A Manual on Subsurface Drip Irrigation for Cereal Systems

ICAR-Central Soil Salinity Research Institute
International Maize & Wheat Improvement Center (CIMMYT)
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Foreword

The rice–wheat (RW) cropping system in North-West region of the India is the mainstay of the national food security since green revolution. Despite the fact, the practice of rice–wheat cultivation has brought forth several edaphic, environmental, ecological and social implications over the years. Continuous cultivation of rice–wheat system in North-Western Indo-Gangetic plains (NW-IGP) of India has led to emergence of several second generation problems over the last five decades, threatening the sustainability of the system. Over-exploitation of fresh ground water reserves, poor soil health, low carbon content and multiple nutrient deficiencies. Over-exploitation of ground water reserves leading to depletion of ground water level, low carbon content, emergence of multiple nutrient deficiencies, increased cultivation cost, labour shortage and climate change all pose threats to the sustainability of this system in NW India. Evidence is accumulating that the RW system is now showing signs of fatigue and yields of rice and wheat in this region have reached a plateau or are declining, the soils have deteriorated, the groundwater table is receding at an alarming rate, total factor productivity or input-use efficiency is decreasing, cultivation costs are increasing, profit margins are decreasing, and the simple agronomic practices that revolutionized RW cultivation in the IGP are fast losing relevance, output growth, employment generation and natural resources sustainability.

To overcome formidable problems of soil health, irrigation water shortage and climate change in RW system of North-West India, sustainable intensification based on the principles of conservation agriculture (CA) coupled with micro irrigation technologies has emerged an important alternative to attain the objectives of improved and sustained productivity, increased profits and food security while preserving and enhancing the natural resources and the environmental quality. The CA based agro-technological package, intensified cropping system and holistic farming approach not only saves natural resources but may help in producing more at low costs, improves soil health, promotes timely planting and ensures crop diversification, reduces environment pollution and adverse effects of climate change on agriculture. Implementation of micro irrigation based agricultural diversified systems intensification in NW India may be a productive way to build resilience into agricultural systems for national food security while fulfilling the goal of 'more crop per drop'. Sustainable intensification and micro irrigation are the important components of the overall strategies needed to enable future generations to practice agriculture in NW India.

I am very happy to see that a group of scientists from ICAR and CGIAR has developed sub-surface drip integrated CA based intensified futuristic cereal systems in North-West India to address the second generation problems of Green Revolution and acute shortage of irrigation water. I am sure the National Agricultural Research and Extension System (NARES), in partnership with all stakeholders (CGIAR, NGOs, private sector organizations and farmer's societies) will take full advantage of recommendations emerging from the CSISA and CCAFS project. It is also expected that this publication will be immensely helpful to policy planners, administrators, researchers, extension workers, farmers, stakeholders and other users for efficient management of groundwater, soil and other resources for sustainable crop production while preserving the natural resources base and environmental quality for betterment of livelihood in North-West India. I take this opportunity to congratulate authors as well as ICAR and CIMMYT for bringing out this valuable publication.

(RK Yadav)
Director, ICAR-CSSRI

Contents

1. Introduction

The majority of fresh water worldwide is utilised for agriculture. Currently, agriculture uses 59 percent of the world's total water supply, industry use 23 percent, and household uses consume the remaining 8 percent. Agriculture in our nation also makes the best use of the water that is available. According to a report by the National Commission for Integrated Water Resources Development (NCIWRD), 83 percent of the nation's water is now utilised for irrigation, with the remainder water being used for household, industrial, and other purposes. The country's crops were irrigated by subsurface water to the tune of 60%. Since the 1960s, the usage of ground water for irrigation has been steadily rising in our nation. There is now a 0.1 to 1.0 metre annual decline in the level of subsurface water, which is concerning for the future. It has become imperative to utilise water resources as efficiently as possible in light of both the declining water supply and the rising demand for food grains. In order to meet the challenge of rising food demand while also addressing the issue of diminishing water supplies, it is crucial to design effective agricultural water management technologies that enable farmers to produce more while using less water. The majority of farmers in our nation utilise conventional/surface irrigation, which uses a lot of water and has a very low water usage efficiency. In order to conserve water and improve the effectiveness of irrigation, agricultural practises including bed and drain irrigation, sprinkler irrigation, micro/drip irrigation, etc. The most effective technique to ensure that plants and crops receive the right quantity of water while conserving water is through subsurface drip irrigation. This method sends water and nutrients straight to the root zone. More than 80% of the world's irrigated land is watered using surface irrigation techniques, although these technologies only utilise water at a 50–60% efficiency. In contrast, because to the absence of surface runoff and other sorts of losses, subsurface drip irrigation has a water consumption efficiency that ranges from 70 to 90 percent. Only 4% of farmers worldwide employ drip or micro irrigation. Pivot irrigation is used by around 12% of farmers. While 84 percent of farmers still utilise surface irrigation, this is a different effective method of irrigation. Surface irrigation is an ineffective technique that wastes a lot of water. A low-pressure, high-efficiency irrigation method called subsurface drip irrigation employs underground drip tubes or drip tape to supply crops with water. These technologies have been utilised in irrigated agriculture since the 1960s and have developed fast during the last three decades. A subsurface irrigation system is flexible and can give frequent, light irrigations. This works particularly effectively on sandy soil types in arid, semi-dry, hot, windy regions with little availability to water. The IGP of Northwest India may soon see a drop in agricultural production and farm profitability, as well as a scarcity of drinkable water, which would cause significant socio-economic stress.

In India, there are around 56.5 Mha of net irrigated land, of which 3.1 Mha is supplied by tanks, 17.1 Mha by canal, 17.9 Mha by tubewells, 11.9 Mha by other wells, and 6.5 Mha by drip and sprinkler irrigation. Both monsoon seasons bring good rainfall to the country as a whole, and there is plenty of room for rainwater collection, storage, and recycling (Plate 2). Where annual precipitation totals reach 700 mm, rainwater collecting allows for the watering of more agricultural land. The current per capita water availability for irrigation, which is at a level of 2001 m^3, will decrease to a stress level of 1700 m^3 during the next two to three decades. The country's total irrigation potential has been calculated at 139.9 million hectares, of which 58.5 million ha will come from large and medium irrigation systems, 15 million ha from small irrigation schemes, and 66 million ha through ground water extraction (Singh, 2002). About 53 M hectares of the nation are now irrigated. Even with full irrigation capability, however, around 50% of the total farmed area will still be rainfed. To fulfil the constantly rising demand for drinking water, industrial usage, and other purposes, the amount of water now allocated for agriculture, which accounts for roughly 85% of the developed water resources, is expected to be decreased by 10% to 15%. Water resources are scarce and need to be managed properly for irrigation. The amount of water available per person is dwindling. In 1955, it was 5.3 thousand m^3, then dropped to 2.5 thousand m^3, and it is predicted that by 2025, it will only be 1.5 thousand m^3. Given this trend of declining water supply, it is important to manage limited water resources wisely.

2. Rationale

The last two decades have seen a rise in interest in subsurface drip irrigation (SDI), largely as a result of rising demand to preserve water resources and the availability of dependable system components. Although there has been a long-standing interest in this technology globally, there haven't been many attempts to compile the knowledge until lately. Several assessments of drip irrigation included discussions of subsurface drip irrigation (Howell et al., 1980; Bucks et al., 1982; and Bucks and Davis, 1986). Ayars et al. (1999) released a review of SDI research in Fresno, California, while Camp (1998) gave an in-depth analysis of the topic. Jorgenson and Norum (1992) presented an overview of SDI theory and its implementations. The 1980s saw a rise in interest in subsurface drip, particularly in the latter half of the decade when a large number of study reports were released and suitable commercial items were made available. In terms of system hydraulics, the majority of early SDI systems were constructed in a similar way to surface drip systems. However, models that explain water infiltration, plant extraction, and lateral depth and spacing, as well as mathematical theory for the transport of water from buried point sources, were created quite early (Philip, 1968; Gilley and Allred, 1974a,b; and Zachman and Thomas, 1973). According to a review, Camp (1998), drip lateral depths varied depending on the crop and soil, from 0.02 m to 0.70 m. Most of the time, lateral depth was probably chosen with consideration for the soil and its water properties, as well as the current site circumstances.

By 2025 AD, 34 out of the world's nations will experience water shortage, meaning that the amount of fresh water resources available per person will be less than 100 m^3 $person^{-1}$ $year^{-1}$. A nation that has yearly renewable water supply over 1700 m^3 per person will only occasionally or locally experience water challenges. Countries start to encounter sporadic or ongoing water stress below this line. In the year 2025 AD, India (1400 m^3) and China (1700 m^3) will be the top two countries in this category, while the USA will have more than 7000 m^3 per person per year and would not experience any shortages. Irrigated agriculture is seriously threatened by the global increase in urban and industrial water demand. From the current level of 70%, the allotment of water for agriculture will decrease to 50%. However, India must increase its existing irrigation potential of 91 Mha to 160 Mha in order to produce the necessary amounts of food and fibre with a rising population. The use of surplus runoff collection, storage, and recycling for precision water application in order to meet the increased need of irrigation with enhanced water harvesting technology is nonetheless required. Conveyance losses, which only increase the net usage of irrigation water to 46%, are the main issue with using less fresh water for irrigation. Net irrigation water usage in drip systems is 90%, compared to 82 % in sprinkler systems. Due to these factors, micro-irrigation is of utmost importance and has a promising future.

3. Micro-irrigation

The majority of farmers in our nation utilise conventional/surface irrigation, which uses a lot of water and has very low water usage efficiency. Considering the scenario, there is tremendous pressure on the available water so we need to think of a viable option like pressurized irrigation systems. In order to conserve water and improve the effectiveness of irrigation, agricultural practises including bed and drain irrigation, sprinkler irrigation, micro/drip irrigation, etc. need to be adopted. The use of micro irrigation (drip and micro sprinkler) is rapidly increasing around the world, and it is expected to continue to be a viable irrigation method for agricultural production in the foreseeable future. With increasing demands on limited water resources and the need to minimize environmental consequences of irrigation, micro irrigation technology will undoubtedly play an even more important role in the future. Micro irrigation provides many unique agronomic and water and energy conservation benefits that address many of the challenges facing irrigated agriculture, now and in the future. An in-depth understanding of the unique benefits and limitations of micro irrigation system is needed to successfully design and manage this system. In water scarce areas and in areas where adequate land leveling is either not desirable owing to less soil depth or is uneconomic, micro irrigation offers a sound scientific basis for commercial crop production.

The gradual application of continuous drips, minuscule streams, or small sprays of water above or below the soil surface is known as micro irrigation. You will learn about the key characteristics of the micro irrigation system and its categorization in this session. In comparison to the traditional surface irrigation approach, the micro irrigation system is successful in reducing water consumption and improving water usage efficiency. Additionally, it aids in lowering cultivation costs, weed development, soil erosion, and water use. All types of land can benefit from micro irrigation, particularly those where irrigation via floods is ineffective. A field is inundated with water during the flooding method of irrigation. Significant runoff, anaerobic soil conditions surrounding the root zone, and deep irrigation below the root zone are the effects, and the plants aren't given enough water. As a result, it is among the least effective surface watering techniques. In regions with shallow soils, undulating terrain, rolling topography, hills, and barren land, micro irrigation might be helpful. There are three categories of soil types based on depth: shallow soil (depth less than 22.5 cm), medium soil (depth between 22.5 and 45 cm), and deep soil (more than 45 cm).

3.1 Basic features of micro irrigation

- A pressurised pipe system is used to apply water. Pumps are necessary for micro irrigation in order to create the necessary pressure for delivering water through surface or subsurface water.
- In a drip irrigation system, water is supplied drop by drop over a prolonged period of time.
- To maintain the ideal air-water balance in the root zone, water is administered sparingly.

- Depending on the needs of the plants, water is sprayed often.
- By providing water directly to the plants rather than to other parts of the field, waste is reduced.
- The soil's field capacity for moisture content is always maintained. As a result, crops develop more quickly, steadily, and evenly.

3.2 Classification of micro-irrigation system

Micro irrigation system can be classified into following categories:

I. Sprinkler irrigation system

II. Bubbler irrigation

III. Drip irrigation system

3.2.1. Sprinkler irrigation

Sprinkler irrigation includes micro irrigation such as micro sprinklers, micro sprayers, misters and foggers which apply water close to plants so that only part of the soil in which the roots grow is wetted and permits the irrigator to limit the watering close to the consumptive use of the plants. The water discharge in different sprinkler system is varies from 28-223 litres/hour under operating pressure of 0.8 to 4.0 bar.

Suitability of sprinkler irrigation

- Ideally suitable for hilly terrains with undulating slope
- Suitable for crops like tea, coffee etc.
- Suited to crops like groundnut, cotton and the crops which are not susceptible to easy flower shedding.
- 30-40% saving in cost than conventional irrigation

Advantages of sprinkler irrigation

I) Water conservation

- Saving of water varies from 25 to 50% for different crops.
- The system can be designed to give uniform distribution in sprinkler irrigation.
- When water is spread like rain there is little or no puddling effect on soil.
- Elimination of channels for conveyance, therefore no conveyance loss.
- As the rate of application is less than the infiltration rate of the soil irrigated, there is no surface runoff when properly designed.

ii) Soil conservation and use of land

- There will be no soil erosion problem, no compaction of soil during irrigation, no land levelling required, no land being lost to formation of ditches.
- It will control leaching of alkali and other salts.
- May also be used for undulating area.
- Areas located at a higher elevation than the source can be irrigated.

iii) Crop benefit

- Soil moisture is maintained at optimum level by sprinkler so higher yields are obtained.
- Suitable for irrigating crops where the plant population per unit area is very high. It is most suitable for oil seeds and other cereals and vegetable crops.
- Since the water is spread over the crop, it permits cooling of crops.
- In this system, fertilizers and pesticides can be mixed with water and applied.

Disadvantages of sprinkler Irrigation

i) The water must be clean and free of sand debris and large amounts of dissolves salts.

ii) The sprinkler method usually requires the highest initial investment as compare to surface methods, except where extensive land levelling is necessary for surface irrigation.

iii) Power requirement is usually high.

iv) High water pressure required in sprinkler (>2.5 kg/cm^2)

v) More water is lost by evaporation during sprinkling under high temperature.

3.2.2 Bubbler irrigation

This system is designed to reduce energy requirement through in expensive, thin walled, corrugated plastic pipe with a diameter that operates even at low pressure head from ditch source of water from the laterals of irrigation system, open vertical tubes is so adjusted to get the required discharge rate. Water bubbles out of open vertical tubes. This system can be used to widely spaced crops like coconut, mango, sapota, orange, grape etc.

3.2.3 Microjet irrigation

In this system water leaves the jet at a pressure of nearly 1 bar. This gives through distance of 1-4 metre with a corresponding larger wetting area of ground. The water discharge of jets is 5 to 160 litres per hour.

3.2.4 Drip irrigation

In this method, water is supplied to the soil's surface or subsurface at a rate that is less than that of the soil's natural infiltration. A little amount of water is discharged from the emitters because they disperse pressure from the distribution system via orifices, vortices, and lengthy or tortuous flow routes.

4. Drip irrigation system

A drip irrigation system, commonly referred to as a "trickle irrigation system," is a technique for frequently providing the necessary amount of water through drippers or emitters straight to the root zones of plants. In this method, water is supplied to the soil's surface or subsurface at a rate that is less than that of the soil's natural infiltration. A little amount of water is discharged from the emitters because they disperse pressure from the distribution system via orifices, vortices, and lengthy or tortuous flow routes. Although they can potentially be buried, emitters are often installed on the ground. Most released water flows through the soil system in an unsaturated flow. By means of capillary action, water seeps into the soil and moistens plant root zones both laterally and vertically. In comparison to sandy soil, the lateral flow of water below the surface is stronger in medium to heavy soil. For widely spaced emitters, the wetted soil area will often have an oval form. On windy days and during various field works, drip irrigation can be employed.

4.1 Types of drip irrigation system

Drip irrigation system classified as:

(i) Surface drip irrigation - It is a low-pressure, high-efficiency irrigation method which employs underground drip tubes or drip tape to supply crops with water. The very effective subsurface drip irrigation technology uses plastic drip lines and inline emitters to provide water straight to the root zone of the crop or plants. This technology has been utilised in irrigated agriculture since the 1960s and have developed fast during the last three decades. A subsurface drip irrigation system is flexible and can give frequent, light irrigations. This works effectively, particularly on sandy soil types in arid, semi-dry, hot, windy regions with little availability to water. Since the water is delivered below the soil's surface, subsurface drip irrigation eliminates the consequences of surface irrigation features such crusting, saturated situations of ponding water, and potential surface runoff (including soil erosion).

Water application is very consistent and effective with a properly sized and maintained system. Around the tube, there is wetting, and water usually spreads out in all directions. By preventing surface water evaporation, weeds, and disease, subsurface irrigation conserves water and increases yields. Water is provided directly to the crop's root zone rather than the soil surface, where the majority of weed seeds grow following cultivation. Because of this, there is much less weed seed germination each year, which reduces the impact of weeds on cash crops. Additionally, certain crops may benefit from the increased heat created by dry surface conditions, boosting crop biomass, assuming there is enough water in the root zone. When handled successfully using a fertiliser injector, the efficiency of administering fertiliser and water is enhanced, and labour needs are reduced. Field activities can still be carried out even when irrigation is being employed. It lasts a long time (15-20 years) since the drip pipe is not exposed to direct sunlight.

Its applicability for particular crops depends on the level of investment one is prepared to make in subsurface irrigation technology and upkeep. Although practically all crops may be adapted to operate with it across a wide range of business kinds, it is mostly utilised for high-value vegetable crops, cereals, turf, and landscapes. Vegetables and grains have also showed advances in both yield and quality. When subsurface irrigation and plastic mulches are employed together, the improvements on these crops are boosted. Subsurface irrigation is difficult in soils with poor infiltration rates, and drip tube spacing needs to be changed for clayey soil types. In addition to depth, drip tube spacing has an effect on the health of the crop. Knowing the characteristics of the soil type for your crop is also crucial for subsurface irrigation scheduling.

(ii) Subsurface drip irrigation (SDI) - Sub-surface drip irrigation is a technique for watering crops by burying the drip tubes with embedded emitters that are spaced regularly. Subsurface drip irrigation system is similar in design to surface drip irrigation system except subsurface placement of drip lines and specific emitter.

(iii) Family drip or gravity fed drip irrigation - A low-cost device called a "gravity fed drip irrigation system" was created for tiny household plots. It is appropriate for peri-urban agriculture and indoor gardening. It may also be used to show how a drip irrigation system operates. Family drip systems are intended for 500-1000 m^2 spaces.

Plate-1 Subsurface drip irrigation in Direct seeded rice

Plate-2 Subsurface drip irrigation in Wheat

(iv) Online drip - Emitters or drippers are mounted externally on the laterals in this system at predetermined spacings. As a result, in the event of obstruction, the drippers may be simply examined and cleaned. To accommodate a plant's expanded root zone, the dripper spacing may be adjusted at any moment.

(v) In-line drip - To accommodate the needs of different crops, drippers in this system are installed in the lateral tube at predetermined spacings at the time of production. Row crops including cotton, sugarcane, groundnuts, vegetables, and floral plants all benefit from it. The distance between drippers is determined by how much water a crop needs and by how much water the soil can store. The dripper spacing cannot be altered after installation.

5. Components of SDI

Although an SDI system can operate without every element on the list, it could be hard to administer and maintain and might not perform well. Eventually, the system can stop working as a result of inadequate emitter protection or a lack of performance indications for the management. Each component often comes in a number of variations, which are shown as choices below. Depending on the particular site and system circumstances, a certain solution could or might not be suitable for your application. Under considerations, a list of important aspects for each component's selection is provided. Make sure the SDI system design properly takes into account the features of your site and system.

a. **Pump** - Typically, SDI systems require little pressure. It needed only one pump. Most low-pressure centre pivot sprinkler systems can meet the required pressure. The pump's size is determined by the required overall head and flow rate. For SDI systems, the total head requirements also take into account the pressure loss through the filter and other structural elements such control valves, flow metres, check valves, main and submain supply lines, friction/losses, elevation changes, and pumping lift.

b. **Filtration unit-** To avoid emitter blockage, the filter unit filters suspended particles out of the water. Filtering can be enhanced by using several filters. In order to enhance the overall flow rate, many filters might be fitted in tandem. It has both a sand filter and a water filter (to separate the sand). Depending on the water quality, screens, discs, and sand media filters are frequently employed. When water transports sand load from deep wells, centrifugal sand separators are employed.

c. **Pressure unit-** Pressure gauges should be fitted at the intake and exit locations of the filter(s) to show the pressure differential needed to start manually or automatically flushing the filtering unit. Follow the manufacturer's recommendations for the pressure differential value at which flushing should start. Additionally, flushlines at both the proximal and distal ends of the main supply system should have pressure gauges installed on them. The meter's flow rate and the system's pressure measurement give the operator hints about the efficiency and clogging of the emitter.

d. **Main and sub-main pipe lines –** Main and sub-main are delivery pipe lines made from rigid PVC. It supplies water from the system headworks control to manifolds connecting dripline laterals. They are buried in the soil by digging a trench 1.5-2.0 feet deep, so that due to being buried inside the soil, there is no disturbance in agricultural work.

e. **Laterals -** Laterals are 12-20mm size pipes made up of LDPE. The crop is put out along the rows after the laterals are strategically connected to the feeder lines using tiny connections. The crop type determines the laterals' row-to-row spacing. For maize, this gap is maintained at 60–65 cm, whereas for wheat and rice, it is 45–50 cm. It comprises of drip emitters that are spaced apart by a predetermined quantity (for instance, 30 or 40 cm), releasing a fixed amount of water around the crop or plant's roots.

f. **Dripper (Drip Emitter)-** Drippers are tiny emitters with high-quality plastic construction. Inline drips are now inserted directly in the lateral, and their construction prevents the stomata from closing even after they are pressed into the soil. In the laterals, these drippers are set at a fixed distance. Low volume of water (1.25-2.50 litres per hour) enters the dripper at air pressure of around 1 bar, and it continues to drip continuously at zero atmospheric pressure.

g. **Chemical injector-** Pesticides or fertilisers are accurately injected into the irrigation stream using a chemical injector. Chemical injection units come in two different varieties: 1) Positive displacement pumps with a constant rate: piston, gear, or diaphragm pumps and 2) Variable rate: bladder tanks or venturi pressure differential injectors.

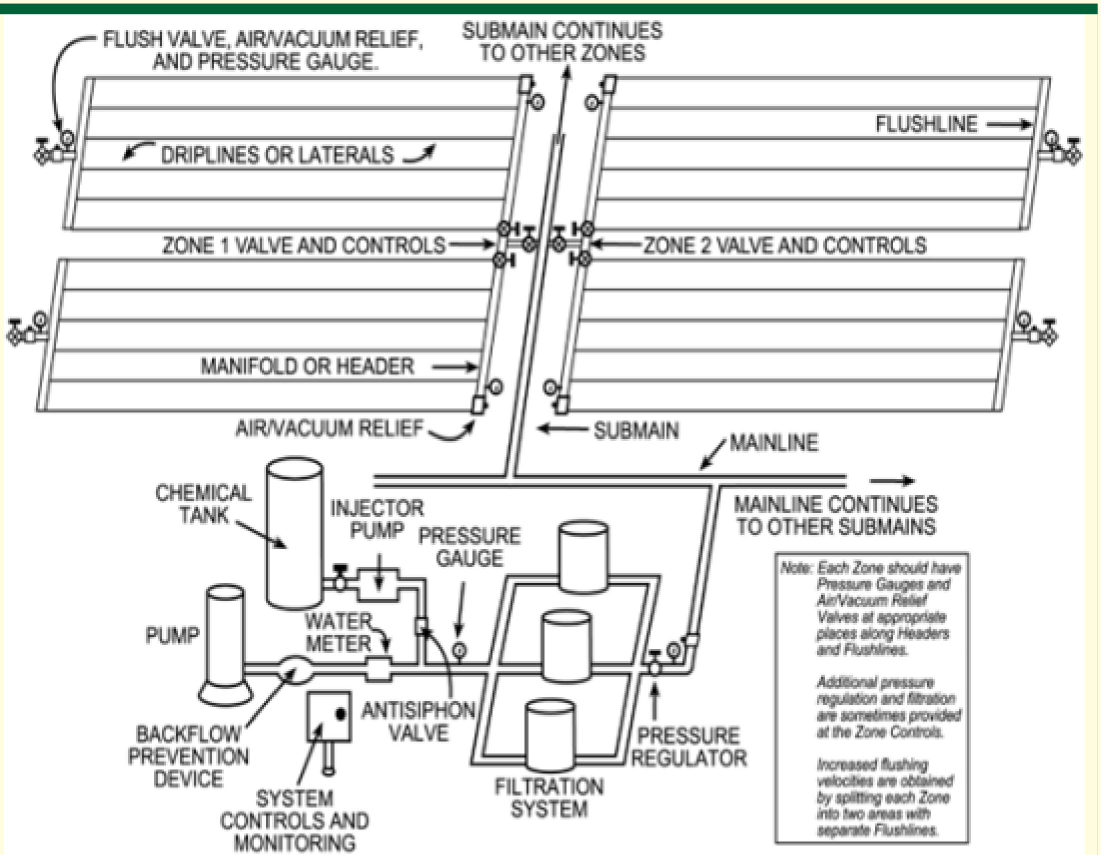

Figure- General SDI system layout

(Courtesy - Freddie Lamm, Kansas State University)

h. **Venturi-** As a subsurface drip aeration mechanism, the venturi plays a significant role in water and fertilizer-aerated irrigation technologies. Air bubbles can be introduced into flowing water through air input holes in a venturi pipe portion (VPP), which raises the concentration of dissolved oxygen (DO) in irrigation water. The DO can accelerate plant development by up to 30% by assisting roots in absorbing nutrients more quickly.

Plate-3 Pumping unit

Plate-4 Drip line view under subsurface of soil

i. **Flush lines-** The flush lines at the system's very end have three functions: 1. Allow positive pressure on both sides of a dripline break to avoid soil ingestion into the dripline, 2. Permit any sediment and impurities to be drained from dripline laterals at a central site and 3. Equalize pressure in the dripline laterals.

j. **Connectors-** The dripline must be connected to the manifold or submain using connectors. System architecture determines the quantity and kind. Connectors are available in different forms such as grommet, compression, and bonded connectors. These may receive a supply tube that is connected to the dripline or may have a direct dripline connection. There are three types of dripline connectors: wired, clamped, and interference (compression) fit.

k. **Emitters** – Drippers are tiny emitters with high-quality plastic construction. For SDI, inline drippers are used, which are directly inserted inside the laterals, and their construction prevents the stomata from clogging even after they are pressed into the soil. In the laterals, these drippers are set at a fixed distance. Low volume of water (1.25-2.50 litres per hour) enters the dripper at air pressure of around 1 bar, and it continues to drip continuously at zero atmospheric pressure. In-line emitters with pressure compensation feature (fitted with diaphragm) are also used in SDI to maintain uniform discharge throughout the field. The in-line emitters with a capacity of 2.0 L h^{-1} at a pressure of 135 kPa spaced at 30 cm are suitable for wheat, maize, and mungbean crops.

6. Laying of lines for SDI

6.1 Laying machine

The pipe lines in subsurface drip irrigation are buried at a predetermined depth by digging trenches or drains with a tractor-drawn drip-trencher in moist soil. A tractor operator two-line drip trencher machine has been developed by BISA, Ludhiana. This machine can dig two no. of tranches at one run with adjustable depth and width of trenches. This machine requires 60 HP tractor to operate through PTO. For ease of trenching, the field should be deep ploughed, planking should be done with laser land leveler, and irrigated before trenching work. After irrigation, trencher machine should be run when soil is in suitable moisture condition.

Plate-5 Digging of trenches with a tractor-drawn drip-trencher in moist soil

6.2 Depth of lines

Depending on the kind of crop, the environment, and management techniques, irrigation pipes are buried in the soil between 15 and 30 cm beneath the surface of the ground. The mains and sub-mains in wheat, maize, and mungbean were set out at a depth of 100 cm, while the laterals were laid out at a depth of 20 cm.

Plate-6 Drip lines installation in trenches

6.3 Width of lines

The lateral line spacing ranged between 33.75 to 67.5 cm depending on the type of crop, type of soil, environment, and management techniques. In north western plain zone of the country, the laterals can be laid out at 33.75 or 67.5 cm spacing for rice, maize, wheat and mungbean crops. Three rows of rice, wheat, mungbean, and one row of maize crop can be sown for each lateral line under 67.5 cm spacing. Likewise, 1.5 rows of rice, wheat and one row of maize can be irrigated with one lateral spaced at 33.75 cm spacing. For rice/maize–wheat–mungbean cropping system in medium textured (loamy/sandy loam) soils of Haryana, the laterals can be laid out at 45 cm spacing at the depth of 18 cm.

7. Advantages of SDI

More efficient water use: There is a significant reduction or elimination of soil evaporation, surface runoff, and deep percolation. Drier surface soils with less crusting can improve infiltration and storage of seasonal precipitation. Depending on the dripline depth, the flow rate, and the limitations of the soil, the system may occasionally be employed for a brief watering event to aid with germination. Decisions concerning irrigation events at the conclusion of the cropping season may be made more water-efficiently because to the inherent capacity to apply minor irrigation volumes. A smaller portion of the soil volume may be wetted in crops that are spread far apart, thereby lowering wasteful irrigation water losses.

Improved opportunities for use of degraded waters

Smaller and more frequent irrigation treatments can keep the soil matric potential more stable and low, which may lessen the dangers of salinity. Application of subsurface wastewater can lower pathogen drift and lower animal and human exposure to such waters.

Plate-7 Irrigation through subsurface drip in crop root zone

Greater water application uniformity

Improved in-field uniformities can lead to improved management of the water, nutrients, and salts. More uniform water application. If sufficient soil moisture is accomplished, crops that are widely spaced may benefit from water delivery closer to the crop.

Enhanced plant growth, crop yield and quality

The optimum water supply in the crop root zone, efficient fertigation and lesser weed competition under SDI improves the growth and yield of the crops compared to surface irrigation methods.

Improved plant health

Dryer, less-humid crop canopies result in lower disease and fungal pressure. There are certain forms of soil fumigation that can be done with the technique.

Plate-8 Mungbean as short-duration summer crop in rice–wheat cropping system

Improved fertilizer and pesticide management

Applying fertilizer and pesticides through the system with more accuracy and promptness can increase their efficacy and, in some situations, reduce their consumption.

Improved weed control

Most of the weed seeds are present in the upper soil layer and required proper moisture for germination. In SDI, water is delivered in the root zone and soil surface receives lesser moisture through capillary action which reduces weed seeds germination. SDI also offers feasibility for conservation agriculture practices which reduces the weed populations over the years of adoption.

Improved sustainable intensification opportunities

Crop timing may be improved since the system doesn't have to be taken out during harvest and put back in before the second crop is planted. In rice–wheat cropping system of NWPZ, there is scope of introduction of third summer crop. The timely sowing of zero tillage wheat after rice harvest enables early harvesting in first week of April which provides scope for growing short duration summer mungbean in the time window available between harvesting of wheat and sowing of next direct seeded rice crop. Besides, growing of mungbean or other summer does not increase the additional irrigation water use as SDI could save about 50% irrigation water in rice and wheat crop.

Improved farming operations and management

During irrigation events, several field operations might take place. Field work reduces soil compaction, and irrigation-related soil crusting is significantly decreased. In comparison to surface drip irrigation, SDI frequently reduces the variability in soil water regimes and redistribution (DI). Furthermore, weather-related application restrictions including strong winds, freezing temperatures, and soggy soil surfaces are less significant. Even when irrigation demands are minimal, necessary fertilizer can be delivered during a brief irrigation event. In situations where preseason irrigation is utilized to efficiently improve seasonal irrigation capacity, the ability to irrigate during freezing conditions might be especially advantageous. Additionally, there is reduced risk of vehicle damage to irrigation equipment. Dryer soils assist manual laborers by lowering manual labour demands and injuries. Less water quality hazards was observed because of deep percolation, there is less nutrient and chemical leaching and runoff into streams.

Advantages related to system infrastructure

The SDI system offers a prime option for automation and sophisticated irrigation control technologies because of its closed-loop pressurized feature, which can lower application variability and variability in soil water and nutrient redistribution. The SDI with pressure compensating emitters can be installed under uneven topography with uniform water and fertilizer application. Compared other micro irrigation methods, the energy requirement under SDI is comparatively low. Once established, the SDI systems can sustain less damage because there is no need to be removed and reinstalled in between crops. When properly constructed and managed, SDI systems can have a long economic life of 15-20 years which enables investment expenditures to be amortized over a long period of time.

8. Disadvantages of SDI

There are occasions and conditions that make choosing an SDI system disadvantageous. These drawbacks can also be classified into three categories: farming and cultural practices, system infrastructure challenges, and water and soil problems.

Disadvantages related to water and soil issues

The SDI system requires comparatively more monitoring and evaluation of irrigation events as mismanagement can result in underirrigation, which lowers crop production and quality, or overirrigation, which causes issues with deep percolation and poor soil aeration. In coarse texture soils, the wetting pattern can be too small due to more downward flow of water which would lead to an inadequate crop root zone. Similarly, in fine textured soils having vertical cracking, the upward flow of emitted water may be restricted and it would result in poor and patchy germination due to dry surface soil. If the emitter discharge is greater than soils' capacity to disperse the water under typical redistribution mechanisms, this may result from water accidentally "surfacing" which may result in tunnelling of the emitter flow to the soil surface.

Disadvantages related to cropping and cultural practices

The placement of the drip line in the shallow depth restricts deep primary and secondary tillage operations as it may damage the lines. The SDI supplies the water directly in the crop root zone, which may restrict the plant root development due to ease of water availability to roots. This may lead to lesser fertilizer uptake from larger soil volume and necessitates fertigation including micronutrients more important. It could be more challenging to accept crops with more variable row spacing in already established SDI systems because of their fixed spatial constraints. When planting annual row crops, extra attention must be taken to ensure that crop orientation and spacing are properly matched to the position of the dripline.

Disadvantages related to system infrastructure

Compared to other alternative irrigation methods, SDI requires a significant upfront initial expenditure. Compared to other irrigation systems, SDI systems often have a shorter design life, which necessitates an increase in annualized depreciation expenses to cover system replacement. Compared to certain surface micro-irrigation systems, SDI may require more sophisticated water quality management because there are no possibilities for manual emitter cleaning in case of clogging. Rodent-related leaks can be more challenging to find and fix, especially in deeper SDI systems. Root infiltration into the driplines must be monitored, and system operating and design processes must have protections to reduce or stop future intrusion. Some perennial plants' roots may cinch driplines, limiting or eliminating flows. To get rid of any possible accumulations of silt and other precipitates in the driplines, the driplines must be cleaned periodically. In SDI, less visual evidence of system performance and application homogeneity is present as water is applied in subsurface.

Procedures for scheduling irrigation are necessary to prevent under- and over-irrigation through flow-meters and pressure gauges. The installation of SDI requires more technical knowhow. Lack of technical support in some areas might lead to improper installation, since the majority of the SDI system is underground, design mistakes are more challenging to correct.

9. Time to irrigate the field

In subsurface drip irrigation, the irrigation is applied based on soil moisture tension and field observation methods.

a. Tensiometer based scheduling

For efficient water use and to ensure optimum water supply to the crops through SDI, proper irrigation schedule is important. Soil moisture meter or tensiometer is used to schedule the irrigation in crops for this purpose. In this approach the soil tensiometers are placed up to 15 cm soil depth in between the crop rows and irrigation is applied at pre-determined moisture

Plate-9 Wetting pattern in field after subsurface drip irrigation

tension based on crop type. In direct seeded rice, irrigation is given when tensiometer reading reaches at –20 to –30 kPa. For wheat crop, tensiometer reading of –40 to –50 kPa is considered for switching the irrigation. Similarly, maize crop is irrigated at soil moisture tension of –50 to –60 kPa.

b. Field observation based scheduling

It recommended to irrigating the field based on tensiometer reading to avoid under irrigation. However, in case of non-availability of tensiometer, field observation based irrigation can be applied. Based on the irrigation intervals recorded with tensiometer readings and corresponding soil wetting visibility, irrigation schedule is developed for farmers not having tensiometers. Sufficient irrigation is applied after sowing of crops to ensure proper germination. In direct seeded rice crop, irrigation is applied at 2-3 days interval by running the SDI for 2-3 hrs at each irrigation till wetting zone stars appearing on soil surface. For wheat crop, first irrigation is applied at 20-21 DAS and subsequently at 15 days intervals depending on the situation. This schedule can be skipped in the event of sufficient rainfall. However, in case of nitrogen fertigation is to be done through SDI, the SDI system should be run to apply nitrogen as per prescribed schedule of crop as described in next section irrespective of rainfall.

c. Fertigation through SDI

Nitrogen fertigation can be made through SDI for saving of fertilizer with improved fertilizer use efficiency. In rice, the recommended rate of nitrogen is applied in 7 equal splits through urea at 15, 25, 35, 45, 65, 75 and 85 days after sowing (DAS). In maize the recommended nitrogen can be applied in four equal splits at 20, 30, 45 and 60 DAS. Nitrogen fertigation in wheat is splited in 4 equal doses at 25, 45, 65 and 85 DAS. Under fertigation through SDI, 20% dose of nitrogen can be reduced without any yield penalty in all the crops.

10. Economics of SDI

The installation cost of SDI system components is almost similar as that of inline surface drip system except additional cost of trenching. The average lifespan of SDI is considered as 15 years. The system may last even up to 20 years with proper maintenance and high-quality water. The cost of subsurface drip irrigation was Rs. 2,50,000 ha^{-1}. The cost of drip irrigation system was computed after taking into account 80 percent government subsidy. Based on a 15-year life expectancy, the cost of SDI with 80% subsidy and without subsidy is Rs. 1530 and 7650 ha^{-1} per principal crop, respectively. Without the need to alter pipes between rotations, the proposed SDI system may be used for rice, maize, and wheat crops, saving both money and labour.

The estimated cost of the SDI system assuming a 15-year life expectancy for the main, sub-main, venturi, and pump and depreciation at 10% per annum was computed as follows for different lateral spacing (Sidhu et al. 2019):

- Drip cost for 33.75 cm spacing (with 80% subsidy and 15-year life) -Rs. 2769 ha^{-1}
- Drip cost for 67.5 cm spacing (with 80% subsidy and 15-year life) -Rs. 1530 ha^{-1}
- Drip cost for 33.75 cm spacing (without subsidy and 15-year life) -Rs. 13,847 ha^{-1}
- Drip cost for 67.5 cm spacing (without subsidy and 15-year life) -Rs. 7650 ha^{-1}

11. Salinity and irrigation interactions

Distributions of soil water and salinity that are both temporal and geographical can be crucial for SDI. Subsurface driplines that carry water upward produces capillaries in the root zone which helps in aeration to roots in sodic soils. Irrigation through SDI also helps in overcome the problem of surface water logging due to low permeability of sodic soils. If irrigation water is saline, it may cause saline zone beneath the root zone through upward movement. To prevent this, crop may be raised on beds higher than usual (Hanson and Bendixen, 1993). For even modestly salinized waters with SDI systems that are utilised for several years, crop site management with regard to dripline placement might be crucial unless periodic leaching is offered. For drip-irrigated tomato and peanut plants on sandy soil, root activity was restricted to the wetted soil volume, although the rooting patterns for fresh and salt water were different (Ben-Asher and Silberbush, 1992). When using freshwater, there was a reasonably significant root density in the wetted volume's perimeter, but with salty water, there was little root activity there. The leached zone underneath the emitter was where the majority of root activity took place.

12. Evidences from SDI in cereal-based systems of NW India

A long-term experiment was initiated under loamy soil in the year 2016 at ICAR-Central Soil Salinity Research Institute, Karnal in collaboration with International Maize and Wheat Research Centre (CIMMYT) under rice–wheat–mungbean and maize–wheat–mungbean cropping sequences with conservation agriculture (CA)-based scenarios (Sc) with and without SDI (Jat et al. 2019). The in-line drip lateral of 16 mm diameter installed at 20 cm soil depth with 45 cm lateral spacing and 30 cm emitter intervals. Irrigations were applied at –20, –50 and –40 kPa soil metric potential in rice, maize and wheat, respectively. Results revealed that during initial years of switching to SDI (2016-17 and 2017-18), system with flooded rice in Farmers' practice (ScI) and improved farmers' practice (ScII, CTR+ZTWM+R+FI), consumed highest amount of irrigation water (2304 and 2184 ha-mm), while maize based diversified system with SDI (ScVI, ZTMWM+R+SDI) consumed the lowest (360 ha-mm) amount of irrigation water compared to the other scenarios. On the system basis, the highest water productivity (4.46 kg grain/m^3) was recorded in the ScVI (ZTMWM+R+SDI) and lowest (0.58 kg grain/m^3) under ScI (Farmers' practice) (Table 1). Maize-based cropping systems (Sc IV and ScVI) recorded 145 and 669% higher mean water productivity compared to traditional rice–wheat system (ScI), respectively. Further, compared to CA based rice–wheat–mungbean system with flood irrigation (Sc II, ZTRWM+R+FI) replacing flood irrigation with SDI (under ScV) resulted in 54.7% and 39% saving of irrigation water during 2016-17 and 2017-18, respectively. Similarly, in CA based diversified maize–wheat–mungbean system, the SDI saved irrigation water to the extent of ~45% during both the years.

The grain yield of CA based zero tilled direct seeded rice (DSR) under SDI (ScV) was improved over zero tilled DSR with flood irrigation (ScIII), narrowed the yield gap to 10.6% compared to puddled rice (farmer's practice) (Table 2). Similarly, marginal improvement in yield of wheat

Table-1 Effect of SDI on water use, water productivity and net returns under different CA-based cropping systems

Scenario	System irrigation water use (ha-mm)		Water productivity (kg grain/m^3)		System net return (Rs/ha)	
	2016-17	2017-18	2016-17	2016-17	2016-17	2017-18
ScI: Farmer's Practice	2302^{a}	2340^{a}	0.59^{d}	0.59^{d}	119732^{c}	128611^{d}
ScII: CTR+ZTWM+R+FI	2078^{ab}	2290^{a}	0.73^{d}	0.73^{d}	147429^{b}	170089^{bc}
ScIII: ZTRWM+R+FI	1961^{b}	2046^{b}	0.67^{d}	0.67^{d}	127551^{c}	157566^{c}
ScIV: ZTMWM+R+FI	624^{c}	678^{d}	2.37^{b}	2.37^{b}	164457^{a}	186456^{ab}
ScV: ZTRWM+R+SDI	888^{c}	1248^{c}	1.59^{c}	1.59^{c}	144712^{b}	176119^{bc}
ScVI: ZTMWM+R+SDI	338^{d}	381^{e}	4.50^{a}	4.50^{a}	168764^{a}	201033^{a}

*Means followed by a similar uppercase letter within a column in a given year are not significantly different at 0.05 level using Tuckey's HSD test. CTR: Conventional tillage rice; ZTWM: zero tillage wheat and mungbean; R: residue retained; FI: flood irrigation; ZTRWM: zero tillage rice, wheat and mungbean; ZTMWM: zero tillage maize, wheat and mungbean.

Table: 2 Effect of SDI on grain and system yield under different CA-based cropping systems

Scenario	Grain yield (Mg/ha)						System yield (Mg/ha)	
	Rice equivalent		Wheat		Mungbean			
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
ScI: Farmer's Practice	7.51^{ab}	6.57^{c}	5.47^{c}	5.88^{c}	----	-----	13.40^{b}	13.33^{c}
ScII: CTR+ZTWM+R+FI	7.39^{b}	6.85^{bc}	5.72^{bc}	6.06^{bc}	0.50^{a}	0.74^{a}	15.08^{a}	16.19^{ab}
ScIII: ZTRWM+R+FI	5.88^{c}	5.85^{c}	6.35^{ab}	6.58^{ab}	0.15^{b}	0.45^{b}	13.19^{b}	14.86^{bc}
ScIV: ZTMWM+R+FI	7.12^{ab}	7.14^{ab}	6.53^{ab}	6.49^{ab}	0.15^{b}	0.45^{b}	14.62^{a}	16.04^{ab}
ScV: ZTRWM+R+SDI	6.21^{c}	6.38^{c}	6.79^{a}	6.61^{ab}	0.20^{b}	0.51^{b}	14.12^{ab}	15.61^{ab}
ScVI: ZTMWM+R+SDI	7.61^{a}	7.35^{a}	6.38^{ab}	6.79^{a}	0.22^{b}	0.53^{b}	15.14^{a}	16.85^{a}

*Means followed by a similar uppercase letter within a column in a given year are not significantly different at 0.05 level using Tuckey's HSD test. CTR: Conventional tillage rice; ZTWM: zero tillage wheat and mungbean; R: residue retained; FI: flood irrigation; ZTRWM: zero tillage rice, wheat and mungbean; ZTMWM: zero tillage maize, wheat and mungbean

also observed under CA based SDI (ScV) compared to CA-based wheat cultivation with flood irrigation (Sc III). In case of CA based maize systems, SDI improved the rice equivalent yield (~3-6%) compared to flood irrigated. Additionally, under CA systems, the subsurface drip irrigation system reduced the fertiliser N use by 20%. The rice–wheat and maize–wheat CA based systems (ScV and ScVI) increased the overall system profitability by 13 and 5% (2-yr mean), respectively considering with 80 percent subsidy SDI system and equivalent profitability without subsidy scenario compared to their respective CA-based system without SDI. Additionally, there was ~20% lesser nitrogen was used in SDI under both rice and maize-based systems. The CA-based diversified maize–wheat–mungbean system with SDI (ScVi) recorded highest system net returns (Rs.168764 and 201033 ha^{-1}).

Punjab

A field study was carried out in silt loam soil at BISA-CIMMYT experimental farm, Ladhowal, Punjab to assess the effects of various spacing and depths of laterals for subsurface drip irrigation on crop Yield, irrigation water productivity (WP), nitrogen use efficiency (NUE) and net returns under CA based rice–wheat system (Sidhu *et al.*, 2019). In rice all the SDI and


क्लाइमेट स्मार्ट खेती : 50 फीसद पानी, 20 फीसद लागत कम


30 क्विंटल प्रति एकड़ पैदावार, पानी की 50% होगी बचत, 25% बढ़ सकता है गेहूं का रकबा

Table 3: Effect different spacing and depth of subsurface drip irrigation system on grain yield (t/ha) of rice and wheat

Treatments	Lateral distance-depth	Rice		Wheat	
		2014	2015	2014-15	2015-16
T1: ZTRW+R+DI	33.75	4.62	4.79	5.60	5.72
T2: ZTRW-R+SDI	33.75-15	4.57	4.66	5.14	5.79
T3: ZTRW+R+SDI	33.75-15	4.59	4.85	5.51	5.7
T4: ZTRW+R+SDI	33.75-20	4.72	4.57	5.32	5.23
T5: ZTRW-R+SDI	67.5-15	5.15	4.83	5.40	5.69
T6: ZTRW+R+SDI	67.5-15	4.79	4.70	5.56	5.48
T7: ZTRW+R+FI	–	4.88	4.67	5.07	5.29
T8: CTRW-R+FI	–	4.71	4.40	4.74	4.38
LSD(0.05)		0.42	NS	0.22	0.25

ZTRW: zero tillage rice–wheat; CTRW: conventional till rice–wheat; +R: with residue (25% wheat, 100% rice); -R: residue removed; DI: surface drip; SDI: subsurface drip; FI: flood irrigation

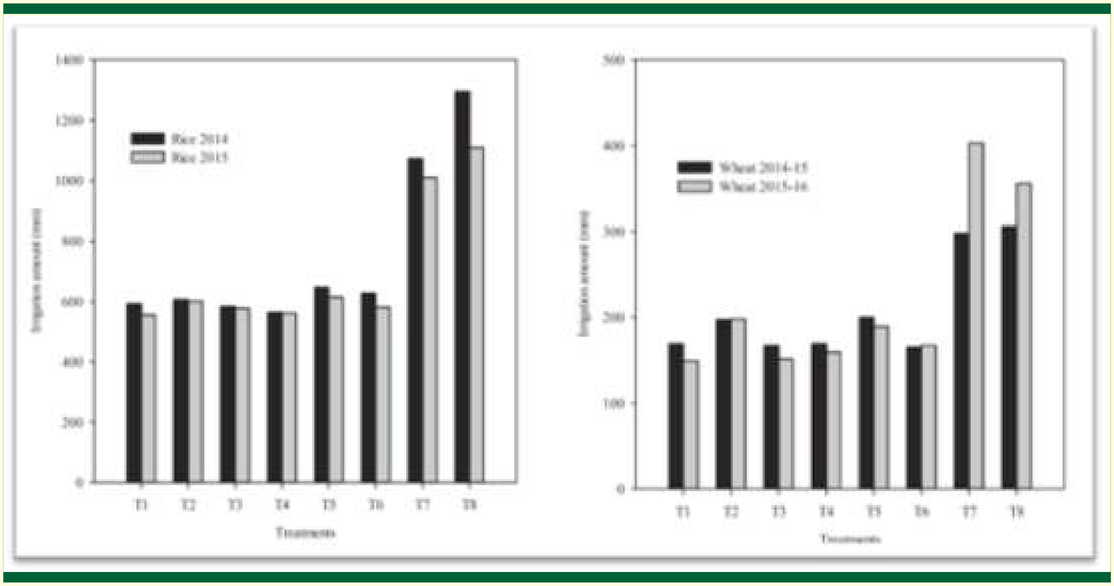

Figure 1: Effect different spacing and depth of subsurface drip irrigation system on irrigation water use in rice and wheat

surface drip (DI) treatment obtained statically similar grain yield while ZTRW-R+SDI with 67.5 lateral spacing and 15 cm depth registered significantly higher grain yield compared to CTRW-R+FI during 2014 (Table 3). Grain yield of wheat was significantly higher in drip irrigated treatments compared to FI (both ZT and CT) in both the years. Among the drip-irrigated treatments, there was no significant difference in wheat yield between the 33.75 and 67.5 cm dripline spacing which indicate that driplines spacing at 67.5 cm can be recommended as the cost of installing a drip system would be markedly reduced.

Amount of irrigation water applied to rice under drip system was 53.0 and 47.6% lower

Table 4: Effect different spacing and depth of subsurface drip irrigation system on economics of rice and wheat (average of two years)

Treatments	Depth (cm)	Variable cost of cultivation ($Rs \times 10^3$)		Net returns ($Rs \times 10^3$)	
		Rice	Wheat	Rice	Wheat
T1: ZTRW+R+DI	33.75	28.52	28.23	123.35[b]	78.08[ab]
T2: ZTRW-R+SDI	33.75-15	25.54	25.48	123.31[b]	76.74[b]
T3: ZTRW+R+ SDI	33.75-15	26.29	25.89	125.86[a]	78.28[ab]
T4: ZTRW+R+ SDI	33.75-20	26.03	25.95	123.65[a]	73.34[c]
T5: ZTRW-R+ SDI	67.5-15	24.67	24.21	136.22[a]	79.85[a]
T6: ZTRW+R+ SDI	67.5-15	25.03	24.73	127.99[a]	79.61[a]
T7: ZTRW+R+FI	–	30.02	25.28	123.84[b]	71.05[c]
T8: ZTRW-R+FI	–	36.64	28.52	110.27[c]	56.71[d]
LSD(0.05)					

Dissimilar alphabet indicates statistically significant differences between the values. ZTRW: zero tillage rice-wheat; +R: with residue (25% wheat, 100% rice); -R: residue removed; DI: surface drip; SDI: subsurface drip; FI: flood irrigation.

compared to CTRW-R+FI (1296 and 1109 mm) respectively in 2014 and 2015 (Fig. 1). Similarly, the drip irrigation saved 41.9 and 52.6% irrigation water in wheat over CTRW-R+FI (306 and 298 mm) during 2014-5 and 2015-16, respectively.

The CA based drip irrigation (T1-T6) reduced the cost of production to the extent of Rs. 8.12–11.97 thousand/ha, respectively in rice and wheat crops over flood irrigation treatments (Table 4). The drip irrigation also increased the net returns of rice and wheat crop whereby ZTRW-R+ SDI (T5) recorded highest net returns (rice + wheat), which was 10.9 and 29.8% higher compared flood irrigated T7 and T8 treatments, respectively.

13. Environmental Benefits of SDI

- The direct application of N fertiliser to crop root zone saves total N use thereby helps in lesser greenhouse gases emissions related to nitrogen fertilization directly and through N fertiliser manufacturing indirectly vis a vis human energy in application.
- In SDI system, the water losses due to deep percolation and runoff into streams is diminished or eliminated, and there is less nutrient and chemical leaching, it reduces the resultant water and soil pollution.
- The SDI saves about 50% of irrigation water, it reduces the electricity/diesel consumption and also reduces the exploitation of under-ground water resources.

14. Conclusions and recommendations

- Use of subsurface drip irrigation system in rice and maize based cereal systems helped in conserving irrigation water, boost water productivity and increased effectiveness of nitrogen fertilizer use.
- Integration of the SDI system under CA based practices further reduced the amount of irrigation water use and raised irrigation water productivity compared traditional farming practices.
- On an average there is 50% saving of irrigation water under SDI which enabled sustainable intensification of the existing rice–wheat system by inclusion of summer mungbean crop.
- In comparison to broadcasting of N under flood irrigation, fertigation through subsurface drip irrigation reduced the amount of nitrogen fertiliser up to 20%.
- In SDI, the energy needed to pump water for drip irrigation is 50% less than that of flood irrigation enables the use of solar-powered pumps to supply the water effectively, which would greatly reduce the water and energy footprints.
- By using the subsurface drip irrigation method in conjunction with CA in NW India, it is conceivable to significantly increase rice and wheat production, irrigation water productivity and N usage efficiency with lower global warming impacts.

15. Future Thrust

Since the 1960s, the usage of ground water for irrigation has been steadily rising in our nation. This led to the decline in ground water table to the extent of 0.1 to 1 metre annually in different region which will adversely affect future water availability for irrigation. By the year 2050, the amount of water needed for irrigation would almost treble, reaching 541 billion cubic metres. The availability of water utilised for irrigation is predicted to drop from 83 percent at today to 73 percent in the year 2025. It is essential to employ water resources with high efficiency with the principal of 'more crop per drop' since there will be less water resources available with a greater demand for food grains. To meet the ever-increasing food grain demand in the face of declining water resources, subsurface drip irrigation system has a potential alternative to produce more with less water, energy and fertilisers. The government must take action to charge the power used for pumping groundwater in Punjab and Haryana (at present minimal; INR 0.30 per kWh of electricity determined by local government of Haryana) in order to accelerate the adoption of SDI in the RW system of NW India.

The SDI system needs the attention of policy makers for upscaling of this technology on larger domain to achieve the Government missions of 'More Crop Per Drop', 'Doubling Farmers' Income by 2022,' and 'Right to Food'. In line of residue management machineries, there is need to provide subsidy on drip trencher machine so that farmers can afford. Large scale demonstrations at farmers' field through various govt. schemes can augment the adoption of this technology. The complete package of SDI installation, including drip lines, accessories, subsurface lying and solar based pump can also be brought under the preview of existing subsidy schemes being given on micro irrigation. The SDI system has great potential for sustainable intensification of CA-based cereal (Rice–wheat and maize–wheat) systems.

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