

# Sub-surface drip fertigation for enhanced resource-use efficiency and profitability

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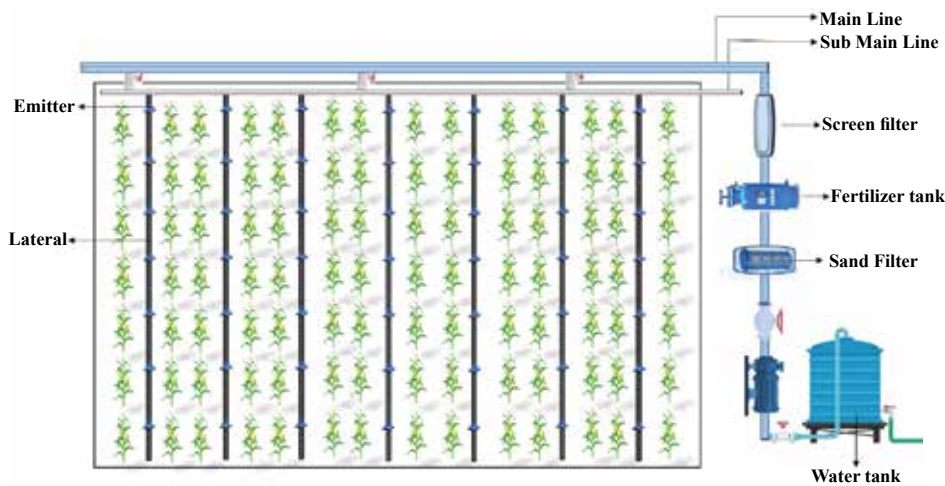
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*Unchecked population expansion and growing climate change-induced vulnerabilities in India and around the world are making the problem of water scarcity severer with each passing year. The nation's food bowl, the Indo-Gangetic plains region of India, has serious issues, such as groundwater depletion, low water productivity, inefficient water-use, nutrient deficiencies, and inefficient nutrient utilization. About 70% of the water used on Earth is used for agriculture, making it the biggest user of the freshwater supply, leaving little for other industrial uses. Conventional ways of applying irrigation water, such as flooding, result in poor water application; irrigation efficiency is about 35–40%, and water productivity is low, which affects long-term food security. In areas with limited water resources, sub-surface drip irrigation offers an alternative to precisely applying irrigation water. Because it makes it simple to apply water and nutrients to crops, increasing the efficiency of water and nutrient use, and thus, need to be popularized among the producers. Sub-surface drip fertigation can boost nutrient and water-use efficiency (WUE) to 80% and 90%, respectively. In order to solve the problems of poor irrigation efficiency and water productivity and simultaneously increase the productivity of cereal-based cropping systems in a sustainable way, the most efficient water and nutrient management technique is discussed in the current article.*

**Keywords:** Drip fertigation, Profitability, Water and nutrient-use efficiency

**I**N India's Indo-Gangetic Plains (IGP), water scarcity is a major issue because of erratic monsoons and rising needs for food production; therefore, effective irrigation techniques must be implemented immediately. The most used approach in India is surface flood irrigation, which results in a low water-use efficiency (WUE) and groundwater resource depletion. Therefore, enhancing crop productivity particularly in water-scarce areas will require conserving water resources and increasing WUE. Given the deteriorating groundwater supplies in northwest India, drip irrigation systems offer a viable way to alleviate the anticipated future water shortage. Although surface drip irrigation (SDI) is the most promising technique, it is labour-intensive to deploy and collect laterals throughout the year. Also, drip lines are exposed to sunlight, which makes them prone to deterioration and complicates cultural operations. Sub-surface drip irrigation (SSDI) systems could offer an alternate way to deal with these issues. SSDI systems increase the laterals' economic life by doing away with the requirement to anchor them during the crop-growing

season. Additionally, the SSDI system lowers labour expenses, prevents weed growth, improves water and nutrient delivery to the active root zone, limits soil evaporation, and makes fertilizer application more effective. In addition, SSDI makes it simpler to carry out cultural operations than SDI. This system uses a technique called fertigation, which applies nutrients by sub-surface drip irrigation, to give nutrients straight to the root zone. Nutrient utilization efficiency is increased as a result of this focused administration of nutrients to the root zone, which also conserves the nutrients and lowers nutrient losses. The drip irrigation method was, first, mostly utilized for high-value crops like fruits and vegetables, but because of its dependability and durability, it is currently gaining popularity in agronomic crops. Depleted groundwater causes low water productivity and WUE in the Indo-Gangetic Plains of northwest India, especially in the area where rice-based agricultural systems predominate. As a result, it is crucial to accurately control irrigation water, safeguard groundwater supplies, and boost the water productivity of the cropping system based on cereals.



Design and installation of sub-surface drip irrigation

technique of applying nutrients and irrigation water directly to the crop root zone is known as fertigation. Although SSDI is more expensive to install initially, it saves money over time by conserving water and nutrients and increasing productivity and profitability.

#### Water-and nutrient-use efficiency

Sub-surface drip irrigation is an extremely accurate irrigation technique in terms of delivering nutrients and water to specific areas as well as determining when and how

#### Installation and design

Main and sub-main pipes, laterals, emitters, flushing valves, pressure gauges, fertigation tanks, venturi, filters (especially sand and screen filters), are components of surface drip irrigation. Crop factor, soil texture, climate, and cultural customs all affect SSDI installation. For the installation of sub-surface drip laterals, the semi-mechanical and Quard-Raw machine methods are frequently employed. Depending on the soil's textural characteristics and crop rooting pattern, the laterals should be established 20–70 cm deep. There are two types of lateral pipes: Flexible, thin-walled laterals (0.15 mm to 0.30 mm) that are used for shallow installations, and thicker-walled laterals (0.38 mm to 0.50 mm) that are installed at deeper depths. Uneven water distribution in the root-zone caused by deeply positioned drip laterals may result in excessive water requirements and poor crop germination. Crop spacing affected the laterals' distance from one another, which typically spans from 0.25–5 m. In SSDI, the emitters are fixed inside the laterals (line source emitters); typically, one emitter has a discharge rate of two liters per hour. The SSDI has a discharge pressure of 135 kph (1.35 bar or 1.37 kg/cm<sup>2</sup>). To add pesticides, fertilizers, or other additives to the irrigation water, SSDI systems frequently use venturi injectors (fertigation). The

often to apply them for the best plant growth. SSDI reduces evaporation, seepage, deep percolation, and surface runoff, which is the primary way it saves water. The factors that contribute to increased crop growth and water productivity include regular water application at a reduced rate, surface retention of crop residue, the development of water-stable aggregates, and enhanced physical and chemical characteristics of the soil. Water consumption in the maize-wheat system was reduced by 54% as a result of SSDI in conservation agriculture, according to a study done at BISA-CIMMYT in Punjab. When compared to furrow irrigation, direct-seeded rice and wheat grown with residual mulch and SSDI yield considerably higher water productivity (0.75–0.84 kg/m<sup>3</sup> and 2.61–3.84 kg/m<sup>3</sup>, respectively).

The term "nutrient-use efficiency" (NUE) refers to the efficiency with which a crop uses its nutrients to sustain growth and photosynthesis. Applying nutrients via SSDI helps minimize nutrient loss via surface runoff, volatilization, denitrification, and leaching. The crop's root zone receives applied nutrients directly, leading to a high nutrient utilization efficiency. Through sub-surface drip fertigation, 75% RDN + 4-split N treatment preserved 25–50% N fertilizer and enhanced the grain production in maize by 20–25.3%. In SSDI, 20% less



Maize and wheat crops under sub-surface drip fertigation (Source: Author's research field)

**Table 1.** Solubility of fertilizers recommended for fertigation in SSDI

Fertilizer	pH (1g/L at 200C)	Solubility (g/L)
Urea	5.8	1060
Ammonium Sulphate	5.5	750
Ammonium Nitrate	5.7	1950
Calcium Nitrate	5.8	1294
Diammonium Phosphate	7.8	692
Monoammonium Phosphate	4.7	374
Murate of potash	7.0	340
Sulphate of potash	3.7	110
Potassium nitrate	7.0	320

Source: International Potash Institute

nitrogen fertilizer is required for rice and wheat crops to get yields comparable to those of flood-irrigated crops. When fertilizing SSDI with five split applications, the mean nitrogen recovery efficiency is increased by 16.5% and 29%, respectively, in comparison to furrow irrigation in maize and wheat.

### Fertigation

Water-soluble fertilizers can be efficiently applied at the right location with drip fertigation systems. The fertilizer material's solubility determines how fertilizer is applied via drip irrigation. Although nitrogen is the ingredient most frequently used, vegetables and other food crops also frequently need potassium and phosphorus. While nitrogen fertilizers are readily soluble in water and can be delivered via SSDI, phosphorous fertilizers have the potential to precipitate in drip laterals, which can cause blockage. According to the kind of fertilizer, the degree of solubility varies. For example, potassium nitrate (13-0-46) has a low solubility of about 1:8, meaning that 1 kg of dry fertilizer dissolves in 8 liters of water. Ammonium nitrate (34-0-0) and calcium nitrate (15.5-0-0) have a high solubility of roughly 1:1, whereas potassium chloride (0-0-62) has a solubility of 1:3. The solubility of dry phosphorous

**Table 2.** SSDI performance in India's main cropping systems

Crop/cropping system	% increase in yield	Water saving
Rice-wheat	2.5% in rice 25% in wheat	75% in rice 45% in wheat
Wheat-mungbean-maize	28–58% in wheat 15–24% in mungbean 28–61 % in maize	40 % in wheat 22 % in mungbean and 23 % in maize
Maize-wheat	30% in CA with SSD over conventional tillage with flooding	54.15%
Rice	10–15% decrease in yield over flooding	40–45 %
Rice-wheat	19% in rice 14.75% in wheat	48–53% in rice and 42–53% in wheat
Maize	20–25.3% higher yield than conventional irrigation	-
Maize	25–50% N save	-

**Table 3.** Economics of SSDI in rice-wheat cropping system

Particular	Cost
33.75 cm spacing drip cost (with 80% subsidy and a 15-year lifespan)	₹ 2769/ha
67.5 cm spacing drip cost (with 80% subsidy and 15-year life)	₹ 1530/ha
Surface drip cost (with an 8-year lifespan and an 80% subsidy)	₹ 5108/ha
33.75 cm spacing drip cost (without subsidy and 15-year life)	₹ 13,847/ha
67.5 cm spacing drip cost (without subsidy and 15-year life)	₹ 7650/ha
Surface drip cost (without subsidy and 8-year life)	₹ 25,540/ha

Source: Sidhu *et al.* 2019

fertilizers is approximately 1:2.5 that of nitrates. The main benefits of fertigation over the traditional way of application are lower labour, fertilizer, energy, and fertilizer use efficiency.

### Productivity

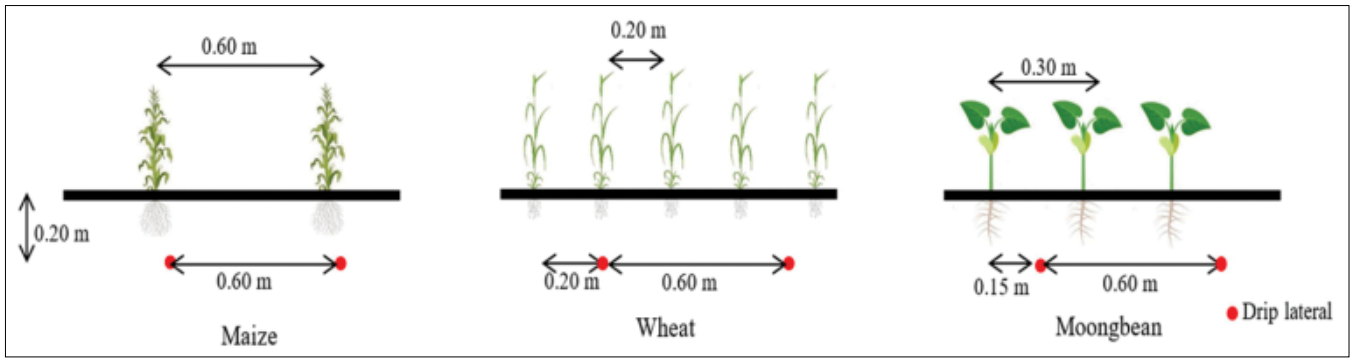
In SSDI, water is sprayed straight onto the root zone, meeting agricultural water needs and preventing moisture stress. The root zone can also receive nutrient applications in accordance with crop needs. Water and nutrients work together in the root zone to increase crop yields and boost the efficiency of water and nutrient utilization. In addition, there is a noticeable decrease in the prevalence of diseases, weeds, and insect pests, which eventually improves crop quality and output.

### Economics

The annual cost of the SSDI system is usually lower than SDI due to the initial installation cost and longer life span. The tractor-operated machine used to install SSDI reduces cost. The lifespan of an SSDI system is 10–15 years, but that of an SDI system is 6–8 years. With the SSDI system, laterals and inlines are protected from sunshine and rodents and do not need to be removed during crop sowing or harvesting. The government of



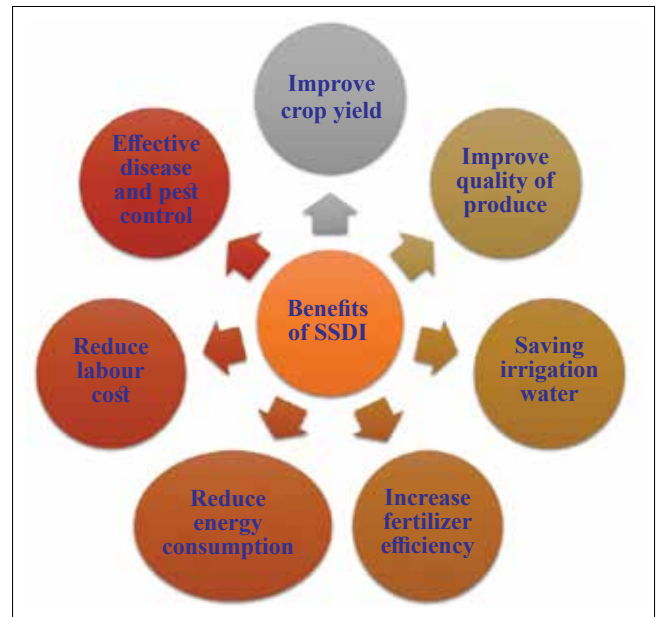
Fertigation through sub-surface drip system  
(Source: Author's research field)



Cross-sectional view of experimental setting depicting crop rows and relative position of sub-surface drip laterals (Source: Daina et al. 2023)

**Table 4.** Challenges and solutions of SSDI

Challenges	Solutions
Emitter clogging	Frequent cleaning of the sand and screen filters Flushing of drip laterals at the end of every crop season Acid treatment: HNO <sub>3</sub> , H <sub>3</sub> PO <sub>4</sub> and HCL
Damage from rodents and other animals	Phorate 10G application
High cost of drip	Initially, it has a high drip cost, but over the long term, it is cost-effective for farmers (life duration of 15 years). The payback period is only 7 years and the remaining years economical The benefit-cost ratio is raised by choosing high-value market crops.
Restricted root development of crops	Numerous factors influence root growth, including soil and plant properties, irrigation system design (number of emitters per plant, location, and emitter discharge rate), and management factors (amount and frequency of water application).



Advantages of SSDI system in crops/cropping system

India is subsidizing 80% of the real cost of drip irrigation, which makes it more cost-effective for farmers.

### Case study

The Indian Agricultural Research Institute in New Delhi conducted a study on the effects of surface drip irrigation (SDI) and SSDI systems on water and crop productivity of wheat-mungbean-maize cropping systems. In contrast to surface flood irrigation and fertilizer application, the results demonstrated that SSDI at 0.8 ETc with 100% fertigation of appropriate doses of NPK fertilizers boosted irrigation water productivity by 118%, total water productivity by 45% and system productivity by 5.4%. Additionally, fertigation with SSDI or SDI lowered the amount of fertilizer needed for this cropping system by 20% while still producing a yield comparable to that of the conventional system. In maize, moongbean, and wheat, fertilization with 60, 80, and 100% of the prescribed NPK levels produced notable yield increases. Additionally, grain yields generated with irrigation scheduling at 0.8 ETc were almost 10% higher than those produced at 0.6 ETc.

### SUMMARY

In India's Indo-Gangetic Plains, sub-surface

drip irrigation may provide a solution to the water shortage. Reduced evaporation, improved nutrient absorption, and less water wastage are a few among many advantages of SSDI. By supplying nutrients and water directly to the root zone, this technique improves water and nutrient conservation and increases its effectiveness. SSDI turns out to be more profitable over time, even with higher initial expenses on installation. When comparing SSDI to traditional methods, studies show notable yields and significant reductions of water and fertilizer consumption. Together, the Indian and state governments are providing significant subsidies, maximum between 70% and 90% depending upon kind of farmer and size of landholding, to encourage the broad use of microirrigation systems. Although there are drawbacks, such as emitter blockage and rodent damage, they are outweighed by the bigger advantages. All these aspects considered together, SSDI offers an accurate and effective irrigation technique that is essential for sustainable farming and resolving water scarcity and also the nutrient deficits (when nutrients are applied through drip fertigation) in areas, like the Indo-Gangetic Plains.

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