Turonian Regions
B. juncea	Hindia mustard	Human food Vegetable oil	Leaves Stems Seed	Asia India China Japonica Europe North America North Africa
B. elongata	Elongated mustard	Gene source		Europe Asia
B. fruticulosa	Mediterranean cabbage	Gene source		Mediterranean Coast
B. rupestris	Rupestris cabbage Sicilian cabbage	Gene source		Italy Sicilia Bosnia and Montenegro
B. tournefortii	Africa mustard Asia mustard Sahara mustard	Invasive weed		Mediterranean Coast Western Asia

5. Conclusion

In this study, the botanical characteristics, nutritional content, and applications of various *Brassica* species have reviewed. The accrued knowledge has the potential to inform and enhance future breeding programs for agronomically significant *Brassica* species, alongside as well as to refine their cultivation, sampling methods, and conservation techniques. These *Brassica* species are widely used in various applications, with specific tissues being utilized for each purpose. They are cultivated in different regions across the world, primarily in temperate climates, though some species are also grown in subtropical areas. Their economic importance is underscored by their diverse applications in human nutrition, oil production, biodiesel, and as spices.

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