Optimized Drip Irrigation System with Scope for Low-Cost Smart Modernization: A Case Study of Cucumber Cultivation

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Abstract - *Drip irrigation is an efficient method of water application that delivers water directly to the plant root zone, thereby reducing losses and improving crop performance. This paper presents a field-based case study of a drip irrigation system implemented for cucumber cultivation at Sinner, Nashik district, Maharashtra, with the objective of evaluating system performance, water application practices, operational challenges, and improvement possibilities under small-scale farming conditions. Water was supplied from an agricultural well through a filtration unit and distributed using PVC mainline and sub-main pipelines along with durable lateral drip pipes fitted with inline emitters at one foot spacing. The total cultivated area was one bigha, equivalent to twenty-one thousand seven hundred eighty square feet, requiring an equal number of emitters for uniform water application. During the initial crop growth stage, lower quantities of water were applied, followed by a gradual increase as plant growth progressed. On average, each emitter delivered approximately one liter of water in ten minutes, with irrigation applied at intervals of two to three days based on crop stage and soil moisture conditions. Field observations revealed uniform water distribution, improved soil moisture retention, reduced weed growth, and nearly forty percent water savings compared to conventional irrigation practices. However, challenges such as emitter clogging due to algae formation and limitations of secondary filtration were observed. To overcome these issues, the study proposes the adoption of soil moisture based irrigation scheduling, improved filtration, and energy efficient pumping systems suitable for small farmers.*

***Key Words*: Drip Irrigation, Water Use Efficiency, Soil Moisture Sensor, Smart Irrigation, Cucumber Cultivation, Low-Cost Automation, Sustainable Agriculture**

1. INTRODUCTION

Water scarcity and inefficient irrigation practices are major challenges faced by Indian agriculture. Traditional irrigation methods such as flooding lead to excessive water loss due to evaporation, runoff, and deep percolation. Drip irrigation offers a modern solution by delivering water directly to the plant root zone in controlled quantities, thereby improving water use efficiency and crop yield.

Vegetable crops such as cucumber require frequent but controlled irrigation for optimal growth. Drip irrigation helps maintain uniform soil moisture, reduces weed growth, and improves nutrient uptake. However, many field-level drip systems still operate with fixed schedules, manual control, and basic filtration, which limits their long-term performance.

This study focuses on a real-time field implementation of a drip irrigation system for cucumber cultivation in Nashik district. The objectives are to analyse system layout, water application practice, operational performance, problems faced during use, and to propose future low-cost smart improvements suitable for small and medium farmers.

1.1 SITE VISIT DETAILS AND SYSTEM DESCRIPTION

The field study was conducted at a cucumber cultivation farm located in Sinner taluka of Nashik district, Maharashtra. The total cultivated area under drip irrigation was one bigha, equivalent to 21,780 square feet. Cucumber was selected as the study crop due to its high water sensitivity and suitability for drip irrigation systems. Water for irrigation was sourced from an agricultural well located within the farm premises. The site visit and system assessment were carried out under the guidance of the farm owner, Mr. Yogesh Shinde, who provided detailed information regarding system operation, irrigation practices, and maintenance routines.

1.2 Drip Irrigation System Components

The drip irrigation system at the study site used an agricultural well with a pump as the water source. Water from the well was passed through a secondary screen filter before entering PVC mainline and sub-main pipelines. From the sub-mains, Pepsi-size lateral drip pipes were laid along the cucumber beds. Inline emitters with a 1 mm opening were provided at regular spacing to supply water directly to the crop root zone. Flush valves were installed at the ends of the laterals to allow periodic cleaning. This system arrangement ensured uniform water application and smooth field operation during the cultivation period.

2. WATER APPLICATION PRACTICE

Water application was adjusted according to the crop growth stage. During the initial stage, when the cucumber plants were small, a lower quantity of water was supplied. As the crop entered the vegetative and flowering stages, the amount of water applied was gradually increased to meet higher moisture requirements. Irrigation was generally scheduled at an interval of 2–3 days based on field conditions. Each emitter delivered approximately 1 litre of water within 10 minutes of operation. This stage-wise irrigation practice maintained adequate soil moisture in the root zone while preventing waterlogging.

Table -1: Drip Irrigation System Design Details

Parameter	Value
Total Farm Area	21,780 sq ft (1 Bigha)
Crop	Cucumber
Emitter Spacing	1 ft × 1 ft
Total Number of Emitters	21,780
Emitter Discharge	1 litre / 10 minutes
Lateral Pipe Type	Pepsi-size drip pipe
Main/Sub-main Pipe	PVC
Pressure Condition	Low pressure
Water Saving Reported	40%
Operating pressure at emitter	kg/cm^2

3. WORKING PRINCIPLE:-

Water flows from the well to the pump and then passes through a filter unit. Filtered water enters the PVC mainline and sub-main pipelines, from where it is distributed through lateral drip pipes. Inline emitters allow water to drip slowly and uniformly at the crop root zone. The system operates at an average pressure of about 1 kg/cm^2 (approximately 100 kPa), which is sufficient to ensure uniform discharge from all emitters without causing damage or excessive flow.

4. METHODS:-

The present study adopted a field-based case study approach to evaluate the performance of an existing drip irrigation system used for cucumber cultivation under actual farming conditions. The research focused on on-site observation to assess system layout, water application practices, operational efficiency, and maintenance issues rather than laboratory experimentation. The study was conducted on a cucumber farm located in Sinner taluka of Nashik district, Maharashtra, covering an irrigated area of one bigha (21,780 sq ft). Cucumber was selected as the study crop due to its sensitivity to irrigation scheduling and its suitability for drip irrigation systems commonly used in vegetable farming.

System evaluation was carried out through direct field observation during irrigation operations and discussions with the farm owner regarding scheduling and maintenance practices. The drip system consisted of an agricultural well and pump, secondary filtration unit, PVC main and sub-main pipelines, Pepsi-size lateral pipes, and inline emitters spaced at one-foot intervals. Emitter discharge was estimated by observing water output over a fixed time period, with an average discharge of approximately one litre per emitter in ten minutes. Water application frequency, soil moisture condition, uniformity of distribution, weed growth, and performance under low-pressure conditions were assessed during different crop growth stages. Operational issues such as emitter clogging, filtration limitations, and over-irrigation due to manual control were identified, based on which low-cost and farmer-friendly modernization options were proposed to improve system efficiency and sustainability.

Fig -1 Pump and filtration unit used in the drip irrigation system

Fig -2 Lateral drip pipes with inline emitters laid along the crop bed for uniform water application

3. RESULTS AND DISCUSSIONS:-

The on-field assessment of the drip irrigation system used for cucumber cultivation in sinner, Nashik indicated reliable performance with respect to water delivery, soil moisture maintenance, and crop growth response. Water drawn from the agricultural well was pumped through a filtration unit and then distributed through PVC main and sub-main pipelines to the lateral drip lines. Water application occurred through inline emitters, which supplied moisture slowly and directly to the plant root zone. Proper pressure regulation across the network ensured nearly uniform discharge from all emitters, reducing water loss due to runoff, evaporation, and uneven wetting, thereby improving overall irrigation efficiency.

Field-level observations showed that water distribution across the plot was uniform and the system functioned efficiently even under low operating pressure. Soil moisture conditions were maintained within the required range, while weed growth was noticeably reduced due to localized water application near plant roots. Compared to conventional irrigation practices, the drip system resulted in nearly 40% water savings. Adjusting water application according to crop growth stages lower amounts during early growth and increased supply during later stages helped support healthy crop development without causing waterlogging.

Despite these benefits, certain operational limitations were observed during extended use. When the system remained unused for several days, algae and weed growth developed inside the drip pipes, leading to blockage of emitter openings and uneven discharge. Furthermore, reliance on only a secondary filtration unit allowed fine particles to enter the system, gradually causing partial clogging of emitters. Such issues are commonly reported in field-based drip irrigation systems where filtration is inadequate.

Another challenge was the manual operation of valves and pumps, which occasionally resulted in excess water application due to lack of continuous monitoring. This sometimes led to soil conditions becoming wetter than required, affecting irrigation efficiency.

To overcome these limitations, affordable modernization options are suggested, such as soil moisture sensor–based irrigation control, timer-assisted automation, improved primary filtration or sediment chambers, solar-supported pumping systems, and sensor-guided irrigation scheduling. These measures can improve system performance, reduce maintenance requirements, and enhance water and energy efficiency while remaining practical for small-scale Indian farmers.

Table -2: Proposed Modern Low-Cost Solutions

Existing Problem	Proposed Modern Solution	How It Can Be Implemented
Fixed irrigation decision	Soil moisture sensor	Low-cost sensor installed near root zone
Manual valve operation	Timer-based automation	Battery or electric timers
Emitter clogging	Improved filtration	Primary filter or sediment chamber
High energy cost	Solar-assisted pumping	Solar panel + DC pump
Over-irrigation	Sensor-based control	Irrigation only when soil is dry

Table -3: Cucumber crop spacing of 1 ft maintained under mulched field conditions

Compared to existing research solutions that rely on high-cost automation and advanced IoT platforms, the proposed system achieves comparable improvements in water efficiency, labour reduction, and crop productivity using low-cost, farmer-friendly technologies suitable for Indian field conditions.

Table 2: Comparison of Site-Level Problems and Modern Solutions

Aspect	Site Problem	Similar Problem Identified in Research Papers	Modern Solution (literature)	Estimated Cost (Their Solution)	Output if Their Solution is Applied	Proposed Low-Cost Solution (India)	Implementation Method (Practically)	Estimated Cost (India)	Output if our Solution is Applied
Irrigation Scheduling	Fixed irrigation interval regardless of soil moisture	Zakari M.D. et al., “Design, Construction and Installation of Localized Drip Irrigation System,” 2013. Santini A. et	Soil-moisture and weather-based irrigation scheduling	₹25,000–₹40,000 (advanced sensors + weather station)	Accurate irrigation, water savings at farm scale	Soil-moisture threshold-based irrigation using basic sensors	Install 2–3 low-cost capacitive soil moisture sensors near root zone; manually or semi-automatically trigger irrigation when	₹3,000–₹6,000	25–40% water saving, reduced stress, suitable for small farmers

		al., “From Flood to Drip Irrigation: A Review,” 2025.					threshold is reached		
System Operation	Manual valve operation causing labor dependency	Zakari M.D. et al., “Design, Construction and Installation of Localized Drip Irrigation System,” 2013.	Fully automated valve and pump control using controllers	₹30,000–₹50,000	Reduced labor and consistent irrigation	Timer-based semi-automation	Use battery-operated irrigation timers connected to control valves	₹2,500–₹5,000	Reduced labor, timely irrigation, minimal training needed
Filtration and Clogging	Improvised filter prone to clogging	Zakari M.D. et al., “Design, Construction and Installation of Localized Drip Irrigation System,” 2013. Jaiswal N. et al., “Smart Drip Irrigation Systems Using IoT,” 2025.	Standard sand + screen filtration with pressure regulation	₹10,000–₹15,000	Less clogging, longer system life	Low-cost screen filter + periodic flushing	Install commercial screen filter and schedule weekly flushing	₹2,000–₹4,000	Acceptable clogging control with very low maintenance cost
Energy Source	Dependence on electric/fuel pump	Khalifa W.M.A. et al., “Farm-Based Environmental and Economic Impacts of Drip Irrigation,” 2020. Santini A. et al., “From Flood to Drip Irrigation: A Review,” 2025 . Jaiswal N. et al., “Smart Drip Irrigation Systems Using IoT,” 2025	Solar-powered pressurized drip systems	₹1,00,000–₹2,00,000	Renewable energy, lower emissions	Small solar pump + gravity-fed drip	Use 0.5 HP DC solar pump to fill overhead tank, gravity flow for irrigation	₹35,000 – ₹50,000	60–70% energy cost reduction, feasible for rural India
Monitoring & Data	No monitoring	Jaiswal N. et al., “Smart	IoT-based real-time	₹40,000–₹80,000	Accurate system	Manual + basic	Use low-cost pressure	₹3,000–₹6,000	Early fault detection,

Use	g of pressure, flow, or moisture	Drip Irrigation Systems Using IoT," 2025.	monitorin g		performan ce tracking	digital monitori ng	gauge, flow meter, and moisture sensors		acceptable accuracy at low cost
Technolo gy Complexi ty	Limited technical skills of farmers	Jaiswal N. et al., "Smart Drip Irrigation Systems Using IoT," 2025.	Smart AI-driven irrigation platforms	Very high (□1–2 lakh)	High accuracy but complex	Farmer-friendly simple tech	Use visual indicators, mobile alerts (optional), manual override	Minimal	High adoption, easy operation

3. CONCLUSIONS

The drip irrigation system studied in this project proved to be efficient in conserving water and improving irrigation performance for cucumber cultivation. The system delivered uniform water at low pressure and resulted in approximately 40% water savings. The site visit provided valuable practical knowledge regarding system layout, discharge control, and maintenance requirements.

However, issues such as clogging, manual operation, and over-irrigation highlight the need for modernization. Low-cost solutions such as soil moisture sensors, timers, improved filtration, and solar energy integration can significantly improve system reliability and sustainability. This study confirms that affordable smart irrigation technologies can support sustainable agriculture and benefit small-scale Indian farmers.

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