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Irrigation Methods in Vegetable Crops

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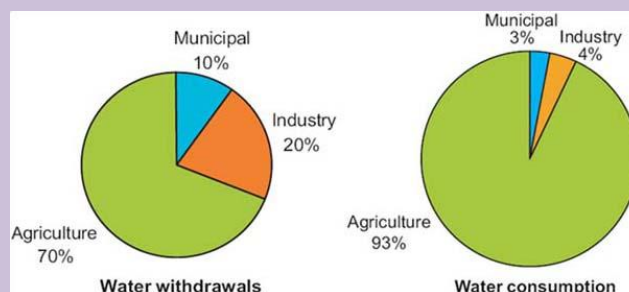
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INTRODUCTION

Water is the most important input in crop production after solar energy, and irrigation accounts for nearly 70% of global freshwater use. Vegetable crops, being high-value and shallow-rooted, require precise and timely water application to achieve optimum growth, yield, and quality. With increasing demand for vegetables and growing pressure on limited water resources, efficient irrigation management has become essential for sustainable production. The choice of irrigation method significantly affects water-use efficiency, crop productivity, soil health, disease incidence, labour requirements, and economic returns. Modern irrigation systems such as drip and sprinkler irrigation can reduce water consumption by 30-60% while increasing yields and improving resource-use efficiency compared to traditional surface irrigation methods.



2. Importance of Irrigation in Vegetable Production

Vegetable crops have specific water requirements that vary by species, growth stage, soil type, and climatic conditions. Most vegetables have a high-water content in their edible parts-ranging from 70% in potatoes to over 95% in cucumbers and lettuce necessitating

consistent moisture availability in the root zone. Inadequate irrigation at critical growth stages-such as germination, transplanting, flowering, and fruit set can cause irreversible yield and quality losses.

For example, tomatoes (*Solanum lycopersicum*) are particularly sensitive to water stress during fruit development, irregular irrigation causes physiological disorders such as blossom-end rot (calcium deficiency induced by water stress) and fruit cracking. Similarly, onions (*Allium cepa*) require uniform irrigation throughout bulb enlargement to achieve marketable bulb size and reduce post-harvest losses. Crops like cauliflower (*Brassica oleracea* var. *Botrytis*) are extremely sensitive to moisture deficit during head formation, which can cause browning and poor curd development.

3. Surface Irrigation Methods

3.1 Flood (Basin) Irrigation

Flood or basin irrigation is the oldest and simplest irrigation method, where water is applied over the entire field surface and allowed to infiltrate. It requires minimal infrastructure and is easy to operate, but has low water-use efficiency (30-40%) due to evaporation, deep percolation, and runoff losses. In vegetable crops, it is generally unsuitable for high-value crops because waterlogging can promote diseases such as damping-off and wilt. However, it may be used for water-tolerant crops like taro and for some leafy vegetables grown on heavy clay soils with good-quality water.

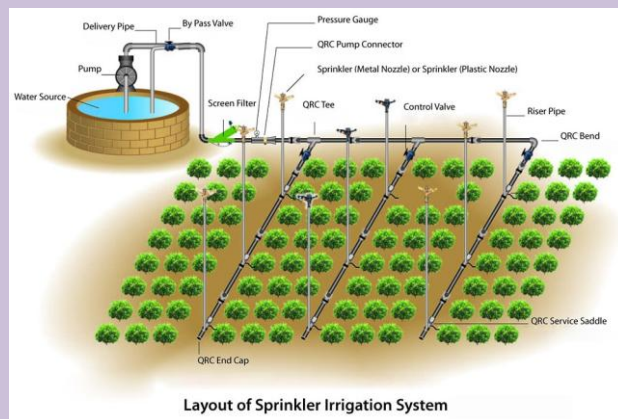
3.2 Furrow Irrigation

Furrow irrigation involves applying water through small channels between crop rows, allowing it to infiltrate into the root zone by gravity. It is widely

used for row vegetables such as potato, sweet corn, cabbage, and beans, as it reduces stem contact with water and lowers the risk of collar rot diseases. Suitable for relatively flat land and soils with moderate to high infiltration, it has a water-use efficiency of about 55-70%, which can be further improved through proper land levelling, optimal furrow spacing and surge irrigation.

4. Sprinkler Irrigation

Sprinkler irrigation distributes water through a network of pressurized pipes and sprinkler heads that spray water in a pattern resembling natural rainfall. The system can be fixed, semi-portable, or fully portable. Common configurations include overhead fixed systems, center pivot systems, lateral move systems and rotating impact sprinklers.

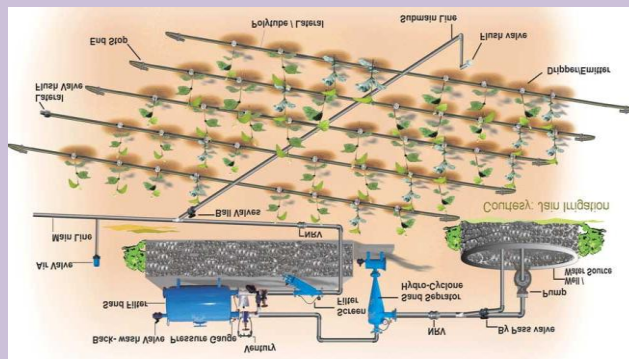


Sprinkler irrigation is suitable for leafy vegetables (spinach, lettuce, coriander), root crops (carrot, radish, beet), and brassicas (cauliflower, broccoli, cabbage), particularly on sandy soils where surface irrigation is less effective. It can also provide frost protection for crops such as strawberries and tomatoes. However,

overhead wetting of foliage may increase fungal diseases like early blight, late blight, and anthracnose, making morning irrigation preferable. Sprinkler systems generally achieve 60-85% water-use efficiency, though high wind speeds can reduce application uniformity and increase evaporation losses.

5. Drip (Trickle) Irrigation

Drip irrigation, also known as trickle irrigation, is a micro-irrigation method that delivers water directly and slowly to the plant root zone through a network of mainlines, sub-mainlines, laterals and small emitters (drippers) placed at or near the soil surface. It is widely regarded as the most water-efficient irrigation method available for row-crop vegetable production.



5.1 Principles and System Components

A standard drip irrigation system consists of: (1) a water source (pump or pressurized supply) (2) a filtration unit (screen, disc or sand media filters) to prevent emitter clogging (3) a fertilizer injection system (fertigation unit) (4) mainlines and sub-mainlines (5) drip laterals with pre-installed emitters or drip tap and (6) control valves and pressure

regulators. Emitter flow rates typically range from 0.5 to 4 liters per hour, depending on crop and soil type.

5.2 Surface Drip Irrigation in Vegetables

Surface drip irrigation is extensively used for high-value vegetables such as tomato, pepper, cucumber, melon, squash and eggplant. Drip tape flat polyethylene tubing with pre-punched emitter holes is the most economical option for annual vegetable crops and is typically placed alongside crop rows at planting.

The combination of drip irrigation with plastic mulch is considered the most efficient system for vegetable production. Mulched beds with subsurface or surface drip virtually eliminate soil surface evaporation, enabling water savings of 74-83% compared to conventional furrow irrigation in demonstration trials. Crops typically grown with mulched drip systems include tomato, pepper, cucumber, watermelon, cantaloupe and strawberry.

5.3 Fertigation through Drip Systems

One of the most significant agronomic advantages of drip irrigation is the ability to deliver fertilizers precisely to the root zone through the irrigation water—a practice known as fertigation. This allows for frequent, small applications of nutrients timed to match crop demand, improving nutrient use efficiency by 20-30% compared to soil application. For nitrogen-intensive crops such as cabbage, onion, and tomato, fertigation through drip systems significantly reduces fertilizer inputs and nitrate leaching.

6. Subsurface Drip Irrigation (SDI)

Subsurface drip irrigation (SDI) places drip laterals and emitters below the soil surface, typically at depths of 15-45 cm, depending on the crop root depth. This

approach further reduces surface evaporation losses and minimizes soil surface disturbance during field operations, allowing harvesting and other field activities to continue during irrigation.

7. Micro-Irrigation and Bubbler Systems

Micro-irrigation includes drip, micro-sprinkler, and bubbler systems that apply water at low rates directly to the root zone. Micro-sprinklers distribute water in a small wetted area and are suitable for widely spaced vegetables and nursery seedlings, while bubbler irrigation supplies water at low pressure to individual plants or small plant groups, making it useful in kitchen gardens, small vegetable plots, and protected cultivation. These systems provide efficient water application, with bubbler irrigation achieving 80-90% water-use efficiency.

8. Comparative Summary of Irrigation Methods

Method	WUE (%)	Suitable Vegetables	Soil Type	Capital Cost	Disease Risk
Flood/Basin	30–40	Taro, aquatic veg.	Clay/heavy	Very Low	High
Furrow	55–70	Potato, corn, cabbage, beans	Loam/clay	Low	Moderate
Sprinkler	60–85	Carrot, lettuce, cauliflower, garlic	Sandy/loam	Moderate	Moderate–High
Surface Drip	85–95	Tomato, pepper, cucumber, onion	All types	High	Low
Subsurface Drip	90–95	Garlic, asparagus, melon	All types	Very High	Very Low
Micro-sprinkler	80–90	Herbs, nursery seedlings, wide-row veg.	All types	Moderate–High	Low–Moderate

9. Factors Influencing Irrigation Method Selection

The choice of irrigation method depends on water availability and quality, soil type, topography, crop characteristics, and economics. Drip irrigation is preferred for saline water, sandy soils, irregular fields, and high-value crops due to its high efficiency, while furrow and sprinkler systems are more suitable for

level land and lower-value crops. Although drip irrigation has higher initial costs, it often becomes economical through savings in water, energy, fertilizer and labour.

10. Fertigation: Maximising Drip Irrigation Benefits

Fertigation, the application of soluble fertilizers through irrigation water, improves nutrient-use efficiency by delivering nutrients directly to the root zone according to crop demand. In vegetables such as tomato, pepper, cucumber and onion, drip fertigation enhances yield and quality while reducing nutrient losses and enabling precise nutrient management throughout the crop growth cycle.

11. Irrigation Scheduling

Irrigation scheduling determines when and how much water to apply to achieve optimal crop water status without waste. The primary approaches include: (1) evapotranspiration (ET)-based scheduling, in which irrigation replaces crop water use calculated from reference ET and crop coefficients; (2) soil moisture monitoring using tensiometers, capacitance probes, or neutron probes; and (3) plant-based indicators such as leaf water potential, stem diameter variation, or canopy temperature measured by infrared sensors.

12. Challenges and Limitations

Despite their advantages, the adoption of modern irrigation systems is limited by high initial costs, technical knowledge requirements, maintenance needs, and system damage risks. Drip systems require proper filtration and upkeep, while sprinklers may increase foliar diseases and perform poorly in windy conditions. Furrow irrigation demands precise land levelling for uniform water distribution. Climate

change is increasing the need for efficient irrigation, but inadequate financial and institutional support remains a major constraint.

CONCLUSION

Irrigation is essential for achieving high and stable vegetable yields, with the choice of method significantly affecting water-use efficiency, productivity, disease management, and profitability. Drip and micro-irrigation systems offer the highest efficiency (85-95%) and yield benefits, while sprinkler irrigation provides moderate efficiency and surface methods are less efficient but economical. As water scarcity increases, adopting precision irrigation technologies supported by adequate training, financing, and infrastructure is crucial for sustainable vegetable production.