



SCIENTIFIC RESEARCH ON FENUGREEK (*T. FOENUM- GRAECUM L.*) UNDER THE CONDITIONS OF UZBEKISTAN

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Abstract: *This study presents a comprehensive analysis of the morphological and anatomical structure of *T. foenum-graecum L.* (fenugreek) seeds, alongside their germination dynamics under laboratory and field conditions. The results scientifically substantiate the eurythermal nature (tolerance to a wide temperature range) and high adaptive potential of the seeds. It was found that the maximum laboratory germination rate occurs at 28°C (98%), identifying this thermal regime as the most effective environment for accelerating biochemical processes (hydrolysis and respiration). In field trials, the highest yields were recorded in September (92%) and March (89%), proving these periods to be the most favorable in terms of the hydrothermal coefficient. The findings provide a robust scientific basis for the successful cultivation of fenugreek across various agro-climatic regions of Uzbekistan and the optimization of sowing dates. Furthermore, the seed structure was thoroughly investigated using advanced histological methods (rotary microtome, differential staining, and micrometry).*

Keywords: *medicinal, seed, morphology, biomorphology, biomass, temperature, wrinkled coat, anatomy, epidermis, embryo, endosperm, *Trigonella foenum-graecum*, seed anatomy, exotesta, diagnostic features, micrometry.*

1. Introduction. Fenugreek (*Trigonella foenum-graecum L.*), historically referred to as “Hulba and Hilba” in the teachings of Avicenna (Ibn Sina), belongs to the *Fabaceae* (Lindl.) family. It holds significant importance in the pharmaceutical industry, particularly for restoring hormonal balance and treating diabetes mellitus due to its high content of steroid saponins (diosgenin) and the alkaloid trigonelline. Beyond its use in the food industry as a protein source and a spice for managing



pancreatitis, it is widely utilized in traditional medicine as a natural anti-inflammatory agent and a galactagogue to enhance lactation.

Studying the morpho-anatomical (leaf mesophyll and the galactomannan layer in the seed coat), phenological (short vegetation period of 60-90 days), and biometric (stem branching degree and pod count) characteristics of this plant facilitates its successful acclimatization in saline and arid regions, while enhancing agricultural productivity through biological nitrogen fixation.

Currently, global interest in this plant is increasing; it is being extensively researched in pharmaceutical laboratories across South Asia, North Africa, and Europe, leading to the discovery of novel properties such as anticarcinogenic and antioxidant effects. Today, *T. foenum-graecum* L. is widely utilized in biolaboratories, cosmetology, and sports nutrition (as a natural testosterone booster). In Saudi Arabia and other Arab nations, "Hulba" is highly popular; not only are the seeds used, but the fresh green leaves are also consumed as a nutrient-dense food source rich in iron and vitamins, and as a medicinal remedy to increase milk production in nursing mothers. In Saudi Arabia, particularly during the month of Ramadan, traditional dishes like "Saltah" are prepared using fenugreek to improve digestion and maintain energy levels.

Modern biochemical analyses have revealed that *T. foenum-graecum* L. is not only rich in proteins and complex carbohydrates but also contains essential minerals such as selenium, zinc, potassium, phosphorus, magnesium, iron, and calcium, as well as vitamins A, C, B1, B2, B6, B12, and PP, along with high concentrations of folic acid. Furthermore, its unsaturated fatty acid profile (omega-3 and omega-6) closely resembles fish oil, contributing to cardiovascular health [11, 12, 13]. Due to their high phytoncide content, fresh leaves are used in dietary meals globally, while dried leaves (Kasuri Methi) serve as an exceptional functional additive and aromatic spice in numerous food preparations and pharmaceutical teas throughout the Indian subcontinent [13].

In the traditional Indian system of medicine, Ayurveda, this plant is prescribed as a vital remedy for enhancing metabolism and treating various digestive



disorders and mucosal inflammations. The mature seeds of *T. foenum-graecum* L. contain essential amino acids such as lysine and L-tryptophan, alongside unsaturated fatty acids, vitamins, and a complex of steroidal saponins, including diosgenin, gitogenin, neogitogenin, homorientin, saponaretin, neogigogenin, and trigogenin. Furthermore, other bioactive components such as 4-hydroxyisoleucine (a blood sugar regulator), dietary fibers, flavonoids, polysaccharides (galactomannan), fixed oils, and identified alkaloids like trigonelline and choline are present. Due to its potent antiseptic and expectorant properties, the plant is utilized against bronchitis, fever, sore throat, wounds, swollen glands, skin irritations (eczema), diabetes, hypercholesterolemia, and gastric ulcers, as well as for bolstering the immune system [4].

Recently, due to the extensive applications and unique biological activity of *T. foenum-graecum* L., numerous fundamental studies have been conducted globally, including in the USA, India, and Europe, to explore its potential in treating metabolic syndrome and chronic diseases. From the early 1960s through subsequent decades, experimental research on animal models (rats and rabbits) has profoundly investigated the pharmacological effects of aqueous, alcoholic, and essential oil extracts of the seeds. A vast array of clinical and preclinical trials have yielded positive results, demonstrating that the seeds are not only safe for human consumption but also possess high therapeutic efficacy for various systemic diseases. Specifically, its effectiveness in treating Type II diabetes (by increasing insulin sensitivity), its potent antioxidant properties, hypocholesterolemic effects (vascular cleansing), antineoplastic (anti-tumor) activity, and its antimicrobial and anti-inflammatory roles (in rheumatism and arthritis) have been scientifically proven at the molecular level [15].

Various bioactive components of *T. foenum-graecum* L. seeds have been identified and isolated using advanced chromatographic techniques. Long-term clinical trials have extensively documented their therapeutic properties, specifically: polyphenolic flavonoids (apigenin, luteolin, quercetin) which exhibit hypoglycemic, hypocholesterolemic, hypotriglyceridemic, and anti-peroxidative effects that protect



cells from free radicals; steroidal saponins (diosgenin and yamogenin) known for potent anti-inflammatory activity, uterine tone balancing, and stimulating lactation by promoting prolactin secretion; and polysaccharides such as galactomannans, which exert anti-diabetic effects by slowing glucose absorption in the intestines. Furthermore, the unique amino acid 4-hydroxyisoleucine has been shown to possess insulin-mimetic properties, directly stimulating insulin secretion from pancreatic beta cells [16, 18].

Building upon this fundamental data, there is a significant opportunity to introduce and cultivate *T. foenum-graecum* L. within the sharply continental climate and specific soil-climatic conditions of Uzbekistan (including saline and arid lands). By conducting in-depth studies on the biochemical composition, morpho-anatomical features (epidermal structure and secretory channels), and ontogenetic characteristics of locally adapted varieties, scientific and practical recommendations can be developed. This research aims to establish a local raw material base for the highly profitable utilization of fenugreek in the pharmaceutical industry (phytopreparations, dietary supplements) and the food industry (functional spices, dietetic products).

T. foenum-graecum L. The plant is an annual, meadow-cultivated plant. Depending on the ecological conditions, it can reach a height of 30-60 cm, and on fertile soils, up to 80-100 cm. The plant has a root system and its roots contain nitrogen-fixing nodules, such as *Rhizobium meliloti*, which absorb free nitrogen from the air (strong symbiosis with bacteria). The stem is straight, cylindrical, hollow or partially full, branched, with soft rounded edges, sometimes slightly swollen (fleshy) due to the mucilaginous substances it contains. The leaves are compound, trifoliate (three-leafed), meaning that each leaf consists of three small leaflets; the shape is ellipsoid or lanceolate, with finely serrated edges and slightly thickened at the top.

The flowers are white, light yellow or sometimes purple in color. The size is small, located singly on the leaf axils or in a short gulband of 1-2 pieces. Flowering



time is mainly from April to June (up to July, depending on the planting time). It is mainly self-pollinating, but also pollinated by insects due to its high nectar content.

The fruit is a pod, oblong, straight or slightly curved (sword-shaped), ending in a thin beak. The size is up to 10-15 cm long. The seeds inside are smooth, yellow or dark brown in color, and each pod contains 10-20 ovoid-angular seeds. The seeds are angular rhomboid, hard, and diagonally grooved. It is yellow-brown in color and has a characteristic herbaceous (hay) smell due to the coumarin it contains, and a slightly bitter and pungent taste. It is widespread in India, Pakistan, Iran, Turkey, Uzbekistan (all regions of Central Asia), North Africa, and the Mediterranean countries. In Uzbekistan, shambala is mainly grown as a medicinal and spice (Figure 1).

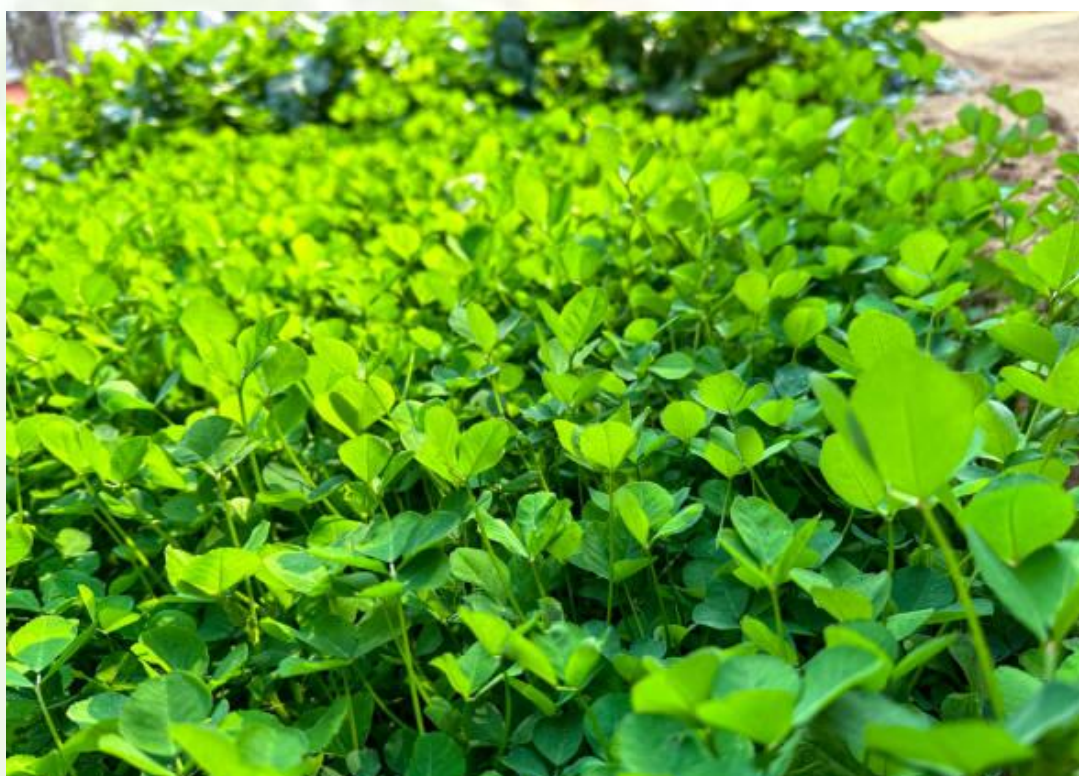


Figure 1. General view of *Trigonella foenum-graecum* L.

2. Materials and Methods. T. in the study of bioecological support and ontogenetic stages of plants. A. Rabotnov [7], I. G. Serebryakov [8] and A. A. The scientific methods of scientists such as Uranov [9] and classical population-ontogenetic methods were used. They identified the plant's methodological diseases,



resistance to various environmental stresses, life form, and growth dynamics in natural and cultural conditions.

T. foenum-graecum L. the seed of the foenum-graecum plant was fixed in a ratio of 1:1 in 70% ethanol alcohol by the "alcohol-glycerin fixation" method (softening method), studied in cross-section in the Fixated material [7].

In the study of anatomical signs of seeds of the *Trigonella foenum-graecum* plant, the method of "histological fixation", preparations made by the "rotational Microtome" method of cross-section of the seed (obtaining serial incisions from seeds hardened to paraffin), as well as a digital light microscope (MOTIC v1) were used.

T. foenum-graecum L. based on the method of "differential staining" of the anatomical preparations of their seeds [21], preperates were dyed with safranin. The linear dimensions of the plant's cells and tissues were measured using a micrometer MOB-15 according to the "Micrometry" method [20, 23]. The few measured traits were seed size, seed coat height, embryo thickness, and endosperm thickness. A. The study was carried out using the "Lakin method" [22] and the "Histological reconstruction" method [21].

Statistical analysis of the data was performed using generally accepted methods on a personal computer (MS Excel). Microphotographs were taken using a high-resolution digital camera (Digital Camera) based on the "Microphotography" method, and mathematical analyses were performed using a MOTIC V1 microscope.

The experimental area is characterized by soils of the typical Boz University under the educational and scientific experience Khojaly of the Tashkent State Agrarian University, and the irrigation system is a well-established experimental area, this land area has all the necessary agrochemical and microclimatic conditions for the scientific study of introduced plants. The study collected long-term comparative data based on biometric (stem metrics, leaf emergence, number of pods) and phenological (phases from germination to maturity) data. Biometric and bioecological monitoring, through dispersion and correlation statistical analysis, obtains accurate things at the level of reliability. All statistical data were

mathematically and statistically processed using Excel and STATISTICA MS-programs, and the results of the analysis of plant vegetative competition indicators and yield were obtained..

3. Results and Discussion. The seeds of *foenum-graecum* L. differ from other legumes in their micromorphological and anatomical characteristics. The seeds are oblique rhomboid or irregularly rectangular in shape, with the surface divided into two unequal parts by a characteristic diagonal groove (sulcus), and with uneven ridges. The specific site (testa) present in the seeds is very hard, with the formation of sclerene, which protects the mortar (embr) from mechanical damage. The color of the seeds of the plant is light yellowish or dark yellowish. It depends on the amount of anthocyanins and flavonoids it contains. The stability of the seeds is determined by their size, which is on average 5-5 mm in length, high germination, and biometric parameters (Figure 2).



Figure 2. Appearance of *Trigonella foenum-graecum* L. seed and leaf raw materials

T. foenum-graecum L. seed organization morphometric appearance the plant's temperate climate is resistant to adaptation to conditions, especially soil



moisture deficiency. The length of the seeds is on average 5-6 mm, and the width is 2-3 mm (thickness 1.5-2 mm). These indicators increase the proportionality, efficiency of the size of the endosperm and murtak (embryo) in the seed. Such optimal sizes help to ensure rapid germination of the seed from the soil and increase the power of the roots to move quickly (due to polysaccharides) (Table 1).

Table 1

Morphological parameters of *T.foenum-graecum* L. seeds

<i>Seeds color</i>	<i>Dimensions (mm)</i>			<i>Weight of 1000 seeds, g</i>
	<i>length</i>	<i>width</i>	<i>thickness</i>	
Yellow or orange and or brown	5-6	2-3	1,5-2	15,4-15,7

T. foenum-graecum L. the absolute weight of the seeds of the plant, that is, the weight of 1000 grains, was on average 15.4-15.7 g. This indicator indicates that the seeds are fully mature and have a high germination endosperm. The study focused on the selection quality of seeds, field germination and production capacity, and the dynamics of safe germination at different planting dates and depths were comparatively studied in field development.

Experiments were carried out in laboratory conditions in 4 variants (with different temperature and humidity regimes) based on international ISTA standards. The growth rates of the radicle and stem of the plants and the cumulative germination rates of the seeds were analyzed individually. Separate control groups and regular phenological observations were conducted to ensure statistical reliability for each option, and the results obtained allowed us to assess the biological potential of the plant.

T. foenum-graecum L. The ecophysiological germination parameters of foenum-graecum L. seeds under different thermal regimes were comparatively analyzed. During the study, in order to determine the temperature requirement of the plant, in 4 controlled temperature conditions (4-7°C, 10-12°C, 18-20°C and 28°C), seeds were sown in a thermostat and their daily germination energy was determined,



as well as the percentage of final laboratory germination. In the study, the metabolic activation of seeds in conditions of a minimum temperature of 4-7°C was slow, the release of the primary murtak rootstock began only on the 6th day, and the overall yield indicator was only 46%. This low value scientifically indicates that Shambhala seeds have a thermophilic (heat-loving) nature and that under such low temperature conditions, an unfavorable stress situation occurs for the seeds due to the blocking of enzymatic processes (mainly amylase activity). The seeds not only remained in a latent state for a long time, but also had a significantly lower overall germination rate due to the increased susceptibility of the embryo to microbiological decay under the influence of low temperatures.

It was observed that the germination dynamics of seeds significantly increased under temperature conditions of 10-12°C. At this moderate temperature, the metabolic processes of Shambhala seeds stabilized, germination began on the 3rd-4th day, and the overall germination rate increased to 68-72%. This result scientifically substantiates that this temperature regime is the minimum acceptable limit for early spring planting of the plant.

Under conditions of 18-20°C (optimal laboratory temperature), the germination energy of the seeds reached its peak. The germination process began rapidly on the 2nd day, and by the 5th day, the total germination rate was 88-92%. At this temperature, the activity of enzymes (alpha-amylase and proteases) reached a maximum, resulting in accelerated vegetative growth of the embryo and uniform germination of seeds.

And in conditions of high temperatures of 28°C, although the germination process began extremely quickly (1-1.5 days), it was observed that some murtaks wither or develop fungal diseases due to rapid evaporation of moisture and thermal stress. This once again confirmed that the range of 18-22°C is the most effective physiological optimum for Shambhala (Table 2).

Table 2

T. foenum-graecum L. indicators of germination according to the temperature regimes



of their seeds (laboratory experiment)

Temperature regime (°C)	Start of flowering (day)	Germination energy (3rd day, %)	Final uniqueness (%)	Note (Physiological state)
4-7°C	6-day	0%	46%	Minimum temperature, stress effect
10-12°C	3-day	22%	71%	Moderate activation effect
18-20°C	2-day	65%	92%	Biological “optimal” developmental effects
28°C	1-day	78%	84%	Fast tensile, but thermal stress risk effect

The results of the study show that *T. foenum-graecum* L. for germination of seeds, a temperature of 18-20 C is the most optimal (optimum). At this temperature, the enzymatic activity of the embryo reaches its maximum, and the hydration (water absorption) of the seed coat and hormonal balance (synthesis of gibberellins) occur at the highest rate. Also, low tensile strength (46%) at 4-7°C proves that Shambala is a thermosensitive plant, while the result at 28°C proves that the biological stability of murtak decreases slightly (84%) if the germination accelerates at high temperatures. This information is an important agrotechnical indicator that indicates the timing of planting the Shambala plant in the conditions of Uzbekistan, namely, that it should be planted when the soil temperature reaches at least 10-12 C.



Figure 3. Germination rate of *Trigonella foenum-graecum* L. plant seeds in laboratory condition

The highest research results were recorded at a temperature of 28°C. Under these thermal conditions, the murtak activity of seeds rose to its maximum, the germination process began rapidly from the 3rd day, and by the 7th, laboratory germination was at a record level of 98%. This result is T. The temperature of 18-20°C for foenum-graecum L. seeds is not only favorable, but also scientifically proven to be the most effective (optimum) environment for accelerating biochemical processes (hydrolysis and respiration).

The dynamic results obtained show that the germination of Shambhala seeds in laboratory conditions is directly and positively correlated with ambient temperature. As the temperature gradient increased from 4-7°C to 10-12°C to 18-20°C, the percentage of germination and energy of development of the seeds increased linearly. In particular, the 92% rate observed at 18-20°C indicates that the seeds of this plant belong to the eurythermal (resistant to a wide temperature range) group according to the ecological classification and their high adaptive potential.

As a eurythermal plant, Shambhala has the ability to germinate and develop over a wide temperature range, which determines its high adaptability to various agroclimatic regions and changing weather conditions. This plasticity feature serves as a solid scientific basis for the successful cultivation of the Shambala plant in



various regions of Uzbekistan, including southern districts with hot climates, with stable and high yields.

At the same time, it was found that the temperature affects not only the percentage of total germination, but also the germination time of seeds. At low temperatures, seed germination was delayed, while at high temperatures it started rapidly. This situation is important in determining the time and conditions for sowing seeds in the agricultural production process.

Field-condition studies were carried out in the spring and autumn seasons, in order to determine the climatic plasticity of the plant, on the basis of a two-repeat (replicated) system that provides scientific reliability. This approach allowed real-time monitoring of the Shambala plant's response to natural Photoperiodism (day length) and variable temperature gradient, as well as its mechanisms of ecological adaptation (adaptation) to local soil-climate conditions. The experimental fields were carefully prepared based on the requirements of the crop, taking into account the mechanical composition and moisture capacity of the soil.

The phenological, morphological and biometric monitoring methods used in the research process made it possible to record in detail all qualitative and quantitative changes in the stages of ontogenesis of the plant - from the formation of the seed cell to the phase of full ripening. In particular, modern methodological approaches were used to determine the morphological and ecological parameters of the plant, including the leaf area index and stem growth rate.

A comprehensive analysis of nutrient samples in the soil layer and plant phytomass samples helped to accurately determine the growth efficiency of Shambala in the agroecosystem and its tolerance limits to external environmental factors. High accuracy and methodological approaches were used to determine the morphological and ecological characteristics of plants. Analysis of soil and plant samples made it possible to study the plant's adaptation to its growth conditions.

T. The results of the long-term experiments on the field germination of foenum-graecum L. seeds were analyzed and scientifically enriched as follows. According to it, the spring sowing dates are as follows:



- In February (10.02.2023). Despite an air temperature of 26°C (abnormal warming) and a soil temperature of 17.6°C, the relative humidity of 55.5% caused the surface layer of the soil to dry quickly. Due to the imbalance of this hydrothermal coefficient, germination was only 50.5-58.0%. Such unstable conditions in February were not enough for the seeds to write a stable murtak;

- In March (10.03.2023). The air temperature was 15°C and the soil temperature was 18.0°C with a relative humidity of 59.0%. This combination of moderate temperature and optimal humidity has created the most favorable environmental environment for Shambala, and the solubility has risen to 80.0-89.0%. This result confirmed that march is the optimum period for the main spring planting;

- In April (10.04.2023). A decrease in air temperature to 13°C and an increase in relative humidity to 71.2% caused excess moisture and lack of air in the soil. As a result, germination decreased to 51.0-63.0%, and some of the seeds were affected by fungal diseases.

The autumn planting dates were also analyzed:

- In September (10.09.2024). During this period, the air temperature was 31°C and the soil temperature was 20.1°C, with a relative humidity of 61.0%. These indicators fully correspond to the eurythermal nature of Shambhala, ensuring a record-breaking germination rate of 90.0-92.0%. September was found to be the most effective period for autumn planting and enriching the soil with biological nitrogen.

- In October (10.10.2024). With a decrease in temperature to 25°C, the germination rate fell to the range of 57.0-69.0%. Although the humidity was balanced (60.7%), the shortened growing season and photoperiodic changes slightly reduced the germination energy.

- In November (10.11.2024). The air temperature dropped to 6°C, causing an enzymatic blockage in the seeds. Although the soil temperature (16.6°C) remained constant, the cold air prevented the emergence of the embryo to the surface, and germination was minimal, at 46.0-48.0%.



The results obtained show that March and September are the most effective planting periods for the Shambhala plant in Uzbekistan, and the balance of temperature and humidity in these months provides the basis for the formation of a high-quality agrophytocenosis (Table 3).

Table 3

Fenugreek (*T. foenum-graecum*) the dynamics of sowing seeds according to sowing time (%)

Sowing dates	Number of seeds planted, pcs.	Air temperature (t°c)	Soil temperature (°C)	Relative air humidity (%)	Uniqueness (%)
10.02.2023 (February)	100x4	26°	17,6°	55,5%	50,5 - 58,0
10.03.2023 (March)	100x4	15°	18,0°	59,0%	80,0 - 89,0
10.04.2023 (April)	100x4	13°	16,7°	71,2%	51,0 - 63,0
10.09.2024 (September)	100x4	31°	20,1°	61,0%	90,0 - 92,0
10.10.2024 (October)	100x4	25°	17,9°	60,7%	57,0 - 69,0
10.11.2024 (November)	100x4	6°	16,6°	63,8	46,0 - 48,0

A comparative analysis of the research results shows that there are extreme and optimal points for germination of the Shambhala plant in field conditions. According to it, the highest fertility rates were observed in September (92%) and March (89%). The high result in September (31°C air and 20.1°C soil temperature) confirms the plant's eurythermal nature and thermophilicity. The high yield in March is explained by the mutual biological balance of soil moisture and temperature (18°C). The low rate in November (46-48%) indicates that the sharp drop in air



temperature to 6°C weakened the embryo's respiratory energy. Despite the anomalous heat (26°C) in February, low tensile strength (50-58%) is due to the rapid loss of moisture in the surface layer of the soil at the expense of evaporative (evaporation) and the complete absence of bulging of seeds. High humidity in April (71.2%) combined with low temperatures created anaerobic conditions (oxygen deficiency) in the soil, preventing germination of seeds by more than 63%.

T. foenum-graecum L. analysis of the field uniqueness of their seeds showed that March and September are the most favorable terms in terms of hydrothermal coefficient (humidity and temperature proportionality). During these periods, the temperature and relative humidity in the 0-10 cm layer of the soil maximally activated the energy of the seed embryo, leading to high biological efficiency (89-92%). Conversely, low air temperatures in April and November, as well as highly saturated soil moisture, caused a metabolic blockage in the seeds, reducing germination rates.

T. foenum-graecum L. the morphology of the seeds, the dynamics of germination in field and laboratory conditions were comprehensively studied, which made it possible to analyze the internal microscopic structure of the seed and identify anatomical and diagnostic (identification) features characteristic of the plant.

The seed is the main generative organ of seed plants, which has a complex structure: the seed stem (testa), the Reserve nutrient tissue - the endosperm, and is made up of the murtak, which is the basis of the future plant [1, 2].

The chambala seed is covered with a tough shell consisting of sclerenchyma cells on the outside, which protects the embryo from drying out, pathogenic microorganisms, and mechanical damage.

The endosperm is a highly energy-rich tissue within the seed that surrounds the embryo and provides it with nutrients during the initial heterotrophic developmental stage. The perisperm also plays an important role in the Shambhala seed; it is the main reserve tissue that contains not only macro- and microelements (Fe, Mg, Ca, P), but also protein, starch, sugar, vitamins, and lipids.

The embryo, located under the seed coat, contains the genetic program of the young plant. *T. foenum-graecum* L. Biochemical analysis of the seeds shows that they contain essential amino acids, essential for the human body, essential oils, minerals, an inactive enzyme system, and unsaturated fatty acids such as omega-3 and omega-6. These seeds are not only medicinal raw materials, but also a rich natural source of biologically active food additives and medicinal herbal oils [3, 5, 10].

The seed is round in cross-section and covered with a seed coat on the outside (Figures 4 and 5).

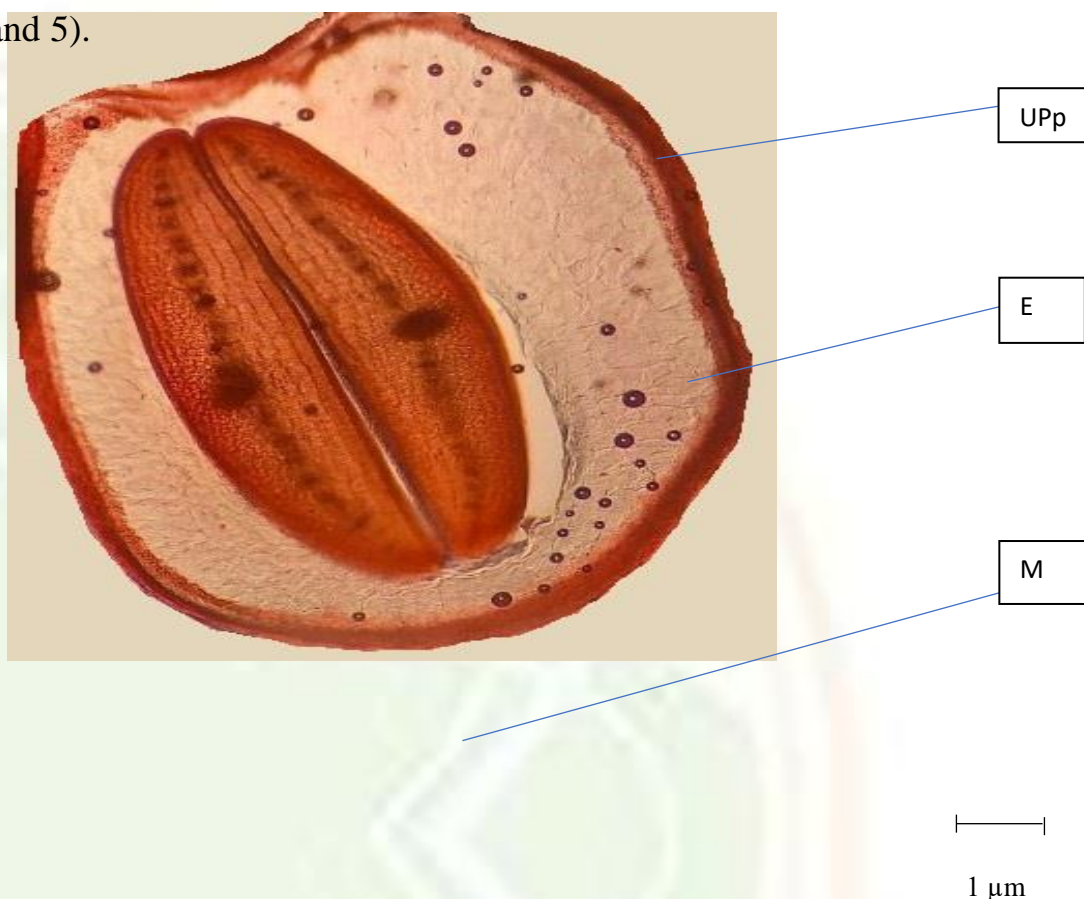


Figure 4. Internal structure of the seed of the plant *T.foenum-graecum* L.: UP-seed coat, E-endosperm, M-embryo

The Stem is multi-layered, protecting the mortar from various external influences and drying out, premature germination. At the base of the trunk is a mortar and an endosperm (4 and 5 photos).

The endosperm is a tissue inside the seed that provides nutrients to the plant during its development. *T. foenum-graecum* L. the endosperm of its seed consists of large, thin-walled host parenchyma cells.

Nutrients are stored inside the protoplast - mainly secondary starch granules, protein granules, and unsaturated fats (lipids) (Figure 5).

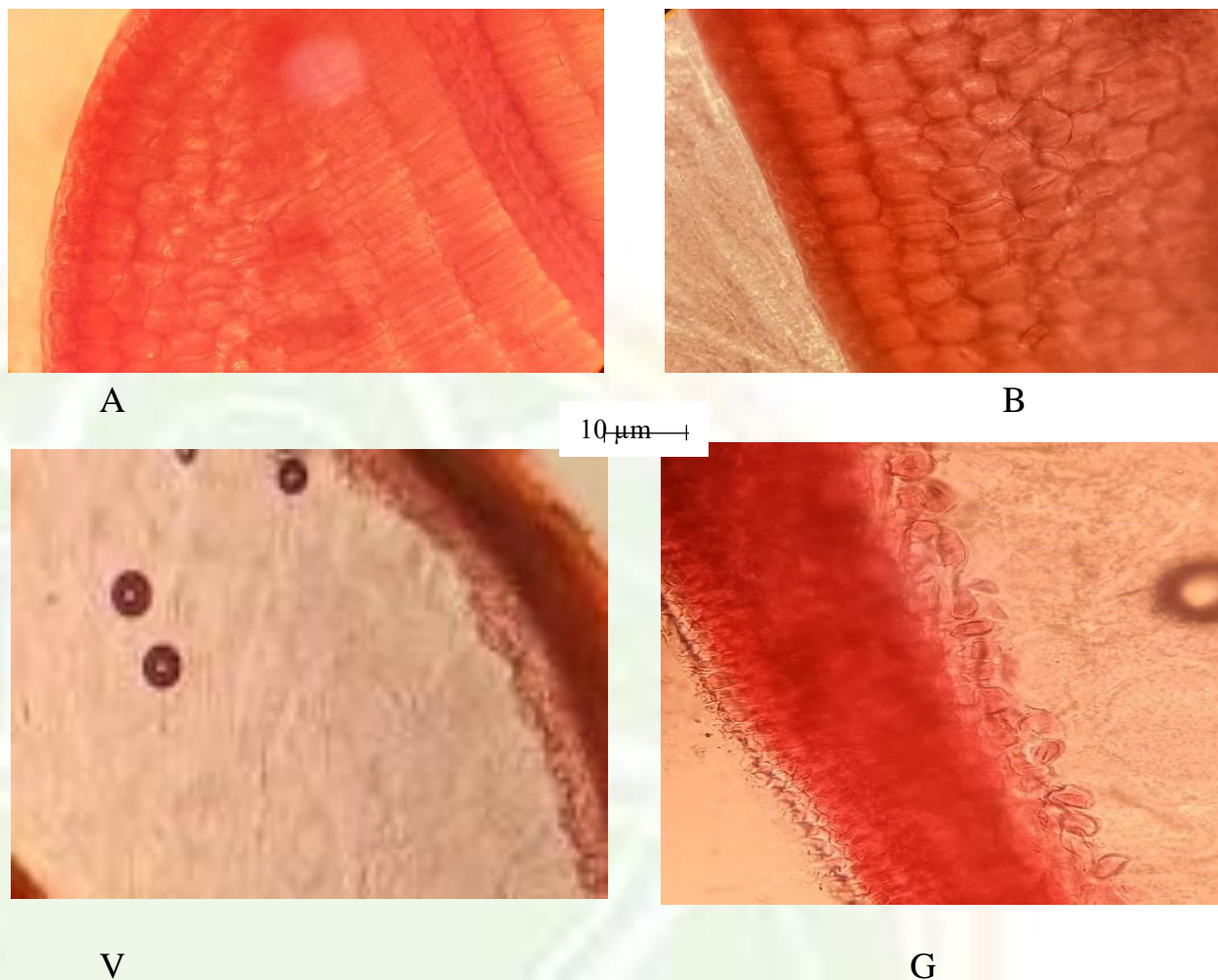


Figure 5. *T. foenum-graecum* L. microscopic appearance of murtak (a, B) and endosperm tissue (V, G) of plant seeds

The seed coat consists of rectangular and oval epidermal cells arranged in a palisade-like manner, which are very tightly packed together. Anatomical measurements show that the total height of the seed coat is 10-15% of the thickness of the entire seed. The endosperm consists of parenchyma tissue, which is densely packed and rich in macro- and microelements, hormones, and chemicals.

The endosperm tissue located under the shell consists of layers of large, densely packed parenchyma cells (Table 4).

Table 4***T. foenum-graecum L. anatomical indicators of seed structure***

<i>№</i>	<i>Symbols</i>	<i>Indicators, μm</i>
1.	Seed diameter	22,1±0,5
2.	Seed coat thickness	1,6±0,1
3.	Endosperm thickness	6,3±0,3
4.	Embryo thickness	9,7±0,4

Diagnostic signs: anatomical-diagnostic analysis of plant seeds shows that its specific structure is characterized by the cells of the Palisade (exotesta), where it is located extremely steep, and parenchyma tissue, which is rich in reserve substances. The presence of a large and well-developed murtak (embryo), which occupies a special place in the interior of the seed, occupying at least 50% of the total volume of the seed, indicates its high tensile potential. The presence of special secretory ducts and essential oil glands in the seed coat and embryo sac is the main diagnostic feature that determines the localization of biologically active substances (coumarins, steroidal saponins) in the composition. The high concentration of macro- and microelements (especially iron, phosphorus, and calcium) in the embryo and endosperm tissues scientifically confirms the high nutritional and pharmacological value of the plant.

Conclusion. Based on the comprehensive research conducted, the following conclusions were reached:

- The results of the study show that the most favorable periods for sowing Shambhala seeds in Uzbekistan are the first ten days of March and mid-September. These terms allow for an increase in field germination of seeds by 30-40%;

- *T. foenum-graecum L.* It has been proven that the plant has a high level of adaptability to the sharply continental climate and various soil conditions (saline and arid lands) of Uzbekistan, and its eurythermal nature;

- The highest germination rates of plant seeds in the field were recorded in March (89%) and September (92%), indicating that these periods are the most favorable for industrial-scale cultivation;



- Diagnostic signs in the morpho-anatomical structure of plant seeds (palisade layer thickness, embryo size) serve as reliable criteria for verifying the authenticity of the plant as a raw material (standardization);

- The results of this study provide a solid scientific and theoretical basis for the widespread use of the Shambala plant in the Republic of Uzbekistan in the field of Medicine (phytopreparations), food industry (natural source of spice and protein), as well as in livestock (high-nutrient crop).

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