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Micro irrigation: A sustainable approach to enhance Water Use Efficiency

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ABSTRACT

The demand for micro-irrigation to fulfil rising food demands will increase as worries over water shortages and food security gain attention on a worldwide scale. Compared to traditional irrigation techniques, micro-irrigation has several benefits, such as the capacity to deliver small volumes of water directly to the crop root zone, the incorporation of fertigation, a decrease in weed and pest infestation, and lower initial and ongoing expenditures. The area under micro-irrigation has grown significantly in the last few decades, mostly due to decreased prices, advancements in emitter and filtration technology, and a rise in grower faith in the system. Micro-irrigation is now adaptable to a wider range of cropping systems, water quality conditions, and applications because of the advancements in research and technology. Water availability and cost are other important factors. The development of precision irrigation, soil moisture sensors, and nano and bio filtration methods have significant potential for the progress of micro-irrigation.

Key words: *Micro irrigation, Drip irrigation, Trickle irrigation, Subsurface drip irrigation (SDI), Surface drip irrigation, Micro sprinkler irrigation, Water use efficiency, Crop yield, Water conservation*

Introduction

With its daily ability to feed billions of people, agriculture is one of the most important sectors of the global economy. However, issues like soil degradation, climate change, and water scarcity are becoming more and more problematic for this sector. In order to stably supply the increasing demand for food, Water use in agriculture is especially crucial for agricultural output and to reduce the risk of drought. Modern agriculture needs to embrace creative methods that are more efficient, eco-friendly, and economical. Not just in Turkey but globally as well, almost 70% of water is used in agriculture. There is pressure on irrigation, the largest user of fresh water in the world, to increase its effectiveness. To increase irrigation's contribution to food production, more efficient irrigation water use is needed by Kumar *et al.* (2023). Reducing salinization while simultaneously raising yields is the double benefit of water-saving technologies, particularly drip irrigation. This is a really important benefit. Furthermore, since neither technique allows water to come into touch with the leaves, brackish water can be used with either strategy for crops that are not particularly sensitive to salinity Ayars *et al.* (2015). In light of irrigation efficiency and environmental concerns, micro-irrigation-the targeted application of water on

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or beneath the soil surface at low pressure using tiny devices that spray, mist, sprinkler, or drip water—is growing in popularity Ajdary *et al.* (2007). The use of micro-irrigation has increased dramatically in the last few decades due to breakthroughs in technology and increased sales. Drip irrigation is a common kind of micro-irrigation. Irrigation statistics show that several countries have seen a rapid increase in the number of acres irrigated by drip irrigation by ye and Liu (2018).

Advantages of micro irrigation

Growth in crop yields and improvements in water management and technology are needed for efficient use of water in agriculture. So India's agricultural sector has implemented a number of demand management programs and measures to increase water efficiency and conserve resources. Growing irrigation water production and water savings during continuous deficit irrigation for areas with severe water shortages are the key advantages to this strategy.

Power saving: One of the key benefits of using a drip irrigation system is that it saves electricity Narayanamoorthy (2003). By utilizing less water, drip irrigation significantly reduces the amount of time a pump set needs to run. As a result, considerably less electricity is needed to water each unit of land Sivanappan, (2001). Narayanamoorthy (1996 and 2001) observed that the use of drip irrigation in Maharashtra produced electricity savings of 29% for bananas, 37% for grapes, and 44% for sugarcane when compared to flood irrigation Yang *et al.* (2019), Patel (2001) and Zapata *et al.* (2022). Similar to this, a 2004 field study by Narayanamoorthy showed that sugarcane could be grown in Pune and Ahmednagar with corresponding power reductions of 41% and 48% Flores *et al.* (2021).

Cost-effective: Installing a drip irrigation system is less expensive than using traditional irrigation techniques because it only costs a set amount that varies depending on the crop Narayanamoorthy (2003). The drip system has the best benefit-to-cost ratio despite having a greater initial cost because of its increased yields, reduced cultivation costs, and water savings. It also has the capacity to preserve nutrients and water by letting water penetrate to plant roots over time Arshad, (2021).

Fertilizer sustainability: A high-yield, high-quality crop depends on the proper ratio of water to fertilizers. The use of fertilizer solution combined with drip irrigation may provide the root zone with adequate water and nutrients, meeting the plant's short- and long-term requirements for these two inputs Sharma *et al.* (2019).

Enhanced Crop Yields: Micro irrigation guarantees that plants receive the right amounts of water and nutrients by delivering them straight to the root zone. This improves crop yields and yields higher-quality harvests.

Water conservation: By delivering water in small, precise doses, micro irrigation systems cut down on water waste and improve water use efficiency. As compared to traditional irrigation

Impact of Micro-Irrigation on Water Conservation and Crop Yield

Micro-irrigation could require less irrigation water when compared to other methods. The smaller moistened area means that less water evaporates. In these systems, surface drainage is basically absent. Micro irrigation has been demonstrated to increase crop output and water usage efficiency over standard irrigation methods by providing a consistent flow of water in the crop zone. Agarwal *et al.* (2023) Postal claims that drip irrigation may at least double crop productivity per unit of water in a variety of applications, such as the irrigation of most vegetables, cotton, sugar cane, orchard, and vineyard crops. A compilation of research findings from several Indian research institutes demonstrates that drip irrigation, for a variety of crops, including cotton, sugarcane, grapes, tomatoes, and bananas, usually increases yields by 20–50% while reducing water usage by 30–60%. The results showed that drip irrigation yielded the highest crop quality and yields. Agarwal *et al.* (2023) Drip irrigation may save up to 55% compared to surface watering, while also having the potential to increase grain output by 15-23% Agarwal *et al.* (2023). This technique can efficiently decrease soil evaporation and deep seepage, increase labour savings, optimize water usage, and enhance operation and management effectiveness. Zhao *et al.* (2022). Because of its many benefits, drip irrigation is currently the most popular type of irrigation technique Ma *et al.* (2022).

Effects of Micro-Irrigation on Soil and Water Resources

Micro-irrigation systems also have the major advantage of being able to use water with a relatively high salt content. Furthermore, wastewater both treated and untreated can be used to target just permissible crops. Micro-irrigation is a superior method for reusing wastewater than regular irrigation because it produces less droplets and doesn't harm plant leaves. In addition, there are less problems with pending, drainage, and odours Agarwal *et al.* (2023). Furthermore, studies show that directly adding nitrogen to plant roots increases plant uptake and lowers the risk of contaminating groundwater. Avoiding emitter clogging is essential when employing wastewater for micro-irrigation. The system needs to be monitored on a frequent basis to ensure a consistent application and smooth operation. In contrast, micro irrigation significantly reduces the amount of salt added to the soil in comparison to traditional watering. Based on research results from Cetin and Bilgel, cotton in Turkey's Harran Plain needs about 1000 mm of water for furrow irrigation and 600 mm for drip irrigation. If the salinity threshold value of 4 dS/m is met, then the amount of salt in the soil is 0.2%. The salt content of the soil for 0.90 m of the effective root depth is known as the salinity threshold value, which is equal to 10000 m^2 × 0.90 m × 1.35 t/m^3 × 0,002 = 24.3 t/ha... According to this estimate, the rates at which salt is added to the soil via furrow and drip irrigation are 2.56 and 1.536 t/ha/year, respectively. Because drip irrigation requires less water than furrow irrigation, the soil retains far less salt Narayanamoorthy (2001).

Classification of micro irrigation system

Drip Irrigation: This method uses tiny, slowly emitting devices called drippers to supply water straight to the root zone of the plant. Since drip irrigation reduces water loss from evaporation and runoff, it is an extremely effective technique of irrigation. It is frequently utilized for vegetables, fruit trees, and row crops. Agarwal *et al.* (2023).

Micro Sprinkler irrigation: A method of pressured irrigation known as sprinkler irrigation irrigates crops by spraying water in the form of tiny droplets, similar to that in a natural rainfall. Sprinkler irrigation has been the subject of numerous studies that have demonstrated its potential and acceptance for commercially increasing crop yield by Narayanamoorthy (1996).

Surface Drip Irrigation: This technique provides water directly to the root zone by placing drip lines on the soil's surface. Fruit trees, vegetables, and row crops are frequently planted using this technique. Agarwal *et al.* (2023).

Subsurface Drip Irrigation: Water is delivered directly to the root zone of this system via drip lines that are buried beneath the soil's surface. This technique can increase crop yields while minimizing soil erosion and water evaporation.

Bubbler irrigation: uses a number of tiny emitters, or bubblers, that are positioned on or close to the soil's surface to distribute water. Like a little fountain, these bubblers release water, which gradually seeps into the ground near the base of plants.

Drip irrigation technology

The affordability, simplicity of installation, simple to use, and low operating expenses of drip irrigation are some of the key factors supporting its adoption Hla and Scherer (2003). The pressure regulation valve, filter, system controller, injectors, gauges, flow pipes, emitters, and other parts are the essential parts of drip irrigation Agarwal *et al.* (2023). Using emitters, flow pipes, hollow tubes, valves, taps, and other components is the primary method of supplying water through drip irrigation. The design, maintenance, operating procedures, and installation process all affect how accurate the setup Narayanamoorthy (2001). Using tiny plastic tubing pipes, drip irrigation is a type of micro irrigation system that provides low pressure water to plants gradually, precisely, and consistently. Depending on the amount of water needed, this frequently irrigates the ground to maintain its moisture content. Surface irrigation is the conventional irrigation technique that doesn't include any machinery. There are two types of drip irrigation: subsurface and surface. One of the most popular irrigation methods nowadays is surface drip irrigation. This technique minimizes evaporation losses by slowing and directly feeding water to the plant's root zone. Because of this, the main idea behind drip irrigation is to provide plants just the proper amount of water where they can absorb it Yang *et al*. (2022). As of right now, drip irrigation is the most effective form of micro irrigation for giving crops the nutrients and water they require to grow well. Drip irrigation schedule reduces salinity issues by allowing for more accurate and efficient

application of agricultural herbicides while preserving a lower and more stable soil matric potential. Drip irrigation has an important impact on resource conservation, cutting cultivation expenses, improving plant growth quality, raising yield, and boosting farm profitability Yang *et al.* (2019).

Drip irrigation equipment quality

For drip irrigation systems to be effective, dependable, and long-lasting, high-quality equipment is essential.

Materials: For drip irrigation equipment to endure a long time and function properly, high-quality materials are needed, such as corrosion-resistant metals, UV-resistant polymers, and sturdy plastics like polyethylene. These materials ought to be resilient enough to endure exposure to mechanical stress, sunshine, moisture, and chemicals found in soil without deteriorating.

Emitters: Because they control the water flow rate and distribution to the plants, emitters are essential parts of drip irrigation systems. Consistent flow rates, even water distribution, and resistance to clogging from silt, mineral deposits, and debris are characteristics of high-quality emitters. Emitters with pressure compensation are very useful for ensuring consistent water distribution on different types of terrain and altitudes.

Filters and Screens: These are crucial parts that guarantee even water distribution and keep emitters from becoming clogged. Good filters should be able to remove organic matter, silt, and debris from water efficiently while still allowing for sufficient flow rates. Self-cleaning screens or filters are preferable because they require less maintenance and last longer.

Connectors and Fittings: The system's tubing and pipe should be compatible with the connectors, fittings, and couplings and they should be safe, leak-proof, and leak-proof. In order to minimize water waste and potential harm to crops or soil, high-quality connectors guarantee tight seals and stop water leakage at connecting points.

Pressure control: To keep the water pressure in the system constant, pressure control components, such as regulators or pressure-compensating emitters, are necessary. In addition to preventing excessive water flow or pressure variations that may cause emitter damage or ineffective irrigation, these devices guarantee uniform distribution of water.

Warranties and Support: You may ensure quality and peace of mind by selecting equipment from reliable manufacturers who give warranties, technical support, and customer service. Manufacturers that have a reputation for dependability and satisfying customers are more likely to provide high-quality equipment and offer prompt assistance when problems arise.

Pipes and Tubing: are usually composed of sturdy, pliable materials that are resistant to sunshine, moisture, chemicals found in the soil, and mechanical strain. Polypropylene (PP), polyvinyl chloride (PVC), and polyethylene (PE) are examples of common materials. High-density polyethylene (HDPE) is especially well-liked since it has superior resistance to abrasion and UV light.

Root Development in Drip Irrigation

Drip irrigation maximizes nitrogen utilization efficiency and promotes root development by providing small amounts of fertilizer and watering in response to the crop's needs. Research has indicated that the proper use of water and nitrogen under drip irrigation can enhance crop output while also increasing the nutrients' uptake and usage Chauhdary *et al.* (2023). Compared to conventional irrigation fertilization techniques, drip irrigation also modifies the root zone's water and fertilizer distribution properties, which impacts root distribution and absorption capacity by Cetin KO *et al.* (2004). Studies showed that using membrane drip irrigation significantly increased soil moisture retention in the 0-30 cm main infiltration layer of wheat, as well as root length density, root surface area density, and root volume density when compared to traditional border irrigation Andal *et al.* (2011) and for soybean, chickpea, and pumpkin, the use of aeration subsurface drip irrigation technology led to a notable increase in total root length, total root surface area, total root volume, and total root activity. After being treated with this technology, tomato plants showed increases in root activity ranging from 7.6 to 17.5% and in root length of 5.6 to 7.5% Andal *et al.* (2011) Narayanamoorthy *et al.* (2004).

Uptake of Nitrogen in Drip Irrigation

The primary element that restricts plant growth is nitrogen. Furthermore, crop nitrogen uptake and use are significantly impacted by fertilization and irrigation techniques.

Water Management: For crops that are drip-irri-

gated, effective water management is essential to maximizing nitrogen uptake. A well-planned irrigation schedule guarantees that plants receive enough moisture for healthy growth and nutrient uptake without flooding the soil, which can reduce the availability of nitrogen.

Application of Nitrogen: Fertilizers can be injected into irrigation water by fertigation (plant root zone fertilization) or incorporated into the soil close to drip lines (plant root zone fertilization). More exact control over nitrogen availability and plant uptake is possible with this tailored application.

Fertigation Timing and Rates: The effectiveness of nitrogen uptake is greatly influenced by the timing and rates of nitrogen fertigation. Growers may make sure that plants have access to nitrogen when they need it most by timing nitrogen applications with crop needs and growth stages.

Soil Properties: A number of factors can affect the availability and uptake of nitrogen in the soil, including texture, pH, organic matter level, and microbial activity. Particularly in soils susceptible to waterlogging or drought stress, drip irrigation systems can assist maintain more consistent soil moisture conditions, which can improve nitrogen availability and uptake.

Nitrogen Losses: Compared to more conventional irrigation techniques like flood or overhead sprinkler systems, drip irrigation can assist reduce nitrogen losses through leaching and volatilization. Drip irrigation improves nitrogen use efficiency and lowers the possibility of nitrogen leaking below the root zone by providing water and nutrients straight to the root zone.

Micro irrigation: Efficient water use

The quantity of biomass or yield generated per unit of water applied or consumed in ecological or agricultural systems is known as water use efficiency, or WUE. It measures the efficiency with which water is used to provide a desired result, including ecosystem productivity, crop production, or forest growth. Conveyance loss is reduced when microirrigation systems are used. The application of micro irrigation techniques reduces evaporation, runoff, and deep percolation. Utilizing water sources with restricted flow rates, like little water wells, is another benefit of conserving water. Micro irrigation's close proximity and focused application lead to significantly higher water usage efficiency. In a survey conducted for the Government of India, which included 5,892 recipients of the National Mission on Micro-Irrigation (NMMI) across 13 states, it was found that the adoption of the micro-irrigation system increased the area under irrigation by 8.41 percent. • Efficient water use also increases the amount of marginal or degraded land that is used for irrigation. The sampled farmers in the same study said that 845.50 hectares of waste/degraded land were not being farmed. Nevertheless, the farmers were able to cultivate 519.43 hectares of similar land after implementing the micro irrigation technology.

The impact of micro irrigation on the economy

As the method reduces the number of pumping hours needed to irrigate an area, it also benefits the economics of irrigation. In addition to saving a significant amount of money and energy, this also helps the pump last longer by reducing wear and tear. This is made possible by the fact that using this technology has reduced the amount of water needed to irrigate a field, as both adopters and non-adopters have noted.Though the economics may work out, resource conservation may suffer because these irrigation cost savings also contribute to the expansion of the irrigated area, which raises the total amount of water utilized to previous levels and requires the use of more energy to irrigate the expanded area. Therefore, in order to improve farm economics, part of the drip irrigation's irrigation economic benefits may also be lost. However, using drip irrigation to irrigate this extended area would result in a significant rise in water demand, which could have extremely negative effects on the ecosystem.In many other indirect ways; technology also has a positive impact on irrigation economics. By ensuring a timely and sufficient supply of water to the farm, it helps eliminate most of the variability associated with farming and productivity, ensuring a yield, productivity, and income for the farmer. A farmer can sign long-term contracts and exert more market power when yield and total production are guaranteed [26]. Due to its potential to reduce conflict and promote adaptation, technology also has a positive effect on the transaction costs associated with irrigation. But even at the village or household level, the actual economics of irrigation won't materialize unless adoption occurs on a large enough scale over time and space to convert savings into inter-farm and inter-sectored transfers.

Challenges for adopting micro-irrigation technology

Due to the high initial expense of setting up a micro irrigation system, farmers with little resources usually cannot afford it. Because farm irrigation management systems and micro irrigation technology were typically seen as separate entities, they were not interconnected.

There was a lack of infrastructure, qualified human resources, suitable technical know-how, and sufficient finance facilities for farmers. The reason micro irrigation is typically seen as a high-tech practice, farmers needed much convincing to adopt it. There was a dearth of knowledge on the best percentage of soil to be wetted, crop- and location-specific irrigation techniques, scheduling of fertilization, and the availability of inexpensive water-soluble fertilizers and other agrochemicals.

Conclusion

Micro irrigation shows promise as a sustainable way to improve agricultural operations' Water Use Efficiency (WUE). Micro irrigation systems maximize the use of available water resources by precisely delivering water to the root zone of plants, minimizing water waste from evaporation, runoff, and deep percolation. Additionally, farmers may customize irrigation schedules to meet the unique water requirements of various crops at different growth stages thanks to the efficient management of water made possible by micro irrigation systems. This precise dousing of water conserves water while maximizing plant development and yield. The use of microirrigation can result in up to (50–90%) savings on water, fertilizer (28.5%), and energy (30.5%) when compared to conventional irrigation. The implementation of micro irrigation techniques has the potential to greatly alleviate the issues associated with water shortages that the agricultural industry faces globally, especially in areas that are vulnerable to drought and water stress. Micro irrigation systems minimize environmental impacts like soil erosion and water pollution while supporting agricultural resilience and food security by encouraging the sustainable use of water resources.

Conflict of Interest: None

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