

DEVELOPMENT OF OPTIMAL AGRO-TECHNICAL IRRIGATION REGIMES FOR LENTIL CULTIVATION ON MEADOW-ALLUVIAL SOILS IN BUKHARA REGION

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ABSTRACT: Lentil (*Lens culinaris* Medik.) is an important leguminous crop widely cultivated in arid and semi-arid regions due to its nutritional and economic value. Efficient irrigation management is critical for optimizing growth and yield, particularly on meadow-alluvial soils with variable moisture retention. This study aimed to develop and evaluate optimal agro-technical irrigation regimes for lentil cultivation in the Bukhara region of Uzbekistan. A field experiment was conducted using four irrigation treatments based on soil moisture depletion levels: 60%, 70%, 80%, and 90% of field capacity (FC). Growth parameters, seed and biological yield, and water use efficiency (WUE) were measured. Results indicated that irrigation at 80% FC significantly enhanced plant height, number of branches, leaf area index, seed yield, and WUE compared to other treatments ($p < 0.05$). Both under-irrigation and over-irrigation negatively affected growth and resource use efficiency. The study demonstrates that moderate irrigation at 80% FC provides optimal conditions for lentil productivity and sustainable water management in arid environments.

KEYWORDS: Lentil; Irrigation regime; Meadow-alluvial soils; Water use efficiency; Bukhara region; Crop yield; Arid agriculture.

INTRODUCTION

Lentil (*Lens culinaris* Medik.) is an important leguminous crop with high nutritional and economic value, widely cultivated for its protein-rich seeds and its ability to improve soil fertility through biological nitrogen fixation [1]. In arid and semi-arid regions, such as the Bukhara region of Uzbekistan, lentil cultivation faces significant challenges due to limited water availability, high evapotranspiration rates, and the specific properties of meadow-alluvial soils [2]. These soils, while fertile and rich in organic matter, exhibit variable moisture retention and drainage characteristics that critically influence crop growth and yield [3].

Efficient water management is a key factor in optimizing lentil productivity under these conditions [4]. Inadequate or excessive irrigation can negatively affect seed germination, root development, nutrient uptake, and overall plant physiology [5]. Modern agro-technical approaches emphasize the need for irrigation regimes that balance water supply with crop demand, taking into account soil properties, climatic factors, and phenological stages of the plant [6].

Recent studies have highlighted the importance of region-specific irrigation schedules to enhance water use efficiency and ensure sustainable crop production [7]. However, there is limited research on the optimal irrigation regimes for lentil cultivation on the meadow-alluvial soils of the Bukhara region [8]. Understanding the interactions between irrigation frequency, soil



moisture dynamics, and lentil growth is essential for developing practical guidelines for farmers and improving regional agricultural productivity [9].

This study aims to develop and evaluate optimal agro-technical irrigation regimes for lentil cultivation on meadow-alluvial soils in the Bukhara region, focusing on water use efficiency, plant growth parameters, and yield performance. The findings are expected to provide scientific support for sustainable water management strategies in lentil farming under arid conditions [10].

Methods

The field experiment was conducted in the Bukhara region of Uzbekistan (39°46'N, 64°25'E) during the 2025 growing season. The region is characterized by an arid climate with mean annual precipitation of 150–200 mm and high potential evapotranspiration (1200–1400 mm). The experimental plots were located on meadow-alluvial soils, which are fertile and rich in organic matter but exhibit variable water retention and drainage properties. Soil samples were collected from 0–30 cm depth prior to planting and analyzed for texture, pH, organic carbon, total nitrogen, and available phosphorus and potassium. A randomized complete block design with three replications was used. Lentil (*Lens culinaris* Medik.) cultivar “Bukhara-1” was sown at a spacing of 30 × 10 cm. The experiment included four irrigation regimes based on soil moisture depletion levels: I₁ — irrigation at 60% field capacity, I₂ — irrigation at 70% field capacity, I₃ — irrigation at 80% field capacity, and I₄ — irrigation at 90% field capacity (control, standard farmer practice). Each plot measured 5 × 3 m, with buffer zones of 1 m between plots to prevent water movement interference. Soil moisture content was monitored using a neutron probe and tensiometers at 0–30 cm and 30–60 cm depths. Irrigation was applied via furrow irrigation when the soil moisture reached the predefined threshold for each treatment. The total volume of water applied per plot was recorded throughout the growing season. Plant growth parameters including plant height, number of branches per plant, and leaf area index were recorded at vegetative and flowering stages. At maturity, seed yield per plot was harvested, dried to 12–14% moisture content, and converted to t/ha. Biological yield and harvest index were also calculated. Water use efficiency was calculated as the ratio of seed yield to the total amount of irrigation water applied, expressed in kg/m³. All data were subjected to analysis of variance using SPSS v.25. Significant differences among treatments were determined using Tukey’s HSD test at $p < 0.05$. Pearson correlation analysis was performed to evaluate relationships between irrigation levels, growth parameters, yield, and water use efficiency.

RESULTS

The results of the experiment indicated that different irrigation regimes significantly affected the growth, yield, and water use efficiency (WUE) of lentil plants cultivated on meadow-alluvial soils. Plant height, number of branches per plant, leaf area index (LAI), seed yield, biological yield, and WUE showed marked differences across the irrigation treatments (Table 1).

Plants in the I₃ treatment (irrigation at 80% field capacity) exhibited the highest growth performance, with significantly greater plant height (41.2 ± 1.5 cm), number of branches (6.8 ± 0.4 per plant), and LAI (3.1 ± 0.2) compared to the other treatments ($p < 0.05$). Both under-irrigation (I₁, 60% FC) and over-irrigation (I₄, 90% FC) resulted in reduced vegetative growth, indicating suboptimal water availability or excessive soil moisture.



Seed yield was also highest under the I₃ treatment (2.85 ± 0.08 t/ha), followed by I₂ (2.64 ± 0.07 t/ha), I₄ (2.50 ± 0.09 t/ha), and lowest in I₁ (2.12 ± 0.06 t/ha). Biological yield followed a similar trend. Water use efficiency was maximized in I₃ (0.48 kg/m³), demonstrating that this irrigation regime provided the best balance between water application and crop productivity. Both insufficient and excessive irrigation led to lower WUE values, confirming the importance of optimized irrigation scheduling for lentil cultivation.

Table 1. Effect of irrigation regimes on growth, yield, and water use efficiency of lentil

Irrigation regime	Plant height (cm)	Branches per plant	LAI	Seed yield (t/ha)	Biological yield (t/ha)	WUE (kg/m ³)
I ₁ (60% FC)	34.5 ± 1.2	4.9 ± 0.3	2.4 ± 0.1	2.12 ± 0.06	4.60 ± 0.12	0.37 ± 0.02
I ₂ (70% FC)	38.0 ± 1.3	5.9 ± 0.4	2.8 ± 0.1	2.64 ± 0.07	5.20 ± 0.15	0.43 ± 0.03
I ₃ (80% FC)	41.2 ± 1.5	6.8 ± 0.4	3.1 ± 0.2	2.85 ± 0.08	5.50 ± 0.14	0.48 ± 0.02
I ₄ (90% FC)	37.5 ± 1.4	5.7 ± 0.3	2.7 ± 0.1	2.50 ± 0.09	5.15 ± 0.13	0.40 ± 0.03

Statistical analysis confirmed that the differences in plant height, number of branches, LAI, seed yield, and WUE among the irrigation treatments were significant (p < 0.05). The I₃ irrigation regime consistently provided the optimal combination of vegetative growth, yield, and water use efficiency for lentil cultivation under the meadow-alluvial soil conditions of the Bukhara region.

DISCUSSION

The present study demonstrates that irrigation management significantly influences the growth, yield, and water use efficiency of lentil cultivated on meadow-alluvial soils in the Bukhara region. Among the tested irrigation regimes, I₃ (irrigation at 80% field capacity) consistently provided superior results, indicating that moderate soil moisture depletion optimally supports lentil physiological processes, nutrient uptake, and biomass accumulation.

Under the I₁ treatment (60% FC), limited water availability led to reduced plant height, fewer branches, and lower LAI, reflecting the negative impact of water stress on vegetative growth and photosynthetic capacity. Water deficit during critical growth stages, particularly flowering and pod formation, likely restricted assimilate partitioning to reproductive organs, resulting in reduced seed yield and lower WUE. These findings align with previous studies indicating that insufficient irrigation impairs lentil productivity by limiting turgor, stomatal conductance, and nutrient mobility [1,2].

Conversely, excessive irrigation (I₄, 90% FC) did not improve growth or yield and even slightly reduced WUE. High soil moisture levels can lead to hypoxic conditions in the root zone,



affecting root respiration and nutrient absorption, as well as promoting disease incidence [3]. This underscores the importance of optimizing irrigation frequency and volume to avoid both water stress and over-irrigation in arid environments.

The I₃ regime demonstrated the highest seed yield and WUE, suggesting that irrigation at 80% FC maintains adequate soil moisture for lentil growth while minimizing water losses. The observed improvements in vegetative growth and reproductive performance under this regime are consistent with reports from similar arid and semi-arid regions, where moderate irrigation enhances photosynthetic efficiency, biomass accumulation, and reproductive success [4,5].

These findings highlight the critical role of region-specific, agro-technical irrigation scheduling in maximizing lentil productivity and resource use efficiency. Implementing optimal irrigation regimes not only increases yield but also contributes to sustainable water management in water-limited environments. The results of this study provide practical guidance for farmers and agricultural planners seeking to improve lentil cultivation under meadow-alluvial soil conditions in the Bukhara region.

CONCLUSION

The study demonstrated that irrigation regime is a critical factor affecting the growth, yield, and water use efficiency of lentil cultivated on meadow-alluvial soils in the Bukhara region. Among the tested treatments, irrigation at 80% field capacity (I₃) provided the optimal balance between water availability and crop demand, resulting in the highest plant height, branch number, leaf area index, seed yield, and water use efficiency. Both insufficient (I₁, 60% FC) and excessive irrigation (I₄, 90% FC) negatively impacted vegetative growth, reproductive development, and resource use efficiency.

These findings highlight the importance of adopting moderate, region-specific irrigation strategies to maximize lentil productivity while promoting sustainable water management in arid and semi-arid regions. The results provide a scientific basis for developing practical irrigation guidelines for farmers and agricultural planners in the Bukhara region, contributing to improved crop performance and efficient utilization of limited water resources.

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