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ARTICLE

Influence of Soil Agro-Physical Properties and Irrigation Regimes on Yield and Productivity of Repeated Sunflower (*Helianthus annuus* L.) Varieties and Hybrids under Arid Conditions of the Bukhara Region

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Abstract

This scientific study is devoted to determining the effect of soil agro-physical properties and irrigation regimes on the yield of sunflower varieties and hybrids cultivated as a repeated crop under irrigated farming conditions in Bukhara region. During the research, the main agro-physical indicators of the soil, such as bulk density, moisture capacity, and water-air regime, were studied under different irrigation variants. The results of field experiments and laboratory analyses confirmed that irrigation rates and timing have a significant effect on soil condition as well as plant growth and development. It was found that under an optimal irrigation regime, the agro-physical condition of the soil improved, the physiological processes of plants became more active, and the formation of yield components occurred at a high level. Insufficient and poorly justified irrigation regimes, however, were observed to reduce yield due to soil compaction and moisture deficiency. The obtained scientific results have important scientific and practical significance for optimizing the technology of sunflower cultivation as a repeated crop, ensuring the rational use of water resources, and achieving stable and high yields.

Keywords: sunflower, repeated crop, soil agro-physical properties, irrigation regime, soil density, moisture capacity, yield, Bukhara region.

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1 Introduction

Today, repeated cropping in agriculture is considered one of the important factors in the efficient use of land resources. In particular, in areas with limited water resources, cultivating sunflower as a repeated crop is one of the urgent agro-economic issues. The soils of Bukhara region are distinguished by their agro-physical properties, particularly mechanical composition, bulk density, and moisture capacity, and these factors directly affect crop growth and yield. The yield of repeatedly cultivated sunflower varieties and hybrids largely depends on the soil water-physical condition and irrigation regimes. Scientifically determining irrigation rates and timing serves to optimize the vegetation process of plants. Therefore, this study aims to scientifically investigate the effect of soil agro-physical properties and irrigation regimes on

the yield of repeatedly cultivated sunflower varieties and hybrids under the conditions of Bukhara region.

In recent years, considerable attention has been paid to studying the interaction between soil agro-physical properties, agrotechnological measures, and irrigation regimes in increasing the yield of agricultural crops. In particular, in the cultivation of oil crops such as sunflower, soil bulk density, moisture capacity, water permeability, and structural condition are recognized as important factors in yield formation. Studies have scientifically substantiated that ecologically balanced farming systems stabilize the agro-physical condition of the soil and increase energy efficiency in sunflower cultivation [1]. This approach contributes to reducing soil degradation and maintaining yield stability over the long term.

Primary tillage methods also have a significant impact on sunflower yield. Some studies have reported that the depth of primary tillage and the use of soil herbicides positively influence biomass formation and seed yield of sunflower [2]. At the same time, the intensity of tillage is considered an important agrotechnical factor in maintaining soil moisture and reducing competition with weeds.

The composition and diversity of weeds within the agrophytocenosis of crops are also directly related to tillage methods and nutrient management systems. According to research findings, changes in tillage and fertilization systems significantly affect the species composition and density of weeds in cultivated fields [3]. Under conditions of climate change, conservation tillage technologies have been found to limit the spread of weeds and help maintain relatively stable yields of main crops [4].

Under conditions of global climate change, the influence of soil and climatic factors on the prospects of crop cultivation is gaining particular scientific importance. In some regions, changes in soil and bioclimatic conditions have necessitated a reassessment of crop adaptability [5]. This situation highlights the importance of adjusting irrigation regimes and maintaining optimal soil moisture levels in the cultivation of repeated crops, including sunflower.

A number of studies have considered crop density and planting systems as important factors influencing yield and economic efficiency [6]. This approach serves as a theoretical basis for determining optimal agrotechnical standards in the repeated cultivation of sunflower varieties and hybrids. The effects of tillage and fertilization rates on the agrobiological indicators of crops have also been extensively studied using leguminous crops as an example, and these findings can be partially applied to oil crops as well [7, 8].

The use of certified seeds has been reported to significantly increase technical efficiency in improving agrotechnological performance [9]. This indicates that, in selecting sunflower hybrids, along with genetic potential, the suitability of agro-physical conditions is also of great importance. Scientific conclusions regarding the availability of reserves in breeding and agrotechnologies for increasing the yield of grain and oil crops remain relevant under current conditions [10].

Studies conducted on the formation, evolution, and chemical properties of soils in Central Asia, particularly in the Zarafshan Valley, provide a deeper understanding of the agro-physical condition of regional soils [11, 13]. These studies highlight the necessity of planning agrotechnical measures in irrigated areas while considering soil degradation, salinization, and anthropogenic impacts. At the same time, research devoted to examining soil contamination under the influence of domestic wastewater emphasizes the need to integrate environmental safety issues with agrotechnical studies [12].

The analyzed literature indicates that a comprehensive study of the interrelationships between soil agro-physical properties, primary tillage methods, irrigation regimes, and crop varieties forms the scientific basis for achieving high and stable yields in the cultivation of sunflower as a repeated crop. These scientific developments serve as a theoretical and methodological foundation for research conducted under the conditions of Bukhara region.

2 Materials and Methods

The object of the study consisted of sunflower varieties and hybrids cultivated as a repeated crop in irrigated farming areas of Bukhara region, as well as the agro-physical properties of the soils on which they were grown. The subject of the research was to study the effect of agro-physical soil indicators-such as bulk density, moisture capacity, and water permeability-and irrigation regimes on sunflower yield.

During the research, field experiments, laboratory analyses, and comparative observation methods were employed. The agro-physical properties of the soil

were determined based on standard agrochemical and agrophysical methodologies, while yield indicators were evaluated through biometric measurements. The obtained results were processed using mathematical and statistical methods, and scientific conclusions were drawn accordingly.

3 Results

The conducted field and laboratory studies demonstrated that under irrigated soil conditions of Bukhara region, soil agro-physical properties and irrigation regimes play a decisive role in the formation of yield in repeatedly cultivated sunflower varieties and hybrids. The results confirm a clear relationship between soil bulk density, moisture capacity, and irrigation rates.

Analyses carried out in the experimental fields revealed that soil agro-physical indicators change significantly depending on irrigation regimes. Under conditions of insufficient irrigation, soil bulk density was higher, which limited the development of the root system. In contrast, under optimal irrigation conditions, the structural state of the soil improved, and the water-air regime became balanced.

According to the data presented in the table, under optimal irrigation conditions, soil bulk density reached $1.31\ \mathrm{g/cm^3}$, which is $0.11\ \mathrm{g/cm^3}$ lower compared to the low irrigation variant. At the same time, moisture capacity increased up to 24.3%, significantly improving the water supply of plants (Table 1).

Table 1. Effect of Irrigation Regimes on Soil Agro-Physical Indicators and Yield

Irrigation regime	Soil bulk density ($\mathrm{g/cm^3}$)	Moisture capacity (%)	Yield (c/ha)
Low irrigation	1.42	18.5	18.6
Moderate irrigation	1.36	21.7	24.9
Optimal irrigation	1.31	24.3	31.4

Sunflower yield was found to be sensitive to irrigation regimes, with the highest results recorded under the optimal irrigation variant.

Under low irrigation conditions, vegetative development of plants was weak, resulting in low seed yield. Although yield increased to some extent under moderate irrigation, it did not reach the level achieved under optimal irrigation.

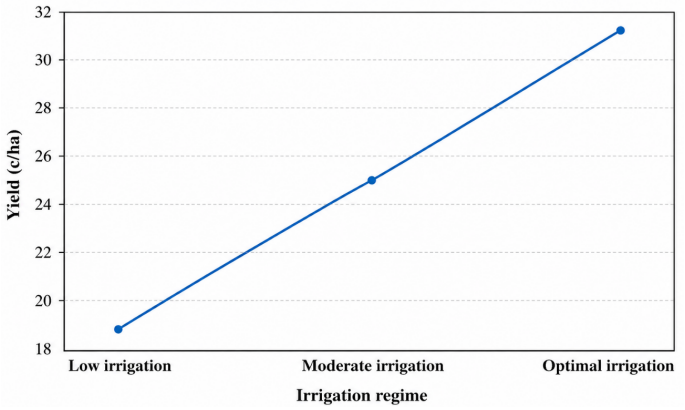

Figure 1. Effect of irrigation regimes on sunflower yield

The analysis of the graph indicates that under optimal irrigation conditions, sunflower yield reached $31.4\ \mathrm{c/ha}$, which is $12.8\ \mathrm{c/ha}$ higher compared to the low-irrigation treatment. This finding underscores the necessity of scientifically grounded irrigation regime management.

During the course of the study, a positive correlation was identified between soil moisture capacity and yield. When soil moisture was maintained at an optimal level, plant nutrient uptake processes were enhanced, and the intensity of photosynthesis increased. As a result, head diameter, seed number, and seed mass improved significantly.

In the cultivation of sunflower as a secondary crop, the shortened vegetation period imposes stricter requirements on irrigation regimes. Under optimal irrigation conditions, plant stress was reduced, ensuring yield stability.

The obtained results demonstrate that, under the conditions of the Bukhara region, achieving high yields from repeatedly sown sunflower varieties and hybrids requires improving the agro-physical properties of the soil and organizing irrigation regimes on a scientific basis. A decrease in soil bulk density and an increase in moisture capacity have a direct positive effect on productivity.

The findings of this study have practical significance for improving the technology of sunflower cultivation as a secondary crop, enhancing the efficient use of water resources, and achieving stable yields.

4 Conclusion

The comprehensive field and laboratory studies conducted have scientifically substantiated that, under irrigated agricultural conditions of the Bukhara region, the productivity of sunflower varieties and hybrids

cultivated as a secondary crop is directly dependent on the interaction between soil agro-physical properties and irrigation regimes. The results indicate that maintaining optimal soil bulk density, increasing its moisture capacity, and balancing the soil water–air regime positively influence root system development and the formation of vegetative organs.

It was established that under optimal irrigation regimes, the agro-physical condition of the soil improves, physiological processes in plants are intensified, and yield components-such as head diameter, seed number, and seed mass—are significantly enhanced. In contrast, insufficient and scientifically unsubstantiated irrigation practices lead to soil compaction, moisture deficiency, and increased plant stress, ultimately resulting in reduced productivity.

In the cultivation of sunflower as a secondary crop, optimizing irrigation norms and scheduling in accordance with regional soil and climatic conditions is of critical importance. Furthermore, the application of agrotechnical measures aimed at improving soil agro-physical properties enables more efficient use of water resources and contributes to achieving stable yields.

Under the conditions of the Bukhara region, the improvement of sunflower cultivation technology as a secondary crop, the implementation of scientifically based irrigation systems in agricultural production, and the attainment of high and stable yields represent significant scientific and practical contributions.

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