



Performance Analysis of Traditional and IoT-Based Irrigation Systems for Pomegranate Crops

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Abstract. Pomegranate cultivation in many regions of India continues to rely on traditional flood irrigation because of its simplicity and low initial cost. However, this method often leads to excessive water use, non-uniform soil moisture distribution, and nutrient losses through runoff and deep percolation. These conditions adversely affect root health and increase the incidence of fruit cracking, reduced fruit size, and yield variability. To overcome these limitations, drip irrigation has emerged as a more efficient alternative for pomegranate farming. Drip irrigation delivers water directly to the root zone at a controlled rate, allowing irrigation to closely match crop water requirements and maintain soil moisture within the optimal range. Uniform moisture supply during critical stages such as flowering and fruit development reduces moisture fluctuations, improves nutrient uptake, and enhances plant vigor. Field observations indicate that drip irrigation can reduce water consumption by 35–45%, lower energy use, and decrease labor requirements compared to flood irrigation. Overall, the adoption of drip irrigation improves water-use efficiency, yield stability, and sustainability of pomegranate production under water-limited conditions.

Keywords: Pomegranate farming, Drip irrigation, Flood irrigation, Water-use efficiency, Sustainable agriculture.

I. Introduction

Pomegranate (*Punica granatum* L.) is one of the most important commercial fruit crops cultivated in semi-arid and arid regions due to its adaptability to diverse soil and climatic conditions, high nutritional value, and strong domestic and export demand. India is among the leading producers of pomegranate, with major cultivation concentrated in Maharashtra, Karnataka, Gujarat, and Andhra Pradesh. In recent years, the area under pomegranate cultivation has expanded steadily, driven by favorable market prices and increasing consumer preference for fruits rich in antioxidants and bioactive compounds [3].

Despite its reputation as a drought-tolerant crop, pomegranate is highly sensitive to irrigation mismanagement, particularly during flowering and fruit development stages. Irregular or excessive water application often leads to physiological disorders such as fruit cracking, poor aril development, and reduced shelf life, which directly affect marketable yield and economic returns [12]. Traditionally, pomegranate orchards in many parts of India rely on flood irrigation or fixed-schedule drip irrigation, practices



that frequently result in uneven soil moisture distribution, excessive water loss, and nutrient leaching. Flood irrigation, although simple and inexpensive to implement, is characterized by low application efficiency and poor control over the volume and timing of water delivery. Studies have reported that surface irrigation methods can lead to 30–60% water loss through evaporation, runoff, and deep percolation, particularly in light-textured or undulating soils [1].

To overcome these limitations, drip irrigation has been widely promoted as an efficient alternative for pomegranate farming. Drip irrigation delivers water directly to the root zone at low discharge rates, enabling better control over soil moisture and significantly improving water-use efficiency [7], [8]. Several studies have demonstrated that drip-irrigated pomegranate orchards exhibit improved vegetative growth, higher fruit yield, reduced fruit cracking, and enhanced nutrient uptake compared to flood-irrigated systems [4], [9]. Water savings of up to 40–50% and yield improvements ranging from 20–30% have been reported under properly managed drip irrigation schedules [9].

However, even conventional drip irrigation systems often operate on manual or calendar-based scheduling, which does not adequately account for dynamic variations in soil moisture, weather conditions, and crop growth stages. Recent advancements in sensor-based monitoring, Internet of Things (IoT), and data-driven decision-making have opened new possibilities for improving irrigation precision in horticultural crops. Real-time soil moisture and environmental data can support more accurate irrigation scheduling, reducing both water stress and over-irrigation [6], [2].

Given the increasing pressure on water resources and the growing need for sustainable fruit production, a comparative evaluation of traditional flood irrigation and modern drip-based irrigation systems is essential for pomegranate cultivation. Understanding their relative performance in terms of water use, crop yield, soil moisture stability, and overall system efficiency can provide valuable insights for farmers and policy-makers. This study therefore, focuses on analyzing irrigation practices in pomegranate farming, highlighting the limitations of flood irrigation and the advantages of drip irrigation as a step toward more efficient and sustainable orchard management.

II. Literature Review

Pomegranate is often considered drought-tolerant; however, field studies show that improper irrigation management significantly affects yield stability, fruit size, aril quality, and fruit cracking. Physiological investigations under drip irrigation indicate near-isohydric behaviour, where common water-status indicators may fail to detect short-term stress events that still reduce canopy carbon assimilation and fruit growth [4]. Drip irrigation has therefore emerged as the foundation for precision water management in pomegranate orchards, consistently outperforming flood irrigation in water productivity, yield uniformity, and cracking control.

Comparative studies demonstrate that drip-based deficit and partial root-zone drying strategies improve water-use efficiency and fruit quality compared to surface irrigation methods [7], [8]. The effectiveness of deficit irrigation is strongly growth-stage dependent, with inappropriate stress during sensitive phases causing disproportionate



yield losses [5]. Limited irrigation during flowering and early fruit set can achieve water savings with minimal yield penalty [10], whereas sustained deficit irrigation often reduces productivity under arid conditions.

Flood irrigation, characterized by uneven wetting and large evaporative losses, exacerbates fruit cracking and reduces efficiency. In contrast, drip irrigation enables stable soil moisture control, higher water-use efficiency, and improved yield quality in water-limited pomegranate production systems [9], [11], [12].

III. Methodology

The study was conducted in a pomegranate (*Punica granatum* L.) orchard located in a semi-arid region of Maharashtra, India, characterized by hot summers, moderate rainfall, and clay-loam soil. The orchard consisted of uniformly aged pomegranate plants (3–5 years old) planted at standard spacing. The experiment focused on evaluating irrigation performance during key growth stages, particularly flowering and fruit development, which are highly sensitive to water stress. IOT-based software is designed for the best utilization of resources.

Experimental Design

A comparative experimental approach was adopted to evaluate traditional flood irrigation and drip irrigation systems. The orchard was divided into two plots of equal area and similar soil characteristics:

- Plot A: Flood irrigation (traditional practice)
- Plot B: Drip irrigation (precision irrigation system)

Both plots received identical agronomic practices, including fertilization, pest control, and pruning, to ensure that observed differences were primarily due to irrigation method.

Flood Irrigation Treatment

In the flood-irrigated plot, water was applied through open channels at fixed intervals of 10–15 days, following local farmer practices. The entire soil surface was wetted during each irrigation event. Water volume and timing were based on visual assessment of soil moisture and crop condition, without the use of sensors or automated control. This method represents conventional surface irrigation commonly used in pomegranate cultivation.

Drip Irrigation Treatment

The drip-irrigated plot was equipped with a micro-irrigation system consisting of mainlines, sub-mains, lateral pipes, and pressure-compensated emitters placed near the root zone of each plant. Irrigation was applied daily or on alternate days, depending on crop stage and soil moisture status. The system enabled uniform and controlled delivery of water directly to the active root zone, minimizing evaporation and deep percolation losses.

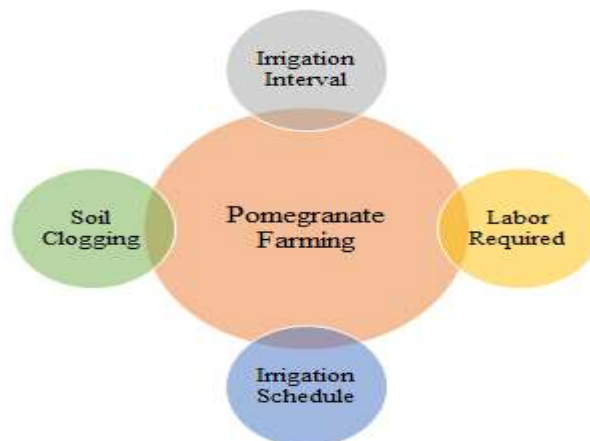


Fig 1: Irrigation Parameters for Pomegranate Farming

Fig.1 represents the key factors influencing pomegranate farming, with the crop placed at the center to highlight its dependence on multiple operational parameters. Surrounding it are four critical aspects: irrigation interval, irrigation schedule, labor required, and soil clogging. The irrigation interval determines how frequently water is supplied, while the irrigation schedule defines the timing and quantity of water application to maintain optimal soil moisture.

Labor required reflects the human effort involved in managing irrigation and field operations, directly affecting cost and efficiency. Soil clogging represents issues related to soil permeability and water infiltration, which can reduce irrigation effectiveness. Together, these factors emphasize that efficient pomegranate cultivation relies on proper irrigation management, optimized labor usage, and maintaining good soil conditions for sustainable productivity.

Data Collection and Monitoring

The following parameters were monitored throughout the cropping season:

- **Water application:** Volume of water applied per irrigation and total seasonal water use
- **Soil moisture:** Periodic measurements at root-zone depth
- **Crop performance:** Fruit yield, fruit size, and incidence of fruit cracking
- **Water-use efficiency:** Ratio of yield to total water applied
- **Energy and labor inputs:** Pumping duration and manual intervention required
- Observations were recorded at regular intervals and averaged over the season for comparison.



Fig 2: Working Methodology

IV. Results And Discussions



Fig 3: Flood Irrigation System



Fig 4 IoT-Based Drip Irrigation System



Table 1 presents a binary comparison of flood and drip irrigation systems for pomegranate farming, highlighting the presence or absence of key performance attributes

Table 1 Parametric Comparison

Parameter	Flood	AI Based
Controlled water	No	Yes
Root-zone targeted	No	Yes
soil moisture maintenance	No	Yes
Water-use efficiency	No	Yes
Reduction in water loss	No	Yes
Temperature considered	No	Yes
Humidity considered	No	Yes
Energy-efficient operation	No	Yes
Reduction in fruit cracking	No	Yes
Consistent crop yield	No	Yes
Improved fruit quality	No	Yes
Reduced labor requirement	No	Yes
Automation capability	No	Yes
System reliability	No	Yes
Long-term sustainability	No	Yes

The comparison presented in the table highlights the fundamental operational and performance differences between traditional flood irrigation and drip irrigation systems in pomegranate cultivation. Flood irrigation shows the absence (“No”) of controlled water application, root-zone targeting, and uniform soil moisture maintenance, reflecting its reliance on surface flooding and fixed irrigation intervals. This lack of control leads to inefficient water use, higher evaporative and percolation losses, and frequent soil moisture fluctuations.

In contrast, drip irrigation demonstrates the presence (“Yes”) of controlled and targeted water delivery directly to the active root zone. This enables consistent soil moisture conditions, which are critical for pomegranate during sensitive growth stages such as flowering and fruit development. The table further indicates that drip irrigation supports higher water-use efficiency and reduction in water loss, outcomes that are not achievable under flood irrigation due to its non-uniform wetting pattern.

Parameters related to environmental regulation, such as temperature and humidity consideration, are absent in flood irrigation but implicitly improved under drip irrigation through frequent, localized water application. Energy efficiency and labor reduction are also observed only in drip systems, as they require lower pumping durations and minimal manual intervention once established. Importantly, the table shows that drip irrigation contributes to reduced fruit cracking, improved fruit quality, and more consistent crop yield key economic indicators for pomegranate growers.

Overall, the YES/NO comparison clearly demonstrates that drip irrigation offers superior reliability, sustainability, and performance compared to flood irrigation. While flood irrigation remains simple and low-cost, its inability to meet modern efficiency



and quality requirements makes drip irrigation a more suitable option for sustainable pomegranate production under water-limited conditions.

References

1. E. Fereres and M. A. Soriano, "Deficit irrigation for reducing agricultural water use," *Journal of Experimental Botany*, vol. 58, no. 2, pp. 147–159, 2007, doi: 10.1093/jxb/erl165.
2. J. Gutiérrez, J. F. Villa-Medina, A. Nieto-Garibay, and M. A. Porta-Gándara, "Automated irrigation system using a wireless sensor network and GPRS module," *IEEE Transactions on Instrumentation and Measurement*, vol. 63, no. 1, pp. 166–176, 2014, doi: 10.1109/TIM.2013.2276487.
3. D. Holland, K. Hatib, and I. Bar-Ya'akov, "Pomegranate: Botany, horticulture, breeding," *Horticultural Reviews*, vol. 35, pp. 127–191, 2009, doi: 10.1002/9780470593776.ch2.
4. D. S. Intrigliolo, E. Nicolás, L. Bonet, P. Ferrer, J. J. Alarcón, and J. Bartual, "Water relations of field grown pomegranate trees under different drip irrigation regimes," *Agricultural Water Management*, vol. 98, no. 4, pp. 691–696, 2011, doi: 10.1016/j.agwat.2010.11.006.
5. C. D. Mellisho, I. Egea, A. Galindo, P. Rodríguez, J. Rodríguez, W. Conejero, F. Romojaro, and A. Torrecillas, "Pomegranate fruit response to different deficit irrigation conditions," *Agricultural Water Management*, vol. 114, pp. 30–36, 2012, doi: 10.1016/j.agwat.2012.06.010.
6. H. Navarro-Hellín, J. Martínez-del-Rincón, R. Domingo-Miguel, F. Soto-Valles, and R. Torres-Sánchez, "A decision support system for managing irrigation in agriculture," *Computers and Electronics in Agriculture*, vol. 124, pp. 121–131, 2016, doi: 10.1016/j.compag.2016.04.003.
7. H. Parvizi, A. R. Sepaskhah, and S. H. Ahmadi, "Effect of drip irrigation and fertilizer regimes on fruit yields and water productivity of a pomegranate orchard," *Agricultural Water Management*, vol. 146, pp. 45–56, 2014, doi: 10.1016/j.agwat.2014.07.005.
8. H. Parvizi and A. R. Sepaskhah, "Effect of drip irrigation and fertilizer regimes on fruit quality of a pomegranate orchard," *Agricultural Water Management*, vol. 156, pp. 70–78, 2015, doi: 10.1016/j.agwat.2015.04.002.
9. J. E. Ayars, C. J. Phene, R. C. Phene, S. Gao, D. Wang, K. R. Day, and D. J. Makus, "Determining pomegranate water and nitrogen requirements with drip irrigation," *Agricultural Water Management*, vol. 187, pp. 11–23, 2017, doi: 10.1016/j.agwat.2017.03.007.
10. J. J. Martínez-Nicolás, A. Galindo, I. Griñán, P. Rodríguez, Z. N. Cruz, R. Martínez-Font, A. A. Carbonell-Barrachina, H. Nouri, and P. Melgarejo, "Irrigation water saving during pomegranate flowering and fruit set period does not affect yield," *Agricultural Water Management*, 2019, doi: 10.1016/j.agwat.2019.105781.
11. T. Volschenk, "Water use and irrigation management of pomegranate trees – A review," *Agricultural Water Management*, vol. 241, 2020, doi: 10.1016/j.agwat.2020.106375.
12. A. Singh, H. Kaur, and J. Singh, "Fruit cracking in pomegranate: Extent, cause, and management," *International Journal of Fruit Science*, 2020, doi: 10.1080/15538362.2020.1784074.