

IMPACT OF IRRIGATION METHODS ON SOIL PROPERTIES AND APPLE YIELD IN INTENSIVE ORCHARDS

Sarimsakov Maksudkhon M.

¹Research Institute of Plant Genetic Resources

Uzbekistan, Tashkent

E-mail: ingenering67@gmail.com

ORCID: 0000-0003-0192-8532

Abstract

Efficient water management is essential for sustainable agricultural production, particularly in arid regions. This study evaluates the impact of different irrigation methods on soil properties and apple yield in intensive orchards. The results show that drip irrigation ensures uniform soil moisture distribution, reduces salinity risks, and improves soil structure. Apple yield increased by 40–60% compared to traditional methods, while water consumption decreased by up to 50%. These findings highlight the importance of adopting water-saving irrigation technologies to enhance productivity and maintain soil fertility.

Keywords: drip irrigation, soil moisture, apple yield, water use efficiency, salinity.

Introduction

Water scarcity and climate change are among the major challenges affecting agricultural productivity worldwide. Efficient use of water resources has become a key requirement for sustainable agriculture, especially in arid and semi-arid regions.

In Uzbekistan, approximately 90% of available water resources are used in agriculture, mainly for irrigation. However, traditional irrigation methods such as furrow and basin irrigation are inefficient, resulting in water losses of up to 25–30% and contributing to soil degradation.

Apple (*Malus domestica*) is one of the most important fruit crops in intensive horticulture. Improving irrigation practices is essential for increasing productivity, optimizing water use, and maintaining soil health.

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The aim of this study is to evaluate the effects of different irrigation methods on soil properties and apple yield in intensive orchards.

Literature review

The concept of food security has evolved from simple physical availability (1974 World Food Summit) to a multi-dimensional framework. The 1996 World Food Summit defined it as a state where all people have physical and economic access to sufficient, safe, and nutritious food (Sarimsakov, 2025). In 2001, the FAO integrated "social access" into this definition, emphasizing that food must meet personal preferences for a healthy life (Sarimsakov, 2025).

Scholars like K.V. Frolov and A.V. Gordeyev define food security as a nation's ability to provide vital nutrients through domestic sources (Sarimsakov, 2025). A.A. Anfinogentova identifies three hierarchical levels:

Global food security is explained by grain reserves per capita and the volume of its production;

State-level food security is determined by the ratio of national food production to imports, the share of imports in food consumption, minimum income per capita, and fluctuations in food prices;

Regional food security is measured through data on population income and food consumption volumes (Sarimsakov, 2025).

Furthermore, A.A. Kudryashova and O.P. Presnyakova argue that food independence is achieved only when domestic production accounts for 80-90% of total consumption – a benchmark maintained by leading economies like the USA, France, and Germany (Sarimsakov, 2025).

In addition to global studies, recent research has focused on improving irrigation efficiency in arid regions through technological innovation. Modern irrigation systems integrate automation, soil moisture sensors, and fertigation, allowing precise control of water and nutrient supply. These technologies not only reduce water consumption but also improve crop quality and uniformity.

Furthermore, several studies highlight that soil moisture dynamics play a critical role in determining crop yield. Maintaining optimal moisture levels in the root zone prevents plant stress and enhances physiological processes.

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In intensive orchards, where planting density is high, such precision becomes even more important.

Therefore, the transition from traditional irrigation methods to modern water-saving technologies is considered a key factor in achieving sustainable agricultural development and food security.

Materials and methods

The methodology of this research is based on a comprehensive comparative analysis of irrigation techniques commonly employed in intensive orchards. The primary objective was to evaluate the technical and agronomic efficiency of modern systems versus traditional practices.

Irrigation Methods

The study involved a comparative analysis of irrigation methods in intensive orchards across the Tashkent, Sirdaryo, and Andijon regions (Sarimsakov, 2025).

Methods Analyzed: Furrow, Basin, and Drip Irrigation.

Evaluated Parameters: Soil moisture tension, electrical conductivity (EC) for salinity, soil bulk density, and apple yield (*Malus domestica*). The study utilized experimental data and monographs from the Research Institute of Plant Genetic Resources (Sarimsakov, 2025).

Results

The results presented in Table 1 demonstrate that drip irrigation significantly outperforms traditional irrigation methods in terms of both yield and water use efficiency. The reduction in water consumption is particularly important under conditions of limited water availability.

Higher yields under drip irrigation are associated with improved soil moisture regulation and reduced plant stress. Water is supplied directly to the root zone in controlled amounts, ensuring optimal conditions for plant growth.

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In contrast, traditional irrigation methods result in uneven water distribution, leading to excessive moisture in some areas and insufficient moisture in others. This negatively affects plant development and yield stability.

Table 1. Impact of irrigation methods on yield and resource efficiency

Irrigation method	Yield (t/ha)	Water use (m ³ /ha)	Efficiency
Furrow	18-22	8,000-10,000	Low (kg/m ³)
Basin	22-26	7,000-9,000	Medium (kg/m ³)
Drip	30-40	4,000-6,000	High (kg/m ³)

The data presented in Table 1 clearly indicate that drip irrigation significantly outperforms traditional irrigation methods in terms of both productivity and water use efficiency. The reduction in water consumption by up to 50% is particularly important in regions with limited water resources.

In addition, the observed increase in yield is associated with improved soil moisture conditions and reduced plant stress. Under drip irrigation, water is supplied in a controlled manner, ensuring that plants receive the required amount without excess or deficiency.

The results also demonstrate that traditional irrigation methods lead to inefficient water distribution, which negatively affects plant growth and yield stability. This highlights the need for modernization of irrigation systems in intensive horticulture.

Soil Dynamics: Drip irrigation ensures a stable and uniform wetting front within the active root zone (30–60 cm depth) (Sarimsakov, 2025). Traditional methods (furrow and basin) result in significant surface evaporation losses and deep percolation, leading to nutrient leaching (Sarimsakov, 2025).

Soil health is significantly influenced by irrigation methods. Unlike flooding techniques, which often lead to soil compaction (reducing productivity at bulk densities approaching 1.70 g/cm³), drip irrigation maintains soil porosity and aeration. It also limits groundwater rise and reduces salt accumulation in the root zone (Sarimsakov, 2025).

The distribution of soil moisture under different irrigation methods is illustrated in Figure 1. As shown, surface (furrow) irrigation results in

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uneven water distribution, with substantial losses due to evaporation and deep percolation. In contrast, drip irrigation provides a uniform wetting pattern directly within the root zone, ensuring efficient water use and optimal conditions for plant growth. Localized irrigation leads to partial wetting of the soil, which reduces water losses but may limit root development compared to drip irrigation.

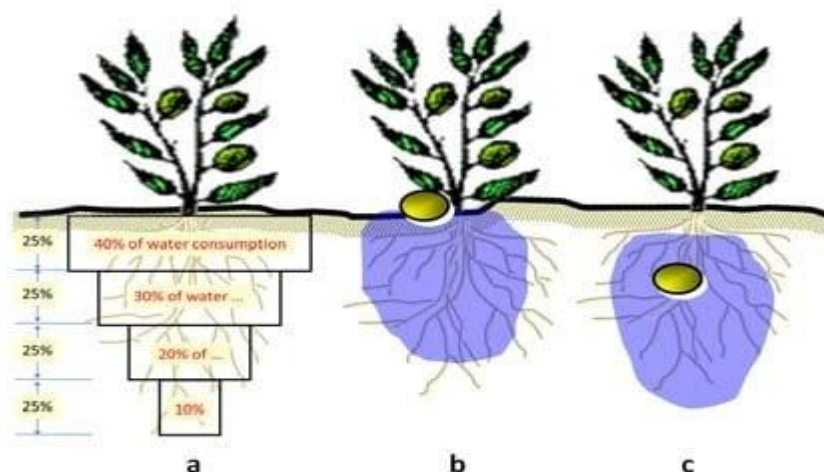


Figure 1 – Soil moisture distribution under different irrigation methods.

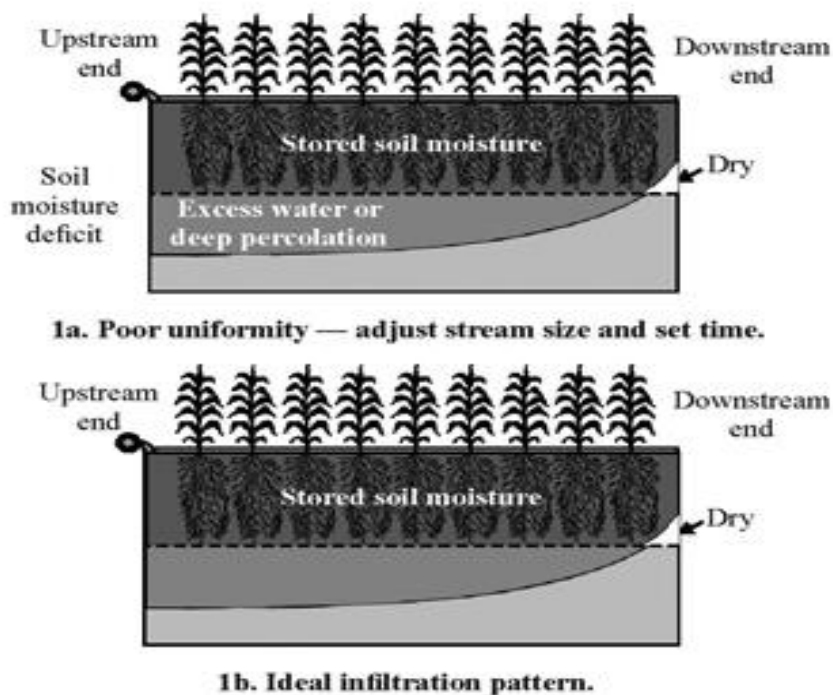


Figure 2. Soil moisture distribution along furrow irrigation.

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Figure 2 illustrates the variability of water distribution along the furrow during irrigation. In the case of poor uniformity (Figure 1a), excessive water accumulates at the upstream end, resulting in deep percolation losses, while the downstream area remains insufficiently irrigated. In contrast, the ideal infiltration pattern (Figure 1b) demonstrates a more uniform distribution of soil moisture, which reduces water losses and supports consistent plant development. These findings highlight the importance of proper irrigation management.



Figure 3. Drip irrigation system in an intensive apple orchard

The practical implementation of drip irrigation in an intensive apple orchard is shown in Figure 3. The system delivers water directly to the root zone through drip lines installed along the rows of trees. This method minimizes evaporation losses and ensures precise water application. As a result, soil moisture is maintained at optimal levels, improving plant growth and increasing yield. The use of such systems is especially important in regions with limited water resources.

Discussion

The results of this study confirm that irrigation method is a critical factor influencing soil properties and crop productivity in intensive orchards. Drip irrigation demonstrated the highest efficiency due to its ability to regulate water supply directly within the root zone.

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This advantage can be explained by several factors. First, drip irrigation provides stable soil moisture conditions, which enhances root development and improves water uptake. Second, it minimizes non-productive water losses such as evaporation and deep percolation.

In addition, drip irrigation reduces soil salinity risks. Unlike traditional methods, where evaporation leads to salt accumulation, drip systems maintain consistent moisture levels, preventing salt concentration in the root zone.

Improved soil aeration under drip irrigation also enhances microbial activity and nutrient availability, which positively affects plant growth and yield.

Furthermore, drip irrigation increases water use efficiency (WUE), which is a key indicator of sustainable agricultural production. By supplying water according to plant needs, it reduces stress and improves productivity.

From an economic perspective, although drip irrigation requires higher initial investment, its long-term benefits include reduced water costs, higher yields, and improved product quality.

Therefore, the adoption of drip irrigation systems is essential for sustainable agricultural development, particularly in water-scarce regions.

Conclusion and Recommendations:

Conclusion: The study demonstrates that irrigation methods significantly influence soil properties and apple yield in intensive orchards. Drip irrigation is the most effective method, providing optimal soil moisture conditions, reducing salinity risks, and improving soil structure.

The use of drip irrigation increases apple yield by up to 60% while reducing water consumption by up to 50%. These results confirm the importance of water-saving technologies for sustainable agricultural production.

These results emphasize that improving irrigation efficiency is a strategic priority for ensuring long-term agricultural sustainability and food security.

Recommendations:

Include the wider implementation of drip irrigation systems, integration of fertigation technologies, and the use of soil moisture monitoring to optimize irrigation scheduling.

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