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MICRO IRRIGATION: A WAY TO SUSTAINABLE AGRICULTURE

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ABSTRACT

Micro-irrigation is an advanced agricultural practice that offers a sustainable solution to address the growing challenges of water scarcity, environmental degradation, and the increasing demand for food production. Through a network of pipes with varying sizes known as the main line, the sub-main lines, and the lateral lines, water is made to flow under pressure as part of a coordinated and controlled water management system known as micro irrigation. Some emitters allow water directly to the roots of plants through controlled, low-flow systems such as drip irrigation, micro-sprinkler systems, micro jet and bubbler irrigation. By applying water precisely where it is needed, micro-irrigation making highly efficient alternative to traditional flood irrigation methods. The adoption of micro-irrigation not only conserves water but also enhances crop yields and quality by providing a consistent and optimal supply of water to crops. This results in healthier plants, faster growth cycles, and increased agricultural productivity, even in regions with limited water resources. Fertigation improves fertilizer-use efficiency and maintains nutritional balance and nutrient concentration at optimum levels. It saves energy and labor, provides opportunities to apply the nutrient at critical stages of crop growth, and results in high-quality crop productivity. Moreover, micro-irrigation systems contribute to the sustainability of agriculture by reducing energy consumption, improving soil health, and mitigating the negative environmental impacts of conventional irrigation practices.
***Keywords*:** Micro Irrigation, Drip, Micro-sprinkler, Fertigation, yield and water use efficiency.

Introduction

Water is a key factor in increasing agricultural production. About 90 percent of India's water resources are used for agriculture out of this only 50 percent is actually used by plants and the remaining water resources are wasted either as deep percolation or as evaporation (FAO, 2010). Therefore, efficient use of water which is delivered for irrigation purposes needs to be given primary attention for improving water delivery efficiency. This requires appropriate method of measuring and evaluating how effectively water extracted from a water source is used to produce crop yield. India is majorly an agricultural country and has a huge requirement of water to produce commodities. Current and future agricultural needs can be met by increasing water consumption more efficiently in agriculture, enabled by the introduction of innovative measures and technologies such as micro-irrigation (Rathore *et al.*, 2021). We already have various micro-irrigation systems in use; however, the economics of these systems is a barrier for adoption by small landholder farmers in developing countries like India. The growing population of India will increase the demand for food, which can be fulfilled by the adaptation of micro-irrigation to improve agricultural production through efficient water use (Maheriya *et al.*, 2020). Micro-irrigation is a key Innovative technology for efficient water use and enhanced agricultural output (Eslami *et al.*, 2025).

Water is a precious resource, so minimizing waste means lower costs for homeowners, business and farms. In countries with higher peak hour tariffs, smart irrigation systems can be programmed to take benefit of the low tariff periods ensuring substantial cost benefits to the user.

Need of micro-irrigation system-

- Reduce the salinity of soil.
- As an initiative to increase farmer income and reduce poverty.
- As a means to save water in irrigated agricultural land.
- To reduce the evaporation and infiltration loss.
- Agricultural chemicals can be applied more efficiently.
- To get higher production to compete the increasing population of our country.

What is Micro-irrigation

For decades India predominately used flood irrigation, which was extremely wasteful and inefficient form of irrigation. Micro-irrigation, also known as drip irrigation or trickle irrigation,

In a microirrigation system, water is distributed through a network of pipes or tubes with emitters such as drip emitters and microsprinklers placed near the plants. These emitters release water slowly and locally, directing water to the root area of each plant. This targeted approach ensures water is applied only where it is needed, reducing evaporation and wasteful runoff.

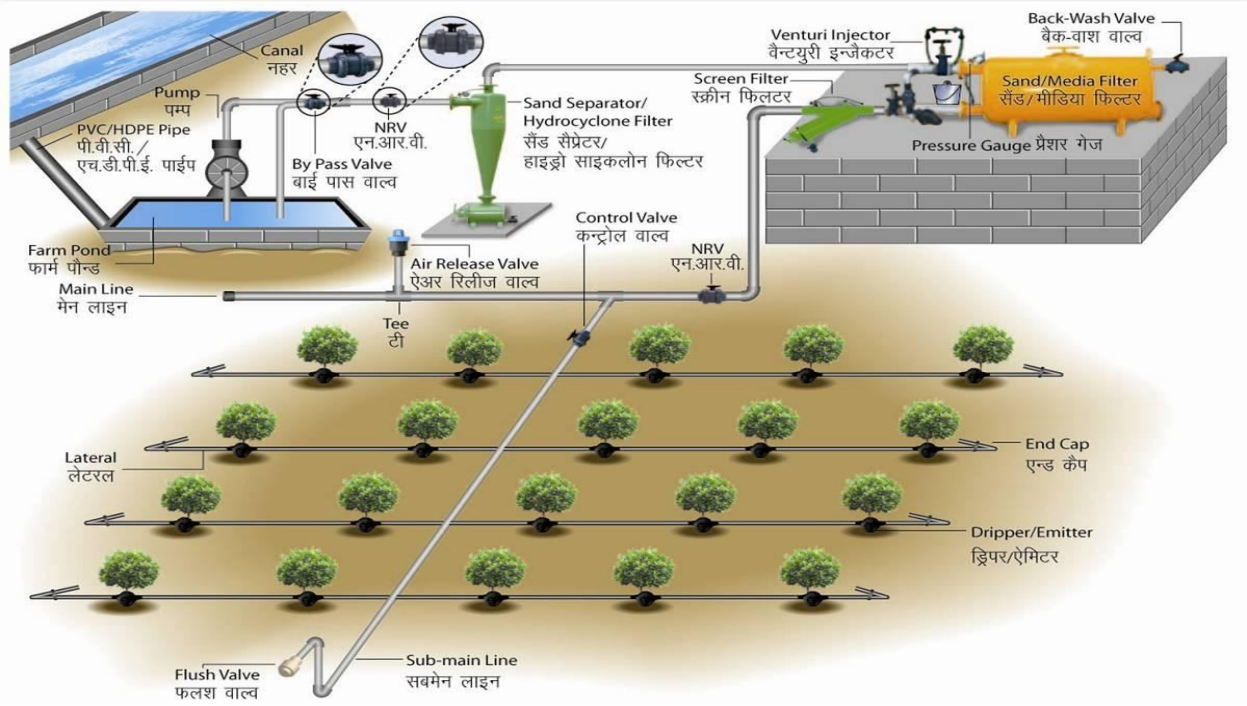

Fig. 1: Layout of micro-irrigation system

Components of a micro-irrigation system

1. Control head- Delivers water from the source to the mainline.

- Control the amount and pressure of water delivered, filter that water to avoid operational problems.
- Add fertilizer and chemicals.
- Major components: Pumping station, Control and monitoring devices, Fertilizer and chemical injectors, Filtration system.

2. Mainlines, sub mains and manifolds

- Receive irrigation water from the control head and deliver it to the lateral and emitters.
- Proper design of the mains, sub mains and manifolds ensures that pressure loss through these conduits does not adversely affect operation of the system.
- Pressure control points are provided at the inlets to the manifold.

- The manifold or header connects the mainline to the laterals.

3. Laterals and emitters

- Irrigation water is delivered to the plant from emitters, which are located on the lateral.
- Water flows from the manifold into the laterals, which are usually made of polyethylene plastic tubing ranging from 3/8 to 1 inch in diameter.
- Emitters are used to dissipate pressure and discharge water at a constant rate and uniformly from one end of the field to the other.

4. Flushing system

- Remove particles and organisms that pass through the filtration system and accumulate in the pipelines, manifolds and laterals.
- Flushing involves pushing water through the system at a sufficient velocity to resuspend the sediment that has accumulated and allowing the flush water to exit the system.
- Includes flush valves and flush manifolds at the downstream end of the laterals.

(Source- S.R. Reddy, 2007)

Types of micro-irrigation systems

(i) Drip Irrigation

In drip irrigation, small emitters or drippers are placed along the irrigation line. These emitters release water drop by drop, providing a slow and steady supply of water to your plants. In drip irrigation, water is applied as droplets or trickles. Drip irrigation adopted mostly in areas where water scarcity is very acute and suited especially for wider crops such as Ber, Pomegranate, Citrus, Cotton, Castor, Maize, Tomato, Brinjal and Plantation crops. The emitter is a metering device made up of plastic and delivers a less but precise discharge. These emitters dissipate water pressure through the use of long-paths, small orices or diaphragms. Some emitters are pressure compensating, in which water emits at a constant rate over a range of pressures. Emission devices deliver water in drip, bubbler and microsprinkler modes. Emitters for each of these modes are available in several discharge increments. (Sivanappan *et al.*, 1987)

(ii) Micro-sprinkler irrigation

Micro-sprinkler irrigation uses low-volume sprinklers or mini sprinklers that atomize water into a fine mist or spray pattern. Water is sprinkled, sprayed, ormisted in the micro-sprinkler mode. Sprinkler irrigation system conveys water from the source through pipes under pressure to the field and distributes over the field in the form of spray of rain like droplets. It is also known as overhead irrigation. Different types of sprinkler systems namely portable, semi-portable, semi-permanent and permanent are in vogue by in habitants of Rajasthan depends on availability of labor, energy costs, type of crop (arable cop or permanent orchards), distance from water sources etc. The use of foliar application of nutrients directly to the plant leaves is much suitable due to its low cost per unit area as compared to the application to soil. These sprinklers can cover a larger area compared to drop emitters and are widely used in Greenhouse nurseries, landscaping and gardens (Keller *et al*., 1990)

(iii) Bubbler irrigation

Bubbler irrigation is a micro-irrigation method using small emitters (bubblers) to deliver water slowly and directly to the root zone of individual plants, often in orchards, landscapes, or container gardens, creating small basins or "bubbles" of water that seep into the soil, ideal for deep watering without much runoff or evaporation, suitable for trees, shrubs, and even row crops. It's efficient, reduces water waste, and works with low pressure, often featuring buried pipes and above-ground risers for easy installation and maintenance (Reddy & Reddy, 2006)

(iv) Micro- jet irrigation

Micro-jet irrigation is a precise, low-pressure watering method using small sprinklers (jets/micro-sprays) to deliver water as fine sprays or streams near plant roots, significantly saving water and boosting efficiency compared to flood irrigation, ideal for orchards, nurseries, and landscapes by targeting specific areas, reducing weeds, and minimizing evaporation. It involves pipes, filters (essential for preventing clogs), and adjustable emitters, providing gentle precipitation for seedlings or wider coverage for mature plants, working with low flow rates and low pressure (Tiwari, 2006)

Advantages of micro irrigation are:

Micro irrigation has several advantages over other irrigation methods.

(i) Water Efficiency-

Micro-irrigation delivers water directly to the root zone of plant, minimizing evaporation and runoff to reduce water waste, improved water use efficiency (Metha *et al*., 2010) and ensuring more efficient water intake, resulting in healthier plants with less risk of disease and pests is obtained.

In traditional types of surface irrigation, huge amount of water is lost through seepage and deep percolation while conveying water from the source to field. Whereas in case of drip systems the water is applied to the root zone of the crop in smaller droplets which results in less loss of water and improved water use efficiency. Narayanamoorthy (2004) in Maharastra registered a water saving of 12-84 percent in vegetables, 45-81 percent in fruit crops and 40-60 percent in field crops like cotton and groundnut; and 65 percent in sugarcane with the adoption of drip irrigation over conventional surface irrigation.

(ii) Soil salinity and NO_3 levels

Drip irrigation can be advantageous in using poor quality waters high in salt contents (up to 8–10 dS/m) without affecting the yield. By using good-quality canal water, instead of brackish groundwater, without any percolation through drip system may help in arresting the dangerous rise in water table resulting in sustainable use of land resources (Rajak *et al*., 2006). Ramakrishna (2003) reported that properly designed trickle irrigation system has the ability to minimize the salt concentration of the soil water in the vicinity of plant roots, salt movement and hence salt distribution in soils is directly related to water movement. Adoption of drip irrigation resulted in concentration of salts at 0-50 cm depth and it reduces with the increase in depth. Fertilizer application through drip irrigation (fertigation) can reduce fertilizer usage and minimize groundwater pollution due to less fertilizer leaching from irrigation. The fertilizer application through fertigation device is restricted to the wetted volume of soil where the active roots were concentrate and hence was available to plants fully (Patel and Rajput, 2001). Mirjat *et al*. (2008) studied the nitrate movement in the soil profile at Tanndojam,

(iii) Fertilizer saving

The right combination of water and nutrients is the key for high yield and the quality of produce. Fertigation (application of fertilizer solution with drip irrigation) has the potential to ensure that the right combination of water and nutrients is available at the root zone, satisfying the plants total and temporal requirement of these two inputs (Patel and Rajput, 2001). Fertigation in addition to saving of fertilizers also permits applying fertilizer in small quantities according to the plants nutrient requirements. It is also considered ecofriendly as it avoids leaching of fertilizers (Permi *et al.,* 2013). Micro-irrigation ensures uniform nutrient distribution and allows adjustment of fertilizer schedules based on crop stage. It also reduces labor, minimizes environmental pollution, and lowers overall fertilizer use compared to conventional broadcasting (Rathod *et al*., 2014).

(iv) Weed Suppression

Weed management through drip irrigation is achieved by delivering water directly to the crop root zone, minimizing moisture in inter-row areas where weeds typically germinate. This localized watering reduces weed seed emergence and suppresses growth compared to surface irrigation. Using mulches along with drip lines further limits light and moisture available to weeds. Fertigation through drip also prevents nutrient availability in non-target areas, reducing weed competitiveness. Overall, drip irrigation enhances water-use efficiency while significantly lowering weed pressure in field crops (Shirazi *et al*., 2016)

(v) Power saving

Electricity savings is one of the important advantages of drip method of irrigation (Andal, 2011). Drip irrigation substantially reduces the working hours of pumpset by reducing the water consumption. As a result, electricity required for irrigating unit area of land also reduces significantly (Narayanamoorthy, 2004). Narayanamoorthy (1996 and 2001) reported that the adoption of drip irrigation resulted in a power savings of 44 percent in sugarcane 37 percent in grapes and 29 percent in banana over flood irrigation in Maharastra. Similarly the field survey conducted by Narayanamoorthy, 2004 revealed a power saving of 41 percent in sugarcane at Pune and 48 percent at Ahmednagar.

(vi) Labor saving

The labor requirement for weeding and spraying of pesticides for pest control is reduced in this irrigation practice because water is delivered exactly in the required amount and at the precise point leaving very little for other unwanted plants to grow and proliferate.

(vii) Flexibility

The microirrigation system can be easily adapted to different crop types, soil conditions, and topography. Sprinkler system of irrigation is suitable to undulating lands. Micro/drip and sprinkler irrigation suitable to waste lands. Possibility of using saline water through the emission devices.

- **Overall,** microirrigation is an efficient and sustainable irrigation method that saves water, increases crop productivity, and promotes environmental protection. With in emphasis on irrigation in india, micro irrigation technology

can be used to enhance the utilization of our limited water resources.

- The following are higher benefits of the micro irrigation technology:

The efficiency of irrigation increased by 50% to 90%.

28.5% more fertilizer can be used per unit of area (Camp *et al*., 2001).

Up to 30.5% less energy usage (Moin and Kami, 2018).

Disadvantages of micro irrigation are

- Initial investment is high.
- Damage due to rodents is more.
- Cause difficultly in intercultural operations.
- Clogging of emitter due to precipitation. This regular clogging and other associated expenditure raises costs of its operation which run against the possibility of its adoption as it puts an additional economic burden on the poor farmers.
- Sometime not uniform application (concentration of the solution decreases as solution dissolve) leading to poor nutrient placement.
- Possible pressure loss in the main irrigation line.
- Sprinkler irrigation may cause foliar burn (with high concentrations of agro-chemicals and incompatibility with certain other agro chemicals) and leaf damage (Necrosis and burning).
- There is a general lack of awareness among the farmers regarding micro/drip and sprinkler irrigation use and advantages.
- The pipes and tubes have shorter lifeline due to clogging, its cracks, breaks and requires regular monitoring and maintenance.

Constraints in Adoption of Micro-irrigation

Although the farmers are well versed with multiple advantages of drip system, yet their decision on adoption of drip irrigation was influenced by many factors, notably among them is high initial cost and scarcity of water in over exploited groundwater regions. Other application problems include salt encrustation and clogging of conveyance pipes irrigating salt water. As per Garetts ranking technique for non adoption of drip irrigation include salt encrustation and clogging of conveyance pipes as 1st rank, high initial cost as 2nd followed by delay in subsidy amount disbursement (Palanisamy and Palanisamy, 2000). Government of India has at present extended subsidies for varying categories of farmers up to 50 percent of the drip cost to meet the high installation cost and to popularize these water saving methods in the long run.

Table 1: Comparison of efficiency in various irrigation methods

S. No.	Irrigation method	Water use efficiency
1.	Surface irrigation	50-60 % Low
2.	Level Basin	60-80 % Low
3.	Sub irrigation	50-70 % Low to medium
4.	Overhead irrigation	60-80 % Medium
5.	Sprinkler irrigation	60-85 % Medium
6.	Drip irrigation	80-90 % Medium to high

(Source: Bonanomi *et al*., 2011)

Table 2: Irrigation efficiencies under different methods of irrigation

S. No.	Irrigation efficiencies	Method of irrigation		
		Surface	Sprinkler	Drip
1	Conveyance efficiency	40-50 (canal)		
		60-70 (well)		
2	Application efficiency	60-70	70-80	90
3	Surface water moisture evaporation	30-40	30-40	20-25
4	Overall efficiency	30-35	50-60	80-90

(Source: Sivanappan 1998)

Governmental efforts for adoption of micro irrigation technology by Indian farmers

- **National Mission for Sustainable Agriculture**

In this scheme, some amount of funds was expended on on-farm level water management. This scheme focuses on promoting sustainable agriculture by paying attention to climate change, encouraging location specific agronomic activities. This scheme also has some limitations like it does not focus on a single idea, it does not provide complete guidelines to the farmers, and implementation on their targets is very poor.

- **Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)**

This scheme was started by Prime Minister Narendra Modi in the year of 2015 with two slogans for fulfilling the water scarcity:

1. Har khet Ko Pani (focuses on extension of irrigation facilities)
2. Per drop more crop (focuses on water use efficiency)

The main emphasis was given to increase the area under improved method of irrigation for enhancing agricultural productivity. From the advent of this scheme a good scope for area under micro irrigation in Rajasthan. The State Government is born 40 % subsidy as state share and 60% will be borne by centre government. The contribution of farmer for drip and sprinklers syeme is different and different for small marginal farmers and rest of farmers. The grant for farmers also varies with DPAP (Drought Prone Area Programme) and Non DPAP or DDP (Desert Development Programme) or non DDP areas. The grant is borne either by farmer from his/ her own resources or loan from various nancial institutions. The farmer as individual, Cooperative Societies/Self Help Groups, Incorporated Companies/Panchayati Raj Institutions/NGOs/ Trusts/Growers Association etc. are eligible to avail assistance under this scheme (https://pmksy. gov.in).

Objective of PMKSY: The scheme was launched with following objectives.

- To Increase the area under micro irrigation through improved technologies.
- To enhance the water use ef ciency in the country.
- To increase the productivity of crops and farmers income.
- To establish convergence and synergy among on-going Government programmes.
- To promote, develop and disseminate micro irrigation technology for agriculture/ horticulture development with modern scienti c knowledge.
- To create employment opportunities for skilled and unskilled person especially unemployed youth.

Conclusion

Micro-irrigation is a highly efficient and sustainable irrigation technology that addresses the pressing challenges of water scarcity, declining soil health, and the growing demand for food production. By delivering water directly to the crop root zone through systems such as drip and micro-sprinklers, it minimizes losses due to evaporation, runoff, and deep percolation, thereby significantly improving water-use efficiency. This precise water application ensures uniform moisture availability, leading to healthier plant growth, improved crop yield, and better produce quality.

The integration of fertigation enhances nutrient-use efficiency by supplying fertilizers in controlled amounts along with irrigation water. This reduces nutrient losses, lowers input costs, and minimizes environmental pollution caused by fertilizer leaching. Additional benefits include reduced weed growth, savings in energy and labor, improved soil structure, and the ability to use saline or limited water resources effectively.

However, widespread adoption is constrained by high initial investment, maintenance requirements, emitter clogging, and limited awareness among farmers. Government initiatives and subsidy programs are playing a vital role in promoting micro-irrigation adoption, especially among small and marginal farmers.

Overall, micro-irrigation represents a crucial step toward sustainable agriculture, ensuring efficient resource use, enhanced farm productivity, and long-term environmental conservation while supporting food security in water-limited regions.

Competing interests disclaimer

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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