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DRIP IRRIGATION AS A STRATEGY FOR ENHANCING POMEGRANATE PRODUCTIVITY AND WATER-USE EFFICIENCY UNDER SEMI-ARID CONDITIONS OF SOUTHERN UZBEKISTAN

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Abstract. This study evaluated the effects of drip and furrow irrigation on the productivity and water-use efficiency of three pomegranate cultivars grown under moderately saline soil conditions in the Sherabad District of southern Uzbekistan during 2022-2024. The cultivars Kzyl Uluchshenniy, Kazake-Anar, and Desertniy were assessed in terms of fruit number, average fruit weight, yield, and seasonal water consumption. Drip irrigation increased yield by 43.9-67.4% compared with furrow irrigation while reducing irrigation water use by approximately 55.4%. The results demonstrate the potential of drip irrigation to improve water productivity and support more sustainable pomegranate production in water-limited environments.

Keywords: pomegranate, drip irrigation, furrow irrigation, water-use efficiency, fruit yield, saline soils, semi-arid climate, irrigation management.

1. Introduction. Agricultural production in arid and semi-arid regions is increasingly constrained by limited water resources, rising temperatures, soil salinity, and the need to improve the efficiency of irrigation systems. These challenges are particularly important in southern Uzbekistan, where fruit production depends heavily on irrigation and where water-saving technologies can contribute to sustainable agricultural development.

Pomegranate (*Punica granatum* L.) is an economically valuable fruit crop adapted to relatively dry climatic conditions. Nevertheless, its productivity depends on the availability of soil moisture during flowering, fruit formation, and fruit development. Insufficient or irregular water supply may reduce fruit number, fruit size, and marketable yield. Therefore, selecting an appropriate irrigation method is essential for improving both crop productivity and water-use efficiency.

Drip irrigation delivers water directly to the root zone, reducing losses associated with surface evaporation and uneven distribution. Research has demonstrated that irrigation scheduling and the selection of an appropriate irrigation system can significantly affect pomegranate growth, yield, and water-use efficiency [1; 2]. Prasad et al. reported the positive effects of drip irrigation on pomegranate growth, productivity, and fruit quality under arid conditions [3]. Other studies have shown that irrigation strategies influence fruit development and yield under Mediterranean and semi-arid environments [4; 5].

The relationship between irrigation and crop water requirements is also influenced by climatic conditions, soil properties, root distribution, and crop

development. The FAO methodology provides a widely used framework for assessing crop evapotranspiration and irrigation requirements [6]. Volschenk emphasized the importance of appropriate irrigation management in maintaining pomegranate productivity while improving water conservation [2].

Despite the growing body of research on pomegranate irrigation, local conditions require specific evaluation because soil salinity, climatic characteristics, and cultivar responses may differ between production regions. In southern Uzbekistan, assessing the performance of different pomegranate cultivars under drip and furrow irrigation is particularly relevant for developing efficient irrigation practices.

The objective of this study was to evaluate the effects of drip and furrow irrigation on the yield components, productivity, and seasonal water consumption of three pomegranate cultivars grown on moderately saline soils in the Sherabad District.

2. Materials and Methods. The research was conducted during 2022–2024 in the Sherabad District of Surkhandarya Region, southern Uzbekistan. The experimental orchard was established on moderately saline soils under semi-arid climatic conditions. Three pomegranate cultivars were investigated: Kzyl Uluchshenniy, Kazake-Anar, and Desertniy.

The trees were planted at a spacing of 4×4 m, corresponding to approximately 625 trees per hectare. During the study period, the trees were 5–7 years old. Two irrigation methods were compared: conventional furrow irrigation and drip irrigation.

The assessment included the number of fruits per tree, average fruit weight, yield per tree, yield per hectare, and seasonal water consumption. Water consumption was evaluated using the contribution of irrigation water, precipitation, and changes in soil moisture reserves within the upper one-metre soil layer.

The average seasonal water consumption values for the three-year study period were 5,971 m³/ha under furrow irrigation and 2,970 m³/ha under drip irrigation. Irrigation water use was 5,416 m³/ha and 2,415 m³/ha, respectively. Precipitation contributed 181 m³/ha under both irrigation methods, while the estimated contribution from changes in soil moisture reserves was 374 m³/ha.

The experimental results were evaluated descriptively by comparing cultivar performance under the two irrigation methods. Since the available dataset did not include measures of variability or statistical test results, no claims of statistical significance are made.

3. Results and Discussion

3.1. *Effects of irrigation methods on pomegranate yield components*

The results demonstrated that irrigation method was associated with clear differences in fruit number, average fruit weight, and yield per tree. Across all three cultivars, drip-irrigated trees produced more fruits and had higher average fruit weights than trees irrigated by furrows.

For Kzyl Uluchshenniy, drip irrigation increased the average number of fruits per tree from 55.0 to 70.2 and average fruit weight from 430 to 480 g. Yield per tree increased from 23.8 to 33.7 kg. These results indicate that improved water delivery to the root zone was associated with better fruit development and greater productivity.

Table 1

Yield components of pomegranate cultivars under different irrigation methods

Cultivar	Irrigation method	Fruits per tree (pcs.)	Average fruit weight (g)	Yield per tree (kg)
Kzyl Uluchshenniy	Furrow	55.0	430	23.8
Kzyl Uluchshenniy	Drip	70.2	480	33.7
Kazake-Anar	Furrow	59.3	480	28.5
Kazake-Anar	Drip	91.3	540	50.0
Desertniy	Furrow	63.8	470	30.0
Desertniy	Drip	82.0	530	43.8

Kazake-Anar demonstrated the strongest response to drip irrigation. The number of fruits per tree increased from 59.3 to 91.3, while average fruit weight increased from 480 to 540 g. Yield per tree rose from 28.5 to 50.0 kg. This cultivar therefore showed a particularly favourable response under the experimental conditions.

Desertniy also responded positively to drip irrigation. The number of fruits per tree increased from 63.8 to 82.0, average fruit weight rose from 470 to 530 g, and yield per tree increased from 30.0 to 43.8 kg.

The observed differences may be related to the more direct and regular supply of water to the root zone under drip irrigation. Maintaining a more favourable soil-moisture regime can support nutrient uptake and reduce moisture stress during critical stages of fruit development. Previous research has likewise highlighted the importance of irrigation scheduling and water availability for pomegranate productivity [1; 3; 5].

3.2. Effects of irrigation method on yield per hectare

Yield per hectare is a key indicator for evaluating the practical effectiveness of irrigation technologies. The results showed that drip irrigation increased the productivity of all three cultivars compared with conventional furrow irrigation.

Table 2

Pomegranate yield under furrow and drip irrigation

Cultivar	Furrow irrigation (t/ha)	Drip irrigation (t/ha)	Yield increase (t/ha)	Increase (%)
Kzyl Uluchshenniy	15.5	22.3	6.8	43.9
Kazake-Anar	18.7	31.3	12.6	67.4
Desertniy	18.8	28.1	9.3	49.5

Kzyl Uluchshenniy produced 15.5 t/ha under furrow irrigation and 22.3 t/ha under drip irrigation. The increase was 6.8 t/ha, equivalent to 43.9%.

Kazake-Anar achieved the highest yield under drip irrigation, reaching 31.3 t/ha compared with 18.7 t/ha under furrow irrigation. The yield increase was 12.6 t/ha, or 67.4%. This result identifies Kazake-Anar as the most productive cultivar among the three tested under the drip-irrigation conditions of the experiment.

Desertniy yielded 18.8 t/ha under furrow irrigation and 28.1 t/ha under drip irrigation. Its yield increased by 9.3 t/ha, corresponding to 49.5%.

Overall, drip irrigation was associated with yield increases ranging from 6.8 to 12.6 t/ha. The strongest response was recorded for Kazake-Anar, followed by Desertniy and Kzyl Uluchshenniy. These findings support the use of cultivar-specific irrigation management when improving orchard productivity.

The positive response of all three cultivars is consistent with published studies indicating that well-managed drip irrigation can improve pomegranate yield in arid and semi-arid environments [3; 4; 7]. However, the magnitude of the response may depend on cultivar characteristics, soil conditions, irrigation scheduling, and orchard management practices.

3.3. Seasonal water consumption and water-saving potential

Water consumption data showed substantial differences between furrow and drip irrigation. The average seasonal water consumption was 5,971 m³/ha under furrow irrigation and 2,970 m³/ha under drip irrigation. Irrigation water use accounted for the largest share of seasonal water consumption under both methods.

Table 3

Seasonal water consumption under different irrigation methods

Water-consumption component	Furrow irrigation (m ³ /ha)	Drip irrigation (m ³ /ha)
Contribution from soil moisture reserves	374	374
Precipitation	181	181
Irrigation water	5,416	2,415
Total seasonal water consumption	5,971	2,970

Irrigation water use under drip irrigation was 2,415 m³/ha, compared with 5,416 m³/ha under furrow irrigation. The absolute reduction was 3,001 m³/ha, equivalent to approximately 55.4% of the irrigation water used under furrow irrigation.

Total seasonal water consumption was also lower under drip irrigation, decreasing by 3,001 m³/ha, or approximately 50.3%. This difference demonstrates the potential of drip irrigation to reduce water demand in pomegranate orchards under the conditions studied.

The lower water consumption under drip irrigation can be attributed to the targeted delivery of water to the root zone and the potential reduction of surface-water losses. However, the actual efficiency of a drip system depends on emitter design, irrigation duration, soil texture, water quality, and the maintenance of the irrigation network. Consequently, the reported values should be interpreted in relation to the specific experimental conditions rather than as universal irrigation requirements.

The results are in agreement with research emphasizing the role of irrigation management in improving water productivity and reducing unnecessary water application in pomegranate cultivation [2; 5; 7]. In areas affected by soil salinity and water scarcity, efficient irrigation is particularly important because excessive or poorly managed water application may contribute to uneven soil moisture and salt distribution.

3.4. Water consumption per unit of yield

Water-use efficiency can also be assessed by comparing seasonal water consumption with the harvested yield. Lower water consumption per unit of production indicates that more fruit is obtained from a given volume of water.

Table 4.

Seasonal water consumption per unit of pomegranate yield

Cultivar	Irrigation method	Irrigation water (m³/centner)	Total water consumption (m³/centner)
Kzyl Uluchshenniy	Furrow	34.9	38.5
Kzyl Uluchshenniy	Drip	10.8	13.3
Kazake-Anar	Furrow	29.0	31.9
Kazake-Anar	Drip	7.7	9.5
Desertniy	Furrow	29.3	32.3
Desertniy	Drip	8.6	10.6

The values in Table 4 were recalculated using the reported irrigation-water volumes and the corresponding yields in centners per hectare. For Kzyl Uluchshenniy, irrigation water consumption per centner decreased from approximately 34.9 m³ under furrow irrigation to 10.8 m³ under drip irrigation. Total seasonal water consumption per centner declined from 38.5 to 13.3 m³.

For Kazake-Anar, irrigation water consumption decreased from approximately 29.0 to 7.7 m³ per centner, while total water consumption fell from 31.9 to 9.5 m³ per centner. Desertniy showed a similar trend, with irrigation water consumption decreasing from approximately 29.3 to 8.6 m³ per centner and total water consumption declining from 32.3 to 10.6 m³ per centner.

These results indicate that drip irrigation improved the relationship between water use and harvested production for all three cultivars. Kazake-Anar showed the lowest water consumption per unit of yield under drip irrigation, reflecting its comparatively high productivity.

The findings underline the importance of considering both yield and water consumption when evaluating irrigation technologies. A system that increases yield while reducing water use can provide important advantages in regions where water resources are limited. Nevertheless, further studies incorporating irrigation scheduling, soil-moisture monitoring, water salinity, and economic assessment would help determine the most appropriate operating conditions for commercial orchards.

4. Conclusions

Drip irrigation improved the yield components of all three pomegranate cultivars grown on moderately saline soils in the Sherabad District. The number of fruits per tree, average fruit weight, and yield per tree were higher under drip irrigation than under furrow irrigation.

Drip irrigation increased yield per hectare by 6.8 t/ha for Kzyl Uluchshenniy, 12.6 t/ha for Kazake-Anar, and 9.3 t/ha for Desertniy. Kazake-Anar demonstrated the highest productivity under drip irrigation, reaching 31.3 t/ha.

Drip irrigation reduced irrigation water use by 3,001 m³/ha, or approximately 55.4%, compared with furrow irrigation. Total seasonal water consumption decreased by approximately 50.3%, while water consumption per unit of yield was lower for all three cultivars. These findings support the potential of drip irrigation to improve water productivity in pomegranate orchards under the semi-arid conditions of southern Uzbekistan.

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