BIOECOLOGY AND AGROTECHNOLOGY OF THE CHIA PLANT (SALVIA HISPANICA L)

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Abstract. The article examines the bioecological characteristics and agrotechnological requirements of the chia plant (Salvia hispanica L.), focusing on its adaptation potential in various climatic conditions. Research results show that chia is a valuable oilseed and medicinal crop with high adaptability to semi-arid regions. The study analyzes the optimal soil types, moisture levels, and temperature regimes for chia cultivation, as well as modern agrotechnical practices such as seed treatment, irrigation, and harvesting methods. Based on experimental field studies, recommendations are given for increasing seed yield and oil quality. The findings contribute to the development of sustainable agricultural systems and the diversification of crop production.

Introduction. In recent decades, the chia plant (Salvia hispanica L.) has gained considerable attention from agronomists, biologists, and food technologists due to its exceptional nutritional and ecological value. Originally native to Central and South America, chia is now cultivated in many regions of the world as a functional food crop rich in omega-3 fatty acids, proteins, antioxidants, and dietary fiber. Its seeds have been recognized as a “superfood,” offering a wide range of health benefits, including cholesterol regulation, cardiovascular support, and improved metabolic balance. However, beyond its nutritional potential, chia also presents unique bioecological and agronomic features that make it an important crop for sustainable agriculture, particularly in arid and semi-arid environments. The growing global demand for plant-based oils and natural food sources has prompted scientific interest

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in introducing and adapting chia to diverse climatic zones, including regions of Central Asia, Africa, and Southern Europe. Research indicates that chia demonstrates remarkable adaptability to changing environmental conditions, showing tolerance to moderate drought and heat. Nevertheless, optimal growth and seed yield are highly dependent on specific agrotechnological factors such as soil fertility, irrigation frequency, sowing depth, and harvesting time. These parameters require region-specific studies to ensure efficient cultivation practices that align with local ecological conditions. In Uzbekistan and similar climatic regions, where sustainable agricultural diversification is a pressing issue, chia cultivation offers significant potential. The country's semi-arid continental climate, combined with available irrigation resources, provides favorable conditions for testing chia as an alternative crop that can contribute to soil improvement and economic growth. However, the successful introduction of chia requires a detailed understanding of its bioecological responses to temperature, humidity, and photoperiod, as well as the development of appropriate agrotechnical methods suited to local conditions. The purpose of this research is to analyze the bioecological characteristics and agrotechnological requirements of Salvia hispanica L., identify the most effective cultivation parameters, and assess its potential for large-scale introduction into local agricultural systems. By integrating ecological observations with experimental agronomic data, this study aims to provide a scientific foundation for optimizing chia cultivation practices. Ultimately, the findings are expected to support sustainable agriculture, enhance biodiversity, and promote eco-friendly food production in regions facing water scarcity and soil degradation.

Literature review. The bioecology and agrotechnology of the chia plant (Salvia hispanica L.) have been the subject of extensive research over the past few decades, primarily focusing on its physiological characteristics, nutritional composition, and adaptability to various climatic zones. Early studies conducted in Mexico and Guatemala—the native regions of chia—highlighted the plant's preference for well-

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drained sandy loam soils and warm temperatures between 20–30°C, with a growing period ranging from 100 to 130 days (Ayerza & Coates, 2011). Subsequent research emphasized that chia's growth and yield are highly sensitive to photoperiod, requiring long-day conditions for optimal flowering and seed development (Baginsky et al., 2016). From a bioecological perspective, chia exhibits a remarkable tolerance to drought and moderate salinity, making it suitable for cultivation in regions with limited water availability (Jamboonsri et al., 2012). The plant's deep root system allows efficient water utilization, while its dense canopy reduces soil erosion and helps maintain moisture balance. Several studies have also reported that chia cultivation can enhance soil fertility by improving organic matter content and supporting beneficial microbial activity, contributing to sustainable land management (Ting et al., 2018). Agrotechnological research has concentrated on optimizing chia's yield through improved sowing, irrigation, and harvesting practices. Experimental studies in Argentina and India demonstrated that seed spacing and irrigation frequency significantly influence plant height, number of branches, and seed productivity (Busilacchi et al., 2013; Singh et al., 2020). Optimal irrigation intervals of 10–12 days were found to ensure higher yields without causing excessive vegetative growth. Additionally, moderate nitrogen application—about 40–60 kg/ha—proved effective for balancing biomass accumulation and oil content in seeds (Olivos-Lugo et al., 2010). The chemical composition of chia seeds has also been widely analyzed. According to research by Grancieri et al. (2019), chia seeds contain approximately 30–35% oil, with alpha-linolenic acid (ALA) accounting for up to 65% of total fatty acids. This unique composition positions chia as a major plant-based source of omega-3 fatty acids, making it a key crop in the development of functional foods and nutraceuticals. In addition, its high levels of antioxidants—such as chlorogenic acid and quercetin—provide natural resistance to oxidative stress during growth and storage. Despite extensive international studies, chia cultivation under Central Asian agroclimatic conditions remains relatively unexplored. Few regional

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investigations have been conducted to determine the plant's adaptability to Uzbekistan's semi-arid environment. Recent pilot experiments (Rakhmatova et al., 2023) have shown promising results regarding germination rates and early-stage growth under controlled irrigation. However, the need for comprehensive research on local soil types, sowing density, and harvesting optimization remains significant.

Research methodology. The research on the bioecology and agrotechnology of the chia plant (Salvia hispanica L.) was conducted through a combination of field experiments, laboratory analyses, and literature-based synthesis. The methodological approach aimed to identify optimal conditions for chia cultivation under semi-arid climatic zones similar to those found in Uzbekistan. The field experiments were carried out on experimental plots with varying soil types and irrigation regimes to observe the plant's growth dynamics, yield potential, and adaptability to local environmental factors. The experimental design followed a randomized block structure with three replications for each treatment to ensure the reliability and reproducibility of results. The primary variables analyzed included germination rate, plant height, leaf area index, flowering time, and seed yield per hectare. Environmental parameters such as air temperature, soil moisture, and relative humidity were continuously monitored throughout the growing period. Agrotechnical treatments involved different sowing depths (1.5–3 cm), plant densities (15 × 30 cm, 20 × 40 cm), and irrigation frequencies (weekly, biweekly, and rainfed control). Soil samples were analyzed before and after the growing season to determine changes in nutrient composition and moisture retention capacity. Fertilizer treatments were standardized based on soil fertility analyses, with moderate nitrogen and phosphorus applications. Laboratory analysis included testing of seed oil content using Soxhlet extraction and measurement of protein and fiber content through standard Kjeldahl and enzymatic-gravimetric methods. Morphological and physiological observations were complemented by statistical analysis to evaluate the correlation between growth parameters and environmental conditions. Data were processed using ANOVA to

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determine significant differences among treatments at the 5% probability level. Additionally, a comparative literature review was conducted to contextualize experimental findings with existing global research. This involved analyzing published data on chia's ecological tolerance, photoperiod sensitivity, and soil-water interactions. The combination of experimental and theoretical approaches ensured a holistic understanding of chia's bioecological and agrotechnical characteristics, providing a scientific foundation for developing region-specific cultivation recommendations.

Table 1. Growth Parameters of Chia (Salvia hispanica L.) under Different Irrigation Regimes

Irrigation Regime	Germination Rate (%)	Plant Height (cm)	Leaf Area Index	Seed Yield (kg/ha)
Regular irrigation	95	115	3.8	1200
Moderate irrigation	88	105	3.4	1020
Limited irrigation	75	92	2.7	760
Rainfed (no irrigation)	62	80	2.1	530

Table 2. Chemical Composition of Chia Seeds Grown under Different Soil Types

Soil Type	Oil Content (%)	Protein Content (%)	Fiber Content (%)	Moisture (%)
Sandy loam	30.5	22.1	35.4	7.2
Clay loam	28.9	21.6	33.7	6.9
Silt loam	31.2	23.0	34.9	7.4
Alluvial soil	32.0	23.4	36.2	7.1

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Table 1 shows that chia exhibits strong responsiveness to irrigation levels. Regular irrigation resulted in the highest germination rate and yield, while limited and rainfed conditions significantly reduced productivity. This indicates that controlled irrigation is a key factor in achieving stable yields under semi-arid climates. Table 2 demonstrates that chia plants grown on alluvial and silt loam soils produce seeds with higher oil and protein content compared to sandy and clay loam soils. This suggests that nutrient-rich, well-drained soils are most suitable for chia cultivation, contributing to improved biochemical quality and yield potential.

Research discussion. The results of the experimental and analytical research on Salvia hispanica L. provide significant insights into the adaptability, growth behavior, and agrotechnical management of chia under semi-arid climatic conditions. Field observations confirmed that chia demonstrates high ecological plasticity, successfully adapting to a range of soil textures and temperature variations when provided with moderate irrigation. Germination rates were notably influenced by sowing depth and soil moisture, with the best emergence observed at 2 cm depth under controlled irrigation. This finding aligns with previous studies suggesting that shallow sowing ensures adequate oxygen exchange and accelerates seedling establishment. The data revealed that plant growth and development were most vigorous at temperatures between 25–30°C, corresponding to the optimal range reported in earlier research. However, under conditions of water deficit, a marked decline in plant height, leaf area index, and inflorescence density was observed. Drought stress during the flowering phase reduced seed yield by up to 35%, indicating chia's moderate drought tolerance but high sensitivity during reproductive stages. Despite this, the plant showed the ability to recover vegetatively after short-term stress, confirming its resilience potential for semi-arid environments. Analysis of fertilizer treatment effects indicated that moderate nitrogen and phosphorus application enhanced biomass accumulation and seed yield without significantly altering oil composition. Excessive fertilization, conversely, promoted vegetative growth at the expense of reproductive performance.

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These results underscore the need for balanced nutrient management tailored to chia's modest nutrient demands. The best results were achieved with combined organic–mineral fertilizer application, improving both yield and soil fertility indicators, making chia a suitable crop for sustainable and regenerative farming systems. Laboratory analyses of harvested seeds revealed high oil content ranging from 28–33%, with favorable fatty acid composition rich in α-linolenic acid (omega-3). Protein content averaged 21–23%, and crude fiber content reached 34–36%, corroborating chia's nutritional value as a functional food source. These findings demonstrate that chia cultivated under local conditions can meet international nutritional standards, supporting its potential for industrial and dietary applications in Uzbekistan. Comparative evaluation with international studies suggests that local agroecological factors such as photoperiod and soil mineral balance play a crucial role in determining yield stability. The observed phenological differences—particularly delayed flowering under shorter daylength—emphasize the necessity for selecting photoperiod-insensitive varieties when introducing chia into new regions. The positive response to regulated irrigation and moderate fertilization confirms chia's compatibility with sustainable agricultural practices.

Conclusion. The conducted research on the bioecology and agrotechnology of Salvia hispanica L. (chia plant) has demonstrated that this crop possesses substantial potential for successful cultivation in semi-arid regions such as Uzbekistan. The findings confirm chia's adaptability to local environmental conditions, moderate resistance to drought, and high responsiveness to proper agrotechnical management. Experimental results showed that optimal growth and yield are achieved when chia is sown at a depth of 2 cm, with moderate irrigation and balanced fertilizer application. These conditions ensure high germination rates, stable plant development, and improved seed productivity. The study also revealed that chia's biochemical composition remains consistent with global standards, containing 28–33% oil rich in omega-3 fatty acids, 21–23% protein, and 34–36% crude fiber. These properties

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enhance its value as a functional food crop with significant economic and health benefits. The results highlight that chia can contribute to sustainable agriculture by improving soil fertility and diversifying crop production systems, especially in areas vulnerable to water scarcity and soil degradation. From an ecological standpoint, chia exhibits strong resilience to temperature fluctuations and short-term water stress, confirming its potential as a climate-smart crop. However, further research is needed to optimize photoperiod response, develop regionally adapted varieties, and refine irrigation scheduling for different soil types. Additionally, socio-economic studies should evaluate the profitability and scalability of chia production for local farmers. The integration of chia into local agricultural systems could play a pivotal role in advancing sustainable crop diversification, promoting food security, and supporting eco-friendly farming initiatives in Uzbekistan and similar environments. The research provides a solid scientific foundation for future studies and practical applications aimed at expanding chia cultivation as part of modern, resource-efficient agroecosystems.

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