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33. Drip Irrigation for Water Conservation and Saline / Sodic Environments in India: A Review

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Abstract: India is facing innumerable challenging problems associated with land and water resources. Declining land resource, depleting water resource and decreasing resource productivity are matters of grave concern. While an estimated 8.5 million ha of agricultural lands have turned barren because of excess salts, the receding availability of the fresh quality water for agriculture aggravating over time. Thus, use of water saving technologies and/or technologies that would allow growing crops on salt-affected soils or with the use of poor quality waters would play an increasingly important role in the twin task of utilizing salty land and water resources for agriculture. The use of drip irrigation seems to be the most viable method of irrigation considering the limitations set forth by poor quality land and water resources. The expansion potential of drip irrigation can be gauged from the fact that only 0.36 million ha is currently under drip irrigation against a potential of 27 million ha. Concerted efforts are being made across the country to examine the suitability and adaptability of drip irrigation for growing a wide range of agricultural and horticultural crops under various agro-climatic conditions. A critical review of several research studies has been made to highlight increase in water use efficiency or water saving for several crops. On the basis of drip irrigation experiments conducted across India, the performance of drip irrigation in salt affected soils and water environments has been highlighted. An attempt to develop pitcher irrigation as an indigenous alternative to drip irrigation to minimize initial investment cost is also included.

Introduction

Per capita land and water resources are decreasing at a very fast rate. These resources are also being degraded mainly due to unmanaged over-exploitation in the wake of resource exploiting green revolution. Per capita land resource has decreased from 0.33 ha in 1951 to 0.13 ha in 2001. Similarly, per capita water availability assessed at more than 5300 m^3 in 1951 had decreased to 1905 m^3 in 1999 and is likely to be less than 1500 m^3 by the year 2025. Therefore, to conserve water resource and to utilize salt affected land resource in a most productive manner, improved irrigation techniques including drip irrigation would play a very prominent role.

Research experiments on drip irrigation in India were initiated in the early seventies in many state agricultural universities and research organizations. The researchers picked up momentum after the establishment of the Plasticultural Development Centres and the AICRP on the Use of Plastics in Agriculture. The spread was quite fast during the last decade, when its coverage touched 0.3 million ha (Table 1, Praveen Rao, 2002). The highest coverage is in the state of Maharashtra followed by Karnataka, Tamil Nadu, Andhra Pradesh and Rajasthan (Kumar and Singh, 2002). According to Sivanappan (1999) about 28.5 m ha could be covered under drip irrigation, which is likely to be achieved by the year 2020/25. However, at a annual compound growth rate of adoption of drip irrigation assessed at present at 12 per cent, it would take about 8 years to bring additional one million hectare area under drip irrigation.

Table 1: Growth of area (in thousand ha) under drip irrigation, India

Year	1970	1985	1989	1994	1999	2002
Area (,000) ha	Nil	1.5	12.0	70.9	300.0	355.4

Source: Kumar and Singh (2002).

Yield Benefits and Water Saving

The drip irrigation system is very popular in areas of acute water scarcity and places where commercial cultivation is in vogue of cash or horticultural crops. Numerous studies have been conducted in different parts of the country on various crops to quantify the benefits of the use of drip irrigation in terms of increased production and productivity as well as saving of water (Padmakumari and Sivanappan, 1989; Raman, 1999; Sivanappan, 1999; and Singh et al., 2002 etc.). In order to get a realistic figure out of many multi-location trials, the data were compiled by taking arithmetic average of all the reported values for a given crop (Table 2). Among the top ten crops that gave relatively higher increase in yield under drip irrigation are gherkins, *mosambi*, carrot, beans, mango, turmeric, popcorn, baby corn, papaya and capsicum (Table 2). On the other hand, chilli, coconut, radish, ridge gourd, tomato, guava, cabbage, banana, potato and beet root gave higher water use efficiency. High water saving was observed among beet root, bitter gourd, sweet potato, papaya, radish, sweet lime, *mosambi*, pomegranate, turmeric and cotton crops.

Table 2: Average crop yield, percentage increase in yield, water use efficiency and water saving in drip over the conventional irrigation system for various crops

S. No.	Crop	No. of references	Yield (t ha^{-1})	Yield Increase (%)	WUE (t $ha^{-1}cm^{-1}$)	Water saving (%)
1	Acid lime	1	78.00	56.00	1.30	50.00
2	Baby corn	1	9.88	72.40	0.48	43.80
3	Banana	7	71.52	29.27	2.95	42.50
4	Bean	1	10.25	81.80	0.37	36.90
5	Beet root	1	48.87	7.00	2.76	79.00
6	Ber	3	71.03	27.67	0.66	34.33
7	Bitter gourd	4	2.68	44.38	1.43	69.50
8	Bottle gourd	1	55.80	46.80	1.03	35.70
9	Brinjal	7	16.01	44.63	1.47	42.55
10	Cabbage	5	50.49	37.48	3.17	37.35
11	Capsicum	1	22.50	66.60	0.78	43.10
12	Carrot	1	26.26	92.30	0.81	33.60
13	Castor	2	7.27	30.24	1.73	32.99
14	Cauliflower	3	19.50	39.73	0.68	37.10
15	Chickpea	1	3.80	66.60	1.60	42.60
16	Chilli	5	67.98	28.74	7.47	47.28
17	Coconut, No /plant	2	181.00	7.10	6.89	50.50
18	Cotton	3	36.00	40.00	0.86	51.10
19	Cucumber	1	22.50	45.10	0.94	37.80
20	Gherkins	1	4.88	100.60	2.30	36.10

Contd…

Table 2: Contd.

S. No.	Crop	No. of references	Yield (t ha^{-1})	Yield Increase (%)	WUE (t $ha^{-1}cm^{-1}$)	Water saving (%)
21	Grain corn	1	6.50	52.90	2.20	45.00
22	Grape	5	29.93	20.94	0.95	43.00
23	Groundnut	2	3.50	62.50	1.00	32.40
24	Guava	2	25.50	63.00	3.53	9.00
25	Mango	3	19.50	80.67	2.40	28.93
26	*Mosambi*, 1000 pcs	1	15.00	98.00	0.23	61.00
27	Oil Palm	1	-	-	-	21.00
28	Okra	12	20.05	20.69	1.94	44.72
29	Onion	3	17.01	42.60	1.20	36.70
30	Papaya	5	56.64	71.97	0.91	67.97
31	Pomegranate, 100 pcs	3	44.67	55.67	0.53	57.33
32	Popcorn	1	5.50	75.40	2.10	42.00
33	Potato	5	28.66	50.02	2.80	24.62
34	Radish	2	17.00	27.50	5.04	64.00
35	Ridge gourd	3	17.39	14.50	4.36	43.39
36	Round gourd	1	36.60	24.00	0.46	0.00
37	Sapota	1	-	17.20	-	21.40
38	Sweet potato	1	50.00	39.00	1.98	68.00
39	Sugarcane	6	145.87	43.59	1.19	46.67
40	Sweet lime	1	15.00	50.00	2.30	61.40
41	Tapioca	2	54.60	12.60	0.55	23.40
42	Tomato	11	36.57	46.00	3.82	37.35
43	Turmeric	2	18.44	76.30	0.56	53.10
44	Watermelon	3	46.80	64.83	2.13	46.10

WUE = Water Use Efficiency

Drip irrigation in Saline / Sodic Environment

Similar to experiments on water conservation with drip irrigation, studies on the use of this technique in manging saline environment have also been reported although not as extensive as in the first case. It is now known that crops can tolerate saline environment better under drip than any surface irrigation method because of low matric stress that is a characteristic of the drip irrigation.

Agrawal and Khanna (1983) compared the relative performance of drip and surface irrigation methods and reported significant differences in yield and water use efficiency when saline and fresh canal water were used (Table 3). Apparently, reduction in the yield in case of saline water (12 %) with drip is much less as compared to surface irrigation method (40 %). Kumar and Sivanappan (1983) concluded that drip irrigation gave higher crop yield than any other irrigation method when irrigating with 5 levels of saline water (EC of 0.85, 2.5, 5.0, 7.5, and 10.0 dS m^{-1}) and prescribed that saline water having an EC of 7.5 dS m^{-1} is safe for growing several crops with drip irrigation.

Subba Rao et al. (1987) observed up to 50 per cent decrease in yield of tomato when EC of irrigation water exceeded 6 dS m^{-1}. Singh and Kumar (1988) studied the comparative performance of trickle and subsurface irrigation systems on tomato for different EC and IW/PET

Table 3: Water use efficiency as affected by irrigation methods using saline and good quality waters

Method of Irrigation	Good quality water (EC= 0.25 dS m^{-1})		Saline water (EC= 6.5 dS m^{-1})	
	Yield (t ha^{-1})	WUE (t $ha^{-1}cm^{-1}$)	Yield (t ha^{-1})	WUE (t $ha^{-1}cm^{-1}$)
Sub surface drip	26.8	3.0	23.6	2.6
Surface drip	17.5	1.9	15.7	1.8
Surface irrigation at 35 mm CPE	16.4	1.4	9.9	0.9
Surface irrigation at 60 mm CPE	13.9	1.2	6.7	0.6

Table 4: Yield, irrigation depth, water use efficiency and soil EC for tomato under drip

Year	IW/PET	Yield (t ha^{-1})	Irrigation depth (cm)	WUE (t ha^{-1} cm^{-1})	EC (dS m^{-1})
1986	0.7	5.47	40.4	0.14	2.03
	0.5	15.14	29.4	0.52	0.82
	0.3	14.22	21.2	0.61	0.70
1987	0.7	13.06	38.1	0.34	0.83
	0.5	12.23	30.0	0.40	0.32
	0.3	7.83	23.5	0.33	0.55

ratios. Results reported in Table 4 suggest that a low IW/PET ratio for irrigation scheduling could be preferable to get high yields, water saving and minimum salt build-up.

Jain and Pareek (1989) observed that salt accumulation was minimal in drip irrigation when saline waters of EC ranging from 2.7 to 9.0 were used to irrigate date palm trees. Singh et al. (1990) reported similar results when sodic waters containing RSC 2.1, 8.45 and 12.45 me l^{-1} were applied to grow kinnow (*Citrus reticulata*) plantation. Drip irrigation system was also found more effective in the establishment of fruit garden on salt affected soils (Dwivedi et al., 1990).

In a study on the effect of frequency of water application, it was observed that yields were higher by 13 and 33 per cent at irrigation intervals of 3 and 4 days in comparison to 2 days interval provided total water applied was the same. In another study on tomato crop, yield decreased from 38.7 to 29.8 t ha^{-1} as salinity of irrigation water increased from 0.21 to 5 dS m^{-1} which was about 24 per cent less over the normal water application (Kadam and Patel, 2001). A study conducted on sugarcane (Anonymous, 2000) revealed that irrigation scheduling under drip with alkali waters (pH 8.8, EC 2.2 dS m^{-1}, RSC 12.9 me l^{-1} and SAR 18.2) at 60 per cent of pan evaporation (PE) gave higher water use efficiency than 80 and 100 per cent of PE and farmers' practice (surface irrigation), under both the sub-treatments of no gypsum or 50 per cent application of gypsum requirement (Table 5). Gypsum application increased the yield only slightly.

Table 5: Effect of irrigation schedules on growth and yield of sugarcane under drip irrigation

Main treatments of irrigation at percentage of PE	Yield (t ha^{-1})		Water applied		Water use efficiency (t $ha^{-1}cm^{-1}$)	
	50 % of Gypsum requirement	No Gypsum application	Depth (cm)	Reduction in water applied (%)	50 % of Gypsum requirement	No Gypsum application
100	99.3	95.6	44.8	7.14	2.21	2.13
80	107.4	98.5	33.8	42.01	3.18	2.91
60	96.6	91.1	23.0	108.69	4.20	3.96
Farmers' practice	99.5	93.8	48.0	-	2.07	1.95

Drip Irrigation Studies at CSSRI, Karnal

Several studies on drip irrigation have been conducted at CSSRI, Karnal since its inception. Three levels of residual sodium carbonate of 0.6, 4 and 8 me l-1 (at a fixed value of EC of 3 dS m-1) were given through drip irrigation in kinnow orchards at 3 l hr-1 at an irrigation interval of 3 days. Hydraulics of wetting front could be well described by the Wooding solution for steady state infiltration (Anonymous, 1986). An empirical equation was developed to compute moisture extraction at different depths in pomegranate under drip irrigation in reclaimed sodic soils (Anonymous, 1988). Field studies were conducted at three rates of water application for line and point sources of trickle irrigation. The results revealed that to maintain the same moisture mid-way between the emitters, the discharge rate needs to be increased with the spacing. A graphical relationship between emitter spacing and discharge rate of emitters was developed (Anonymous, 1991).

Singh et al. (2000) compared the plant performance and soil salinity before and after three years of application of 0.4, 4.0, 8.0 and 12.0 dS m^{-1} saline water through drip and basin irrigation in sapota crop. Compared to the basin method, plant performance was better and salinity build-up was less in the case of drip irrigation under all the treatments. Subsurface drip gave 1.5 times more yield of okra over surface drip using poor quality domestic sewage water (Pandey, 2003). However, yield increase in the case of cabbage crop was not observed. While comparing the surface and subsurface drip for irrigation with saline water, favourable and unfavourable results have been reported calling for more researches on this issue.

A study is presently underway on the litchi (*Litchi chinensis* Sonn.) crop by the authors in a varying sodic environment (pH value ranging from 7.34 –10.01 for 30 - 90 cm depth). Plant height and annual percent increase in height showed linear decline with increased values of pH (Fig. 1). While more than 50 per cent annual growth in plant height was recorded for pH up to 8.11, the growth reduced to less than 5 per cent in plants where pH was more than 9.0. The variation in water application depth didn't show any beneficial effect during the period of observations.

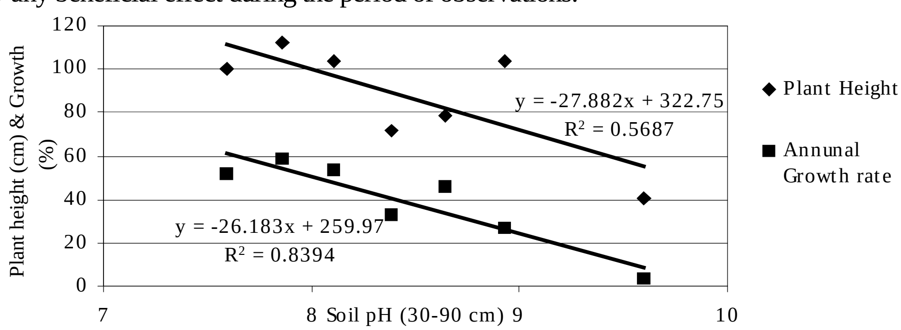

Fig. 1: Height, growth and soil pH (30-90 cm) relationship for litchi under drip irrigation

Indigenous Alternative to Drip

Several indigenous alternatives to drip irrigation like use of earthen pitcher, porous cups, bamboo tricklers and suction irrigation have been tried successfully in India (Gupta and Gupta, 1987). Since the relative role of matric and osmotic stresses in drip favours the use of comparatively more saline water for crop production, similar situations can be created by indigenous alternatives. Due to locally available input materials and simple design, Indian farmers can easily adopt these systems.

Table 6: EC_{iw} under pitcher at which crop yield is same as with fresh water

Crop	EC_{iw} with surface irrigation method	EC_{iw} under pitcher for same yield as with fresh water
Tomato	2.4	5.7
Brinjal	2.3	9.8
Cauliflower	-*	15.0
Ridgegourd	-	3.2
Cabbage	-	9.7
Watermelon	-	9.0
Muskmelon	-	9.0
Grapes	-	4.0

* Data not available, EC_{iw} = salinity of irrigation water (dS m^{-1})

Table 7: Estimated irrigation water use efficiency

Irrigation Method	Water Use Efficiency (t $ha^{-1}cm^{-1}$)
Closed furrow (basin)	0.7
Sprinkler	0.9
Drip	1 – 2.5
Porous capsule (pressure)	1.9 +
Porous capsule (no pressure)	2.5 +
Buried clay pot	2.5 – 7

Pitcher irrigation is one such technique which has been extensively researched and is gaining popularity. Gupta and Dubey (2001) compiled and reported the results of pitcher irrigation experiments being conducted since 1974. Vegetable crops could be grown with relatively high salinity water with pitcher irrigation (Table 6) as compared to surface irrigation methods. Besides the data presented in Table 6, the observation is fully supported by the general observation that vegetable crops are sensitive to salts and the threshold value of EC_{iw} is usually less than 4 dS m^{-1} (Minhas and Gupta, 1992). Gupta and Dubey (2001) also reported that pitcher irrigation could save a major fraction of water when compared with surface irrigation methods. This observation is fully supported by data provided by Bainbridge (2001) on this issue (Table 7**)**. Apparently there is a scope to develop other indigenous alternatives for use of saline / sodic waters for crop production.

Conclusions

Drip irrigation technology ensures increased crop yield, high water use efficiency, reduced water and energy consumption and minimal weed problems. Results confirm that it is safe to recommend its use for most horticultural and vegetable crops particularly those which are widely spaced. Although application of drip irrigation in salty environments has been quite encouraging in experimental fields yet its popularity and adoption under these conditions is not satisfactory. It is recommended that research and development activities be strengthened to develop complete package for various crops under different agro-climatic conditions. Investment needs being high, the technology could be popularized through one window system of financial assistance including subsidy. Development of indigenous alternatives and technology transfer in association with NGOs could also help to utilize the poor quality land and water resources in a more fruitful manner.

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