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Introduction and biochemical composition of *Chrysanthemum coronarium* L. in Non-Chernozem regions

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Abstract. This study discusses the introduction and adaptation of edible chrysanthemum (*Chrysanthemum coronarium* L.) in the Non-Chernozem Zone of the Russian Federation. The focus is on studying the plant's biochemical composition, nutritional value, and pharmacological properties. Data on high content of vitamins, minerals, antioxidants, and other bioactive substances such as flavonoids and amino acids are presented. The influence of growing conditions, including lighting regimes and salt stress, on the accumulation of beneficial components in the plant is examined. The importance of further research to optimize agricultural practices and assess the economic viability of cultivating *Chrysanthemum coronarium* L. in this region is emphasized.

Keywords: edible chrysanthemum**,** flavonoids, amino acids, antioxidant activity, growing conditions, cultural practices

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Introduction

Expanding the range of vegetable crops in the Non-Chernozem Region is a priority for ensuring the region's food security. Climatic conditions and a short growing season dictate the need to find cold-resistant and fast-maturing plants capable of adapting to challenging growing conditions. Therefore, research aimed at studying ability of the introduced crop *Chrysanthemum coronarium* L., a member of the Asteracea family, to adapt to new growing conditions is relevant for this risky agricultural zone [1]. The analysis should cover a wide range of parameters: frost tolerance, length of the growing season in specific regions, soil requirements (pH value, fertility, moisture), resistance to common diseases and pests in the region, as well as optimal cultivation practices: sowing time, planting density, fertilization system, and weed control methods.

Garland chrysanthemum (*Glebionis coronaria* (L.) Cass.ex Spach., *Chrisanthemum coronarium* L.) is a leafy vegetable popular in many countries of Southeast Asia, especially China and Japan. In the United States, it is cultivated under the Japanese name Shunguku. Unlike ornamental chrysanthemums, this variety is cultivated as a leafy vegetable. Its popularity is due to its rich content of vitamins (C, B1, B2, PP), beta-carotene, minerals, including iodine and selenium, as well as various biologically active compounds [1, 2]. Of particular note is the high content of quercetin, a flavonoid with powerful antioxidant properties and a beneficial effect on the cardiovascular system. The delicate texture of the leaves and stems of young chrysanthemums, as well as a pleasant, slightly bitter taste, allow them to be used for various culinary purposes. Young leaves and shoots are added to salads, soups, vegetable stews, and used as a garnish for meat and fish dishes. In addition to decorative purposes, chrysanthemum flowers are used to produce tinctures and wines, as well as to flavor tea, contributing an exceptional aroma and delicate flavor. A study of the pharmacological properties of garland chrysanthemum has shown that it possesses anti-inflammatory, antioxidant, and immunomodulatory properties. Extracts from the plant are traditionally used in folk medicine for prevention and treatment of cardiovascular and liver diseases, as well as for strengthening immune system. Miyazawa and Hisama established the antimutagenic activity of flavonoids isolated from chrysanthemum, opening up prospects for the use of these compounds in preventive medicine [3].

International studies [3–6] demonstrate growing interest in the garland chrysanthemum due to its following characteristics: high content of biologically active substances; significant antioxidant potential; adaptability to various climatic conditions; and potential for functional nutrition.

For successful introduction of garland chrysanthemum into Non-Chernozem Region of the Russian Federation, comprehensive research is needed to determine optimal cultivation techniques for specific climatic conditions. This includes not only studying the plant's resistance to frost and disease but also developing effective pest control methods and optimizing fertilization systems taking into account the soil characteristics of Non-Chernozem zone. Such research and its theoretical analysis will enable consideration of the possibility of widespread introduction of this promising crop into regional agricultural production. It is also necessary to evaluate economic feasibility of growing garland chrysanthemum in comparison with traditional leafy vegetable crops, and to study market potential for this product.

Biological and mineral composition. The genus *Chrysanthemum* L. belongs to the tribe Anthemideae (or Pupaucaceae) of the family Asteraceae. The tribe Anthemideae comprises approximately 12 genera and 1,600 plant species, most of which grow in South Africa and the Mediterranean [7]. Garland chrysanthemum is widespread in the Mediterranean region and is a common plant in ruderal flora of field margins, roadsides, and urban wastelands [8].

Chrysanthemum coronarium L. has a powerful, branched root system, a fleshy, highly branched stem up to 1 m tall, and pinnately dissected, narrow, dark green or broadly lobed, light green leaves. In regions with a warm climate, broad-leaved varieties are cultivated, while in cold climates, intermediate or narrow-leaved type is grown, as it adapts well [9]. The inflorescences are solitary flower heads, up to 6 cm in diameter, simple or semi-double, on peduncles 15–20 cm long. The flowers are large, with white and yellow petals. It should be noted that the leaves of garland chrysanthemum can be harvested as early as 30–40 days after sowing, when the plants reach a height of 20 cm. Both leaves and flowers of the garland chrysanthemum are utilized for human consumption. The flowering period lasts 1.5–2 months, the seeds ripen in August-September. The garland chrysanthemum is characterized by a high content of beta-carotene, ascorbic acid, and phenolic substances that are part of the plant's antioxidant system. In addition, due to the P-vitamin activity, flavonoids exhibit an antispasmodic effect (quercetin glycosides), promote blood clotting and reduce blood cholesterol levels. The presence of 14 amino acids in the plant has been established, 9 of which are essential. The greatest number of amino acids accumulates in the leaves. The total amino acid content ranges from 8.27 to 10.67%, including essential ones — from 3.47 to 4.78%, which reflects the biological value of the study object [10]. Garland chrysanthemum (cv. 'Uzorchataya') synthesizes anthraquinone pigments, offering potential for utilization in health-promoting laxative mixtures and as a biological factor in soil humus formation. In this regard, vegetable crops rich in oxyanthraquinones are of particular value in human nutrition. Emodin (in the form of aglycone and glycoside) and chrysophanol were found in the stems of garland chrysanthemum [11]. Chrysophanol and chrysacin were isolated from the roots of the plant. These pigments are derivatives of 1,8-dioxyanthraquinone, therefore garland chrysanthemum can be used as a therapeutic and prophylactic agent in herbal infusions [1]. It was found that the extract from garland chrysanthemum leaves is close to ginseng extract in antioxidant activity. Antioxidant activity is due to the high content of phenolic acids (caffeic, gallic, p-coumaric, vanillic, ferulic and protocatechuic acids) and flavonoids (quercetin, myricetin) [7, 8, 12]. Studies on Wistar rats demonstrated pronounced gastroprotective activity of the methanol extract of *Chrysanthemum coronarium* L. leaves. Analysis of the methanol extract revealed the presence of 19 phenolic compounds, representing 46.47% of the total sample. The dominant components were o-coumaric acid (9.55%), chlorogenic acid (6%), myricetin (4.19%), and benzoic acid (2.87%) [8].

Propylparaben, 3-hydroxyflavone, ferulic acid, linoleic acid, vanillic acid, ascorbic acid, protocatechuic acid, quercetin, catechin hydrate, caffeic acid, p-coumaric acid, epicatechin and p-hydroxybenzoic acid have also been identified [1, 8]. Polyphenols (including bioflavonoids) are widespread in plant-based foods, which determine their organoleptic properties, and in combination with ascorbic acid increase capillary resistance (P-vitamin activity), normalize carbohydrate-phosphate metabolism, and promote more efficient use of ascorbic acid. Physicochemical analysis showed the presence of quercetin in the leaves and inflorescences in the form of an aglycone, a glycoside of quercetin with glucose in the form of isoquercetin, and a bioside of quercetin with rhamnose and glucose in the form of rutin. The content of oxyanthraquinones in the stems and roots of garland chrysanthemum (% of absolutely dry weight) is: in stem — chrysophanol 0.97%; emodin 0.34%; rhamnoemodin 0.43%; total pigments 1.74%; in root — chrysacin 0.54%; chrysophanol 0.33%; total pigments 0.87% [1]. The study of aromatically active compounds by gas chromatography-mass spectrometry and analysis of dilution of aromatic extract revealed 18 compounds. Myrcene (31.9%) was the most abundant compound, followed by α-bisabolol (16.5%), (E, E)-α-farnesene (11.0%), and (E)-β-farnesene (8.4%). High coefficients were shown by (Z)-3-hexenal, (E)-2-hexenal, methional, myrcene, nonanal, and (E, Z)-2,6-nonadienal [13]. Chrysanthemum pollen contains 0.22% proline, which is 26.1% of all free amino acids, and the sum of essential amino acids is 36.2% [14]. *Chrysanthemum coronarium* L. pollen also showed a unique composition of volatile substances, the main compounds of which were perillaldehyde, cis-chrysanthenyl acetate, and camphor; many carbonyl compounds and linear hydrocarbons were found exclusively in pollen [15].

Comprehensive studies of elemental composition of various organs of garland chrysanthemum revealed the plant's high capacity to accumulate biologically important elements. The presence of 14 amino acids was demonstrated, of which 9 are essential (lysine, methionine, threonine, valine, isoleucine, leucine, phenylalanine, cysteine, histidine, arginine, serine, proline, glycine, and tyrosine). The highest concentration of amino acids is found in the leaves [1, 2, 7].

The effect of growing conditions. Soil salinity is a major abiotic stress factor that inhibits and limits plant growth and development. It has been established that under salt stress, active pathways of carbohydrate and energy metabolism, as well as glutathione metabolism, allow plants to accumulate more energy and increase antioxidant capacity. This may play a protective role in supporting growth and development, as well as mitigating the effects of reactive oxygen species on garland chrysanthemum under stress. Identifying marker proteins that control plant responses to stress may accelerate the development of salinity-tolerant varieties [16].

Studies of the effects of graduated nitrogen and potassium levels on physiological growth parameters and flower yield revealed optimal fertilizer rates. Maximum yields were achieved with 200 kg/ha of nitrogen combined with 150 kg/ha of potassium: leaf count per plant: 98.00 leaves, leaf area per plant: 988.00 cm^2, LAI (leaf area index): 0.618, LAD (leaf activity duration): 268.04; flower yield per hectare: 25.25 centners [17].

The garland chrysanthemum is an ecologically flexible plant, resistant to recurrent spring frosts and autumn low temperatures. A study examining the effect of low temperatures on the content and composition of low-molecular-weight metabolites, antioxidants in garland chrysanthemum plant organs, revealed that the plant's tolerance to low temperatures and reduced light levels enables the cultivation of the crop for greens with high antioxidant content in August–September in open ground and in September–October in a plastic greenhouse after harvesting early-ripening crops. Higher antioxidant levels were found in the roots of garland chrysanthemum compared to the stem, indicating an important role in protecting the plant shoot during hypothermia. Thus, under low temperature conditions, garland chrysanthemum has a strategy for survival and protection of vegetative plant by altering the content of low-molecular-weight antioxidants in organs. The crop adapts to suboptimal conditions in the autumn period by changing the total content of antioxidants (TCA), sugars and ascorbic acid in photosynthetic leaves and stems.

Characteristics of cultivation in the Non-Chernozem Zone. The Non-Chernozem Zone of the Russian Federation is characterized by low-fertility soils, low winter temperatures, and excessive moisture. Sod-podzolic soils contain 0.8–2% humus and are deficient in nitrogen, phosphorus, and calcium. Biological activity in such soils, especially in uncultivated ones, is low due to lack of nutrients and acidic environment, which inhibits decomposition of organic matter and mineralization of nutrients. This requires application of organic and mineral fertilizers to improve fertility. Gray and dark gray forest soils predominate in the southern Non-Chernozem Zone. They are characterized by a higher humus content (2 to 4%) compared to sod-podzolic soils and a lower degree of podzolization. This makes them more fertile and suitable for agriculture. Due to unfavorable soil and climate conditions, increasing the diversity of vegetable crops is an important goal of vegetable growing in this region.

Six varieties of garland chrysanthemum (edible) are included in the Russian State Register of Varieties and Hybrids of Agricultural Plants Approved for Use (gossortrf.ru). In the Moscow Region, 'Uzorchataya' variety, developed at the Federal Scientific Center for Vegetable Growing, grows in open ground until late autumn, retaining its green leaves. The crop can be grown both as seedlings in greenhouses and by early spring sowing in open ground in central Russia. The yield can be affected by scheme and timing of seed sowing and planting of seedlings. In the spring and summer, 2–3 cuttings of greenery can be carried out, depending on the sowing time. Standard edible chrysanthemum seeds should have a germination rate of at least 55% for seed crops, and at least 45% for commercial crops, with a moisture content of 11% [18]. Under Moscow region conditions, 'Uzorchataya' variety enters the budding phase in 22–35 days, and blooms 40–60 days after emergence. The flowering period lasts at least 60–70 days. Seed ripening begins 30–60 days after the onset of flowering. In this regard, it is recommended to conduct seed production using seedlings, sowing in February — March in a greenhouse. When sowing seeds in open ground in early May, it was observed that the seeds were only suitable for commercial crops [18].

Studies of the adaptive properties of edible chrysanthemum conducted at Federal Scientific Center for Vegetable Growing, Moscow region, revealed a relationship between leaf morphological characteristics and resistance to environmental stress factors. The experiment showed that chrysanthemums with intermediate and narrow-leaf leaf types exhibit significantly greater flexibility and resistance to adverse conditions than their broad-leaf counterparts [1, 2, 18]. This is especially important for a region with an unstable climate, typical of the Moscow region. The study examined three main leaf types of edible chrysanthemums: broad-leaf, intermediate, and narrow-leaf. Each leaf type differed not only in size and shape of leaf blade but also in its anatomy, which likely explains the varying degrees of adaptation to stress factors. During the abnormally rainy summer, growth was stunted in all plants studied, but broadleaf plants suffered particularly severely. Their slow development during the initial stages of vegetation was likely caused by a lack of heat and excess moisture, which promoted the development of root rot. Furthermore, excess soil moisture could have led to a lack of oxygen in the root system further slowing plant growth. The presence of additional stress factor — a lack of sunlight at the beginning of the growing season — exacerbated the situation for broadleaf chrysanthemums, which, unlike narrowleaf varieties, have a larger leaf surface area and, accordingly, require more solar energy for photosynthesis. Despite the unfavorable conditions, biochemical analysis showed that the dry matter content in the leaves of all chrysanthemum types remained high (13–13.5%). The content of ascorbic acid (more than 32 mg%) and beta-carotene (more than 3 mg%) also confirmed the high physiological activity of plants, which indicates the ability of edible chrysanthemum to adapt to stressful conditions due to internal reserves [1, 12]. However, the difference in response to stressful conditions indicates that these reserves are used more effectively in narrow-leaved and intermediate varieties.

Elements of cultivation technology for edible chrysanthemum in the Central Region of the Non-Chernozem Zone of Russia have been developed in the Kostroma Region. The influence of abiotic factors on chrysanthemum cv. 'Uzorchataya' was studied under open-field and winter greenhouse cultivation conditions, and the economic efficiency of recommended agricultural practices was assessed. It was shown that the region's natural and climatic conditions allow for cultivating the crop and obtaining stable yields of green mass and seeds. The yield obtained in open and protected ground, according to calculations, confirms the profitability of cultivating the crop for green production in both open and protected ground [19]. In the forest-steppe zone of Bashkir Cis-Urals, members of the genus *Chrysanthemum* L. were grown for the purpose of introducing and expanding the zonal assortment of medicinal plants. It was found that all studied *Chrysanthemum* L. species, including and edible chrysanthemum are suitable for introduction and can be recommended for replenishing the zonal assortment of plants in the Republic of Bashkortostan [9]. Introduction studies conducted in 2000–2017 at the South Ural Botanical Garden-Institute showed that edible chrysanthemum tolerates the conditions of Bashkir Cis-Ural region well. The plant successfully adapts to the conditions of central Russia when grown as an annual crop [7, 18].

Research on the introduction of vegetable chrysanthemum in various regions of Russia demonstrates that the crop can be cultivated both in protected ground and in the open field. Recommended average values for various soil and climatic conditions in the Russian Federation include the following planting pattern: row spacing: 45–50 cm, distance within row: 25–30 cm, plant density: 8–10 plants/m², primary fertilization: N 100–120 kg/ha, P_2O_5 100–120 kg/ha, K_2O 120–150 kg/ha, and additional fertilizing: 1st: 2 weeks after planting (N), 2nd: at the beginning of budding (N: P: K = 1:1:1), 3rd: at the beginning of flowering (K). The best green yields of edible chrysanthemum were achieved by sowing seeds directly into the open ground in the late second decade of May, using 30 cm between rows (5.7 kg/m^2). When using the seedling method of establishing plots, the yield amounted to 6.1 kg/m^2 [20, 21].

The results of research by Russian and international scientists provide a scientific basis for optimizing the cultivation of *Chrysanthemum coronarium* L. and maximizing the potential of this crop. Promising areas for further research include studying the genetic mechanisms of adaptation to various climatic conditions, developing methods for increasing the bioavailability of active components, optimizing processing technologies and creating functional products, breeding new varieties with increased content of biologically active substances, and improving greenhouse cultivation technologies for regions with a short growing season. Practical recommendations for maximizing the accumulation of bioactive substances include maintaining an optimal temperature regime of 20–25 °C, using combined lighting (red and blue spectrum), balanced mineral nutrition, and controlled stress levels.

Conclusion

Chrysanthemum coronarium L. (edible chrysanthemum, garland chrysanthemum) is rich in minerals, has high biological productivity and ecological plasticity, is easy to cultivate and maintain, and its qualitative traits are not adversely affected by low temperatures. Therefore, it is a promising crop for introduction to the Non-Chernozem zone. Further research on the introduction of edible chrysanthemum could include studying the influence of genetic factors on formation of different leaf types, as well as analyzing expression of genes responsible for stress resistance under different conditions and enhancing antioxidant properties of plant products. A more detailed study of the rhizosphere microflora will help determine the role of soil microorganisms in adaptation of edible chrysanthemum to adverse conditions. Analyzing the levels of various phytohormones in leaves, depending on leaf type and weather conditions, can reveal the mechanisms by which *Chrisanthemum coronarium* L. plants adapt to stress factors. To increase resilience to adverse factors, hardening off seedlings, using modern growth regulators, and foliar feeding with microelements are recommended. The yield of green mass and the possibility of seed production cover the production costs, making the crop profitable for cultivation and sale to consumers, as well as for obtaining seeds of the edible chrysanthemum.

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Интродукция и биохимический состав *Chrysanthemum coronarium* L. в условиях Нечерноземья

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Аннотация. Рассмотрены вопросы интродукции и адаптации овощной хризантемы (*Chrysanthemum coronarium L.*) в условиях Нечерноземной зоны Российской Федерации. Основное внимание уделено изучению биохимического состава растения, его пищевой ценности и фармакологическим свойствам. Представлены экспериментальные данные авторов и обзорная информация о высоком содержании витаминов, минералов, антиоксидантов и других биологически активных веществ, таких как флавоноиды и аминокислоты. Рассмотрены особенности влияния условий выращивания, включая режим освещения и солевой стресс, на накопление полезных компонентов в растениях. Подчеркнута важность дальнейших исследований для оптимизации агротехнических приемов и экономической оценки перспективности выращивания хризантемы увенчанной в Нечерноземье России.

Ключевые слова: хризантема овощная, флавоноиды, аминокислоты, антиоксидантная активность, условия выращивания, агротехника

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