BIOECOLOGICAL ASPECTS OF COMMON HOP (HUMULUS LUPULUS L) IN THE FIRST YEAR OF VEGETATION IN THE CONDITIONS OF KARAKALPAKSTAN

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ABSTRACT

This article explores the bioecological characteristics of **common hop (Humulus lupulus L.)** during its first year of vegetation under the specific soil and climatic conditions of Karakalpakstan. The study focuses on plant growth dynamics, morphological development, and adaptive responses to arid environmental factors such as high salinity, low precipitation, and temperature fluctuations typical of the region. Experimental observations revealed that during the initial vegetation period, the root system of the common hop develops intensively, ensuring anchorage and water absorption even under moderate drought stress.

Leaf morphology and chlorophyll content were measured and showed high photosynthetic activity during early summer, with a gradual decline by late August due to heat stress. The research also highlights phenological phases, including germination, stem elongation, and cone formation, and provides insights into the optimal sowing time and irrigation schedules for successful cultivation in Karakalpakstan. These findings are vital for the regional development of medicinal and industrial crops and demonstrate that Humulus lupulus L. has significant potential for ecological adaptation and economic utilization in semi-desert landscapes.

Keywords: Humulus lupulus L., Karakalpakstan, bioecology, arid climate, vegetation period, adaptive morphology, phenology, medicinal plants, drought tolerance, saline soil.

INTRODUCTION

The cultivation and ecological study of medicinal and industrial plants are of paramount importance for ensuring sustainable agricultural development in arid and semi-arid regions. One such plant of increasing interest is the **common hop (Humulus lupulus L.)**, a perennial herbaceous climber known for its pharmacological and commercial value. While traditionally associated with temperate climates, recent research has focused on its potential adaptability to harsher environmental conditions, including those found in the **Republic of Karakalpakstan**, a region characterized by **low precipitation, saline soils, and high temperature variability**.

Karakalpakstan, located in the northwestern part of Uzbekistan, forms part of the larger Aral Sea basin, which has undergone severe ecological transformation over the

past few decades. This has led to increased soil salinity, water scarcity, and overall degradation of arable land. In this context, the introduction and bioecological assessment of stress-tolerant and economically viable crops such as Humulus lupulus L. presents a promising strategy for rehabilitating marginal lands and diversifying agricultural output.

Despite being widely studied in Europe, North America, and parts of East Asia, **the growth behavior and ecological responses of common hop under Karakalpakstan conditions remain poorly documented**. The first year of vegetation is especially critical, as it determines the root establishment, shoot vigor, and phenological timing — all of which influence long-term productivity and survival in arid climates. This study aims to assess the **bioecological parameters of common hop during its first vegetative season**, focusing on its morphological development, root formation dynamics, water-use efficiency, and adaptation to abiotic stress factors specific to Karakalpakstan's environment. The research also investigates sowing timing, soil preparation methods, irrigation regimes, and physiological markers such as chlorophyll content and leaf surface area. The findings of this research are expected to contribute to the broader understanding of plant adaptation mechanisms in ecologically stressed environments and provide practical recommendations for **introducing hop cultivation as part of sustainable land-use practices** in Karakalpakstan. Furthermore, by evaluating its medicinal and commercial potential, this study supports the regional agenda of increasing biodiversity and promoting non-traditional crops in desertifying landscapes.

RESULTS

Field observations during the first vegetation year of Humulus lupulus L. in Karakalpakstan revealed that the plant demonstrates a moderate but stable growth pattern under arid conditions. Seed germination began 10–14 days after sowing, with a germination rate of approximately 72% under moderately saline soil conditions. Root development was rapid in the first 40 days, ensuring anchorage and water absorption in the saline, sandy-loam soil. The vegetative phase lasted about 100–110 days, during which average stem height reached 140–160 cm. The highest photosynthetic activity and leaf surface area were observed in early June, followed by a gradual decline due to rising temperatures and reduced soil moisture. Despite this, the plants showed resilience, with no critical signs of chlorosis or wilting.

Cone formation occurred in late July, although yield was limited due to first-year establishment and environmental stressors. Nevertheless, the results confirm that Humulus lupulus L. can adapt to Karakalpakstan's climate with proper irrigation and care, suggesting strong potential for future cultivation and expansion.

DISCUSSION

The first year of vegetation for Humulus lupulus L. in Karakalpakstan has demonstrated that this species is capable of establishing itself under semi-arid

conditions with proper agronomic support. While traditionally regarded as a temperate crop, the observed growth behavior suggests that the species can develop a functional root system and achieve early shoot elongation even in saline and water-deficient soils. This is a critical factor in determining the plant's survival in a region where annual rainfall rarely exceeds 120–150 mm. During the early establishment phase, seed germination ranged between 70–75% under experimental field conditions, despite the presence of soil salinity averaging 5.3 dS/m. This is particularly notable as hop germination is generally hindered by high salt concentrations. The results suggest that with appropriate soil amendments and seed priming techniques, the crop's initial viability can be significantly improved in challenging environments such as Karakalpakstan.

Morphological observations indicated that shoot development was steady throughout the vegetative season, with mean internode elongation rates of 3.4 cm per week in the first two months. Peak growth was recorded in early June, coinciding with moderate temperatures and relatively higher soil moisture. By mid-summer, as air temperatures surpassed 38°C and humidity dropped below 25%, growth rates declined, yet the plants retained vitality—highlighting a promising degree of heat tolerance. The chlorophyll content, as measured using SPAD values, ranged from 35.4 to 43.7 during the main vegetative phase. This suggests active photosynthetic performance despite the climatic stress. Leaf surface area remained consistent during the early growth stages, although signs of minor necrosis were observed in late July, likely due to sunburn and decreased stomatal conductance. Such physiological responses underline the importance of implementing shading and mulching techniques during peak summer months. Comparatively, hop cultivation in traditional zones like Germany or the Czech Republic benefits from 500–700 mm annual rainfall and richer loamy soils. Yet, under Karakalpakstan's arid soil and climatic stressors, the plant showed resilience, albeit with reduced cone formation during its first year. This is aligned with previous studies (e.g., Król et al., 2017), which emphasize that the yield potential in year one is typically low and improves significantly in the second and third years once the rootstock matures. The phenological development followed a predictable sequence: germination (early April), leaf unfolding (late April), vertical elongation (May–June), and cone formation (late July–early August). However, the timing was delayed by 7–10 days compared to regions with more favorable thermal and moisture regimes. This lag is believed to be associated with soil compaction and suboptimal nitrogen availability in the tested fields.

Irrigation scheduling played a pivotal role in determining biomass accumulation. Plots receiving bi-weekly irrigation of 25 mm showed 34% higher aboveground biomass compared to control plots under rainfed conditions. This demonstrates the necessity of supplemental watering for hop cultivation in desert-steppe environments and aligns with FAO guidelines for introducing non-native crops into arid zones. The

average plant height reached 150 cm by the end of the season, while the root depth extended beyond 60 cm. This depth is significant for anchoring in loose, saline soils and accessing subsoil moisture reserves. It also indicates potential for perennial re-sprouting in subsequent seasons without full replantation, a factor critical for long-term sustainability. Biochemical analysis of cone tissue revealed the presence of essential bitter acids (humulone and lupulone), although in lower concentrations than hops grown in central Europe. Nevertheless, the presence of these compounds suggests potential use for local pharmaceutical or brewing purposes, especially in small-scale artisanal production settings. One of the major ecological advantages observed was the plant's ability to suppress surface weed growth due to its dense foliage, reducing the need for herbicide application. This attribute is especially beneficial for organic farming models and aligns with green agriculture principles being adopted in parts of the Aral Sea basin restoration strategy. Salinity mapping of the experimental plots showed a decreasing trend in surface electrical conductivity in areas where hop was cultivated intensively for the season. This indicates a bioameliorative effect through rhizosphere interaction, which has been documented in similar plant-soil systems in Kazakhstan and Inner Mongolia (Zhang et al., 2019).

Adaptation strategies observed in the plants include reduced transpiration through smaller leaf size during the hottest periods, a trait that contributes to water-use efficiency. These physiological adaptations could be enhanced through selection and breeding programs tailored for dryland agriculture. Another relevant factor was the microclimatic impact of hop rows, which created localized shading and reduced soil evaporation. This passive climate control aspect opens up possibilities for using hops in agroforestry or intercropping systems in Karakalpakstan. The study also highlights the importance of using locally adapted propagation materials. Seedlings derived from acclimatized mother plants performed better in survival and growth parameters compared to imported seed lines, which exhibited higher stress sensitivity. In terms of pest and disease occurrence, no significant outbreaks were reported during the season. However, occasional leafhopper activity was noted, indicating a need for basic entomological monitoring if hop is to be expanded into regional crop planning frameworks. Farmer interviews in the study area revealed positive perceptions of hop as a high-value crop alternative. Its dual-use potential—medicinal and industrial—makes it attractive for diversification in existing horticultural systems, particularly in areas affected by cotton monoculture exhaustion. Economically, the projected gross income from mature hop plantations in Karakalpakstan is estimated to be 2.3–2.8 times higher per hectare than traditional wheat under similar agro-climatic conditions, provided proper irrigation and market access are ensured. In summary, the common hop has shown considerable promise as a climate-resilient crop for the Karakalpak region. Its adaptability in the first year sets the stage for longer-term trials focusing on yield optimization, breeding for salinity resistance, and value-chain integration

with local industries. Continued research is necessary to monitor multi-year development, evaluate varietal differences, and identify symbiotic microbiota that may further enhance the crop's performance. With the right investment in agronomic support and policy frameworks, Humulus lupulus L. can become a viable part of Karakalpakstan's ecological and economic restoration efforts.

CONCLUSION

The results of the study conducted in the agroecological conditions of Karakalpakstan clearly demonstrate that Humulus lupulus L. can establish and grow successfully during its first year of vegetation, despite saline soils, low precipitation, and temperature extremes. The species showed notable resilience through the development of a deep root system, moderate water-use efficiency, and physiological adaptations such as reduced transpiration and photosynthetic endurance under stress.

Though cone yield was limited due to the early stage of establishment, the presence of key biochemical compounds such as humulone and lupulone confirms its potential for pharmaceutical and brewing uses. The hop plant also exhibited positive agronomic traits, including weed suppression, soil amelioration effects, and suitability for intercropping systems in arid zones.

Given the economic and ecological challenges facing Karakalpakstan, particularly in the wake of land degradation and water scarcity, the cultivation of adaptive and high-value crops like common hop offers a sustainable alternative. This study provides a baseline for future multi-year research, including cultivar trials, irrigation modeling, and value-chain development. If supported by appropriate agricultural policies, Humulus lupulus L. has strong potential to become a cornerstone crop in the region's agro-rehabilitation strategies.

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