Comparative study on water use efficiency of SWAR irrigation system and drip irrigation system

Study conducted for

Centre for Environment Concerns

Hyderabad
Website: *cechyd.org*

Study conducted by

BCT-KVK, Haripuram
Visakhapatnam district, Andhra Pradesh

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Background

In 1980 development prescription was simple; “water is central to successful farming, small farmers get subsidy and bank loans, dig or drill bore wells, get electricity and pump the groundwater”. Poverty will be history. Soon open wells dried up and bore wells got deeper. Farmers were saddled with bank loans.

In the last two decades, we have seen thousands of peak yield aged fruit trees with many more years of productive life ahead dry and die in summer, causing huge loss to farmers and our nation. The tragedy unfolds as follows: Based on available groundwater and using the subsidized drip irrigation systems, farmers plan the plant species and their numbers. As they grow and mature, plant water demand goes up while the groundwater availability falls dramatically. It starts with slow, stunted plant growth and later, poor fruit yield and quality. In desperation, farmers buy water to save their fruit trees, only to see them die soon after. Rising and prolonged summer heat waves exasperate the crisis.

Tippa Reddy is a farmer in Buchayyagaripalli village, in Anantapur district of Andhra Pradesh. He had five acres of fifteen year old high export quality mango fruit orchard and used drip system to irrigate. In 2016-17 his bore well yield fell down. He invested a hundred and fifty thousand rupees to buy tanker water to irrigate and save his trees. Not one survived.

When we asked Tippa Reddy to come to his farm, with tears in his eyes he replied “Sir, I will not come. If I see I will commit suicide”. One farmer and co-creator of SWAR weeps on seeing the trees dry and with uncontrollable tears said “

Introduction

To address the depleting groundwater situation in Peninsular India and the Deccan Plateau, efforts to encourage water conservation activities and recharge groundwater has been taken up with considerable investments. There has been poor fruit-yield tree mortality and rising mortality. In addition, cultivation of vegetables and flowers during the summer months, when demand and prices are high, is no longer possible in these regions. A High-Level ICAR committee was constituted by the Prime Minister to study and recommend remedial measures to tackle the alarming rise of fruit tree mortality in Vidharba in Maharashtra. This led to a scheme called “revitalization of old fruit trees”, but this could not arrest the rise in fruit tree mortality. A Right to Information query filed by us lists compensation for fruit tree mortality, while the department has no data on how many fruit trees died due to moisture stress in the last five years. The AP govt. provides subsidy for tanker water purchase to irrigate fruit trees in summer, only to see them die the next year, while the Telangana govt. gives 24x7 free electric supplies to mine all the groundwater.

The Centre for Environment Concerns, a Hyderabad based non-govt. organization, sought to dwell deep on the causes for low yield and high fruit tree mortality, farmer’s ideas and practices of changing groundwater regime and climate change to observe the following.

Problems and Practices

The “state of the art” and most efficient use of water in agriculture is the drip system. Yet, studies on farmer practices of water use in drip shows them to use 60-65% higher than what is recommended by agriculture scientists based on species, plant age, soil and temperature.

Farmers do not shift dripper locations as plants grow. Often they remove the drippers that control water flow and with pressurized irrigation as in drip system, the water jet and wastage is very high. This is also with the lateral pipes bursting.

To the farmer, the drip irrigation value is not to saving of water, saving on labour in flood irrigate, supply soluble plant nutrients and fertilizers and comes with huge subsidy.

Farmers believe copious water insures possible risks to plant health, disease and yield.

In Israel, irrigation water supply is by a central grid. Its quantum is based on competitive bidding by farmers listing measurable indicators of productivity, economic value and returns, etc. Farmers compete to innovate, compete and adopt conjunctive measures for high productivity with measured water. In India, groundwater is private property and the winner takes all. They get subsidies or free electricity, leading to huge abuse and inequity in groundwater use.

With governmental support, farmers dig large farm ponds to store water with bottom and sides lined with high micron thick plastic sheet. Farmers pump water in the post-monsoon season, filling them to supplement water and irrigating crops in summer when the water yield falls dramatically. This is a key cause for severe water shortage in summer months, leading to most villages being supplied with water tankers for household purposes.

To eliminate high and rising surface water evaporation loss, subsidized plastic mulch increasingly covers the drip pipeline. While this prevents evaporation loss, it causes the collateral damage of no soil aeration or an enabling ecosystem for living micro-organisms to survive in the soil. The farmer, at his own cost, must replace the plastic sheet every year and this left-over pile of plastics is another environmental nightmare. Soil is now an anchor to the plant, not provider of plant food harvests and stored rainwater. The farmer is dependent entirely on industrially produced external nutrient inputs. To cut input costs, the government will provide subsidies.

Scientists and extension agencies seek ways to maximize agricultural yield and income. Alongside we need plans, investments and extensions to safeguard productive incomes and valuable farm assets; especially horticulture and forestry crops of a long gestation period to reach peak yield age and with many years of most productive life.

Finding Answers

Farmers pump the growing water to the extent possible to make their crops survive. Drip systems are not being used as suggested by the scientists and extension workers. Further, drip system hasn't been maintained well the farmers. Addressing the following questions could give a possible solution to this problem.

1. Steps to stop water wastage in drip by farmers: leaky pipes, removing drippers etc?
2. Address farmer belief that more irrigation hinders potential pest and disease in plants.
3. How to provide farmer confidence on adequate water availability at plant root zone?
4. What conjunctive measures will maximize water use effectiveness?
5. How and retrofit irrigation theory and technology development that foster synergy of productive natural resources of water, soil, micro-organisms?

The Idea

The Centre for Environment Concerns (CEC), is a Hyderabad based Non-Governmental Organisation established in 1984 to work on environment-development issues. CEC focus has been on innovation in policies, practices and technologies. See www.cechyd.org. In 2012 CEC began to explore the scope for efficient water use solutions for fast and healthy growth with high yield while also to salvage them from drying when water shortage is acute. CEC sought innovative ideas, technologies, and approaches in irrigation centred on farmer confidence with using much less water and maximize yield.

It has observed farmer practices to evolve ways to improve the efficiency of drip pipeline-based irrigation. A decade back, after seeing women workers making multiple trips to fruit plantations in MGNREGS, it has decided and provided them with a 200-liter water trolley. To its dismay it found no reduction in their drudgery and travel. This is because in summer when watering is most crucial for fruit plantations, they walked much longer distances to find water and had to wait for more time to collect water. This experience of the toil of old women inspired them to find ways to manage horticulture in summer when water is most needed but is also highly scarce.

CEC believes that if product functional outputs are well defined, finding technological solutions is possible. This is more easily doable with new knowledge, sciences, technologies, testing facilities and Google's search engine. This paid us rich dividends. For instance, to increase wage labour productivity and reduce the drudgery and occupational hazards of women, we could easily develop the next generation of work tools in the National Rural Employment Guarantee Scheme. This has emboldened us to be innovative in the use of groundwater and rain water harvested from farm-pond-based irrigation to suits drought prone, water scarce areas for the growth of horticulture and agro-forestry crops. The team has ventured to build make an innovation that meets all the criteria laid down to define *"Ideal Irrigation Architecture"*.

Defining Ideal Irrigation Architecture

Ideal Irrigation Architecture should address low water availability for horticulture, forestry and flowers and vegetables in low rainfall, groundwater depleting farms in drought-prone areas of Peninsular India. The following were listed as deliverables of the architecture:

1. End surface drip and find ways of sub-surface plant root zone area irrigation as the ambient summer soil temperature exceeds 60^0C with water evaporation of 15-20 mm per day.
2. Plants need moisture at the root zone. Hence, shift to root zone moisture level as the measure and not the quantity of water as adopted in the drip system.
3. Arrive at appropriate and optimum moisture at root zone moisture level as a range and based on empirical data on soil type, plant species and age and climatic factors.
4. The above must reduce irrigation water quantities in drip and lead to saving considerable quantities of water.
5. The technology must be dual purpose to drastically reduce and ration water supplies to ensure keeping fruit trees alive.
6. Irrigation must extend beyond plants to include fostering of soil micro-organisms. Soil-living organisms widen and deepen in the capillary spread of moisture, forage food in edible form to the plant, enhance soil capacity to store and to release moisture based on plant root suction demands and improves soil health and organic carbon.
7. Revisit drip irrigation logic of "Field capacity to wilting point". It is chemicals centric and fails on deliver biological soil health.
8. Ensure adequate moisture at the root zone to end their practice of removing the dripper.
9. As drip pipelines are extensively available with farmers, the innovation must use be an add-on to drip water conveyance to make it affordable to farmers.

10. Product shall deliver high value to farmers so as to transform irrigation practices in low rainfall drought-prone areas facing severe water shortage and low productivity leading to loss of farmer income and assets.

Technology Innovation & SWAR

Five years of product iterations lead CEC in 2018 to develop and successfully field test the product named "System of Water for Agriculture Rejuvenation (SWAR) that complied with all the irrigation architectural requirements. At the product development stage itself, SWAR won two global champion innovation prizes: *Paris International Agriculture Exposition and Securing Water for Food (SWFF)*, a USAID/SIDA/Netherlands Govt. joint international innovation competition on the water for food. The earlier product versions delivered on the functional features sought in the architecture criteria but CEC wanted to further reduce costs to be affordable to farmers, easy to install and maintain.

The final version is an add-on to drip wherein water from the dripper is taken through a micro-tube and is delivered into a box perforated containing insulating materials to avoid hairy root invasion and the box is placed at the plant root zone area. This depth for its location varies from six to twenty inches based on the plant while the number per plant is based on plant age and growth stage. From this moisture diffuser box at the root zone, water is slowly released and the moisture level is measured and maintained using moisture sensors. Based on moisture level farmers develop their irrigation schedule and water quantum for different seasons, plant species and growth stage and soil types. Given below is the system wherein the long pipe is 16 mm drip pipeline, a dripper from where a 5mm micro-tube delivers water into a violet coloured perforated box.

SWAR Hardware attached to drip pipe with box buried at the plant root zone

An advisory guides farmer, to upgrade locally available farmyard manure to prepare Living Compost that works as microbe inoculates in the soil. Famers apply Living Compost around SWAR buried moisture diffuser and its quantum varies from half kg in vegetables/flowers to five to ten kg in forestry and fruit trees.

Field Experience and Learning

Since 2018 April, forty thousand SWAR units are deployed in multiple species and soil types. Water quantum saved varies based on its availability with the farmer. SWAR users have low water yield, share groundwater with other farmers, buy tanker water to irrigate or have rainwater harvested farm ponds as the source of water. Their feedback is unanimous: compared to drip, SWAR requires half the water, very rare is sapling mortality, healthy and fast plant growth, new foliage in summer and more biomass. There was no weed growth, saving the money of farmers, and end of plant root disease caused by excess irrigation. With rationed water, fruit trees survived in summer, saving a valuable farmer asset. Farmers who fetched water reduced their purchases by half. In farms where Living Compost (microbes inoculate) was applied, we expect that the availability of oxygen at root zone keeps disease-causing pathogens to be dormant and improves plant mineral uptake, allowing for aggressively healthy root systems and leading to high plant metabolism.

SWAR has been field tested on multiple plant species and soil types to cultivate fruit, forestry, vegetables and in flowers, using less of the water compared to drip. Field findings and farmer response convinced CEC that irrigation of moisture at the plant root zone drastically reduces plant water use.

Roof top vegetable cultivation in Hyderabad using SWAR

Mango Plantations at Bukkapatnam, Anantapur District, Andhra Pradesh

Case study:1

Nitin Bakali, Yavatmal district in Maharashtra grows tuberose plants using drip system. With HDFC support he put half of them under SWAR in Feb 2019. The following picture shows forty days crop under drip and SWAR. This led to NGO Sanjeevani Institute of Empowerment and Development to install SWAR in orange and vegetable crops.

Variation in Nishigandha flower plant health after 45 days SWAR and DRIP installation

Case study: 2

SEED, an NGO installed SWAR and applied Living Compost (microbe inoculates) on fruits and vegetables at their demonstration farm in Duttalur village of Nellore district in Andhra Pradesh. SEED CEO Suresh says "We face severe water shortage. We find SWAR to use much less water, no plant mortality, fast and healthy growth of plants and no weed growth. SWAR will be very useful to farmers as water shortage is rising every year. Our moment of truth: for the first time after several years our fruit trees have begun to yield and yield good".

Case study: 3

Venkataswamy of Podili village in Prakasam district of AP installed SWAR in April 2018 on his Sweet-lime and Acid-lime plantations. On 21st June Dr.Ariz Ahammed, IAS, Managing Director, National Horticulture Board, New Delhi, visited his farm to study SWAR working, water savings, and root-zone moisture level and tree health. He invited CEC for a presentation to officials in Delhi.

Field Study by BCT-KVK

To validate the performance of SWAR scientifically, CEC approached BCT-Krishi Vigyan Kendra (BCT-KVK), Haripuram, Vishakhapatnam District in Andhra Pradesh. Bhagavathula Charitable Trust (BCT) is non-profit, non-sectarian social service organization established in 1976 and working for the development of rural areas around Visakhapatnam (located in Andhra Pradesh, Southern part of India). It has conducted over 100 pilot programs—a few of which have become models for replication across the country—in the areas of women's self-help groups (precursor to the DWACRA and SHG), rural banking, wasteland development, development of literacy primers for literacy training program, agriculture development and growth of allied activities.

In 1995 BCT was sanctioned Krishi Vigyan Kendra for Visakhapatnam district by the Indian Council of Agricultural Research (ICAR). The major thrust of the KVK continues to be Technology Assessment and Refinement, solution for practical problems of farmers Through OFTs - On Farm Trials, FLDs - Front Line Demonstrations, Trainings, Field visits, advisory services, organization of vocational trainings and other extension activities etc. BCT-KVK conducted the field study to compare the water use efficiency of SWAR over the conventional drip irrigation system. It conducted the comparative field study with a hypothesis that SWAR could equal or better performance of drip irrigation system.

Objectives

This field study aims to

I. Compare and calculate the quantity of water saving by using SWAR over drip irrigation system
II. Study crop performance under drip and SWAR system of irrigation with reference to flowering, growth, yield, biomass, etc.
III. Calculate the total savings to be realized by farmers by using SWAR with reference to reduced water use, less power, and irrigation pipe infrastructure.

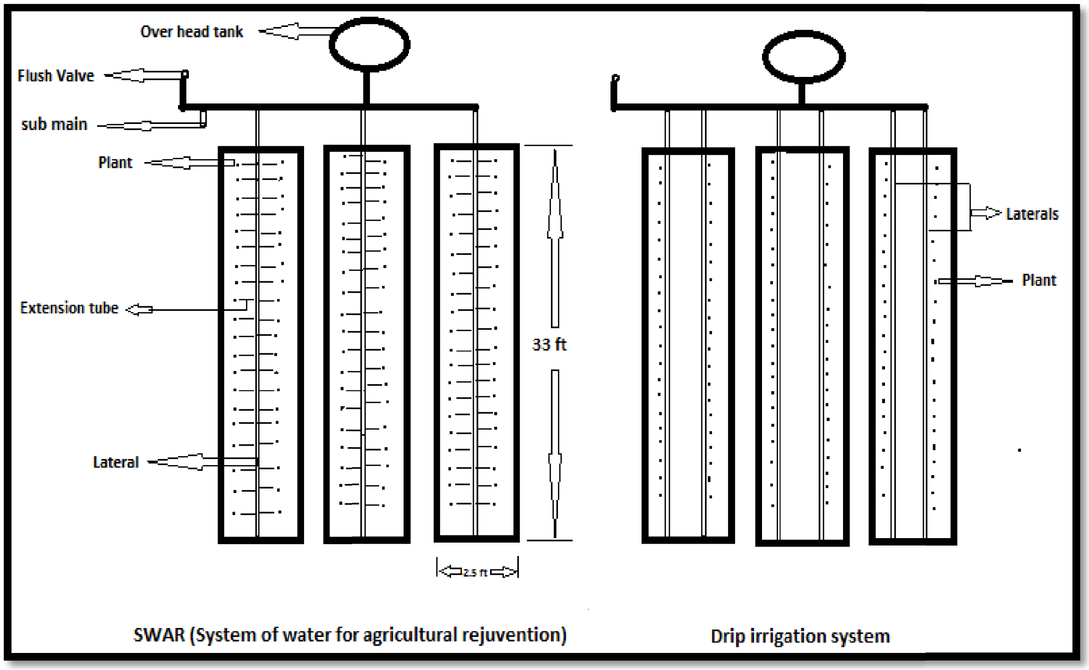
Methodology

The study was carried out at BCT-Krishi Vigyan Kendra farm campus which falls under the semi-arid region characterized by mild winter, short monsoon, and hot summer. The mean annual temperature is above 27.8º C. Summers record temperatures up to 43º C, whereas winter season (November to February) is relatively cool and dry. The hottest months are April and May, and the coolest month is January. The annual average rainfall is 1008 mm of which most quantities are received during south-west monsoon (June-September).

Experimental plot design

The field experiment was carried out in an area of 90 m^2 from November 2018 to March 2019. Experiment plot was divided into two equal plots of 45 m^2 for drip and SWAR irrigation systems. A space of one meter was provided between SWAR and Drip plots to avoid any scope for water seepage. Each plot had three raised beds of 75 cm width with a bed to bed spacing of 30 cm. The height of the bed was 30 cm and length 10 meters. In both the cases i.e. SWAR and drip system, irrigation was provided with gravity flow of water through

300-liter capacity overhead tank placed at a height of five feet individually. Both the treatment and control plots had three beds i.e. one each for Tomato, Chilli and Brinjal. Each bed had 40 plants with a plant spacing of 50cm which totals to120 plants. Layout of the SWAR and Drip Systems is given below.



SWAR consisted of plastic boxes having perforated base buried to 6 cm depth from the soil surface through which water is released at the root zone. These boxes were installed @ one each for individual plants and connected to the laterals through micro-tube extension pipes. One lateral HDPE line served 40 plants with one plant each on either side in SWAR. In drip two lateral pipes were provided to serve 40 plants on either side of the raised bed.

Field Site: SWAR on Left side and Drip on the Right Side with large space in between

Irrigation water supply

Each system had overhead water tank. From there water was sent through HDPE 16 mm drip pipes to SWAR and Drip. One 16 mm HDPE pipe irrigated two plants in SWAR (pipe placed in the centre of the bed water is delivered from there) while two pipes were used in Drip for dripper being close to the plant. Standard Irrigation water requirements are followed in drip. I SWAR system crops are irrigated with 40% less water compared to drip. The following table gives the details on quantity of water applied to crops at different crop stages.

Water application in Drip during crop cycle

Crop Growth Stage	Quantity of water applied at different stages (Litres)	No. of days	Total quantity of water applied (Litres)
Transplanting to Flowering	160	31	4960
Flowering to first pick up	200	32	6400
Flowering to Last pick up	320	66	21120
Total		**129**	**32480**

Water application in SWAR during crop cycle

Crop Growth Stage	Quantity of water applied at different stages (Litres)	No. of days	Total quantity of water applied (Litres)
Transplanting to Flowering	96	26	2496
Flowering to first pick up	120	37	4440
Flowering to Last pick up	192	66	12672
Total		**129**	**19608**

Growth and yield parameters

To know the behaviour of crops under SWAR and drip irrigations systems when irrigated with the above defined quantities of water, the following parameters are recorded

1. Plant height, number of branches, number of leaves produced
2. Yield
3. Biomass production

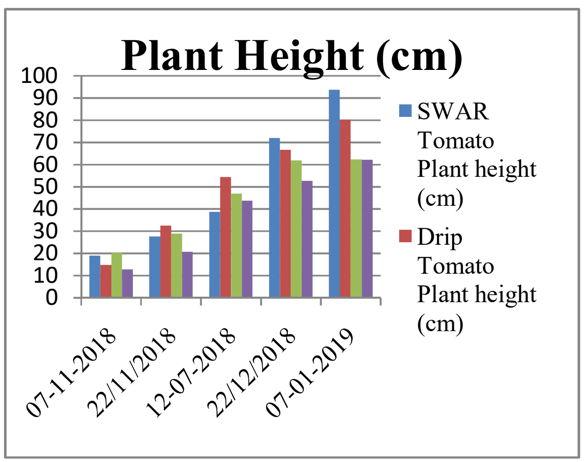
Results and Discussion

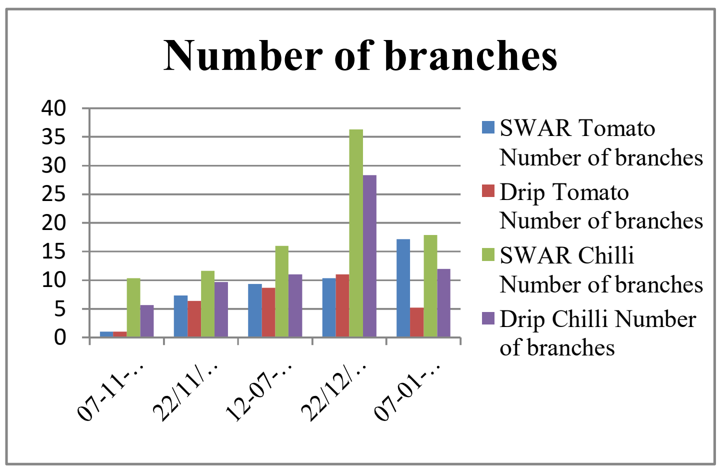
Growth parameters

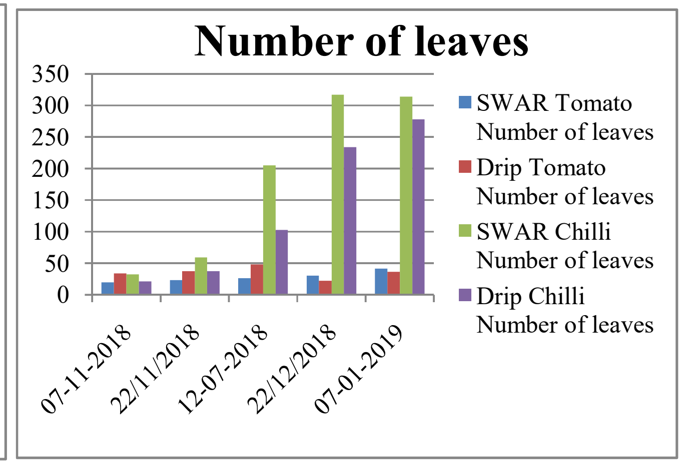
To understand the growth characteristics under SWAR and drip systems, plant height, number of branches and number of leaves were recorded on

Table: 1- Plant height, No of branches, no of leaves

		SWAR			Drip			SWAR			Drip		
		Tomato			**Tomato**			**Chillies**			**Chillies**		
SI No	**Date, Days after planting**	**Plant height (cm)**	**Number of branches**	**Number of leaves**	**Plant height (cm)**	**Number of branches**	**Number of leaves**	**Plant height (cm)**	**Number of branches**	**Number of leaves**	**Plant height (cm)**	**Number of branches**	**Number of leaves**
1	07-11-2018, 15	19	1	19.333	14.83	1.00	34.00	20.33	10.33	32.33	12.83	5.67	21.00
2	22/11/2018, 30	27.67	7.33	23.33	32.67	6.33	37.33	29.00	11.67	59.00	20.67	9.67	37.67
3	12-07-2018, 45	38.67	9.33	26.33	54.33	8.67	48.33	47.00	16.00	205.33	43.67	11.00	102.67
4	22/12/2018, 60	72.00	10.33	30.67	66.67	11.00	22.33	62.00	36.33	317.00	52.67	28.33	234.00
5	22/12/2018, 75	93.76	17.15	41.4	80.3	5.2	36.3	62.4	17.9	313.7	62.26	11.95	278.28
	Average	**50.22**	**9.03**	**28.21**	**49.76**	**6.44**	**35.66**	**44.15**	**18.45**	**185.47**	**38.42**	**13.32**	**134.72**







In Tomato average plant height, number of branches and average number of leaves were 50.22cms , 9.03 and 28.21 respectively in SWAR system, similarly 49.76, 6.44 and 35.66 in Drip system. Number of branches under SWAR system is 28.68% higher than the drip system. The increased number of branches has contributed to biomass production. However the number of leaves produced under reduces with the age of the crop which could be contributed to leaf senescence.

In chillies average plant height, number of branches and average number of leaves were 44.15cms, 18.45 and 185.47 respectively under SWAR as compared to 38.42cms, 13.32 and 134.72 under drip. The average plant height recorded under SWAR is 12.97% higher than drip. The number branches produced and average number of leaves produced under SWAR is 27.80% and 27.36% higher compared to drip.

Root production

Under SWAR system, water is supplied directly at the root zone. Hence, it is implicit to record the root length and number of roots produced. The following table shows the average number of roots produced and the average root length in tomato

Table: 2: No of roots and Root length in Tomato

Plant No	SWAR		DRIP	
	Root length (cm)	No. of roots	Root length (cm)	No. of roots
1	15	11	22	4
2	32	8	27	3
3	25	19	20	7
4	23	8	33	6
5	15	10	15	3
Average	22	11.2	23.4	4.6

The average root length recorded under SWAR is 22 cms which is 23.4 cms under drip. However, SWAR system has triggered the tomato crop to produce about 58.92% more roots and compared to drip system. Improved root system development recorded under SWAR could contribute to increased yields.

In chillies root length under SWAR system is only 1% more than the drip system. However, number of roots under drip is slightly higher compared to SWAR. This differential performance of crops under SWAR and Drip system are to be studied in detail.

Table: 3: No of roots and Root length in Chillies

Plant No	SWAR		DRIP	
	Root length (cm)	No. of roots	Root length (cm)	No. of roots
1	27	16	26	27
2	26	27	24	28
3	25	50	24.5	25
4	27	14	21	27
5	30	20	26	30
Average	**27**	**25.4**	**24.3**	**27.4**

Biomass production

After the harvest the total dry weight of the plant is recorded for tomato and chillies. The following table depicts the dry weight of each drop under SWAR and drip system.

Table: 4 Biomass productions under SWAR and Drip system

Tomato

Plant no	SWAR	Drip
	Dry matter of plant (gms)	Dry matter of plant (gms)
1	329	70
2	235	270
3	345	220
4	253	223
5	50	110
Average	**242.4**	**178.6**

Chillies

Plant no	SWAR	Drip
	Dry matter of plant (gms)	Dry matter of plant (gms)
1	130	134
2	160	45
3	140	73
4	163	65
5	103	76
Average	**139.2**	**78.6**

SWAR has recorded high biomass production in tomato and chillies. In tomato SWAR has recorded 26.32% more biomass production compared to drip. Biomass production in chillies under SWAR is very high and recorded 43.53% more as compared to drip system. This increased biomass production under SWAR could help in increased yield. Further, this increased biomass production could be more beneficial in forage crops production.

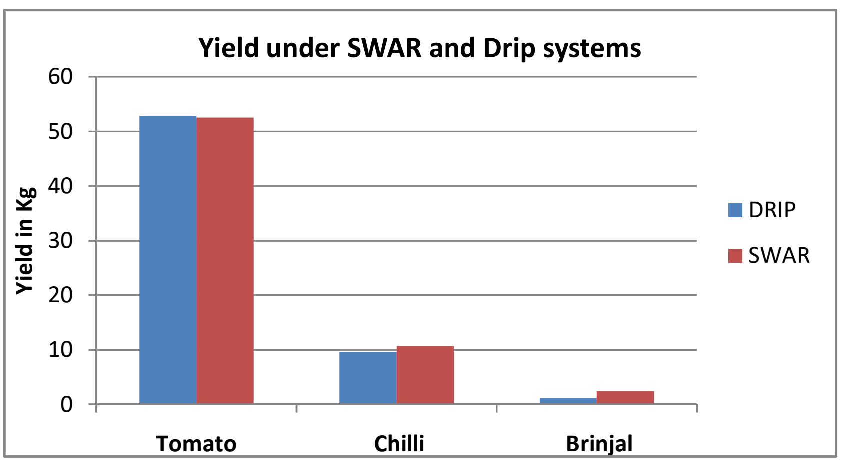
Yield

Yields were recorded periodically and compared between SWAR and drip and the data is given in the table below.

Table: 5: Yield of tomato and chillies under SWAR and Drip systems

Date	Tomato (kg)		Chilli (kg)	
	SWAR	DRIP	SWAR	DRIP
04-01-2019	1.8	0	3	1.8
07-01-2019	1.9	1.8	0	0
12-01-2019	3.6	2.16	2.7	1.9
18-01-2019	5.5	3.5	0	0
19-01-2019	0	0	0.8	0
22-01-2019	5	6.5	0	0
25-01-2019	5.5	5.25	0	0
26-01-2019	0	0	2	3
27-01-2019	2.5	4	0	0
08-02-2019	5	7	0	0
12-02-2019	4.8	6	1.1	1.1
16-02-2019	2.9	2	0	
19-02-2019	5	7	0	0
22-02-2019	5	3.5	0	0
06-03-2019	2	1.9	1.1	1.8
11-03-2019	2	2.25	0	0
Total	**52.5**	**52.86**	**10.7**	**9.6**

Table 6: Yield under SWAR and Drip system



It is observed that the yield data of Tomato in SWAR system is about 52.5 kg and in Drip system it is about 52.86 kg. In chillies, SWAR recorded yield of 10.7 kg whereas Drip system recorded was 9.6 kg. Thus, the yields under SWAR are almost comparable to drip system. However, SWAR has recorded the similar yield levels of drip with 40% less water application. This attribute of SWAR in recording similar yields to drip makes it more suitable for dry land farmers to grow more crops per drop.

Net savings realised -SWAR Vs Drip

The cost incurred and net savings realised during the study, under SWAR and Drip irrigation system is compared and presented in the table given below

Table: 7: Cost and savings details of SWAR and Drip irrigation system

SI No.	Parameter	1st season		2nd season		3rd season	
		SWAR	Drip	SWAR	Drip	SWAR	Drip
	Initial cost of investment						
1	Cost of bed preparation	1200	1200	1200	1200	1200	1200
2	Cement rings to get gravity flow	1370	1370				
3	Pipe line connection	6566	7016				
4	Cost of earth work for pipeline connection and cement ring filling with soil	1800	1800	1800	1800	1800	1800
5	Cost of SWAR system	3600	-		-		-
	Operational cost						
5	Cost of weeding	800	800	800	800	800	800
6	Labor cost for Fertilizer application	750	750	750	750	750	750
7	Labor cost for pesticide application	1000	1000	1000	1000	1000	1000
8	Cost of harvesting	1200	1200	1200	1200	1200	1200
	Total cost of each system (Rs)	**18286**	**15136**	**6750**	**6750**	**6750**	**6750**
	Money saving in terms of water (Rs)	**1287**		**1287**		**1287**	
	Net cost of operation over three seasons (Total Cost-Savings) (Rs)	**16999**	**15136**	**5463**	**6750**	**5463**	**6750**

Under SWAR, the net water saving was 12872 litres. Assuming the cost of buying 5000 litres of water and using a tanker the cost per litre of water works out to Rs 0.10. Hence net savings under SWAR is Rs 1287 per crop season.

Recommendations

Study results show that the SWAR system excels the drip irrigation systems by demonstrating increased plant height, number of branches and biomass production. The yield levels are nearly similar in both systems. However, recording same levels of yields as recorded under drip, with 40% less water application makes SWAR is highly effective in producing more crop per drop of water irrigated. Also, the savings to be realised under SWAR makes it more attractive to dry land farmers. Though, the results of this trial study are encouraging, it is recommended to conduct a detailed research study in the ensuing seasons to scientifically establish the effectiveness of SWAR.

Dr. Sailaja, Senior Scientist and Head,
Krishi Vigyan Kendra, BCT, Vizag, Andhra Pradesh