

Drip irrigation of maize

A good agricultural practice for enhanced yield,
water saving and higher profits

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Adoption of drip irrigation is still limited to horticultural crops such as fruits and vegetables, and some field crops like sugarcane and cotton in India. The acreage under irrigated maize is increasing at a very faster rate to meet the increasing demand in India, as the Country would require 45 million tonnes of maize by 2050. In recent years, drip irrigation with fertigation is widely applied to maize production by farmers in countries like the USA, Australia, Turkey, Europe, Brazil, Israel, China, Iran, Egypt and Argentina owing to varied benefits. At Hyderabad, drip lines spaced at 1.2 m apart with 40 cm emitter spacing with 2 L/hour emitter discharge gave higher productivity in maize grown at 60 cm row distance on sandy loam soils. Surface drip systems at Water Technology Centre, PJTSAU, Hyderabad without any replacement and degradation for >7 years found to be cost-competitive with higher maize grain yields of 7.4 to 10.0 t/ha. The application efficiency of a drip system can approach 95% through ET-based scientific irrigation scheduling. The drip-irrigated maize in farmer's fields registered a 30.6-33.5% reduction in water use, owing to water saving, an additional 0.44-0.50 ha area of maize can be brought under irrigation. Drip irrigation caused a marked reduction in production costs, which varied between 15.1 to 18% without consideration of the cost for the drip system because of water saving and various operations for water application. The drip-irrigated maize had yield gains of 27-84.6% over furrow irrigated crops while the profit accrued was about ₹48,667 to ₹1,05,903/ha higher than furrow irrigated crop. The net profit without subsidy varies from ₹1,05,848 to ₹1,44,047/ha. Whereas, with a 25% subsidy on the drip system, the net profit varies from ₹1,11,911 to 1,50,110/ha and at 90% subsidy it varies from ₹1,27,677 to ₹1,65,876/ha. The subsurface drip (SSD) has more life than the surface drip method and is suitable for growing maize. The SSD placed at 15 cm depth at 1.2 m interval with emitter spacing of 40 cm found effective for enhancing yield at Karnal, Haryana. Therefore, surface/subsurface drip irrigation/fertigation to be adopted/out scaled for maize in India towards higher productivity, profitability and realization of per drop more crop.

Keywords: Crop evapotranspiration, Drip irrigation, Good agricultural practice, Maize

Introduction

Water of appropriate quality and quantity is essential for agriculture viz., crops, fisheries and livestock. Water is also important for the energy, industry and other economic sectors. Irrigated agriculture in India uses almost 91% of annual freshwater withdrawals of 761 billion m³, which

is well above the global average of 70%. The per capita water availability in India decreased by 72.3% between 1950 (5047 m³) and 2015 (1611 m³) and is likely to decline by 77.8% by 2050 (1292 m³). Projected future developments, such as population growth, changing food preferences towards high-value

products having high water-foot prints, increasing climatic and hydrologic variability, and inefficient use are likely to further aggravate water resource scarcity. As per United Nations projections, nearly 3.4 billion people would be living in 'water-scarce' Countries by the year 2025 and maize growing States of India

would be at the centre of it. In response to these conditions, policymakers, researchers, NGOs and farmers are increasingly pursuing various innovative technical, institutional and policy interventions to enable the efficient, equitable and sustainable use of scarce water resources in agriculture to ensure food security and realize sustainable development goals. Drip irrigation technology is believed to be one of such innovative intervention approaches.

Why drip irrigation in maize?

Maize is the third most important crop in India after rice and wheat. Approximately 15 million farmers are engaged in maize cultivation in the country spread over 9.5 million ha of area with a production of 29 million tonnes, of which 89% is consumed domestically. According to Federation of Indian Chambers of Commerce and Industry, by 2022 India would need 45 million tonnes – 30 million tonnes for feed and another 15 million tonnes for food. However, it is very pertinent to observe that the national average productivity of maize is one of the poorest in the world at 3.05 tonnes/ha as against the global average of 5.86 tonnes/ha. The low average yields could be attributed to maize being predominantly a rainfed crop in India occupying 73% of the area. In rainfed maize growing areas of Karnataka, Telangana, Maharashtra and Madhya Pradesh the total in-season precipitation usually meets the water needs of maize in most years but poor rainfall distribution in relation to crop water demand often leads to water stress at critical stages of tasselling, silking, pollination, kernel setting and grain filling, etc., resulting in reduced grain yields. The rainfed maize crop yields are, on an average, only 40-50% of the attainable potential yields in many maize growing states. On the other hand, the post rainy season irrigated crop is predominantly raised under surface furrow irrigation, which is not only inefficient but the crop is also subjected to numerous wetting and drying irrigation cycles causing a mild to moderate stress limiting



Fig. 1. Surface drip irrigated corn in beneficiary fields of Telangana State Microirrigation Project

attainable potential yields.

In another scenario, summer or spring maize is gaining much popularity in many states, like Punjab and Haryana, which are at the peak of ground water deficit threat. Summer maize in general requires 100-400% more irrigation to keep the vapour pressure deficit (VPD) low. Hence, through summer maize though realized grain yield is 9-10 t/ha, water consumption is alarming high as well. Similarly, speciality corns *viz.*, baby corn and sweet corn provide high remuneration, and water consumption is substantially high.

Precise application of water along with constant wetting techniques maintaining higher soil water potential would be achievable under

surface and subsurface drip irrigation with grain yields ranging between 9 to 12 tonnes/ha (Fig. 1). Moreover, fertigation can improve yield potential of maize by applying split doses of fertilizers precisely at the right time in the right place. Also, physiology of the maize crop is significantly influenced by optimal soil water-air relations under drip irrigation with enhanced growth, water, nutrient and resource use efficiency.

As a result, in recent years both surface and subsurface drip irrigation combined with fertigation has been widely applied to maize production by farmers in countries as diverse as China, USA, Australia, Turkey, Europe, Brazil, Israel, Iran, Egypt and Argentina owing to varied

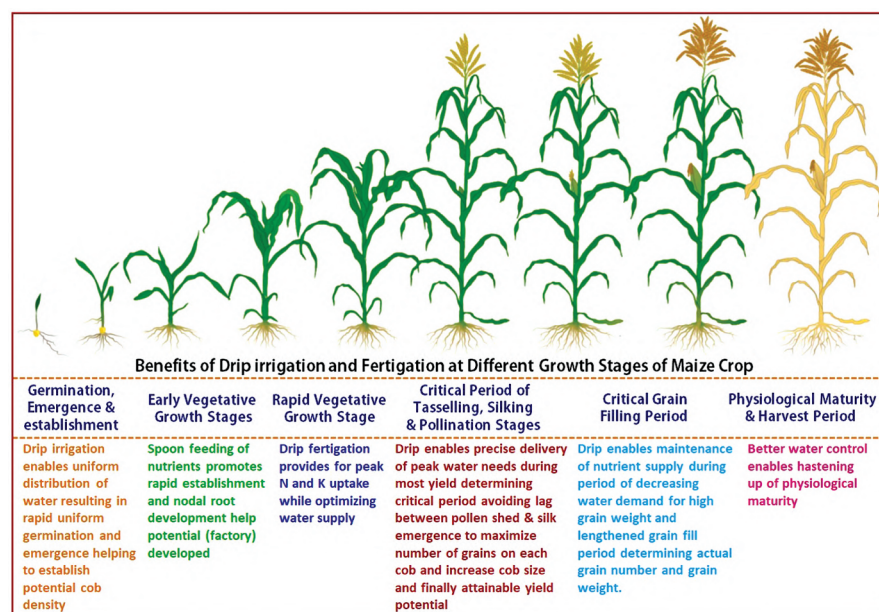


Fig. 2. Benefits of drip irrigation and fertigation in maize production

benefits (Fig. 2) and the technology proved to be technically feasible and economically viable. However, the adoption of drip irrigation is still limited to horticultural crops such as fruits and vegetables and some commercial field crops like sugarcane and cotton in India with a total coverage of only 4.5 million ha, although the potential exists for 27 million ha of drip and 42 million ha of sprinkler irrigation. Additionally, adoption of drip, over 90%, is confined to states of Maharashtra, Gujarat, Andhra Pradesh, Karnataka, Telangana, Tamilnadu, Rajasthan, Haryana, and Madhya Pradesh, which are either facing frequent water scarcity or have the benefit of higher subsidies (25 to 100% depending upon the social category) provided by the respective State Governments or both of the above.

Drip irrigation – Merits

Today, drip technology figures prominently in proposed solutions to save water in irrigated agriculture and avert the water scarcity crisis, as a strategy to increase income and reduce poverty among the rural poor, and to enhance the food and nutritional security of rural households. Higher incomes and poverty reduction are attained through substantial increases in crop yields besides substantial savings in water, energy, fertilizer and labour. Sandra Postal author of "Pillar of Sand: Can the irrigation Miracle Last?" and of "Last Oasis: Facing Water Scarcity", for instance claims that in Countries as diverse as India, Israel, Jordan, Spain, and the United States, studies have consistently shown drip irrigation to reduce water use by 30-70% and raise – crop yields by 20-90% – often leading to a doubling of water productivity, when compared to surface gravity irrigation. It also results in better quality of produce, early crop maturity, realization of higher unit output prices, and reduced production costs - particularly for operations like irrigation scheduling, fertilization and weed control. Additionally, efficient water use leads to extra benefits such as increasing area under irrigation as well as more

usage of marginal and degraded lands. This "Soft Water Path" approach of rational application of modern technology and economics, by decision-making at the right scale, seeks to improve the overall productivity of water use and deliver water services matched to the needs of end users, rather than seeking sources of new supply through traditional hard-path approach of capital-intensive projects that fail to deliver their promised benefits. As a result flagship schemes such as Telangana State Microirrigation Project (TSMIP) in Telangana, Andhra Pradesh microirrigation Project (APMIP) in Andhra Pradesh, Gujarat Green Revolution Company (GGRC) in Gujarat and Ramthali Drip Irrigation Project (RDIP) in Karnataka have been launched with the aim of extending irrigation cover in tune with "Har Khet ko Pani", enhancing crop yields, water productivity and farmer's income producing "Per Drop More Crop and Revenue" in a focussed manner in the area of field water management.

Drip design module for maize

Maize crop drip systems always employ dripline of 12 mm and 16 mm diameter with molded integral drippers. Depending upon local topographical conditions this dripline can be either pressure compensating thick-walled driplines or non-pressure compensating medium and thin-walled driplines (Fig. 3). Additionally, factors such as length of run, zone size, water quality etc.,

have to be considered while choosing the appropriate dripline for maize.

One of the inherent advantages of a drip irrigation system is the ability to irrigate only a fraction of the crop root zone. Careful attention to proper dripline spacing is, therefore, a key factor in conserving water and protecting water quality (Fig. 3). Typically, for maize grown at 60 cm row distance on sandy loam soils under Hyderabad conditions, driplines spaced at 1.2 m apart with 40 cm emitter spacing and 2 L/hour emitter discharge, placed on raised beds in the middle of alternate rows, with one dripline feeding two crop rows resulted in uniform water application and produced the largest grain yield, greatest water productivity, smallest year to year grain yield variation and was most economical. Current cost competitive dripline spacings employed in different countries include 1.4 m in Turkey, 1.5 m in the USA, Australia, Argentina and Mexico; and 1.92 m in Israel. However, different soil types, such as light textured sands and close growing rotational crops might require closer dripline spacing. The subsurface drip lines can also be placed at 15 cm depth at 1.2 m interval with emitter spacing of 40 cm. The SSD has more life than the surface drip method and is suitable for growing maize.

Crop water requirements

Estimation of crop water requirement is an important factor in irrigation management for efficient

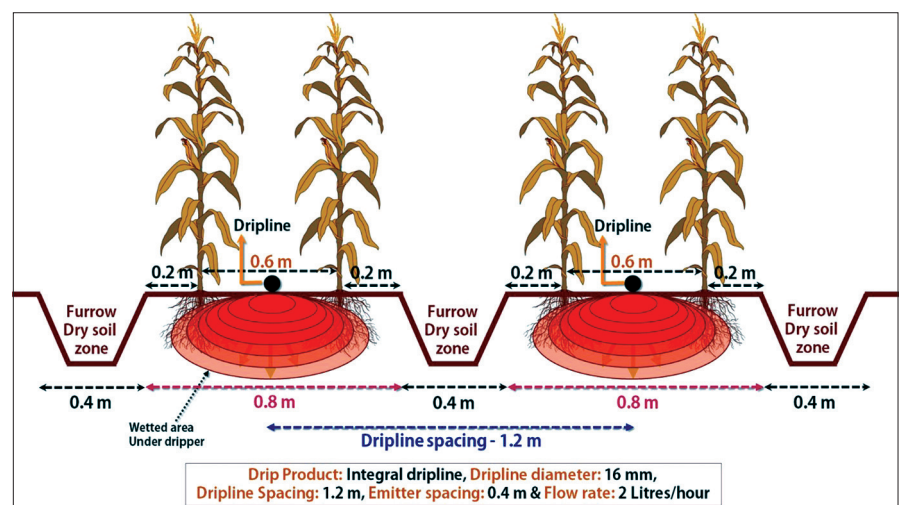


Fig. 3. Physical arrangement of the surface dripline in relation to the corn grown in paired row at 60 cm on raised beds

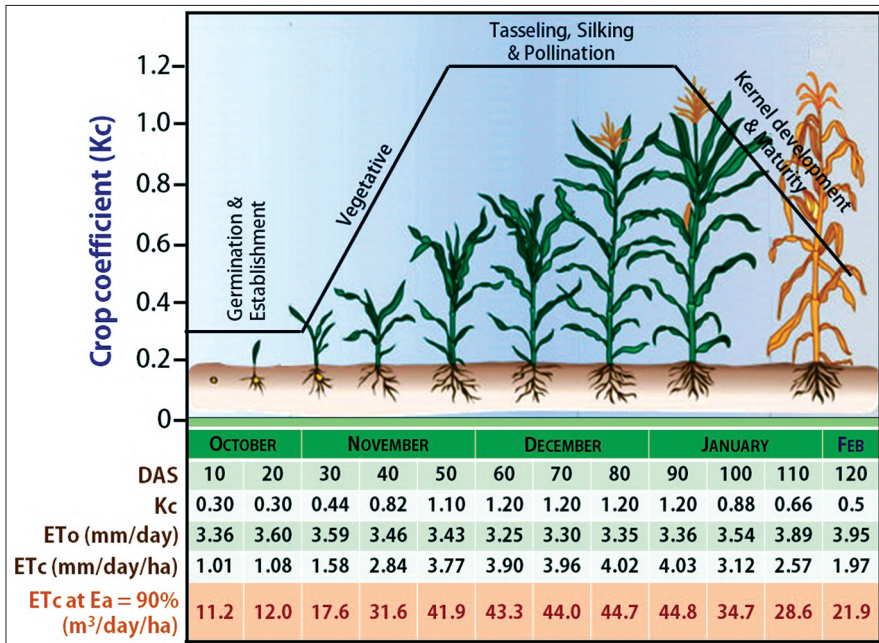


Fig. 4. Field irrigation scheduling programme for drip irrigated maize

water use. The crop water requirement for maize refers to the amount of water required to compensate the evapotranspiration loss from the cropped field. Whereas, the crop evapotranspiration (ET_c) refers to the combined loss of water by soil evaporation and crop transpiration from disease-free, well-fertilized crops, grown in large fields, excellently managed under optimum soil water conditions, and achieving full production under the given climatic conditions. Estimate daily ET_c of maize (Fig. 4) as a product of daily reference crop evapotranspiration (ETo) calculated using local weather data and experimentally derived crop coefficient (Kc) which varies according to the crop growth stage (ET_c = ETo x Kc).

These values (Fig. 4) as an example determined for drip irrigated maize grown under Hyderabad agro-climatic conditions represent net water requirement and need to be adjusted in case of incident rainfall during the crop growing season. Irrigation would be required, when maize ET_c exceeds the supply of water from rainfall during a given day or crop growth sub-period. The irrigation water requirement represents the difference between the ET_c and effective rainfall. Furthermore, in estimating crop water requirements, efficiency of the

irrigation system should also be considered. As ET_c varies with crop growth stage and weather conditions, both the amount and timing of irrigation are important to achieve better results.

Maize water use – Drip versus furrow irrigation

Irrigation scheduling and water application pattern under drip method is totally different from furrow method of irrigation. Unlike furrow irrigation, water is frequently and precisely delivered through a pipe network in the crop root zone tailored to meet crop needs at various growth stages enabling a high degree of water application control avoiding

any over irrigation and wastage in the form of conveyance, run off and deep percolation losses. Past seven years of research at Water Technology Centre, PJ Telangana State Agricultural University, Hyderabad indicated that irrigation water use of maize can be reduced by 19.5 to 21.8% when using surface drip irrigation compared with conventional form of surface furrow irrigation that typically operates at 50-60% field application efficiency. The application efficiency of a surface drip system can approach 95% when carefully managed to limit wastage through ET-based scientific irrigation scheduling. Similarly, drip irrigated maize in farmer's fields registered 30.6 to 33.5% reduction in water use (Fig. 5).

Additionally, water savings indicate that with the same amount of water used for irrigating one ha of maize under furrow method of irrigation, about 1.44-1.5 ha of maize can be irrigated using drip system. In other words, an additional area of 0.44-0.5 ha of maize can be brought under drip method irrigation from the saving of water realised through drip. A dripline spacing of 1.2 m, emitter spacing of 40 cm and emitter discharge of 2 L/hour has been found to be technical feasible for field application. Nitrogen fertigation was a very effective management tool with drip irrigation, helping to maximize maize grain yield, while obtaining high efficiencies of nitrogen and water use.

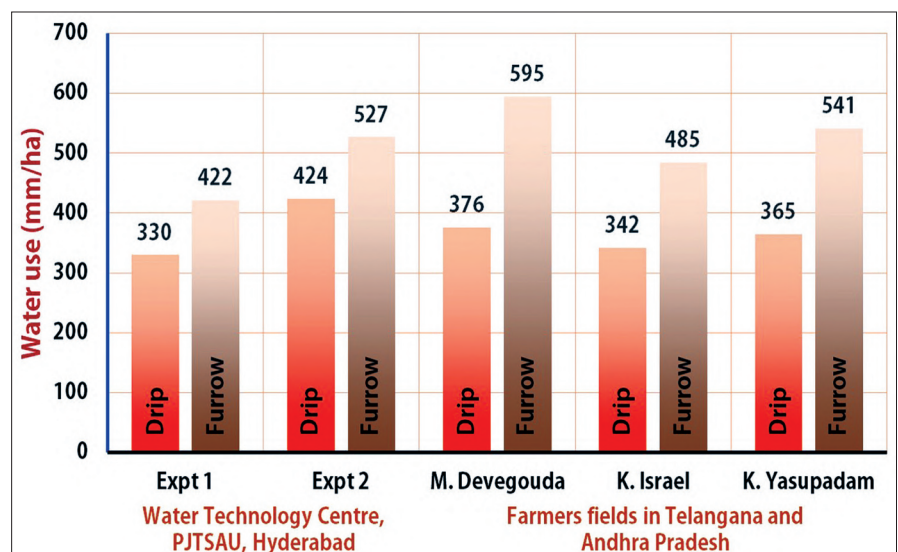


Fig. 5. Maize water use – Surface drip versus conventional furrow irrigation



Fig. 6. Sub-surface drip irrigated maize at CSSRI-CIMMYT platform, Karnal

Surface drip systems were being utilized at Water Technology Centre, PJTSAU, Hyderabad for more than seven years without any replacement and degradation and found to be cost competitive with higher maize grain yields ranging from 7.4 to 10.0 tonnes/ha. Similarly, a 10-year research using subsurface drip irrigation in maize at Kansas State University, Colby, in the U.S.A., indicated that 35 to 55% irrigation water can be saved using subsurface drip irrigation (Fig. 6) over surface furrow irrigation while still

maintaining top yields in the range of 11.9-12.5 tonnes/ha.

Grain yield and Economic analysis – Drip versus furrow irrigation

Drip irrigation cause marked reduction in production costs, which varied between 15.1 to 18% (Table 1). Cost reduction is generally realised from labour intensive operations such as weeding and costly inputs *viz.*, irrigation and fertilization. Since water is applied directly in the crop root zone partially wetting the soil, it results in limited

weed growth and thus the cost required for weeding operations reduces markedly. Irrigation costs under drip method of irrigation are substantially less for the following two reasons: First, the labour hours required are less for managing irrigation scheduling (1-2 hours a day) under drip method of irrigation of maize. Second, since water saving (30.6-33.5%) is very high under drip irrigated maize owing to high field application efficiency, it substantially reduces the working hours of pump set which extensively reduces the electricity costs. Third, water soluble fertilizers are applied combined with each irrigation event precisely in the crop root zone according to crop developmental stages termed as fertigation, cuts down the wastage, improves nutrient use efficiency thereby reducing fertilizer doses (25%) and associated labour costs.

The drip irrigated maize yield gains over furrow irrigated crops were in the range of 27-84.6%. The per ha net profit without considering fixed capital investment on drip irrigation system amounted to ₹ 1,31,528 to 1,69,727/ha among different farmers using drip irrigation, whereas it varied only

Table 1. Economic analysis of maize performance under surface drip irrigation versus furrow irrigation

Symbol	Particulars	Farmer: Karra Israel Location: Kottapalli		Farmer: K. Yasupadam Location: Kottapalli		Farmer: Devegouda Location: Nizamabad	
		Drip	Flood	Drip	Flood	Drip	Flood
A	Production cost (₹/ha)	45,785	53,972	46,232	54,781	41,473	50,576
B	Water use (m ³ /ha)	3,244	4,811	3,375	4,867	3,420	5,141
C	Water saving by drip (%)	32.6	48.3	30.6	44.2	33.5	
D	Grain yield (Tonnes/ha)	10.8	8.5	10.1	7.6	12.0	6.5
E	Selling price, MSP (₹/Tonne)	17,600	17,600	17,600	17,600	17,600	17,600
F	Gross returns (₹/ha) (D x E)	1,90,080	1,49,600	1,77,760	1,33,760	2,11,200	1,14,400
G	Net income (₹/ha) (F - A)	1,44,295	95,628	1,31,528	78,979	1,69,727	63,824
H	Water footprint (Litres/kg grain)	300	566	334	640	285	791
I	Fixed cost (₹/ha) of drip	1,15,500		1,15,500		1,15,500	
	a) Life (years)	10		10		10	
	b) Depreciation (₹/ha)	11,550		11,550		11,550	
	c) Interest @11% (₹/ha)	12,705		12,705		12,705	
	d) Repairs & Maintenance (₹/ha)	1,425		1,425		1,425	
	e) Total Cost (b + c + d) (₹/ha)	25,680		25,680		25,680	
J	Total cost (Rs./ha) (A + Ie)	71,465	53,972	71,912	54,781	67,153	50,576
K	Profit without subsidy (₹/ha) (F - J)	118,615	95,628	105,848	78,979	144,047	63,824
L	Profit with subsidy at 25% (₹/ha)	124,678	95,628	111,911	78,979	150,110	63,824
M	Profit with subsidy at 90% (₹/ha)	140,444	95,628	127,677	78,979	165,876	63,824
N	Benefit cost ratio for without subsidy, at 25% and 50% subsidy and furrow	1.66 [#] , 1.74* & 1.96 ⁺	1.77	1.47, 1.55 & 1.77	1.44	2.14, 2.23 & 2.47	1.26
O	Payback period (years)	<1.0	—	<1.0	—	<1.0	—

[#]Without subsidy, *at 25% and ⁺50% subsidy

from ₹ 63,824 to 95,628/ha for furrow irrigated maize. This suggests that the profit accrued with drip irrigated maize is about ₹ 48,667 to 1,05,903/ha higher than furrow irrigated crop. This higher profit under drip irrigated maize over furrow irrigation could be purely attributed to enhanced yield and not to selling price effect since maize yield from both methods of irrigation fetched identical prices. However, the capital cost of the drip system, interest on the fixed capital and the longevity of drip system under field conditions are important variables that determine the real profit. Moreover, since drip is a capital-intensive technology, the higher initial investment needed for installing drip system remains the main obstacle for the widespread adoption of drip irrigation in maize by small and marginal farmers. To what extent this discouragement effect is real and to what extent such effect can be counter balanced by government subsidy are important policy issues requiring answers. Hence, in order to find out the economic viability of investment on drip system in maize, the net profit was calculated considering depreciated cost over ten years of expected life of drip system, interest on fixed capital and maintenance costs. The fixed capital cost of drip system for maize raised at 0.60 m row spacing and a dripline spacing of 1.2 m, emitter spacing of 40 cm and

a flow rate of 2.0 litres/hour works out to ₹ 1,15,500/ha for the sample farmers without subsidy. Subsidy prevalent in maize growing states of India varies from 25 to 90%. After deducting the subsidy, the capital investment on drip system for maize comes down to about ₹ 11,550 to ₹ 86,625/ha. For instance, the net profit without subsidy varies from ₹ 1,05,848 to ₹ 1,44,047/ha. Whereas, with 25% subsidy on drip system, the net profit varies from ₹ 1,11,911 to 1,50,110/ha and at 90% subsidy it varies from ₹ 1,27,677 to ₹ 1,65,876/ha. The benefit cost ratio under different scenarios for drip irrigated maize varied from 1.66 to 2.47 when compared to 1.26 to 1.77 for furrow irrigation. Further, it can also be noticed that the payback period is less than one year, which means all the farmers can recover their investment on drip system within one year even without subsidy.

SUMMARY

Maize is the third most important crop in India after rice and wheat. Demand for maize feed and food is projected to increase and India would need 45 million tonnes by 2022. But the average productivity is very low 3.05 tonnes/ha. The use of drip irrigation in irrigated maize cultivation is a contemporary yield enhancing and water-saving strategy. While, the productivity gains per ha due to drip irrigation of maize varied

from 27 to 84.6%, water saved by drip varied from 30.6 to 33.5% among different farmers when compared to furrow method of irrigation. Besides these advantages, the farmers could reduce the production costs per ha to the tune of 15.1 to 18%. Discounted cash flow analysis employed suggests that drip investment in maize is economically viable even without subsidy. These incentives are the key to scaling adoption of yield enhancing and resource conserving drip irrigation technology in irrigated maize to meet future food demand. The present policies like PMKSY (Pradhan Mantri Krsihi Sinchayee Yojana) at country level and some state level policies like TSMIP, APMIP, GGRC and RDIP implemented in maize growing states with the aim of extending irrigation cover in tune with “*Har Khet ko Pani*” and enhancing farmer’s income i.e., “*Per Drop More Revenue*” may encourage farmers in large scale adoption of drip irrigation in maize with continued support of research and extension agencies.

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