ADAPTIVE POTENTIAL AND BIOCHEMICAL PROFILING OF INTRODUCED WHITE SWEET CLOVER (MELILOTUS ALBUS L.) VARIETIES UNDER ARID SALINE CONDITIONS OF THE KHOREZM REGION, UZBEKISTAN

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Abstract. *White sweet clover (Melilotus albus L.) is a multipurpose legume valued as a source of coumarins, bioflavonoids, and forage biomass, yet its varietal performance under the extreme agro-ecological conditions of the Khorezm region of Uzbekistan—characterized by high summer temperatures (up to +45 °C), low precipitation (94–100 mm·year⁻¹), and moderate soil salinity (0.4–0.6% total salts)—remains largely unexplored. This three-year study (2024–2026) aimed to comparatively assess the introduction success, morpho-physiological traits, yield potential, and biochemical composition of three introduced white sweet clover varieties (Almaz, Iney, Volzhanin) against the local standard Kibray. Field trials were conducted on moderately saline meadow-alluvial soils of the Khorezm Mamun Academy experimental station (Xiva district). Significant genotypic differences were observed: Volzhanin exhibited the highest field germination rate (92.4%), emergence energy (91.5%), and green biomass yield (40.8 t·ha⁻¹), while Almaz showed superior germination (94.0%) and the highest overall green yield (44.5 t·ha⁻¹). Both varieties demonstrated superior water-holding capacity (47.5% and 46.8% at branching, respectively) and lower water deficit across phenological stages compared to the control. Transpiration rates peaked at midday across all varieties but were notably higher in Volzhanin (up to 2.62 g·m⁻²·h⁻¹), indicating efficient cooling under heat stress. Biochemical analysis revealed Volzhanin as the most promising source of bioactive compounds, accumulating the highest total coumarin content (1.84%, including free and bound forms), dominating in melilotic and o-coumaric acids. It also contained the highest levels of key bioflavonoids—rutin (0.46 mg·100g⁻¹), apigenin-7-glucoside (0.65), isoquercetin (0.72), vitexin (0.78), and kaempferol (0.210). Protein content was highest in Volzhanin (20.5%), followed by Almaz (19.8%), significantly exceeding the control. The varieties Volzhanin and Almaz are recommended for large-scale cultivation as sustainable sources of high-value bioactive compounds and forage biomass in the arid, saline conditions of the Khorezm region.*

Keywords: *Melilotus albus, white sweet clover, introduction, drought tolerance, coumarins, flavonoids, plant physiology, salinity, Khorezm region, Uzbekistan.*

1. Introduction

White sweet clover (*Melilotus albus* L.), a member of the Fabaceae family, is increasingly recognized as a valuable crop for its dual-purpose potential in phytoremediation, forage production, and as a source of bioactive phenolic compounds such as coumarins and flavonoids. It exhibits notable tolerance to drought and salinity, making it suitable for cultivation in marginal lands. The Khorezm region of Uzbekistan represents an extreme environment for crop production, characterized by a sharply continental arid climate with very low annual precipitation (94–100 mm), high summer temperatures (frequently exceeding +45 °C), and prevalent moderate soil salinity (0.4–0.6% total salts). These conditions are representative of many semi-arid regions globally where salinization and water scarcity are intensifying due to climate change and unsustainable irrigation practices. The introduction and evaluation of stress-resilient genotypes like *M. albus* is therefore of strategic importance for both pharmaceutical raw material production and sustainable agriculture.

2. Materials and Methods

The study was conducted during the 2024–2026 growing seasons at the experimental station of the Khorezm Mamun Academy, located in the Xiva district (41°22′N, 60°49′E). The soil at the site is classified as moderately saline meadow-alluvial soil (topsoil: pH 7.6, humus 0.75%, available N 52 mg·kg^{-1}, available P_2O_5 24 mg·kg^{-1}). The experiment included four white sweet clover varieties: three introduced from the Volga Region Research Institute (Almaz, Iney, Volzhanin) and the local variety Kibray, which served as the control. A field experiment was set up in a randomized complete block design with three replications. Seed germination and emergence energy were determined according to the requirements of the seed industry standard (GOST 34221-2017). Water-related physiological parameters—leaf water-holding capacity, water deficit, and transpiration intensity—were assessed using standardized gravimetric methods (methods of Nichiporovich, Catsky & Stocker, and Ivanov, respectively). Total coumarin content (free, bound, and total) was determined spectrophotometrically. The identification and quantification of individual coumarins and bioflavonoids were performed using high-performance liquid chromatography (HPLC-PDA) at the Institute of Bioorganic Chemistry, Academy of Sciences of the Republic of Uzbekistan.

3. Results and Discussion

The three-year study revealed clear genotypic differences in key agronomic, physiological, and biochemical traits (Table 1). Regarding seed quality and yield, the variety Almaz achieved the highest germination capacity (94.0%) and green biomass yield (44.5 t·ha^{-1}), significantly surpassing the local Kibray control (85.6% and 34.0 t·ha^{-1}, respectively). Volzhanin also performed very well, with a germination capacity of 92.4%

and a green yield of 40.8 t·ha⁻¹, and additionally recorded the highest protein content (20.5%).

Table 1. Key agronomic and biochemical traits of white sweet clover varieties (average 2024-2026)*

Trait / Variety	Almaz	Iney	Volzhanin	Kibray (Control)
Field germination rate, %	94.0 a	90.8 b	92.4 ab	85.6 c
Green biomass yield, t·ha⁻¹	44.5 a	37.8 b	40.8 ab	34.0 b
Crude protein content, %	19.8 a	18.2 b	20.5 a	17.5 b
Total coumarin content, %	1.38	1.09	**1.84**	0.74

Note: Different letters indicate significant differences at $p<0.05$.

Regarding water relations and drought stress, both Volzhanin and Almaz demonstrated superior adaptive capacity. The Volzhanin variety maintained the highest leaf water-holding capacity during the critical branching (47.5%), budding (43.7%), and flowering (41.6%) phases, while also exhibiting the lowest corresponding water deficits (28.2%, 26.8%, and 25.3%, respectively). This strong water retention ability, coupled with a high transpiration rate of up to 2.62 g·m⁻²·h⁻¹ at the branching stage, reflects an effective cooling mechanism under extreme heat.

Regarding bioactive compounds (phytochemical profile), the Volzhanin variety was confirmed as a superior source of biologically active compounds. It accumulated the highest total coumarin content at 1.84%, which is approximately 2.5 times higher than the control variety. Within the coumarin fraction, Volzhanin showed a particularly high abundance of melilotic and o-coumaric acids. Its flavonoid profile was also the most impressive, with the highest recorded levels of rutin, apigenin-7-glucoside, isoquercetin, vitexin, and kaempferol. Notably, the compounds isorhamnetin and formononetin were exclusively detected in the Iney and Volzhanin varieties.

4. Conclusion

This comprehensive investigation into the introduction and performance of white sweet clover varieties in the extreme conditions of the Khorezm region has yielded several key conclusions. First, the results conclusively demonstrate that successful introduction depends heavily on selecting genotypes with specific adaptive traits to arid saline environments. The Volzhanin and Almaz varieties, in particular, have proven to be resilient to the region's harsh climate. Second, the Volzhanin variety is identified as a highly promising source of high-value bioactive compounds, including total coumarins and several key bioflavonoids, making it an excellent candidate for pharmaceutical raw material production. Finally, for dual-purpose applications (bioactive compound and biomass production), both Volzhanin and Almaz are strongly recommended for large-scale cultivation. Their high yields and superior physiological and biochemical characteristics

can contribute significantly to securing a sustainable supply chain for the pharmaceutical industry and strengthening the forage base for livestock in arid regions.

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