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New Research on the *Brassicaceae* Burnett. Family: A Systematic Review

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ABSTRACT

The study of the *Brassicaceae* family holds particular relevance in the modern era, especially in the context of ecosystem conservation. The ecological plasticity of the species within this family allows them to be regarded as resilient plants under conditions of global warming. Research on this family is also of great importance for agriculture and food security. Some species of *Brassicaceae* are widely used in the production of pharmaceuticals, bioactive compounds, and industrial products. Scientists around the world are conducting comparative studies on the distribution and adaptation strategies of *Brassicaceae* species across various climatic and geographical conditions. The study of the *Brassicaceae* family by scientists worldwide constitutes a significant part of the natural sciences and geography. The *Brassicaceae* family provides insights into the dynamics of natural phenomena, which are dependent on various factors related to changes in climate conditions and ecosystems on Earth. These studies also have a broad impact on the analysis of vegetation, animal diversity, water resources, soil formation, and other ecological factors. This article discusses recent global research on the *Brassicaceae* family by scientists. The analyses conducted by researchers and their findings are summarized here. Information about the research directions of scientists on *Brassicaceae* plants is provided. The results obtained by researchers while studying these plants and their contemporary significance are also discussed.

Keywords: *Brassicaceae* Burnett.; Family; Genus; Plant; Species

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ARTICLE INFO

Received: 7 July 2025 | Revised: 14 July 2025 | Accepted: 23 July 2025 | Published Online: 11 November 2025
DOI: https://doi.org/10.30564/re.v7i5.10733

CITATION

Aliyeva, A.M., 2025. New Research on the *Brassicaceae* Burnett. Family: A Systematic Review. Research in Ecology. 7(5): 45–58. DOI: https://doi.org/10.30564/re.v7i5.10733

1. Introduction

In recent years, the intensity of scientific research related to ecosystem sustainability, climate change, and biodiversity conservation has significantly increased worldwide. In this context, the comprehensive study of the *Brassicaceae* Burnett. family from various perspectives has gained particular relevance. Due to its wide geographical distribution and the abundance of ecologically and economically important species, this family has attracted the attention of many researchers. However, scientific literature concerning this family is often presented in a fragmented manner across different regions. Therefore, there is a need to systematize and synthesize the findings obtained so far. The aim of our study is to provide a general overview of the research conducted since the 2000s by a number of scientists from various regions of the Russian Federation, Mongolia, Germany, the Czech Republic, and Jordan on the Brassicaceae family, covering areas such as systematic botany, ecological botany, introduction, floristics, and other related fields. The study also aims to analyze the main research directions, scientific innovations, and the ecological significance of these investigations. According to our research, most studies related to the family are floristic in natüre (**Figure 1**). Investigations in other directions are relatively scarce. In this regard, the existing research is insufficient. There is a need for a comprehensive regional study of the family.

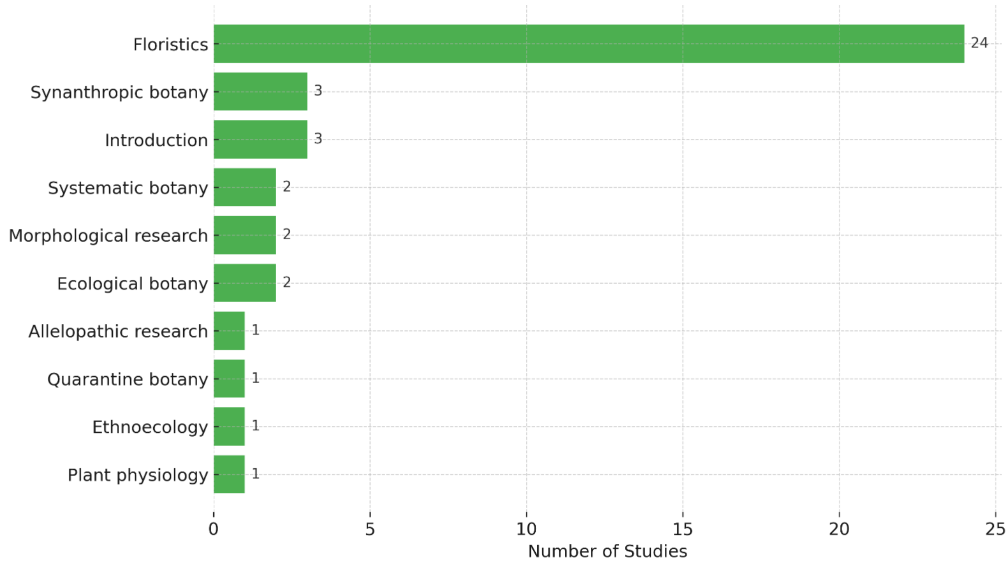

Figure 1. Research Distribution in Botanical Fields.

2. Theoretical Framework

The mustard family (Brassicaceae or Cruciferae) belongs to the order Brassicales and is readily distinguished from other flowering plant families by a cruciform (cross-shaped) corolla, six stamens (the outer two shorter than the inner four), a capsule often with a septum, and a pungent watery sap [1]. The Brassicaceae family comprises insect-pollinated plants with alternate leaves, characterized by a specific flower structure: it consists of four sepals, four petals alternating with the sepals, 6 stamens-of which 2 are shorter than the others-and 1 pistil with a superior two-chambered ovary [2]. The *Brassicaceae* family is one of the most extensively studied families in various branches of botany due to its significant economic and agronomic importance. Numerous species within this family possess high utility value, contributing both to global food systems and medicinal applications. Scientific investigations conducted by researchers worldwide have established a robust theoretical foundation for studying this family, encompassing its broad geographic distribution, taxonomic richness, ecological adaptations, and biomedical relevance. Recent research across diverse regions has demonstrated that species of the *Brassicaceae* family exhibit remarkable ecological plasticity and adaptability in response to anthropogenic pressures. These studies reveal that *Brassicaceae* members not only thrive in natural ecosystems but also dominate synanthropic vegetation, underscoring their resilience and ecological significance. From a theoretical perspective, ongoing investigations into the taxonomy, morphology, and phylogenetic diversity of the family have contributed to a comprehensive understanding of its evolutionary trajectory and systematic structure. These insights are critical for assessing regional floristic diversity and for informing biodiversity conservation strategies. Furthermore, the family has become a focal point in studies related to plant selection and breeding, particularly in the development of economically valuable cultivars. The theoretical framework established through these studies provides an essential basis for exploring the role of *Brassicaceae* species in shaping floristic composition, responding to climatic and anthropogenic changes, and supporting sustainable ecosystem management. Collectively, the accumulated knowledge on the *Brassicaceae* family-its taxonomic diversity, ecological characteristics, roles within various floristic complexes, and patterns of distribution under anthropogenic influence-offers a rich and detailed foundation for comparative floristic analyses. This framework not only deepens our understanding of plant biodiversity and phylogeographic patterns but also supports the development of effective conservation and land-use planning policies in ecologically sensitive regions.

3. Materials and Methods

This article is based on a systematic literature review of scientific studies conducted worldwide on the Brassicaceae (mustard or cabbage) family in the fields of bioecology, phytochemistry, and taxonomy. For the purpose of this research, scientific articles, monographs, and sources indexed in international databases such as ScienceDirect, Web of Science, Scopus, and PubMed were collected and organized. The research material primarily consists of recent publications that explore various aspects of Brassicaceae species. Scientific and theoretical ideas were analyzed through a comparative methodology. Priority was given to high-impact sources during the data collection process. Depending on the aim and scope of each study, researchers have applied diverse methodological approaches to the topic. Particular attention was paid to differences in analytical methods, conceptual frameworks, and potential applications of the results from studies conducted in various regions of the World, as shown in the **Figure 2**.

Figure 2. Regions where research has been conducted on the Brassicaceae family.

4. Discussions

Scientists worldwide have conducted studies on the Brassicaceae family in various fields, including systematic botany, quarantine botany, ecological botany, synanthropic botany, floristics (hydroflora, regional, weed flora), ethnoecology, introduction, plant physiology, morphology, and allelopathic research.

4.1. Systematic Botanical Research

R.V. Kamelin has written monographs on the global species diversity of the Brassicaceae family, with a particular focus on their phylogenetic and taxonomic relationships. In his research, the author mentions that the proposed system is primarily dedicated to displaying the internal taxa of large tribes. Kamelin views the Brassicaceae as the first relict types, particularly in the case of 10 tribes [3].

4.2. Morphological Research

V.I. Dorofeyev wrote a PhD dissertation on the topic and stated that the study of the Cruciferae (Brassicaceae) family drew the attention of botanists, leading to the conclusion that it possesses all the characteristics of the group to which it belongs. He conducted research on the history of the study of Brassicaceae in the flora of European Russia and the North Caucasus, including aspects such as their morphological structure, some aspects of their evolution, geographical distribution, ecological characteristics of key representatives, evolutionary processes within the family, the history of wild herbaceous flora, issues related to the conservation of the biodiversity of Brassicaceae flora, and economically significant species. He reported that the family consists of 330 genera and 3500 species, with 76 genera and 250 species found in European Russia, and 69 genera containing 239 species in the North Caucasus region. In the studied area, he recorded 90 genera and 352 species. His research on the Brassicaceae family is more extensive and scientifically advanced. He confirmed that one of the distinctive and relatively rare characteristics of the family is heterocarpism, which often develops simultaneously with heterospermy. The scholar notes that this process (heterocarpism) has been discussed since the late 19th century, referencing the interesting and original ideas of E. Huth and F. Delpino. Dorofeyev highlights that M. Zohari and V.F. Voitenko analyzed the phenomenon of heterocarpism and heterospermy in the family for its evolutionary significance. He stated, based on the works of researchers such as Avetisyan, Eigner, James, Wilson, Janchen, Kozo-Polyanski, Puri, Ritz, Voitenko, and Zohari, that there are very few studies concerning the carpological (fruit structure-related) evolution of this family. In all the mentioned scientific literature, it is stated that evolution follows traditional positions regarding the directions of fruit formation. The authors believe that the primary type of fruit is a bilaterally symmetrical, two-chambered, multi-seeded fruit with a capsule and pod types, known to all, similar to the Sisymbrium type. The dissertation reveals that the general structure of the fruit and its evolution are still debated. The scholar, relying on the views of Eigner, Kamelin, Kozo-Polyanski, Lotova, Rud'ko, and Zohary, identifies the number of pistils in cruciferous plants (Brassicaceae) as a key issue in the debate. Modern representatives (with the exception of *Rorippa barbareifolia*) have only 2 pistils. Referring to the works of Kozo-Polyanski, the author notes that if it is initially assumed that the fruit consists of two carpels, the origin of these carpels remains entirely unclear. B.M. Kozo-Polyanski and R.V. Kamelin proposed that the presence of 4 fruits in one pod in cruciferous plants is an original assumption. Kozo-Polyanski considered the leaves as a sterile pair of "carpids" (fruit leaves), and in his view, the other two fruit leaves transform into partitions and columns. In fact, the two fertile leaves are well known, and they are provided with very important structural details, including the cavity and walls of the fruit leaves, which are characteristic features, clearly expressed as the pistil head. L.I. Lotova, A.I. Rud'ko, and R.V. Kamelin note that at the points of fusion of the fruit leaves, in addition to the usual arrangement of xylem and phloem, small inverted bundles are also characteristic. Such a structure can only arise during the reduction process of a once well-developed fruit leaf. The framework is surrounded by a partition on the sides and inside, which forms a parchment layer (with the thin edges of the developed fruit leaves along with seeds) that is either bilayered or, rarely, multilayered (as in *Sisymbrium strictissimum*). In many species, the parchment layer forms due to the elongation of cells in the width direction.

In the fruit leaves, the cells are elongated in the direction of the fruit's length. This means that the partition expands due to the elongation of the epidermal cells. Two main types are distinguished based on the structure of the embryo among the numerous seeds: the lateral-rooted (where the root is adjacent to the edges of both cotyledons (embryonic leaves, the first leaves that form when the seed germinates)) and the dorsal-rooted embryos (where the root is adjacent only to the middle part of one cotyledon). A.R. De Candolle divided the Brassicaceae family into 5 subfamilies based on the placement characteristics of the embryo, root, and cotyledons. A phenomenon of heterospermy has been observed among the crucifers, which arises in the context of fruit heteromorphism and manifests within the fruit (Erucaria, Hirschfeldia) as well as at the fruit boundaries (Aethionema carneum, Diptychocarpus strictus, Isatis boissieriana, Spirorhinchus sabulosus). H.J. Crantz, A.R. De Candolle, E. Boissier, Velenovski, K. Prantl, A. Hayek, and O.E. Schulz attempted to recreate the general character of the evolution of the family. F. Dvorak and V. Titzin reflected this most comprehensively in their works. Thus, they contributed to enriching the field of science [4].

4.3. Allelopathic Research

In the field of botany, J.R. Qasem also holds a certain position. In his scientific research, he discusses the biological characteristics of *Cardaria draba* (L.) Desv. and presents valuable scientific ideas [5].

4.4. Quarantine Botanical Research

One of the researchers studying the Brassicaceae family is I.A. Mishina. In her dissertation titled "Development characteristics of some quarantine plant species in the Altai territory," she also examined the abundance of weeds. She demonstrated that a number of plants, including *Thlaspi arvense*, are represented in minimal amounts in terms of abundance [6].

4.5. Ecological Botanical Research

L.B. Musina, in her dissertation titled "Characteristics of the Impact of Different Cattle Species on Vegetation and Soils in the Trans-Ural Steppe Ecosystem of Bashkortostan: (Example of the Abzelilovsky District)," in Chapter 4 titled "Study of the Dynamics of Steppe Plant Communities Under the Grazing Impact of Different Animal Species," notes that as one approaches cattle grazing areas, the above-ground vegetation decreases. This trend is particularly evident in sheep pastures. The strong grazing regression under the influence of sheep is explained by the minimal increase in phytomass and the increase in the presence of plant species resistant to trampling and unsuitable for grazing (such as *Alyssum turkestanicum*, *Lepidium ruderale*) in the forage composition [7].

S.N. Ryabtsev, in his dissertation "Effect of Pyrogenic Load on the Steppe Vegetation of the Southern Urals", in Chapter 4, titled Flora and Vegetation of the Study Area, paragraph 4.1, reports that 118 plant species from 27 families were identified in the study area. The number of species in these families ranges from 17 to 9, while the number of genera varies from 10 to 5. The Brassicaceae family includes 4 species. According to K. Raunkiyer's classification, the majority of plants belong to hemicryptophytes (83 species), and 15 species are classified as chamaephytes, among which *Alyssum tortuosum* Waldst et Kit ex Willd is included. I. G. Serebryakov identified 10 life forms, with 5 species classified as shrubs and 17 species as semi-shrubs, including *Alyssum tortuosum* Waldst et Kit ex Willd among them [8].

4.6. Floristic Research

T.M. Kopytina, in her dissertation "Flora of the City of Rubtsovsk and its Surroundings," listed 22 plant genera for the Rubtsovsk area. Of these, 21 are synanthropic genera, which include 39 species. Among these species, 33 are synanthropic species. In her research, T.M. Kopytina ranked the Brassicaceae family third in terms of flora and second in terms of synanthropic flora. The flora is characterized by a group of Eurasian-North American geoelements (23 species or 4.9% — *Camelina sylvestris*, *Cynoglossum officinale*, *Senecio viscosus*, *Tripolium vulgare*, etc.). Forty-nine species (9.9%) are of Central Eurasian origin. These are mainly species that grow in wild areas, particularly in saline or steppe environments, such as *Artemisia nitrosa*, *Hordeum nevskianum*, *Lactuca altaica*, *Lepidium affine*, and *Lotus sergievskiae*. As can be seen, the Brassicaceae family is also represented among the species. Among the species with an anthropocultural distribution area, there are introduced species, locally naturalized species, and adventive species that have not spread beyond the places where they were introduced. These include *Armoracia rusticana*, *Beta vulgaris*, *Bryonia alba*, and others. It is difficult to assign such species to any specific geoelement. The adventive flora of the city of Rubtsovsk and its surroundings consists of species from 25 families. Brassicaceae (12.9%) is one of the main families here. Among the adventive plants, a large percentage (71.3%) consists of species accidentally introduced through human economic activity — xenophytes, which include *Brassica campestris*. In cultivated areas, 29 species (26.9%) are wild or ergaziophytes, with *Armoracia rusticana* being among these species. Most of the introduced plant species (89.8%) settle in habitats and participate in the formation of ruderal and segetal phytocoenoses. Epiphytes (plants that live on other plants or in their vicinity without needing a root system) also include *Capsella bursa-pastoris*. Kopytina shows that, as a result of research, six species that had not been previously recorded in the Siberian flora were discovered in the Rubtsovsk city and surrounding area between 1987 and 1997, with *Litwinowia tenuissima* being one of them[9].

L.M. Buginova, in her dissertation titled "Weed Flora and Plant Communities of the Central Stavropol City Agglomeration," in the second table titled "Weed Plants and Associations of Young Ecotopes in the City of Stavropol," notes that in a 9-year-old *Polygonum aviculare* + *Thlaspi perfoliatum* + *Amoria repens* association, there are 30 species per 100 m². The species *Capsella bursa-pastoris* is also commonly found in the former "field" - segetal vegetation. In the paragraph titled "Floristic and Synoptic Characteristics of the Agglomeration," weed plant series groups are identified, including the *Polygonum aviculare* + *Thlaspi perfoliatum* + *Bromus japonicus* group[10].

E.V. Garin, in his dissertation titled "Flora and Vegetation of the Shaded Areas in the Yaroslavl Region," reported that the number of macrophytes found in only one shaded area in the flora of 5–20-year-old water bodies is small (27.3%). At the same time, the number of species typical for the study area is also the smallest. However, this group accounts for 87.1% of the vascular flora list of shaded areas. In the 5–20-year-old water bodies, a total of 27 species were found, including *Rorippa amphibia*. In these water bodies, all species found in other age groups are also present. The flora of 20–30-year-old water bodies contains a large number of trees and shrubs, accounting for 12.9% of the vascular water body species list. Species such as *Armoracia rusticana* are found in these water bodies[11].

E.M. Pyzhikova, in her dissertation titled "Flora of the Amalat River Basin: Composition, Structure, and Characteristics of Economic Use (North Transbaikalia)," presented the *Brassicaceae* Burnett. family in a table reflecting the genus and species numbers of the multi-species families of the Amalat River Basin, listing it in 9th place with 15 genera and 20 species[12].

A.P. Laktionov, in his dissertation titled "Flora of the Lower Volga Basin," notes that the local flora is represented by 810 species from 85 families and 340 genera (80.2% of the species in the region's flora). Among the top 10 species in terms of species count in the region's natural flora, the Brassicaceae family (9.8%) is also included. The adventive flora is represented by 155 genera and 54 species. Among the leading families in the adventive flora, Brassicaceae (6.0%) is also present. Ten families of adventive flora, totaling 123 species, make up 61.5% of the total number. During the study, 19 species, including *Isatis praecox* and *Leptaleum filifolium*, were noted as endangered. The characteristic of the Volgograd-Stupinsk floristic region includes a group of species with *Turritis glabra*, most of which do not cross the southern boundary. *Draba nemorosa* is among the plants that define the southern border. Species such as *Lepidium coronopifolium* and *Rorippa dogadovae* are rare and characteristic of Russian flora but are typical for the region's biocomplex[13].

R.V. Dudkin, in his dissertation titled "Flora of the Limestones in the South of the Primorsk Region," notes that Brassicaceae (9 species) is one of the leading families in the flora. In the table he compiled, titled "Leading Families Spectrum in the Limestone Flora of the South of the Primorsk Region," the Brassicaceae family is ranked 8th with 9 species. The coastal area is represented by 8 species (3.5% of the flora), covering plants growing on sand, stones, and rocks along the coastline. These populations were formed on sedimentary rocks during sea transgressions and are currently considered relict species. Based on the works of Dudkin, the author regards *Sisymbrium luteum* (Maxim.) O.E. Schulz as a relict species. Ruderal plants are represented by 11 species, accounting for 4.8% of the flora. These are part of the weed group. Most species in this group are introduced, although there is no information about this in the summary of "Vascular Plants of the Soviet Far East" (1985-1996). Among the weeds, *Arabis sagittata* (Bertol.) DC is noted [14].

A.A. Achimova, in her research titled "Flora of the Left Bank of the Katun River (Central Altai)," lists the Brassicaceae family in 7th place, with 31 genera and 48 species, ranked 7-8. The flora of the study area includes neoendemic species (such as *Erysimum inense*), which proves the development of autochthonous (locally native, developed, and naturally occurring) species in the flora [15].

O.N. Zhikhareva, in her scientific work on the flora of the northern foothills of Altai, justifies that Brassicaceae (52 species) is one of the leading families of the flora. Referencing previous studies (including Kumino's works), she claims that the Brassicaceae family is prominent in terms of species diversity, which aligns with the information about the Altai flora. The flora of the Altai foothills includes a significant number of mesophytes (495 species, 42.4%) in accordance with ecological-senotic analysis. 196 xerophytes, along with 249 xeromesophytes, constitute 38.1%. This group comprises 22 species of Brassicaceae (40.7%). Based on the ideas of Plozhiy and Krapivkina, the researcher shows that among the 12 species classified as belonging to the nemoral Pliocene broadleaf forests of Siberia, the species *Cardamine impatiens* is also included [16].

I.V. Chimonina, in her scientific work on the flora of the Prikalaus floristic region (Central Eastern Caucasus), notes that the families Asteraceae, Poaceae, Fabaceae, and Brassicaceae together account for 37.0% of the entire flora by species count. The author places the Brassicaceae family in 4th place among the largest families of the Prikalaus flora, with 38 genera and 61 species [17].

N.A. Eremenko, in his research "Seasonal Development of Plants and Plant Communities of the Southern Kuril Islands", notes that Brassicaceae (4 species) is one of the families with the highest number of species. V.A. Yedryonkina, in her dissertation titled "Flora and Vegetation of the Green Zone of Ufa: Human Impact and Conservation Issues", places the Brassicaceae Burnett family 8th in the ranking of leading families of the flora, with 20 genera and 31 species [18,19].

A.V. Verkhozina, in her research on the flora of the tubular plants of the Sayan region of Irkutsk province, places Brassicaceae in 7th place, depending on whether alien species are considered. In the table titled "Spectrum of Leading Families of the Sayan Flora", *Brassicaceae* Burnett. is represented with 31 genera and 55 species in the entire flora and with 23 genera and 39 species in the aboriginal flora. When comparing the spectrum of the leading families of the Prisayan flora with those of other Siberian floras, it was found that the Brassicaceae family also ranks among the top eight families (in positions 5–8) in most of these floras — including the Taishet region, Eastern Sayan, Angaro-Sayan, Prilensko-Katangsky, Verkhiyeniseisky, southwestern Pribaikal, and the Irkutsk region. This conclusion is based on the author's comparative analysis of studies conducted by Vodopyanova, Malyshev, Malyshev et al., Zarubin et al., and Osipov. In Chapter 6, titled "Adventive Flora of Prisayan and Its Analysis", information is provided about 16 alien plants in the Brassicaceae family [20].

O.V. Khitun, in his research "Zonal and Ecotopological Differentiation of the Flora of the Central Part of the Western Siberian Arctic (Qidan and Tazov Peninsulas)", observes that in the northern part of the Qidan Peninsula, better-drained watersheds are covered with rare plants and surrounded by moss tundras rich in various herbaceous plants. These tundras are characterized by Arctic-alpine herbaceous plants, including the abundant presence of *Draba alpina*. The twofold increase in the Brassicaceae family is mainly associated with the increase in the number of species of the *Draba* genus (9 species). The flora of the central part of the Western Siberian Arctic, along its longitudinal section, encompasses 46 families and 135 genera, representing 332 vascular plant taxa. In this flora, Brassicaceae (22 species) is one of the most represented families. In the local flora, the rank of the main families changes in a regular manner across various sub-zones, reflecting regional specificity and distinguishing them from neighboring sectors (in the southern hypoarctic tundra, Brassicaceae occupies a lower position) [21].

S.O. Omarova, in her research "Comparative Analysis of the Flora of the Local Highland Type of the Inner Regions of Dagestan", in the second table titled "Spectra of 10 Leading Families in 3 Highlands", lists the Brassicaceae family as follows: for the Qunib Highland, it is ranked 8th with 24 species; for the Khunzakh Highland, it is ranked 5th with 25 species; and for the Keqer Highland, it is ranked 7th with 21 species. In all three highlands, the family is represented by 32 species in 8th place [22].

A.I. Pyak, in his research "The Petroplants of the Russian Altai (composition, ecology, geography, genetic features)", has ranked the Brassicaceae family 3rd in the floristic spectrum of the petroplant families of the Russian Altai. In the table he created, the Brassicaceae family is represented by 15 petroplants (5 obligate, 10 facultative) and 11 genera. In the second table, titled *The Main Families of the Petroplant Flora of the Altai Region and the High Mountain Flora of Altai*, he classified the Brassicaceae family 4th for the petroplants of the Russian Altai with 31 genera and 69 species, and 6th for the high mountain flora of Altai with 29 genera and 55 species. The less extensive, but more diverse and contrasting regions are rich in species from Southern Siberia, Central Asia, Middle Asia, and East Asia (e.g., *Thlaspi cochleariforme*). The author notes that the dry steppe-desert floristic complex has limited distribution within the territory of the Russian Federation and is dependent on certain altitude levels. He included *Alyssum desertorum* and *Lepidium cordatum* species in this complex. A table illustrating the elevation distribution of characteristic species from the stony-waste floristic complex of the Kurai Mountains shows that *Draba fladnizensis* occurs at altitudes of 2700-3000 meters. He also studied the distribution of true alpine plants, including *Draba fladnizensis*, across the entire alpine zone [23].

E.G. Lagunova studied the flora of the Abakan and Agh Ius river plains (Republic of Khakassia) and, in the table summarizing the ratio of main families in the flora of the Abakan and Agh Ius river plains, ranked the Brassicaceae family 7th with a total of 30 species (4.8% of all species). Of these, 26 species (4.6%) belong to the Abakan River plain flora, and 26 species (4.8%) are found in the Agh Ius River plain flora. In her research, the author substantiated that the wide distribution of Brassicaceae species in these regions is influenced by anthropogenic factors, as the grasslands are intensively used for grazing areas (pastures) and recreation purposes. In the flora of the Abakan and Agh Ius river plains, she also included *Dentaria sibirica*, a species from the nemoral third period relics. All glacial relics are divided into glacial and periglacial-steppe species. Among the glacial relics, she also mentioned the species *Thlaspi cochleariforme* [24].

A.Yu. Doronina, in her dissertation "Flora of the Karelian Strait (Leningrad Region)," listed the Brassicaceae family among the families with the most species, with 21 species (2.6%). In the sixth chapter, "Analysis of the Adventive Fraction of the Karelian Strait," she noted that 314 genera and 63 families, totaling 573 adventive plant species, had been recorded in the region. The author investigated that the ten most significant families, including Brassicaceae with 62 species, encompassed 417 adventive plant species, which accounted for 72.8% of the total number of species in the adventive fraction. She studied *Draba incana* as a plant species whose distribution areas are associated with crystalline mountain rocks in the region. In the ninth chapter, "A Brief History of the Development of the Flora of the Karelian Strait in the Last Glacial Period," she emphasized that after the Atlantic period, the flora was primarily enriched due to anthropogenic changes. The species *Berteroa incana*, *Bunias orientalis*, *Lepidium ruderale*, and *Sisymbrium officinale* were introduced to the region in the 18th century, while in the 19th century, *Alliaria petiolata* and *Camelina microcarpa* were brought. The author investigated the first discoveries of *Descurainia sophoroides* and *Erysimum repandum* in the first half of the 20th century, and *Erysimum canescens* and *Sisymbrium orientale* in the second half of the 20th century. In recent years, *Lepidium latifolium* has been identified as a new species for the Karelian Strait. The researcher studied the disappearance of *Camelina alyssum* due to the cessation of beetroot cultivation, while species such as *Berteroa incana* and *Lepidium ruderale* have continued to spread widely and show a tendency for further spread in the region [25].

M.V. Kazakova, in her dissertation "The Natural Flora of the Ryazan Region as a Basis for Developing Biodiversity Conservation Measures," notes that the natural flora of the Ryazan region includes 47 species, among them *Rorippa vallicola* and *Sisymbrium strictissimum*, which are part of the 82 new vascular plant species. She indicates that 35 new species (such as *Lepidium latifolium*, *Neslia paniculata*, *Rapistrum perenne*, *Sisymbrium polymorphum*, etc.) belong to the adventive component. The author obtained documentary herbarium confirmations based on literary sources for the presence of 29 species (*Sisymbrium polymorphum* and others) in the Ryazan region. She also concluded that 29 species (*Arabis sagittata*, *Brassica juncea*, and others) may potentially be discovered in the future, and 7 species – such as *Draba sihirica* and others – are of East European-Asian origin [26].

In his study on the allergenic plants of Mongolia (floristic composition, geography, ecology, medical, and biological significance), S. Begziin presents the taxonomic composition ratio of allergenic plants in Mongolia. In the table he created, he lists the Cruciferae family in 17th place with 1 genus and 2 species. The author mentions that Brassicaceae (6%–7%) is among the dominant families in terms of systematic relations. The significant presence of pollen from Brassicaceae species in the regional spectrum of the Prihingai mountain-forest steppe zone of the Mongol-Daur region has also been investigated [27].

E.V. Karachaeva, in analyzing the flora of the city of Nalchik and its surroundings, presents 453 species (59.1% of the flora's species composition) and 227 genera (60.7% of the total genera count) from 10 leading families, including Brassicaceae. The first five families account for 318 species, or 41.5% of the total number, with Brassicaceae being one of them. In the table titled "Spectrum of Dominant Families," the Brassicaceae family is listed in 3rd place with 31 genera (8.3%) and 54 species (7%). The author concludes that the Brassicaceae family, due to its abundance of species, is widely distributed in both Arctic and Mediterranean floras. In the subsection "Analysis of Adventive Elements in the Flora," it was found that the Brassicaceae family (10.3%) is dominant [28].

T.I. Kazantseva, in her dissertation "Dynamics and Productivity of Plant Groups in the Gobi Region of Mongolia," in the third chapter titled "Composition and Structure of Plant Groups in the Gobi Region," states that according to E.I. Rachkovskaya and Ch. Sanchirin (1983), the entire Trans-Altai Gobi flora consists of 305 species. The author has studied 76 species from 21 families and 56 genera based on the ecological profile of the Trans-Altai Gobi. She included the Brassicaceae family among the less common families [29].

E.F. Shlikhislamova, when analyzing the dynamics of segetal (wild) vegetation in the Trans-Urals of the Republic of Bashkortostan over a period of 20 years, notes in the fourth chapter titled "General Characteristics of the Segetal Flora of the Trans-Urals of the Republic of Bashkortostan" that the Brassicaceae family (including *Camelina microcarpa, Sisymbrium loeselii, Sinapis arvensis, Raphanus raphanistrum*, etc.) plays a significant role. In a table regarding the effect of certain weed species on the quantitative aspects of the crop rotation phase, the author studied the overall averages of *Thlaspi arvense* [30].

T.N. Bliznyuk, while researching the flora of the Norsk Reserve (Amur region), classified the Brassicaceae family as follows: 7th rank with 15 species for the entire flora, 9–10th rank with 14 species for the aboriginal complex, and 2nd rank with 4 species for the adventive complex [31].

L.S. Galenkovskaya, when studying the flora of the "Small Abakan" section of the Khakassky Nature Reserve, notes that there are 12 species introduced (non-naturalized) due to human activity in the conservation zone. The author observed that the proportion of introduced species is relatively low (2.3%) and that these species (such as *Erysimum cheiranthoides* and *Draba nemorosa*) are found within the conservation zone, in areas where human activity is partially allowed. The Brassicaceae family is represented by 8 species in the flora, and the author investigated the relationship between the presence of species like *Erysimum cheiranthoides* and *Draba nemorosa* and the changes in the plant cover caused directly or indirectly by human activity [32].

4.7. Synanthropic Botanical Research

O.V. Telegova, in her work on the regularities of the synanthropization of plant cover in specially protected natural areas (using the example of the Middle Urals), includes the Brassicaceae family among the leading families of the synanthropic flora [33].

L.M. Abramova, in her research titled "Synanthropization of plant cover: examples and opportunities for managing the process (on the example of the Republic of Bashkortostan)," classifies the Brassicaceae family in 2nd place in the taxonomic composition of the synanthropic flora species of the Republic of Bashkortostan, with 29 genera and 47 species, in Table 1 of her work [34].

K.V. Kachkin, in his dissertation "Synanthropic Vegetation of the Right Bank of Novosibirsk", provides information on the 10 leading families in the synanthropic plant communities. The author, based on the data provided by Baikovidri, notes that in the first table categorizing the natural flora of the Novosibirsk right bank and the Novosibirsk region, the Brassicaceae family ranks third in the urban synoflora, accounting for 8.55% of the total species, and sixth in the natural flora, with 4.55% of the total species. Kachkin mentions that the participation of Brassicaceae family representatives has nearly doubled. In the second table, "Program of Synanthropic Meadow Vegetation of the Right Bank of Novosibirsk City", he considers species such as Lepidium ruderale, Capsella bursa-pastoris, and Sisymbrium loeselii as diagnostic species. He evaluates Lepidium ruderale as the species least sensitive to the impact of highways. The species that demonstrate harsh environmental conditions account for 77.65% of the 10 main families, among which Brassicaceae is included [35].

4.8. Ethnoecological Research

N.Yu. Suntsova, in her ecological and biological analysis of resource plants, fungi, and lichens of Udmurtia and their use history, mentions that the extracts of *Descurainia sophia* (K.) Webb ex Prantl. are included among the original (hygienic) medicines used by the Udmurt people. In the table she created, titled "Use of Plants and Fungi by the Udmurt Population as Insecticides, Rodenticides, and Repellents (Republic of Udmurtia, 20th century)," she lists *Capsella bursa-pastoris* (L.) Medik. among the plants used [36].

4.9. Research on Plant Introduction

G.A. Ruban and V.P. Mishurov, in their research on the introduction of forage plants in the North-East of Europe, studied the Brassicaceae Burnett family in the context of species such as *Brassica napus*, *Barbarea vulgaris*, *Raphanus sativus* L., *Sinapis alba*, and *Bunias orientalis*. They noted these species as fast-growing, productive (2.5–4.0 kg/m² of green mass), and nectar-producing plants that efficiently utilize long-daylight, positive temperature sums, and rainfall [37].

Based on Saqalaev, A.V. Lukonina notes in her research on the plant cover of the Volgograd region as a source for introduction that the steppe flora of the Volgograd region includes 547 vascular plant species from 43 families. She found that the Brassicaceae family is dominant among the major families. Among them, stenotopic species - calciphiles (*Lepidium meyeri*, etc.) - are present, and their introduction is significant not only from a practical application perspective but also from a scientific interest standpoint. The author investigated the petrophilous subshrub *Alyssum tortuosum* (a species from the steppe) and noted that some individuals in the introduced population have the ability to self-repair by seed, and they flower at the end of the vegetative season in the first year of life. She concluded that 43 plant species with long vegetative cycles from the Brassicaceae and other families produced secondary branches and a second flowering in late August and September, when the temperature dropped and the humidity levels increased. Additionally, she observed that the seeds of *Matthiola fragilis* germinated rapidly after being stored for several months [38].

T.Yu. Rogozhina, in her research "Prospects of Using Ornamental Perennials in Central Yakutia," notes that the Brassicaceae family is represented by fewer genera, with 5–7 genera containing the introduced species. Under the short heading *Perennial Plants with Long Vegetation Period*, evergreen plants are characterized by their leaves remaining active for more than one year, typically 13–15 months. This category includes 26 species, including Alyssum lenense, all of which belong to the flora of Yakutia. In perennial plants, the wintering buds can develop at various levels. For example, the main root of the Alyssum lenense species is located on or near the surface of the soil [39].

4.10. Research in Plant Physiology

I.B. Minich, in his research "Effect of Low-Energy Red Luminescent Radiation on the Morphogenesis of Plants and Endogenous Hormone Balance", selected plants from the Brassicaceae family as research subjects: *Arabidopsis thaliana* (L.) Heynh., *Brassica oleracea* L. var. capitata L. f. alba (L.) Ditch – medium-ripening variety "Legend," and *Raphanus sativus* L. "Ladushka" early spring variety. The seeds of *Arabidopsis* were sown in containers filled with pre-drained soil and germinated under control and experimental conditions. The growth cycle and germination start time of *Arabidopsis thaliana* (L.) Heynh. wild type Ler and hy4 mutant were determined under white light (29 W/m²) with 16 hours of UV light exposure (4 W/m²), as shown in Table 2, with the experiment conducted at 41 days old. The pigment content in the leaves of *Arabidopsis thaliana* (L.) Heynh. wild type Ler and hy4 mutant at 27 days old, grown under white light (29 W/m²) and 16 hours of UV light exposure (4 W/m²) in control (1) and experimental (2) films, was assessed in Table 3. At 47 days old, the growth parameters of *Arabidopsis thaliana* (L.) Heynh. wild type Ler and hy4 mutant were evaluated under white light (29 W/m²) and 6 hours of UV light exposure (4 W/m²), with hormone content measured in both control (1) and experimental (2) films. Additionally, growth parameters for the *Arabidopsis hy3* mutant at 36 days old were also determined under the same conditions. The results were summarized in Tables 4, 5, and 6 [40].

5. Conclusion

From the above-mentioned studies, it becomes clear that there is considerable scientific interest in the *Brassicaceae* Burnett. family worldwide. Research in this field continues across various countries. The comprehensive and systematic investigations by distinguished scientists such as Kamelin, R.V., and Dorofeyev, V.I., into the taxonomic, morphological, phylogenetic structure, and evolutionary aspects of the *Brassicaceae* family serve as evidence of the family's importance to botanical science. Based on historical and modern literature, hypotheses regarding fruit evolution and embryonic structure reveal the existence of diverse morphological and anatomical variations within the family. This underscores the necessity of studying the family from physiological, taxonomic, and ecological perspectives. The regional and applied research by scholars such as Qasem, Ruban, Mishurov, Kopytina, and Mishina has practical significance, highlighting the family's distribution under various ecological conditions, resistance to anthropogenic impacts, and introduction potential. Studies in the Rubtsovsk and Altai regions demonstrate the unique position of the family among both synanthropic and adventive flora. Musina, L.B., and Ryabtsov, S.N. have noted the persistence of species such as *Alyssum turkestanicum*, *Lepidium ruderale*, and *Alyssum tortuosum* under pyrogenic conditions in pastures. Researchers, including Buginova, L.M., Kachkin, K.V., Abramova, L.M., and Telegova, O.V., emphasized the high representation of the *Brassicaceae* family in urban and synanthropic floras, identifying species like *Capsella bursa-pastoris* and *Sisymbrium loeselii* as diagnostic and synanthropic elements. Garin, E.V., reported the presence of species such as *Rorippa amphibia* and *Armoracia rusticana* in aquatic plant communities. Other authors - Laktionov, A.P., Dudkin, R.V., Achimova, A.A., Zhikhareva, O.N., Chimonina, I.V., Verkhozina, A.V., Omarova, S.O., and Yedryonkina, V.A. - documented the dominance of the family with varying species numbers across different regional floras. In their studies, Eremenko, N.A., Omarova, S.O., and Galenkovskaya, L.S. highlighted the presence of *Brassicaceae* species in both protected areas and those affected by anthropogenic impacts. Minich, I.B. conducted experimental studies on model species (e.g., *Arabidopsis thaliana*), providing key findings on light exposure, UV radiation, and hormonal composition. Rogozhina, T.Yu. emphasized that in Central Yakutia the family is represented by a limited number of genera and highlighted *Alyssum lenense* for its long vegetative period. Pyak, A.I. classified the family among the dominant taxa in the petrophytic and alpine flora of the Russian Altai. Lagunova, E.G. showed that the family is widespread under anthropogenic influence in the floodplains of the Abakan and White Iyus rivers, also present among relict species such as *Dentaria sibirica* and *Thlaspi cochleariforme*. Doronina, A.Yu., noted the prominent role of the family in the adventive flora of the Karelia Isthmus. Kazakova, M.V. documented 47 species of the family in the natural flora and 35 in the adventive component of the Ryazan region. Lukonina, A.V., explored the ecological adaptation and introduction potential of the family in the steppe flora of Volgograd. Begziin, S. discussed the ecological traits of nectariferous species from the family in Mongolia's allergenic flora. Karachaeva, E.V., identified *Brassicaceae* as one of the leading families in the flora of Nalchik. Kazantseva, T.I., reported the family as few in number but ecologically significant in the flora of the Trans-Altai Gobi. Suntsova, N.Yu., provided data on the use of *Brassicaceae* species in Udmurt traditional medicine. Shlikhislamova, E.F., substantiated the family's high dominance in agroecosystems within the segetal flora of Bashkortostan. Bliznyuk, T.N. classified *Brassicaceae* in both aboriginal and adventive contexts in the Amur region. Galenkovskaya, L.S., reported an increase in *Brassicaceae* species in anthropogenically affected areas of the Khakassky Reserve.

The findings of these studies offer valuable insights that can be used in botanical science, particularly in the theoretical literature on the *Brassicaceae* Burnett. family. Furthermore, these results can benefit young researchers. Research on this family not only contributes to the understanding of plant biodiversity but also facilitates the discovery of scientific innovations of global importance.

Funding

This work received no external funding.

Institutional Review Board Statement

This study did not involve human participants or animals and therefore did not require ethical approval from an institutional review board.

Informed Consent Statement

Not applicable.

Data Availability Statement

No new data were created.

Conflicts of Interest

The author declares no conflict of interest.

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