RESEARCH ARTICLE AGROBIOLOGICAL RECORDS
ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

COMPREHENSIVE CHARACTERIZATION OF THE CHEMICAL AND BIOACTIVE PHYTOCHEMICAL COMPONENTS OF CYNARA SCOLYMUS L.

Eldor Isomov [1], Aminjon Karabaev [2], Zebo Rasulova [3], Makhsuda Bekmuradova [2], Khudoyor Gafforov [2], Karim Gaziev [4], Khusniddin Kuvvatov [5], Feruz Kurbanov [5], Jasur Mahammadiev [1], Nodirjon Bobokandov [1]* and Zebunisso Nomozova [3]

[1]Samarkand Agroinnovations and Research University, Samarkand, Uzbekistan
[2]Samarkand State Medical University, Samarkand, Uzbekistan
[3]Sharof Rashidov Samarkand State University, Samarkand, Uzbekistan
[4]Bukhara State Medical Institute, Bukhara, Uzbekistan
[5]Samarkand State University of Veterinary Medicine, Livestock and Biotechnologies, Samarkand, Uzbekistan

*Corresponding author: nboboqandov@gmail.com

ABSTRACT

In recent decades, the rapid growth of the global population has led to a concomitant increase in the demand for both food and medicinal products. Meeting the full spectrum of human nutritional requirements depends not only on the quantity of food intake but also on the diet's diversity and nutritional quality. Consequently, the identification and introduction of novel forage or functional plants necessitate a comprehensive assessment of their chemical, nutritional, and functional properties. For a detailed evaluation, several parameters must be considered. These include the chemical composition of the fresh (wet) biomass, the nutritional value of organic constituents, digestibility metrics, and the potential for silage production or other processing methods. Such assessments provide crucial insights into the feasibility of incorporating a given plant species into animal feed systems or human dietary applications. Despite the economic and functional importance of *Cynara scolymus* (artichoke), studies evaluating its nutritional and forage potential remain limited. Existing literature indicates that the edible parts of the plant, particularly the flower heads (capitula), have a high water content of approximately 86.5%, with nitrogenous compounds accounting for 2.5% of the wet weight. The carbohydrate fraction is represented by 1% simple sugars and 2% dextrins, while dietary fiber constitutes 1.3%, and ash content 1.3%. Notably, the fleshy portion of the involucral leaves or "basket" accumulates approximately 2.2% sugar, indicating a moderate energy contribution from soluble carbohydrates. These compositional characteristics suggest that *C. scolymus* not only provides hydration through its high-water content but also contributes essential nutrients, including nitrogenous compounds and soluble sugars, which are vital for both metabolic and fermentative processes in animal digestion. Furthermore, the relatively balanced content of fiber and minerals indicates its potential suitability for silage preparation, providing an additional avenue for extending its utility in forage and nutritional applications. Given the limited data currently available, further systematic investigations are warranted to fully characterize the nutritive value, digestibility, and functional properties of *C. scolymus*, particularly under diverse cultivation and processing conditions. Such studies would facilitate evidence-based recommendations for integrating human nutrition and livestock feeding systems, ultimately enhancing dietary diversity and food security.

***Keywords*:** *Cynara scolymus*, Artichoke, Nutritional Composition, Forage Potential, Digestibility, Silage Production, Functional Properties

Article History (ABR-26-041) || Received: 12-Feb-2026 || Revised: 11-Mar-2026 || Accepted: 15-Mar-2026 || Published Online: 19-Mar-2026
This is an open-access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. INTRODUCTION

Nowadays, the increase in the number of the world's population, in turn, increases the demand for food and medicinal products, and at the same time, the full supply of the human body's needs for all necessary substances does not depend only on sufficient nutrition, but the variety of food also requires enrichment at the expense of nutritious plants. In order to search for and introduce any new fodder plant, it is first necessary to make a detailed assessment of its nutritional properties. For this, the chemical composition of the wet weight of this plant, the nutritional value of organic matter, its digestibility, as well as the possibility of making hay and silage, are taken into account. The flower head of *Cynara scolymus* contains 86.5% water, 2.5% nitrogenous matter, 1% sugar, 2%

Citation: Isomov E, Karabaev A, Rasulova Z, Bekmuradova M, Gafforov K, Gaziev K, Kuvvatov K, Kurbanov F, Mahammadiev J, Bobokandov N and Nomozova Z, 2026. Comprehensive characterization of the chemical and bioactive phytochemical components of Cynara scolymus *L*. Agrobiological Records 23: 185-196. https://doi.org/10.47278/journal.abr/2026.016

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

dextrin, 1.3% fiber, and 1.3% ash. 2.2% of sugar content accumulates in the fleshy part of the basket leaves. The local supply of raw materials for pharmaceutical production and the cultivation of medicinal plants are currently major concerns. From an economic perspective, it is crucial to identify new medicinal plants, determine their chemical composition, and integrate them into conventional treatment methods. In the medium-saline soils of the Bukhara region, the methodology, formalization, and observed maturation processes of the Imperial Star and Violettto *Cynara scolymus L*. cultivars were examined under Uzbekistan's slightly salinized soil conditions. The following adaptability characteristics were identified. The anatomical structure of the vegetative organs of the Artichoke Green Gold variety, which is cultivated in the Bukhara region's medium salinity areas, has been examined for the first time. Xeromorphic and meso-xeromorphic characteristics emerged, indicating that cell size in the leaf epidermis decreased, stomatal density increased, stem bark parenchyma thickened, the diameter and number of conducting tubes increased, and lignification intensified (Isomov et al., 2024). Potassium chloride stress in artichoke leaves has been associated with reduced leaf dry biomass and significant alterations in mineral composition. Modifications in hormonal networks and phenolic profiles have also been documented under such conditions; however, morphometric changes in vegetative organs were not examined in that context (Lucini et al., 2016). The effects of chloride salts on biomass production and phytochemical composition in artichoke and cardoon have been comparatively assessed, revealing that KCl application enhances phenolic and flavonoid accumulation, whereas NaCl and $CaCl_2$ treatments improve leaf quality at later developmental stages (Borgognone et al., 2014). Plant physiological responses to heterogeneous salinity conditions have been widely investigated, yet detailed information on soil salinity–induced morphometric modifications in the vegetative organs of *Cynara* L., together with their phytochemical characterization, remains limited (Bazihizina et al., 2012). Soil salinity has been shown to influence the growth of *C. cardunculus*, with measurable variations in shoot and root length observed across different salt concentrations. Concurrently, phytochemical analyses demonstrated increased total phenol content and enhanced antioxidant activity under salinity stress (Pappalardo et al., 2020). Elevated salinity levels in nutrient solutions were reported to reduce leaf dry biomass and leaf number in *C. cardunculus* cultivars, while simultaneously stimulating antioxidant activity and the accumulation of phenolic compounds such as chlorogenic acid, cynarin, and luteolin (Colla et al., 2013). Investigations of salinity tolerance mechanisms within the Asteraceae have largely focused on species such as Aster tripolium and Aster alpinus, providing insight into adaptive strategies but offering limited evidence on soil salinity–driven morphometric responses and phytochemical traits in *Cynara* species (Wiszniewska et al., 2021). More broadly, salt tolerance has been examined in relation to general physiological mechanisms and the role of beneficial soil microorganisms in improving crop performance, without specific consideration of vegetative organ morphometry and phytochemical dynamics in *Cynara* under soil salinity conditions (Hanin et al., 2016). Comprehensive analyses of crop responses to multiple abiotic stresses have further expanded understanding of plant adaptive strategies; nevertheless, an integrated evaluation of the effects of soil salinity on the morphometric characteristics of vegetative organs in Cynara species, combined with detailed phytochemical assessment, remains underexplored (Boscaiu & Fita, 2020). Desert environments in Central Asia, such as those in Uzbekistan, are home to tremendous biodiversity and unique plant groups. However, the loss of plant cover and habitat degradation have been made worse by increasingly extended droughts caused by climate change and human pressure (Bobokandov et al., 2024). These results suggest that conventional feeds and plant-based feeds can compete. However, external environmental factors, especially light conditions, directly affect the amount and quality of plant biomass. When *Chelidonium majus* L. was cultivated under several light regimes, the best lighting resulted in a 20–25% increase in biomass production. These findings highlight the importance of optimizing agro-technical conditions for growing aquatic and semi-aquatic plants (Hamrayeva et al., 2025). One of the most pressing issues at the moment is the local availability of raw materials for pharmaceutical manufacturing and the cultivation of medicinal plants (Bobokandov et al., 2024). The technique, formalization, and observed maturity processes of the Imperial Star and Violetto *Cynara scolymus* L. cultivars were investigated in the slightly salinized soils of the Bukhara region in Uzbekistan. The following traits of adaptability were found. (Isomov et al., 2024) For the first time, the anatomical structure of the vegetative organs of the Artichoke Green Gold variety, grown in medium-salinity areas of the Bukhara region, has been investigated. (Isomov et al., 2025). Global warming and drought have led to habitat destruction in Central Asia, increasing the number of endangered species. Intense human activity and prolonged droughts driven by climate change have resulted in habitat destruction and a corresponding vegetation cover crisis in these regions (Akhmedov et al., 2025, Mustanov et al., 2026). Growth stage and salinity stress have been shown to significantly influence the accumulation of bioactive compounds in cardoon; however, detailed evidence linking soil salinity to morphometric alterations in vegetative organs remains limited, and comprehensive phytochemical evaluation in this context has not been sufficiently elaborated (Petropoulos et al., 2018). Phytochemical and biological characterization of the "Carciofo di Procida" cultivar has revealed pronounced antioxidant and cytotoxic properties, emphasizing its pharmacological potential, yet without considering soil salinity–induced morphometric variability in the vegetative organs of *Cynara* species (Tommonaro

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

et al., 2025). Under salinity conditions, potassium silicate application has been investigated in *Cichorium intybus* L., demonstrating improved stress tolerance and physiological performance; nevertheless, comparable analyses integrating morphometric parameters and phytochemical traits in *Cynara* (Asteraceae) under soil salinity remain scarce (Mohammadi et al., 2024). Recent phytochemical investigations of *C. cardunculus* leaves have confirmed high antioxidant capacity and the presence of diverse bioactive constituents, further supporting the medicinal value of the genus, although structural responses of vegetative organs to saline soils were not assessed (Cerulli et al., 2024). The artichoke (*C. scolymus*) is a perennial species native to the southern Mediterranean region of North Africa and is now cultivated worldwide as a vegetable crop. Beyond its nutritional importance, it holds a prominent place in traditional medicine for its antioxidant and anti-inflammatory properties. The presence of phenolic acids and flavonoids enables effective scavenging of reactive oxygen species, thereby reducing oxidative stress and inflammatory processes. Traditional applications include blood purification and supportive use in the management of anemia (Keramati et al., 2022). The globe artichoke (*C. cardunculus* L. var. *scolymus* (L.)) is widely distributed across the Mediterranean basin, where the edible capitulum (head) represents the main economic organ. Its functional value is associated with high concentrations of polyphenolic compounds and inulin. "Carciofo di Paestum," a traditional Italian variety recognized as a PGI product from the Campania region, constitutes an important agricultural and economic resource. Chemical investigations of this variety have identified 17 compounds, including caffeoylquinic acid derivatives, phenolics, flavonoids, and terpenoids, primarily from methanolic extracts (Cerulli et al., 2022). Nitrogen assimilation and fertilizer efficiency in *Cynara scolymus* under varying soil conditions have been extensively examined (Abzalov et al., 2016). Independent of phosphorus supply levels, ammonium sulfate and, especially, urea have been shown to enhance the intensity of nitrogen biosynthesis and protein accumulation in plant tissues. Morphologically, artichoke varieties are characterized by large, fleshy, homogamous, spherical capitula with multi-rowed involucral bracts. The lower bracts are narrowed and pinnatifid, often terminating in a spine, although spineless forms with rounded margins also occur. The receptacle is flat and slightly fleshy, covered with long bristles, while the corolla is straight and five-lobed with unequal divisions (Lishchuk, 1991). The varieties Green Gold, Imperial Star, and Violetto are perennial herbs reaching 0.5–2 m in height. Stems are thick, erect, and pubescent with a grayish surface. Basal leaves are large and densely pubescent abaxially, with lower stem leaves reaching up to 1 m in length and 50 cm in width. Upper leaves are progressively reduced and modified into involucral bracts. Capitulum diameter ranges from 32–46 cm in Green Gold, 30–38 cm in Imperial Star, and 28–33 cm in Violetto. The involucre is ovoid to nearly spherical, composed of overlapping bracts with fleshy bases; outer bracts may be slightly reflexed, whereas inner bracts remain straight and spineless. Numerous bluish-violet tubular flowers develop within the head. Flowering occurs in May–June, followed by seed formation. Cultivation is typically performed in moist soils of southern regions (Lishchuk, 1991). Within the Republic, bioecological and chemical investigations of artichoke under introduction conditions have provided valuable insights. Adaptive anatomical features of vegetative organs under irrigated and non-irrigated regimes were described. The influence of mineral and organic fertilizers on the uptake of microelements was analyzed by Abzalov et al. (2016). Elemental composition and biologically active substances in leaves were quantified by Mirrahimova & Yunuskhojaev (2015), and subsequent work contributed to the standardization of the preparation "Cinaron Bio" derived from globe artichoke (Mirrahimova & Yunuskhojaev, 2015). Related agronomic and physiological investigations were further expanded by Aramov & Aliev (2020).

In this context, the present study was designed to comprehensively analyze and compare the chemical and phytochemical composition of selected *Cynara scolymus* L. species, with the aim of elucidating interspecific and varietal differences in bioactive compounds, thereby enhancing the understanding of their nutritional, medicinal, and agronomic potential.

2. MATERIALS AND METHODS

2.1. Experimental Site and Planting Conditions

The field experiments were conducted at the Botanical Garden of Samarkand State University, Uzbekistan. The experimental site is located in the Zarafshan Valley, characterized by a continental climate. The soil of the experimental plots is classified as typical gray soil (sierozyom). Pre-sowing soil analysis indicated a pH of 6.0–6.5, providing a suitable environment for plant growth and nutrient uptake. In the autumn season, the plots were prepared by plowing to a depth of 25–30 cm to improve soil structure and aeration. Artichoke seeds were sown manually at a uniform depth of 3–4 cm. To ensure optimal plant density and light interception, a planting scheme of 70 x 40 cm was employed. Standard agrotechnical practices, including regular irrigation based on soil moisture levels and mechanical weed control, were consistently applied throughout the entire vegetation period.

2.2. Phenological Observations

Phenological stages of the plants were monitored throughout the vegetation period following the methodology

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

described by Bedeman (1960). The observations included the following growth stages: commencement of vegetation, budding stage, onset and mass flowering, fruit formation, commencement of fruit ripening, and full physiological maturity.

2.3. Chemical Analysis of Plant Material

To determine the nutritional value and chemical composition of the artichoke hay, samples were collected during the [typical gray soil, pH value of 6.0–6.5] stage. Chemical analyses were performed at the Samarkand Geological Laboratory. The following parameters were determined using standardized biochemical methods:
Nitrogen and Crude Protein: Determined using the Kjeldahl method (Alikayev et al., 1967).
Inulin and Carbohydrates: Analyzed according to the methods described by Razumov (1986).
Crude Fiber and Fat: Determined using the Henneberg-Stohmann and Soxhlet extraction methods, respectively.
Ash and Dry Matter: Measured through gravimetric analysis (dry ashing in a muffle furnace at 550°C).
Carotene: Analyzed using spectrophotometric methods.
Micro and Macroelements: Determined following the procedures proposed by Lukashik and Tashilin (1976).

2.4. Statistical Analysis

All experimental data were subjected to statistical processing to ensure the reliability of the results. Data management was performed using Microsoft Excel 2019. The mathematical statistics were calculated according to the methods of Gorya (1978). The significance of differences between the means was evaluated using Student's t-test, with a confidence level of ($P<0.05$). The results are presented as the mean ± SD. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications.

3. RESULTS

When growing *Cynara scolymus* as fodder, it is very important to have information about its organic composition, which determines its nutritional value According to the results of the experiment, it was found that crude protein (16.45%) in the composition of its above-ground organs in the experimental area was high in the flowering phase, and oil in the fruiting phase and in the composition of the seeds (4.63 and 30.0%). Crude protein (11.69-12.67%) is accumulated in the beginning of the vegetation and fruiting phases of development, and the least amount of fat is accumulated in the beginning of the vegetation and flowering phases (2.85-3.02%) (Fig. 1).

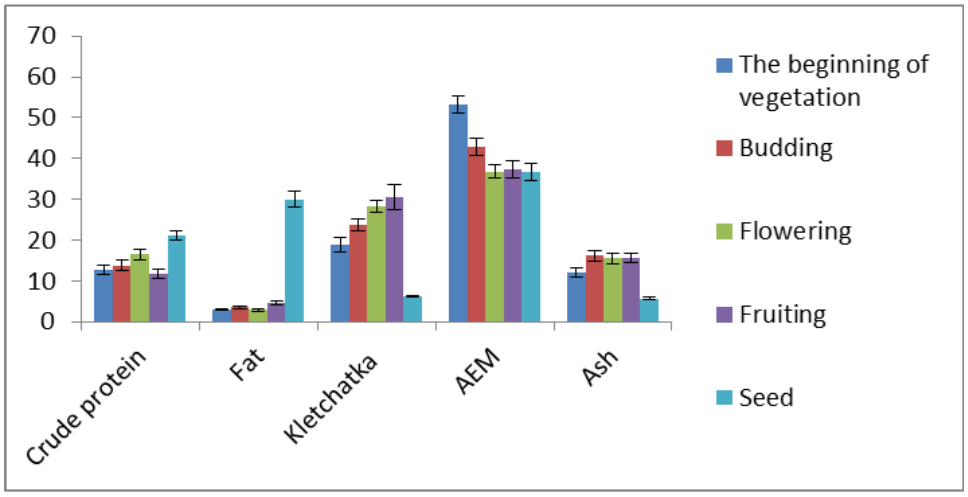


Fig. 1: Chemical composition of *Cynara scolymus* according to development phase (irrigated area, absolute dry mass, %); Chemical composition of thorny artichoke according to development phase (irrigated area, absolute dry mass, %).

Plants in the non-irrigated area also have a large amount of crude protein (16.0%) in the flowering phase, and oil in the budding and fruiting phases (3.20-4.14%). On the contrary, crude protein (12.10-11.3%) and fat (2.11%) are less accumulated in the flowering phase (Fig. 2).

To confirm that *Cynara scolymus* is a valuable fodder plant, the chemical composition of several individually grown grassland plants was compared (Table 1).

Information about all plants except *Cynara scolymus* from the work of. According to the analysis of the given data, Cynara scolymus is high in protein, fat, and fat content, and cellulose is low (Table 1).

In addition, fructose and inulin accumulated in the leaves. According to the results of the experiment, fructose 16.0-19.0 mg%, inulin 6.66-8.64% accumulate in the plants in the irrigated field. The non-irrigated area contains 14.8-17.4 mg of fructose and 5.40-7.20% of inulin. These results indicate that *Cynara scolymus* is of great

Citation: Isomov E, Karabaev A, Rasulova Z, Bekmuradova M, Gafforov K, Gaziev K, Kuvvatov K, Kurbanov F, Mahammadiev J, Bobokandov N and Nomozova Z, 2026. Comprehensive characterization of the chemical and bioactive phytochemical components of Cynara scolymus *L*. Agrobiological Records 23: 185-196. https://doi.org/10.47278/journal.abr/2026.016

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

economic importance.

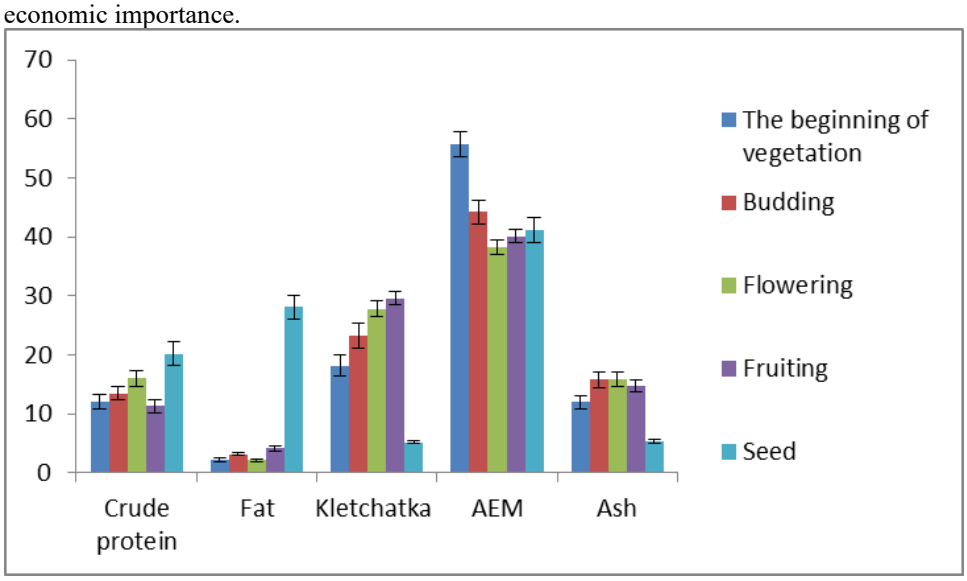


Fig. 2: Chemical composition of *Cynara scolymus* according to development phase (non-irrigated area, absolute dry mass, %).

Table 1: Comparative analysis of the chemical composition of *Cynara scolymus* and other grassland plants (absolute dry mass, %)

Plants names	Sample time	Kletchatka	Ash	Fat	Protein	Protein
Color or black	10.05	32.30 ± 1.25^{b}	9.00 ± 0.75^{b}	4.35 ± 0.20^{b}	8.35 ± 0.45^{c}	3.70 ± 0.15^{c}
Konirbash	18.06	29.70 ± 1.10^{c}	12.78 ± 0.95^{b}	2.62 ± 0.18^{c}	5.95 ± 0.30^{d}	3.68 ± 0.20^{c}
Water wheat	27.05	26.48 ± 0.95^{d}	4.52 ± 0.35^{c}	–	10.15 ± 0.60^{b}	7.80 ± 0.50^{b}
Wormwood	16.06	35.60 ± 1.50^{a}	5.95 ± 0.40^{c}	3.10 ± 0.22^{c}	10.35 ± 0.55^{b}	6.55 ± 0.40^{b}
Tar	26.05	23.00 ± 0.80^{e}	18.00 ± 1.10^{a}	3.17 ± 0.25^{c}	14.20 ± 0.75^{a}	10.86 ± 0.70^{a}
Artichoke	12.05	23.77 ± 0.90^{e}	16.18 ± 0.85^{a}	4.63 ± 0.30^{a}	16.45 ± 0.90^{a}	11.77 ± 0.85^{a}

Values (mean ± SD) bearing different alphabets in a column differ significantly (P≤0.05).

Provitamin A carotene is also mainly in plant leaves, and its amount varies. The amount of carotene accumulation varies with the amount of chlorophyll in chloroplasts, and it actively participates in photosynthesis (Sinkovsky et al., 1974). In the experiments conducted by Agalina in Tajikistan, 115.47 mg/kg of carotene was accumulated in the dried above-ground part of artichoke.

The analysis of the results revealed that the carotenoid content in Cynara scolymus varies across developmental stages. The obtained data are presented in Table 2. As can be seen from the table, carotene (384.0 mg/kg) is highest during the flowering phase of the plants in the irrigated field, but it is lower (142.5 mg/kg) at the beginning of the vegetation phase. In the non-irrigated field, carotene is accumulated in the highest amount (378.1 mg/kg) in the flowering phase, but in a low amount (136.7 mg/kg) in the beginning phase of vegetation (Table 2).

Table 2: Accumulation of sugar and carotene according to the development phases of *Cynara scolymus* (absolute dry mass)

Growth phases	In irrigated conditions		In non-irrigated conditions	
	Sugar %	Carotene mg/kg	Sugar %	Carotene mg/kg
Beginning of vegetation	6.34 ± 0.32^{c}	142.5 ± 7.5^{c}	6.01 ± 0.30^{c}	136.7 ± 6.8^{c}
Budding	9.95 ± 0.48^{b}	246.7 ± 12.3^{b}	9.63 ± 0.46^{b}	220.2 ± 11.0^{b}
Flowering	10.70 ± 0.52^{a}	384.0 ± 15.6^{a}	10.4 ± 0.50^{a}	378.1 ± 14.9^{a}
Fruiting	11.80 ± 0.60^{a}	248.2 ± 12.0^{b}	11.5 ± 0.58^{a}	204.1 ± 10.2^{b}
Seed formation	3.99 ± 0.20^{d}	-	3.2 ± 0.18^{d}	-

Values (mean ± SD) bearing different alphabets in a column differ significantly (P≤0.05).

The amount of sugar is also variable across development phases, and it is higher in the fruiting phase of plants in the irrigated area (11.80%) and in the non-irrigated area (11.5%). During the initial phase of vegetation, less sugar accumulated in the irrigated area (6.34%) and the non-irrigated area (6.01%) (Table 2). Cynara scolymus is a cold-resistant plant; its leaves remain green even under snow. Therefore, this process, that is, the high content of carotene and sugar in the leaves formed in the fall (wintering leaves), increases the cold resistance of plants.

The concentration of mineral substances in the wet weight of *Cynara scolymus* is of great interest because the amount of mineral substances in their feed is important for the smooth functioning of vital processes in the animal's body. Deficiency of any of these substances in the diet of animals can lead to the development of pathological conditions in their organism. Therefore, the accumulation of mineral elements in the aboveground organs of Cynara

Citation: Isomov E, Karabaev A, Rasulova Z, Bekmuradova M, Gafforov K, Gaziev K, Kuvvatov K, Kurbanov F, Mahammadiev J, Bobokandov N and Nomozova Z, 2026. Comprehensive characterization of the chemical and bioactive phytochemical components of Cynara scolymus *L*. Agrobiological Records 23: 185-196. https://doi.org/10.47278/journal.abr/2026.016

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

scolymus was studied across the development phases (Fig. 3).

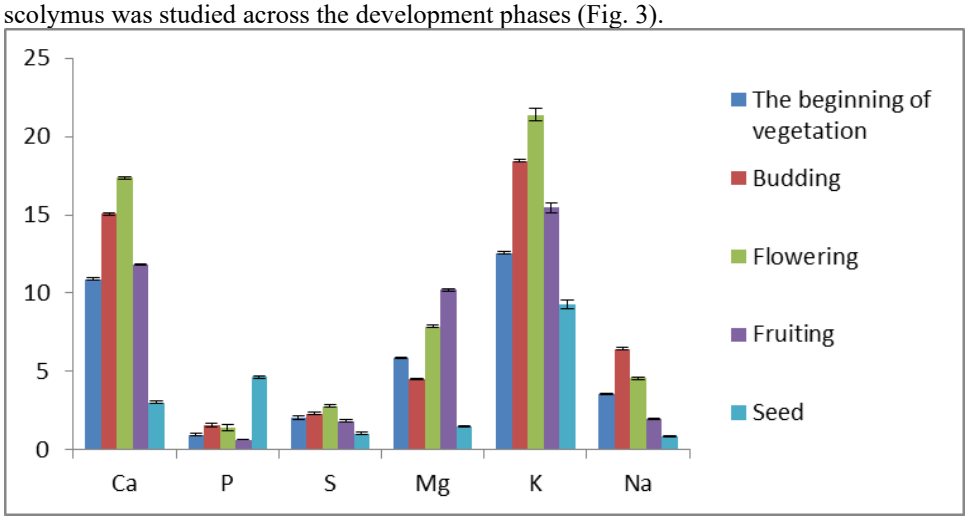


Fig. 3: Macronutrient composition of *Cynara scolymus* varieties (irrigated area, absolute dry mass, g/kg).

From the data presented in the table, it can be seen that calcium (15.05-17.36 g/kg) and sulfur (2.32-2.79 g/kg) accumulate in the irrigated area in the highest amount during the budding and flowering phases, while calcium (10.88 g/kg) in the beginning phase of vegetation, phosphorus (0.66-0.95 g/kg) in the vegetation phase. observed during initiation and fruiting. The magnesium element is the most abundant in the fruiting phase (10.2 g/kg), and the lowest amount is found in the beginning of vegetation and budding phases (4.52-5.83 g/kg). Potassium is found in much larger amounts during the flowering phase (21.36 g/kg) and almost twice as much at the beginning of vegetation (12.56 g/kg). The amount of sodium is much lower during fruiting (1.98 g/kg) than during budding and flowering (4.56-6.45 g/kg) (Fig. 3).

Calcium (14.60-17.2 g/kg) and phosphorus (1.329-1.12 g/kg) are the most abundant in the non-irrigated field, but in the phase of the beginning of vegetation (10.32 g/kg), phosphorus (0.62 g/kg) is the least. The greatest amount of magnesium is in the fruiting phase (10.1 g/kg), and a small amount is accumulated in the beginning of the vegetation and budding phases (5.51-4.32 g/kg). Potassium is more abundant in the flowering phase (21.4 g/kg) and less in the beginning of the vegetation and fruiting phases (12.20-15.4 g/kg). Sodium is absorbed in large amounts in the budding and flowering phase (4.20-6.15 g/kg) and in small amounts in the fruiting phase (1.55 g/kg) (Fig. 4).

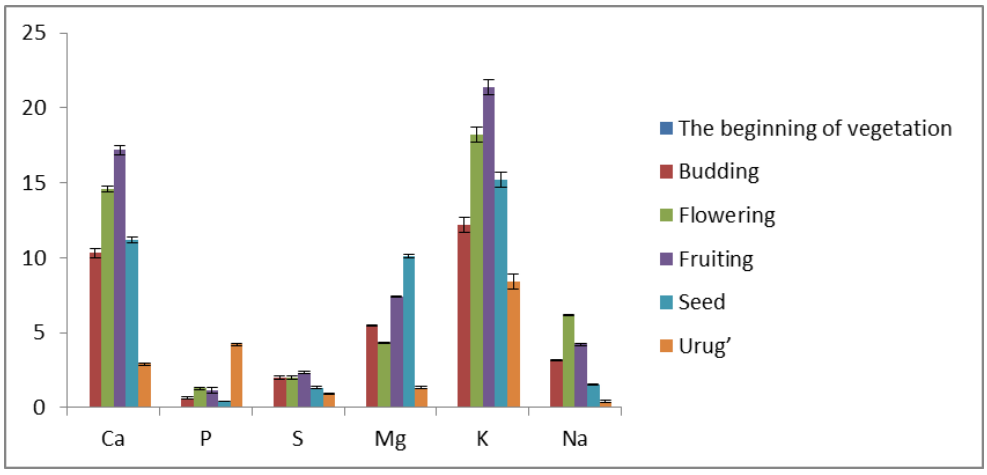


Fig. 4: Macronutrient composition of *Cynara scolymus* (unirrigated area, absolute dry mass, g/kg).

The high nutritional value of the plant depends on the amount of the above-mentioned mineral substances in its composition. In comparison, artichoke has less calcium (17.36 g/kg) than other nutritious plants, such as alfalfa (20 g/kg). But it is more than corn (4.2 g/kg), rye (4.6 g/kg), and sunflower (14 g/kg). Also, the amount of phosphorus, which is one of the important elements, is almost equal to that of traditional fodder plants. Based on these data, it is possible to recommend the use of the thorny artichoke plant as feed to meet the elemental needs of livestock.

The least amount of copper (3-5 mg/g) is accumulated in forage plants growing in meadows. Therefore, the copper needs of livestock are not covered. This process can be significantly observed, especially in summer, when

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

the surface of many plants dries up, because at this time the amount of copper is greatly reduced.

The accumulation of microelements (Cu, Fe, Mn, Zn), important for livestock, in Cynara scolymus varieties was studied across different phases of plant development. The total amount of copper in the above-ground part of the thorny artichoke is 13-14 mg/kg, which is 2-3 times that of traditional nutritious rye, rapeseed, alfalfa, and corn. In the phases of development, it varies widely. These data are presented in (Table 3).

Table 3: Micronutrient composition of Cynara scolymus (irrigated area, absolute dry mass)*

Growth phases	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
Beginning of vegetation	8.75 ± 0.42^{c}	166.9 ± 8.3^{c}	52.7 ± 2.6^{b}	31.8 ± 1.5^{c}
Budding	14.37 ± 0.70^{b}	195.1 ± 9.7^{b}	60.3 ± 3.0^{b}	38.0 ± 1.9^{b}
Flowering	16.67 ± 0.82^{a}	209.7 ± 10.5^{b}	74.2 ± 3.7^{a}	47.3 ± 2.3^{a}
Fruiting	17.86 ± 0.90^{a}	238.2 ± 11.9^{a}	47.4 ± 2.4^{c}	52.9 ± 2.6^{a}
Seed formation	3.02 ± 0.15^{d}	45.7 ± 2.3^{d}	29.6 ± 1.4^{d}	21.1 ± 1.0^{d}

Values (mean ± SD) bearing different alphabets in a column differ significantly (P≤0.05).

It can be seen from the data presented in the table that the amount of copper in the plants in the irrigated area is very low (8.75 mg/kg) in the initial phase of vegetation, and high (16.67-17.86 mg/kg) in flowering and fruiting. Among such important elements, manganese was observed in the highest amount in the budding and flowering phases (60.3-74.2 mg/kg), and the lowest amount was observed in the beginning and fruiting phases of vegetation (47.0-47.4 mg/kg).

It corresponds to the data obtained by (50-100 mg/kg). According to the authors, the amount of zinc in the ration of dairy cows should be 20-50 mg/kg. The amount of zinc in the composition of grassland plants in Uzbekistan is rarely very low, not exceeding 12-15 mg/kg. In the thorny artichoke, it is much higher than in other plants at the beginning of vegetation (31-38 mg/kg) and corresponds to the flowering and fruiting phases (43.7-52.9 mg/kg). Similarly, the amount of iron (Fe) is also variable across development phases and accumulates mainly during flowering and fruiting (209.7-238.2 mg/kg).

In the non-irrigated area, the amount of copper is less in the flowering and fruiting phases (16.20-16.50 mg/kg) than in the beginning phases of most vegetation (8.25 mg/kg). Manganese also accumulates in large quantities in the flowering phase (73.5 mg/kg) and less in the initial phase of vegetation (51.9 mg/kg), and the amount of zinc is high in the flowering and fruiting phases (46.6-51.7 mg/kg), and less in the initial phases of vegetation (30.9 mg/kg) (Table 4).

Table 4: Micronutrient content of *Cynara scolymus* (in non-irrigated field, absolute dry weight)

Growth phases	Cu (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Zn (mg/kg)
Beginning of vegetation	8.75 ± 0.43^{c}	155.9 ± 7.8^{c}	51.9 ± 2.6^{b}	30.9 ± 1.5^{c}
Budding	14.20 ± 0.70^{b}	186.0 ± 9.3^{b}	59.1 ± 2.9^{b}	37.3 ± 1.8^{b}
Flowering	16.20 ± 0.81^{a}	198.0 ± 9.9^{b}	73.5 ± 3.6^{a}	46.6 ± 2.3^{a}
Fruiting	16.50 ± 0.83^{a}	229.2 ± 11.5^{a}	46.3 ± 2.3^{c}	51.7 ± 2.5^{a}
Seed formation	2.85 ± 0.14^{d}	44.2 ± 2.2^{d}	28.4 ± 1.4^{d}	20.4 ± 1.0^{d}

Values (mean ± SD) bearing different alphabets in a column differ significantly (P≤0.05).

4. DISCUSSION

The salt tolerance of *Cynara* species is governed by specialized anatomical adaptations and sophisticated metabolic regulation. According to Chen et al. (2024), these species possess distinct salt-secreting structures, including salt bladders and specialized glands. These anatomical features play a critical role in regulating salt accumulation within leaf tissues by sequestering or excreting excess ions, thereby preventing cellular toxicity and enhancing overall salinity tolerance. The salt tolerance of *Cynara* species is governed by specialized anatomical adaptations and sophisticated metabolic regulation. These anatomical features play a critical role in regulating salt accumulation within leaf tissues by sequestering or excreting excess ions, thereby preventing cellular toxicity and enhancing overall salinity tolerance (Lu et al., 2021; Chen et al., 2024). Beyond specialized glands, the functional integrity of vegetative organs is maintained through precise stomatal regulation. Franzisky et al. (2021) highlighted that guard cells in *Cynara* varieties undergo significant metabolic adjustments to preserve turgor pressure. This adaptation is essential for maintaining stomatal conductance and gas exchange efficiency under osmotic stress induced by high soil salinity (Munns & Tester, 2008; Chaves et al., 2009; Franzisky et al., 2021). Furthermore, the general resilience of these plants to abiotic stress involves a complex interplay of secondary metabolite production and genetic signaling pathways (Hanin et al., 2016; Pappalardo et al., 2020). While many studies focus on the broader mechanisms of salt tolerance and genetic engineering (Muchate et al., 2016; Zhou et al., 2024), the specific anatomical modifications in the vegetative organs of *Cynara* L. varieties serve as a primary line of defense,

Citation: Isomov E, Karabaev A, Rasulova Z, Bekmuradova M, Gafforov K, Gaziev K, Kuvvatov K, Kurbanov F, Mahammadiev J, Bobokandov N and Nomozova Z, 2026. Comprehensive characterization of the chemical and bioactive phytochemical components of Cynara scolymus *L*. Agrobiological Records 23: 185-196. https://doi.org/10.47278/journal.abr/2026.016

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

ensuring survival and growth in saline environments. The article presents the results of an ecological and anatomical study of plants from the coastal shallows of rivers and lakes in the Lower Amur region to identify their resistance and adaptability to environmental conditions. Seven stenotopic species were studied (Tsyrenova, 2024). The metamorphosed stems of both species share a similar structure, with assimilating tissue beneath the epidermis and colorless tissue in the central part. However, Ruscus hypoglossum L. has fewer, larger cells in the central tissue, whereas Ruscus aculeatus has more, but smaller, cells (Timuc & Gostin, 2024). The results of the ecological and anatomical study of plants in the coastal shallows of rivers and lakes in the Lower Amur region are presented to assess their resistance and adaptability to habitat conditions (Tsyrenova, 2024). Plants growing in arid environments developed structural adaptations to reduce water loss and dissipate excessive light energy (Almabek et al., 2024). It was found that *Cyperus rotundus* exhibits typical characteristics of adaptation to an amphibious environment, including tissue air cavities and an apoplastic barrier in roots (Zheng et al., 2024). In taxonomic studies, structural characteristics of vegetative organs, in addition to floral traits, contribute significantly to species identification and classification. To provide insights into these characteristics within the genus, our findings revealed that *P. sinensis* leaves from forests experiencing mild to moderate rocky desertification exhibited higher specific leaf area (SLA) and magnesium concentrations. In contrast, these leaves had lower leaf dry matter content (LDMC) and thinner abaxial and adaxial epidermal layers than those from forests with severe to extremely severe desertification (Li et al., 2025). Dioecious tree species may be more vulnerable to climate warming if sex-related sensitivity to drought occurs, since lower performance of one sex may drive differential stress tolerance and sex-related mortality rates (Rodríguez-Ramírez & Terrazas, 2025). Plants deploy different strategies to optimize the N uptake by roots, based on a complicated regulatory network that controls root phenotype and physiology (Rouina et al., 2025). The diaspores of Asteraceae have three structures that can contain sticky substances: exocarp epidermal cells, exocarp trichomes, and viscid pappus. The South American species *Adenostemma brasilianum* (Asteraceae) has all three features (Dosil Hiriart et al., 2025). This study provides new insight into the plastid genome evolution and phylogenetic relationships. Moreover, it would be fundamental to formulate potential conservation and management strategies for the enigmatic species in the Himalaya (Yu et al., 2022). A set of anatomical and carpological characters indicates a possible relationship between Gymnarrhena and the basal subtribes Cardopatiinae and Carlininae of the tribe Cardueae. The morphophysiological adaptations of G. micrantha and Cousiniopsis atractyloides cypselae to dissemination under desert conditions, which are similar in structural details, apparently suggest a close relationship between the subfamilies Gymnarrhenoideae and Carduoideae (Kravtsova, 2024). The study of the anatomical structure of the roots in the promising artichoke varieties Green Gold, Imperial, and Violetto revealed that, in transverse section, the roots are circular and belong to the non-fascicular type, remaining non-lignified the examines the phytochemical composition of *Cynara scolymus*, highlighting key bioactive constituents such as cynarin, chlorogenic acid, and flavonoids, which contribute to its hepatoprotective, anti-inflammatory, antioxidant, and various therapeutic effects, including anti-cancer properties (Goel, 2025).

Cynara scolymus L. contains high levels of phenolic acids, flavonoids (like luteonin and apigenin), soluble and insoluble dietary fibers (especially inulin and pectins), contributing to its antioxidant power and potential health benefits against cardiovascular, hepatic, and neurological disorders (Ayuso et al., 2024). *Cynara scolymus* leaves contain high levels of phenolic compounds, flavonoids, tannins, and essential minerals. The extracts exhibit significant antioxidant and anti-inflammatory activities, attributed to these bioactive phytochemicals, as analyzed through various methods including HPLC and several antioxidant assays (Ben Salem et al., 2017).

The reviews the phytochemical composition of *Cynara cardunculus* L. var. scolymus, highlighting its rich content of polyphenols, flavonoids, and other compounds, alongside its diverse bioactivities, including antioxidant, anti-inflammatory, and anticancer properties, emphasizing extraction and purification methods (Valduga et al., 2023). Highlights that artichoke (*Cynara scolymus* L.) contains high levels of bioactive compounds, including inulin, minerals, vitamins, fiber, and polyphenols, which contribute to its health benefits and potential in preventing degenerative disorders like cardiovascular diseases and certain cancers (Frutos et al., 2019). *Cynara scolymus* L. contains phenolic acids, flavonoids, and sesquiterpene lactones, with caffeic acid derivatives being predominant. The extracts exhibit significant antioxidant activity, enhancing cell viability in 3T3 fibroblasts, highlighting their therapeutic potential and rich bioactive composition (Nichita et al., 2015). In all the varieties examined, the root anatomy is divided into three main zones: the periderm (cork), the bark parenchyma, and the central cylinder. The periderm consists of three layers: phellem, phellogen, and phelloderm. The periderm, which surrounds the root externally, is composed of these three layers. The phellogen cells are rectangular in shape, elongated radially, and produce the dead phellem cells, which contain suberin, outward. Inwardly, the phellogen gives rise to living cells of the phelloderm; these cells are larger and rectangular in shape, distinctly differentiated from the inner bark parenchyma cells. The bark parenchyma is composed of thin-walled cells that are rounded, oval, or isodiametric in shape. The bark parenchyma cells in the Green Gold and Violetto varieties have a smaller diameter (33.33 ± 0.41 µm) compared to the Imperial Star variety, where they exhibit a larger diameter (60.93 ± 0.68 µm). Furthermore,

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

the bark parenchyma occupied 30% of the root diameter, with cells densely packed. with the cells being densely packed. Overall, the current body of evidence reinforces the critical role of anatomical and morphological plasticity in facilitating plant survival and performance under diverse environmental stresses. The evaluates the biological activity of chemical compounds in *Cynara scolymus* L. using the "Pass online" program, detailing the chemical composition of its body, leaves, flowers, and oil, along with its applications in traditional medicine and healthcare (Asqarov & Mo'minov, 2023).

The study characterizes *Cynara scolymus* L. by analyzing its methanol, ethyl acetate, and n-hexane extracts for total phenolic content, antioxidant activities, and macro/microelement levels, highlighting its potential as a natural source of potassium and zinc (Albayrak et al., 2022). Understanding structural modifications in roots, stems, and leaves, coupled with physiological responses to salinity, drought, and other abiotic factors, offers valuable insights for plant breeding, conservation, and management. The integration of anatomical, physiological, and molecular perspectives provides a robust framework for predicting plant responses to future environmental changes and for guiding sustainable utilization of plant resources

Discusses *Cynara scolymus* L. containing bioactive metabolites like polyphenols and terpenoids, which exhibit hypolipidemic, hepatoprotective, and antioxidant properties. Key compounds include chlorogenic acid, cynarin, luteolin, and sesquiterpenes, contributing to its therapeutic effects (Zadworny, 2024). The study conducted a qualitative and quantitative analysis of *Cynara scolymus* L., identifying key bioactive compounds such as phenolic compounds, chlorogenic acid, cynaroside, and essential minerals like sodium, potassium, calcium, and magnesium, highlighting its potential medicinal applications (Akhmadova et al., 2024).

Further research focusing on the morphometric and phytochemical traits of *Cynara* species under controlled and field conditions will enhance our understanding of their adaptive strategies, informing both ecological theory and practical applications in agriculture and conservation.

5. CONCLUSION

The results of the present study demonstrated that *Cynara scolymus* possesses a rich chemical composition and can be considered a valuable non-traditional nutritious plant under the ecological conditions of our Republic. The analysis of its aboveground parts revealed the presence of essential nutrients and biologically important compounds, including proteins, carbohydrates, carotene, nitrogen-free extractives, inulin, and a wide range of mineral elements such as calcium, phosphorus, potassium, copper, and iron. These components play an important role in improving the nutritional value of plant biomass and may contribute to its potential use as a supplementary feed resource for animals. The chemical composition of *Cynara scolymus* varied with plant developmental stage. The obtained results showed relatively high levels of protein (16.45%), carotene (384.0 mg/kg), nitrogen-free extractives (36.84%), and inulin (6.66–8.64%), as well as significant concentrations of mineral elements, including calcium (17.36 g/kg), potassium (21.36 g/kg), copper (16.67 mg/kg), and iron (209.7 mg/kg). The presence of these nutrients indicates the plant's high biological and nutritional value. In addition, comparative analysis revealed that plants growing in irrigated areas contained higher concentrations of nutrients and mineral elements than those growing in non-irrigated conditions. This suggests that irrigation and environmental factors significantly influence the accumulation of biologically active compounds in *Cynara scolymus*. Overall, the findings of this study confirm that *Cynara scolymus* can serve as a promising unconventional plant resource with high nutritional potential. Its rich biochemical composition and adaptability to local environmental conditions indicate that it may be effectively utilized in agricultural practice, particularly as a supplementary feed source and a valuable plant for further scientific and practical applications.

Declarations

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgement: This work was carried out as part of the scholarship of Samarkand Agroinnovations and Research University.

Conflicts of Interest: The authors declare that there is no conflict of interest regarding the publication of this study.

Data Availability: The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics Statement: This study did not require ethical review, as it did not involve human's data or animal subjects.

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

Author's Contributions: This study was a collaborative effort among all authors. Eldor Isomov, Aminjon Karabaev, Zebo Rasulova, Makhsuda Bekmuradova, Khudoyor Gafforov, Karim Gaziev, Khusniddin Kuvvatov, Feruz Kurbanov, Jasur Mahammadiev, Nodirjon Bobokandov and Zebunisso Nomozova contributed to the study design and data analysis. Eldor Isomov, Aminjon Karabaev, Nodirjon Bobokandov and Zebunisso Nomozova conducted the laboratory experiments, analyzed the data, interpreted the results, and drafted the manuscript. All authors reviewed and approved the final manuscript.

Generative AI Statements: The authors declare that no Gen AI/DeepSeek was used in the writing/creation of this manuscript.

Publisher's Note: All claims stated in this article are exclusively those of the authors and do not necessarily represent those of their affiliated organizations or those of the publisher, the editors, and the reviewers. Any product that may be evaluated/assessed in this article or claimed by its manufacturer is not guaranteed or endorsed by the publisher/editors.

REFERENCES

Abzalov, A.A., Belolipov, I.V., Tulaganov, R.T., Ulugmurodov, N.X., & Nomozova, Z.B. (2016). Prickly artichoke-cynara scolymus L. It is a perspective plant for the pharmaceutical industry of Uzbekistan. International Journal of Applied and Fundamental Research, 6, 13.

Akhmadova, G., Mirrakhimova, T., & Ismoilova, G. (2024). High-quality analysis of dry extract of prickly artichoke raw material (Cynara Scolymus L.) cultivated in Uzbekistan. ScienceRise, 4 (50), 60–66. https://doi.org/10.15587/2519-4852.2024.310826

Akhmedov A, Umurzakova Z, Muminov MA, Bobokandova M, Isomov E, Urokov S, Atayeva S, Rasulova Z, Zhalov K, Ibragimov L, Mamadiyarov M, Dustbekov D, Jumayev N, Bobokandov N. (2025). Assessment of populations of Lagochilus vvedenskyi (Lamiaceae) in the Kyzyl-Kum desert of Uzbekistan under drying climate. Plant Science Today. 12(4): 1-8. https://doi.org/10.14719/pst.8756

Albayrak, S., Denk, B., Karpuz, B., KÜPELİ AKKOL, E., & Avci, G. (2022). Cynara scolymus L. Yaprağının Farklı Ekstraktlarda Invitro Aktioksidan Aktivitelerinin ve Makro ve Mikro Element Seviyelerinin Belirlenmesi. Kocatepe Veteriner Dergisi. https://doi.org/10.30607/kvj.1157121

Alikayev, V.A., Petukhov Ye, A., * Khalenkov, L.D. (1967). Rukovodstvo po kontrolyu kormov i polnotsennosti kormleniya sel'skokhozyaystvennykh zhivotnykh. Kolos, 186.

Almabek, D., Abidkulova, K., Kurbatova, N., Mukhitdinov, N., & Turalin, B. (2024). Comparative anatomical and morphological study of vegetative organs of Gymnospermium altaicum (Pall.) Spach from natural populations. BIO Web of Conferences, 100, 04001. https://doi.org/10.1051/bioconf/202410004001

Aramov, M. K., & Aliev, B.K. (2020). Morphobiological Features and Productivity of Artichoke in the Conditions of Southern Uzbekistan // Vegetables of Russia. – 2020. – № 4. – C. 102–105.

Asqarov, I. R., & Mo'minov, M. (2023). Artishok o'simligi tarkibidagi kimyoviy birikmalarning biologik faolligini baholash. https://doi.org/10.55475/jcgtm/vol2.iss2.2023.177

Ayuso, P., Quizhpe, J., Rosell, M. de los Á., Peñalver, R., & Nieto, G. (2024). Bioactive Compounds, Health Benefits and Food Applications of Artichoke (Cynara scolymus L.) and Artichoke By-Products: A Review. Applied Sciences. https://doi.org/10.3390/app14114940

Bazihizina, N., Barrett-Lennard, E. G., & Colmer, T. D. (2012). Plant growth and physiology under heterogeneous salinity. Plant and Soil, 354(1), 1–19. https://doi.org/10.1007/S11104-012-1193-8

Bedeman, I.N. (1960). Study of plant phenology. Field geobotany. T. 2. -M.- L: Publ. of the USSR Academy of Sciences .333-366.

Ben Salem, M., Affes, H., Athmouni, K., Ksouda, K., Dhouibi, R., Sahnoun, Z., Hammami, S., & Zeghal, K. M. (2017). Chemicals Compositions, Antioxidant and Anti-Inflammatory Activity of Cynara scolymus Leaves Extracts, and Analysis of Major Bioactive Polyphenols by HPLC. Evidence-Based Complementary and Alternative Medicine, 2017, 4951937. https://doi.org/10.1155/2017/4951937

Bobokandov, N., Nomozova, Z., Mukumov, I., Mustanov, S., & Tashpulatov, Y. (2024). Comparative analysis of the biochemical composition of Leontice L. Species. E3S Web of Conferences, 537, 05001. https://doi.org/10.1051/e3sconf/202453705001

Borgognone, D., Cardarelli, M., Rea, E., Lucini, L., & Colla, G. (2014). Salinity source-induced changes in yield, mineral composition, phenolic acids and flavonoids in leaves of artichoke and cardoon grown in floating system. Journal of the Science of Food and Agriculture, 94(6), 1231–1237. https://doi.org/10.1002/JSFA.6403

Boscaiu, M., & Fita, A. (2020). Physiological and Molecular Characterization of Crop Resistance to Abiotic Stresses. Agronomy, 10(9), 1308. https://doi.org/10.3390/AGRONOMY10091308

Cerulli, A., Masullo, M., Pizza, C., & Piacente, S. (2022). Metabolite Profiling of "Green" Extracts of Cynara cardunculus subsp. scolymus, Cultivar "Carciofo di Paestum" PGI by 1H NMR and HRMS-Based Metabolomics. Molecules, –27(10), 3328. https://doi.org/10.3390/molecules27103328

Cerulli, A., Cuozzo, R., Melis, M. P., Serreli, G., Deiana, M., Masullo, M., & Piacente, S. (2024). In-Depth LC-ESI/HRMS-Guided Phytochemical Analysis and Antioxidant Activity Analysis of Eco-Sustainable Extracts of Cynara cardunculus (Carciofo di Paestum PGI) Leaves. Plants, 13(24), 3591. https://doi.org/10.3390/plants13243591

Chaves, M. M., Flexas, J., & Pinheiro, C. (2009). Photosynthesis under drought and salt stress: Regulation mechanisms from whole plant to cell. Annals of Botany, 103(4), 551–560. https://doi.org/10.1093/aob/mcn125

Chen, X., Wegner, L. H., Gul, B., Yu, M., & Shabala, S. (2024). Dealing with extremes: Insights into development and operation of salt bladders and glands. Critical Reviews in Plant Sciences, 43(3), 158–170. https://doi.org/10.1080/07352689.2023.2285536

Colla, G., Rouphael, Y., Cardarelli, M., Švecová, E. B., Rea, E., & Lucini, L. (2013). Effects of saline stress on mineral composition, phenolic acids and flavonoids in leaves of artichoke and cardoon genotypes grown in floating system. Journal of the Science of Food and Agriculture, 93(5), 1119–1127. https://doi.org/10.1002/JSFA.5861

Dosil Hiriart, F. D., Hernández, M. P., Segura, L. N., & Katinas, L. (2025). Myxodiaspory in Adenostemma brasilianum (Asteraceae): morphological and histochemical strategies for diaspore dispersion. Botanical Journal of the Linnean Society, 207(4), 389-405. https://doi.org/10.1093/botlinnean/boae051

Franzisky, B. L., Geilfus, C.-M., Romo-Pérez, M. L., Fehrle, I., Erban, A., Kopka, J., & Zörb, C. (2021). Acclimatisation of guard cell metabolism to long-term salinity. Plant Cell and Environment, 44(3), 870–884. https://doi.org/10.1111/PCE.13964

Frutos, M. J., Ruiz-Cano, D., Valero-Cases, E., Zamora, S., & Pérez-Llamas, F. (2019). Artichoke (Cynara scolymus L.) (pp. 135–138). Academic Press. https://doi.org/10.1016/B978-0-12-812491-8.00018-7

Goel, R. S. (2025). Cynara scolymus in Modern Medicine: The Healing Power of Phytochemicals and Cynarin's Role in Cancer Therapy. International Journal of Newgen Research in Pharmacy & Healthcare, 226–236. https://doi.org/10.61554/ijnrph.v3i1.2025.150

Gorya, V.S. (1978). Algorithms for mathematical processing of research results. - Chisinau. Shtiintsa, 1978.

Hamrayeva, M., Bobokandov, N., Rakhmonov, V., Isomov, E., Kurbanboev, S., Sadikova, C., & Tashpulatov, Y. (2025). Effect of different lighting environments on the biomass and dry matter content of raw materials of Chelidonium majus L.(Papaveraceae) under cultural conditions. International Journal of Agriculture and Biosciences, 14(5), 908-916. https://doi.org/10.47278/journal.ijab/2025.083

Hanin, M., Ebel, C., Ngom, M., Laplaze, L., & Masmoudi, K. (2016). New Insights on Plant Salt Tolerance Mechanisms and Their Potential Use for Breeding. Frontiers in Plant Science, 7, 1787. https://doi.org/10.3389/FPLS.2016.01787

Isomov, E., Tashpulatov, Y., Bobokandov, N., Rasulova, Z., Mustanov, S., Bobokandova, M., Ataqulova, M., Mamadiyarov, M., Ishankulova, K. and Nomozova, Z., (2025). Adaptive anatomical characteristics of vegetative organs in Cynara . varieties under different soil salinity conditions. International Journal of Agriculture and Biosciences 14(4): 710-720. https://doi.org/10.47278/journal.ijab/2025.039

Isomov, E., Nomozova, Z., Djumayeva, G., Bobokandov, N., & Tashpulatov, Y. (2024). Anatomical structure of vegetative organs of Artichoke Green gold variety (in medium saline soil conditions). E3S Web of Conferences. 510, 01008. https://doi.org/10.1051/e3sconf/202451001008

Keramati M., Musazadeh V., Ghadimi K. (2022). Antioxidant and Anti-inflammatory Effects of Artichoke or Cynara scolymus L. as Promising Potential Therapeutic in Anemia. Journal of Nutrition and Food Security. 7(1). 129–135. https://doi.org/10.18502/jnfs.v7i1.8544

Kravtsova, T. I. (2024). Possible phylogenetic relationships of Gymnarrhena (Gymnarrheneae, Gymnarrhenoideae, Asteraceae) based on comparative carpology. Phytotaxa, 675(1), 11-33. https://doi.org/10.11646/phytotaxa.675.1.2

Li, W., Zhang, W., Feng, T., Lv, D., Zou, S., He, B., & Bai, X. (2025). Variations in Leaf Functional Traits of Pseudotsuga sinensis Across Forests with Varying Levels of Rocky Desertification. Ecology and Evolution, 15(2), e70916. https://doi.org/10.1002/ece3.70916

Lishchuk, S.S. (1991). Method for determining the mass of seeds // Botanical Journal. Moscow-Leningrad, 76 (11). 1623-1624.

Lu, C., Yuan, F., Guo, J., Han, G., Wang, C., Chen, M., & Wang, B. (2021). Current understanding of role of vesicular transport in salt secretion by salt glands in recretohalophytes. International Journal of Molecular Sciences, 22(4), 2203. https://doi.org/10.3390/ijms22042203

Lucini, L., Borgognone, D., Rouphael, Y., Cardarelli, M., Bernardi, J., & Colla, G. (2016). Mild Potassium Chloride Stress Alters the Mineral Composition, Hormone Network, and Phenolic Profile in Artichoke Leaves. Frontiers in Plant Science, 7, 948. https://doi.org/10.3389/FPLS.2016.00948

Lukashik, N.A., & Tashchilin, V.A. (1976). Zootechnical analysis of feed. Kolos, 216.

Mirrahimova, T.A., & Yunuskhojaev, A.N. (2015) Quantitative Determination of Ascorbic Acid in Leaves and Extracts of Globe Artichoke (Cynara scolymus L.) Grown in Uzbekistan. IV All-Russian Scientific Conference: "Young Pharmacy – Potential of the Future". 500–502.

Mohammadi, H., Abdollahi-Bastam, S., Aghaee, A., & Ghorbanpour, M. (2024). Foliar-applied silicate potassium modulates growth, phytochemical, and physiological traits in Cichorium intybus L. under salinity stress. BMC Plant Biology, 24. https://doi.org/10.1186/s12870-024-05015-6

Muchate, N. S., Nikalje, G. C., Nikalje, G. C., Rajurkar, N. S., Suprasanna, P., & Nikam, T. D. (2016). Plant Salt Stress: Adaptive Responses, Tolerance Mechanism and Bioengineering for Salt Tolerance. Botanical Review, 82(4), 371–406. https://doi.org/10.1007/S12229-016-9173-Y

Munns, R., & Tester, M. (2008). Mechanisms of salinity tolerance. Annual Review of Plant Biology, 59, 651–681. https://doi.org/10.1146/annurev.arplant.59.032607.092911

Mustanov, S., Mustanova, Z., Gaybullaev, G., Bobomirzaev, P., Makhmatmurodov, A., Xalmirzayeva, L., Bekmuradova, M., Nurmurzaev, Z., Abduraxmanov, D., Ergasheva, M., Bobokandova, M., Khodjayeva, N., Khamdamova, E., Rakhmonov, V. and Bobokandov, N., (2026). Effect of sowing time, planting scheme and Rizovit-AKS inoculant on the productivity and nitrogen fixation of chickpea (Cicer arietinum L.) under Samarkand conditions. Agrobiological Records 23: 65-80. https://doi.org/10.47278/journal.abr/2026.005

Nichita, C., Neagu, G., Cucu, A., & Vulturescu, V. (2015). Therapeutical and free radical scavenging properties of Cynara scolymus L. leave extracts. Scientific Bulletin. Series F. Biotechnologies, 19, 304–310. http://biotechnologyjournal.usamv.ro/pdf/2015/Art52.pdf

Pappalardo, H., Toscano, V., Puglia, G., Genovese, C., & Raccuia, S. A. (2020). Cynara cardunculus L. as a Multipurpose Crop for Plant Secondary Metabolites Production in Marginal Stressed Lands. Frontiers in Plant Science, 11, 240. https://doi.org/10.3389/FPLS.2020.00240

Petropoulos, S. A., Pereira, C., Tzortzakis, N., Barros, L., & Ferreira, I. C. F. R. (2018). Nutritional Value and Bioactive Compounds Characterization of Plant Parts From Cynara cardunculus L. (Asteraceae) Cultivated in Central Greece. Frontiers in Plant Science, 9, 459. https://doi.org/10.3389/FPLS.2018.00459

Razumov, A. N. (1986). Methods of biochemical analysis of plant raw materials. Moscow: Agropromizdat.

Rodríguez-Ramírez, E. C., & Terrazas, T. (2025). Concatenating latewood blue intensity and wood anatomical sensitivity in Neotropical montane podocarps: How does sex-related climate trigger tracheid plasticity. Dendrochronologia, 90, 126298. https://doi.org/10.1016/j.dendro.2025.126298

Rouina, H., Singh, D., Arlt, C., Malekian, B., Schreiber, L., Stich, B., & Marshall-Colon, A. (2025). Regulatory Analysis of Root Architectural and Anatomical Adaptation to Nitrate and Ammonium in Brachypodium distachyon. biorxiv, 2025-01. https://doi.org/10.1101/2025.01.06.631519

Sinkovsky L.P., Rodionenko V.S., Agalina V.G. (1974). Prickly artichoke - a new silage crop// Plant resources. - Leningrad,. 10 (1). 10-17.

Timuc, C., & Gostin, I.N. (2024). Comparative anatomy of the vegetative organs from two species of the genus Ruscus L. Bulletin of the LN Gumilyov Eurasian National University. Bioscience Series, 148(3), 166- 176. https://orcid.org/0000-0003-1519-5122

Tommonaro, G., De Simone, G., Iodice, C., Allarà, M., & Cutignano, A. (2025). A Phytochemical and Biological Characterization of Cynara cardunculus L. subsp. scolymus Cultivar "Carciofo di Procida", a Traditional Italian Agri-Food Product (PAT) of the Campania Region. Molecules, 30(15), 3285. https://doi.org/10.3390/molecules30153285

Tsyrenova, D. J. (2024). Ecological and Anatomical Characteristics of riverbank Plants of Water Currents and Waterbodies of the Lower Amur Region. Biologiâ vnutrennih vod, 17(3), 410-417. https://doi.org/10.31857/S0320965224030053

Valduga, E., Zeni, J., & Steffens, J. (2023). Bioactive Compounds from Artichoke and Application Potential. Food Technology and Biotechnology. https://doi.org/10.17113/ftb.61.03.23.8038

Wiszniewska, A., Koźmińska, A., Hanus-Fajerska, E., Dziurka, K., & Dziurka, M. (2021). Insight into phytohormonal modulation of defense mechanisms to salt excess in a halophyte and a glycophyte from Asteraceae family. Plant and Soil, 463(1), 1–22. https://doi.org/10.1007/S11104-021-04889-X

Yu, S., Yang, X., Tian, X., Liu, X., Lu, X., Huang, C., & Fu, Z. (2022). The complete chloroplast genome sequence of the monotypic and enigmatic genus Cavea (tribe Gymnarrheneae) and a comparison with other species in Asteraceae. Journal of Genetics, 101(1), 20. https://doi.org/10.1007/s12041-022-01360-3

Zadworny, J. (2024). Lecznicze właściwości Cynara scolymus? Krytyczny przegląd dowodów i molekularnych mechanizmów działania. Herbalism, 10(1), 93–104. https://doi.org/10.12775/herb.2024.008

Zheng, H., Wang, Y., Xu, J., Zhu, T. T., Qin, G. G., Zhou, C. Y., & Wei, H. B. (2024). Anatomical and histochemical features of amphibious Cyperus rotundus. Acta Prataculturae Sinica, 33(6), 155. 10.11686/cyxb2023266

Zhou, Y., Chen, F., Wang, Y., Yun, C., Zou, X., Cheng, N., Zhang, W., Jing, Y., & Li, H. (2024). Understanding of Plant Salt Tolerance Mechanisms and Application to Molecular Breeding. International Journal of Molecular Sciences, 25(20), 10940. https://doi.org/10.3390/ijms252010940