

## SALINE WATER IRRIGATION THROUGH DRIPS AND SPRINKLERS

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### ABSTRACT

Saline water irrigation by drips and sprinklers has been examined in relation to crop response to saline water, upper limits of water salinity upto which these methods can be used for different soils and climatic conditions, and relative merits and demerits of these methods for different crops. Various aspects, viz, salt distribution under drip, leaf injury and absorption of nutrients by plants on sprinkling saline water and remedial measures have been discussed. Efficacy of drips and sprinklers has been compared with furrow/flood irrigation.

### INTRODUCTION

In regions where good quality water is either insufficient or not available, saline water irrigation is inevitable. Continuous use of saline water deteriorates chemical and physical properties of the irrigated soils and ultimately influences crop growth (Paliwal, 1972 & 1976; Yaron *et al.*, 1973; Black, 1976; Bresler, 1977 and Meir, 1984).

Drip and sprinkler methods of irrigation are of immense value in some specific situations with not only good waters but saline water too. However, nature and amount of dissolved salts in irrigation water, salt tolerance characteristics of crops, soil type and climatic conditions decide the efficacy of these methods, (Pair *et al.*, 1975; Baker *et al.*, 1979; Bresler, 1981 and Shalhevet, 1984).

This review includes; i) crop response to saline water irrigation by drip and sprinkler methods; ii) salinity limit upto which these methods can be used for various types of soil and crop, and iii) relative efficiency of these methods for saline water irrigation.

### CROP RESPONSE TO SALINE WATER

Crops differ significantly in salt and alkali tolerance. Relative salt tolerance of a crop, as judged by its gross yield as well as relative reduction in yield, is significantly influenced by several factors, e.g., soil and water salinity, crop variety and growth stage, climate, irrigation frequency and discharge rate and their interactions (Maas and Hoffman, 1977; Mass, 1985). Permissible limits of water salinity by drip irrigation for vegetable, fruits and held crops and trees have been summarised in Table 1.

Table 1. Permissible limits of salinity in water for vegetable, fruit, field crops and trees by drip irrigation (Paliwal, 1985)

Crops	*Soil Type	Location	Salinity level EC (dsm <sup>-1</sup> )	References
Vegetable Crops :				
Tomato	Sandy	Israel	3.6	Gormat <i>et al.</i> (1973)
"	"	"	5.6	Goldberg <i>et al.</i> (1970)
"	"	"	5.0	Shumeli (1974)
"	SL	Panama	3.71	Bernar (1974)
"	SL	Delhi	5.0	Ramadevi (1980)
"	SL	Hawaii	5.8	Bower <i>et al.</i> (1975)
Cucumber	Sandy	Israel	4.0	Shumeli & Goldberg (1971)
Cucumber & Potato	Sandy	Jodhpur	3.0	Singh & Mann (1979)
Onion & Lettuce				
Onion & Lettuce	CL	New Mexico	1.22	Swamis <i>et al.</i> (1979)
Onion & Lettuce	SL	Montana	2.4	Melsted & Deboeri (1977)
Radish	SL	Hissar	6.5	Dixit <i>et al.</i> (1971)
Fruit Crops :				
Grapevine	SL	Australia	1.75	Smart <i>et al.</i> (1974)
"	Sandy	California	2.0	Chavez & Andrew (1974)
Grope Fruit	Sandy	Israel	2.0	Bielorai <i>et al.</i> (1980)
Strawberry	SL	Egypt	1.75	Tousset (1975)
"	SL	Florida	3.0	Voth & Ernighust (1971)
Peach	Sandy	Australia	3.01	Taylor (1974)
Muskmelon	Sandy	Israel	4.0	Shumeli & Goldberg (1971)
"	Sandy	Israel	3.6	Pasternaik <i>et al.</i> (1978)]
Field Crops :				
Sorghum	SL		2400 (ppm)	Seifert <i>et al.</i> (1975)
"	SL	Texas	2.5	Ravelo <i>et al.</i> (1977)
"	SL	San Diego	4.2	Jury <i>et al.</i> (1978)
Sugarcane	SL	"	2.5	Gibson (1975)
"	SL	Hawaii	6.1	Ekerson (1977)
"	SL	Israel	2.0	Hill (1977)
Swwet corn	Sandy	Israel	4.5	Goldberg & Shumeli (1969)
Bell pepper	SL	Florida	245 (ppm)	Bernstein & Francois (1973)
Chilli pepper	SL	New Mexico	3.5	Horton <i>et al.</i> (1979)
Pepper	SL	Florida	2.5	Stevens & Rawlins (1979)
Trees :				
Eucalyptus	Sandy	Rajasthan	1000 (ppm)	Ram & Singh (1976)
Date palm	SL		1000 (ppm)	Ruoveni (1974)

\*SL=Sandy loam, \*CL=Clay loam.

## DRIP IRRIGATION

Despite wide variations in experimental conditions, location, soil type, crop variety and water salinity, the studies on drip irrigation with saline water lead us to conclude as follows :

1. More saline water can be used on coarser than medium textured soils;
2. Yield decreases with the increase in water salinity and more so when salinity in soil solution exceeds the salt tolerance limit of the crop variety: at low water salinity, drip is at par with floodings;
3. Crop water requirement is nearly the same as in flood irrigation but water economy is mainly at early stages of growth and low coverage of actual irrigated cropped area;
4. Yield reduction is more on applying water less than the crop water requirement (Table 2) or with low discharge rate (Table 3);
5. Drip is more suitable for wide-spaced fruit crops, and
6. The soil moisture tension near the root zone is less under drip due to continuous supply of water by the emitters near the root.

Table 2. Effect of furrow and drip methods of irrigation at different ET levels and water salinity on the yield of potato (Singh *et al.*, 1978)

Treatment	Water use (cm)	Yield (t/ha)	Tubers No/m <sup>2</sup>	Wt/tuber (g)
<b>Year 1972-73</b>				
1. Drip ET <sub>100</sub>	36.6	33.4	48	98
2. Drip ET <sub>75</sub>	27.4	27.8	33	100
3. Drip ET <sub>50</sub>	18.3	20.5	31	86.8
4. Drip ET <sub>100</sub> (S <sub>1</sub> )	36.6	26.4	36	89.0
5. Furr. ET <sub>100</sub>	36.6	20.2	34	62.5
SEM	—	1.0	3.5	5.6
CD (0.05)	—	3.2	10.8	17.3
<b>Year 1973-74</b>				
1. Drip ET <sub>100</sub>	28.8	27.5	55	59
2. Drip ET <sub>75</sub>	21.4	21.1	40	53
3. Drip ET <sub>50</sub>	14.3	14.7	42	36.3
4. Drip ET <sub>100</sub> (S <sub>2</sub> )	28.6	14.4	42	39.0
5. Furr. ET <sub>100</sub>	34.0	18.1	32	65.8
SEM	—	0.6	8.2	3.3
CD (0.05)	—	1.8	6.7	10.1

S<sub>1</sub> & S<sub>2</sub> = salinity of water, 3 and 10 dsm<sup>-1</sup>, respectively; ET<sub>50</sub>, 75, 100 = percentage of evapotranspiration of the crop; Furr. = furrow irrigation.

Table 3. Mean per cent reduction of tomato yield as influenced by water salinity and discharge rate (Ramadevi, 1980).

Water Salinity (ds/m)	Discharge rate (l/hr)		
	3.38	1.69	1.13
0.5	0	0	0
5.0	4.6	6.5	0
10.0	12.9	22.2	30.5
15.0	29.0	37.3	44.8

The favourable effects of drip irrigation with saline water on salinity hazard and plant growth are mainly due to : 1) displacement of soluble salt beyond the active root zone of the plant, 2) lowering of salt concentration by maintaining a higher soil moisture content, and 3) avoiding leaf burn due to salt accumulation on the surface of leaves which are in contact with saline water. Moreover, in the cases enumerated in Table 1, the effective soil salinity in the root zone was below the salt tolerance limit of the respective crop plant (Yaron *et al.*, 1973; Patterson and Weiranga 1974; Tscheschke *et al.* 1974; Bernstein and Francois. 1973, 1975, Bresler, 1977,1981). More studies on drip irrigation with saline water on long term basis in different agroclimatic zones are needed, particularly in arid region where evaporation-precipitation deficit causes regular increase in annual salt-build up.

#### *Salt Distribution in Drip Irrigation*

Horizontal and vertical distribution pattern of moisture and salt under drip irrigation with saline water is controlled by several factors viz., soil type, profile characteristics, quality and discharge rate of water, spacing of drip nozzles, evaporative conditions and evapotranspiration rate of the crop and their interactions. Salts move along with water and are left behind where water evaporates from the soil surface or enters the root. It is mainly controlled by flow rate, moisture movement characteristics and rate of evaporation from the soil surface (Stevens and Rawlins, 1979; Bresler, 1981). Goldberg and Shumeli (1970) pointed out that salinity in a sandy soil under drip can be divided into 3 main zones viz., 1 (upper zone where salinity increases with the distance from the nozzle; 2) a wide intermediate zone where salinity values are low and 3) a lower zone where salinity level increases with the depth and with the distance from the nozzle.

Ideally, water and salt movement under drip is a three dimensional process but the predominance of lateral or vertical movement is mainly controlled by the discharge rate and effective soil porosity and rate of evaporation. Generally, the soil salinity immediately below the emitters is low and increases towards the wetting front and

consequently it becomes quite high between the out fringe of two emitters in the same direction (Goldberg and Shumeli, 1970; Voth, 1970, 1977; Tscheschke *et al.*, 1974; Seifert *et al.*, 1975; Bernstein and Francois, 1975; Peacock *et al.*, 1977; Kumar and Sivannappan, 1980).

In the sandy soils, where water of 1.2 ds/m was applied, salt distribution pattern was influenced by the rate of evaporation from the soil surface, water uptake by the roots and advances of the wetting front (Yaron *et al.*, 1973). In the sandy loam soils of Delhi, maximum salinity was recorded at the surface followed by middle (20-60 cm), and lower (> 60 cm) zones (Ramadevi and Michael, 1982).

An essential factor in the management of drip irrigation with saline water is to maintain large volume of soil moist with low salt concentration to minimise contact of roots with the zone of high salinity although away from the emitters it cannot be ruled out. If the rains occur after the salt build up at the soil surface between the emitters salts are likely to be pushed towards the zone of low salinity and thereby increasing the salinity of the root zone and affect crop growth.

Success of drip irrigation with saline water will ultimately depend on salinity of the ground water, soil salinity and sodicity before cropping, annual gross rainfall and its distribution and its effect on horizontal and vertical movement of salts in the cropping period. Data on drip irrigation with sodic water i.e. rich in bicarbonates, high in RSC and SAR, precipitation and dissolution of lime and sodiumisation of soil with depth, using different quality waters under different soil-agroclimatic conditions, are lacking.

### SPRINKLER IRRIGATION

Sprinkler can also be successfully used for irrigation with saline water. However, the main considerations are critical limits of chemical constituents in irrigation water and the magnitude of scorching effect of dissolved salts on plant leaves. Such adverse effects are in addition to the osmotic effect of salts present in the growth medium (Couwenoven 1971; Pair *et al.*, 1975).

#### *Crop Response to Saline Water*

Despite these limitations, sprinklers have been used for low to moderately saline (1-5 ds/m) irrigation water in various crops. Generally the salinity hazard increases with increases in water salinity, atmospheric aridity and temperature at the time of irrigation and fineness of soil texture.

Saline water has been successfully used for tomato (Goldberg *et al.*, 1971; Gormat *et al.*, 1973; Shumeli, 1974; Singh and Mann, 1979), cucumber (Shumeli and Goldberg, 1971; Gormat *et al.*, 1973), onion (Duc and Duc, 1975; Melsted and Deboeri,

1977; Swammis *et al.*, 1979), carrot (Melsted and Deboeri, 1977), lettuce (Swammis *et al.*, 1979), potato (Singh and Mann, 1979), pepper (Bernstein and Francois, 1973; Gormat *et al.*, 1973; Shumeli, 1974; Stevens and Rawlins, 1979), muskmelon (Shumeli and Goldberg, 1971), peaches (Natali and Xiloyammis, 1975), citrus (Bingham *et al.*, 1984), sorghum (Ravelo *et al.*, 1977; Jury *et al.*, 1978), sugarcane (Ekerson, 1977), cotton (Shatanawi, 1983) and date palm (Reuveni 1974).

The work of Hellings (1971) indicates that sprinkler irrigation with water of 200-500 meq/l chloride concentration is suitable for moderately salt tolerant vegetable crops. Squash, watermelon and cataloupes give fair response to sprinklers. Forage sorghum shows less leaf burn than grain sorghum followed by maize (Moore and Murphy, 1978). Agarwal and Khanna (1983) showed that sprinkler irrigation with highly saline (12 ds/m) water is more harmful than surface irrigation in bajra, cotton and wheat; barley being more salt tolerant gives better yield. Wheat can be grown well through sprinkling irrigation of diluted 10,000 ppm) sea water (Kurian *et al.*, 1981).

Maas (1985) concluded that cotton, cauliflower, sugarbeet and sunflower can be irrigated with water upto a salinity of 6 ds/m, strawberry upto 4 dsm<sup>-1</sup>, sorghum, sesame, safflower, cucumber, corn, barley and alfalfa upto 2 dsm<sup>-1</sup>, tomato, potato, pepper and grape upto 1 dsm<sup>-1</sup> and plum, citrus, apricot and almond upto 0.5 ds/m only.

#### *Effect of Atmospheric Aridity*

During the hot and dry season, saline water has a scorching effect on the plant leaves, and consequently, several workers recommend night irrigation (Ehlig and Bernstein, 1959; Ploegmann, 1969; Agarwal and Khanna, 1983). Sprinkler irrigation with saline water is risky if air temperature exceeds 22-24°C (Hellings, 1979). Moore and Murphy (1978) concluded that none of the 30 cotton varieties could tolerate extreme dry heat in Texas and night sprinkler irrigation was much better. Sunflower showed similar effects. However, less differences were noted in sixteen sorghum varieties. Cotton, though moderately salt tolerant, showed yield reduction on giving first irrigation in hot summer (Agarwal and Khanna, 1983). Similarly Busch and Turner (1967) observed 15% yield reduction on sprinkling with water of 4.4 ds/m in the day as compared to surface irrigation. But sprinkling at night did not decrease cotton yield.

#### *Absorption of Nutrients*

Direct sprinkling of saline water on the plant leaves may result in excessive foliar absorption of ions, particularly sodium and chloride, which are the main constituents of saline water at higher salt concentration. This may lead to tip burning, scorching and ultimately defoliation of plant leaves.

These effects are closely related with the salt absorption behaviour of the plant leaves. Such effects are accentuated and visible earlier in the arid climate and water

stressed conditions. Grattan *et al.* (1981) pointed out that only soluble salts are absorbed by soybean, pepper, and tomato plants.

Leaves of plant species show specific nutrient absorption characteristics, and are not necessarily related with foliage injury, salt tolerance and crop yield. Several factors e.g. leaf size, shape, wetted surface, age and position on the plant, ionic composition of water, frequency and duration of sprinkling, air temperature and rate of evaporation from leaf surface affect absorption by plant leaves (Franke, 1967; Hayne and Goh, 1977, Maas, 1985).

In citrus though leaves absorb ions slowly, there is scorching effect (Harding *et al.*, 1958). Strawberry is also sensitive to leaf injury by saline water sprinkling (Ehlig, 1961). Ehlig and Bernstein (1959) pointed out that foliar absorption of sodium and chloride ions is very rapid in plum, apricot and almond and slowest in avocado. Plum leaves are injured at low foliar salt concentration than the leaves of other species. Vegetable and forage crops are not injured by water of 86 meq/l concentration of sodium chloride.

Amongst the eleven crops, the mean rate of absorption of sodium and chloride ions in the green house was : Safflower = potato > tomato = barley > sugarbeet = alfalfa = sesame > cauliflower > sunflower = cotton > sorghum. However, the rate of absorption was not strictly related with the leaf injury which was in the order : Potato = tomato > sesame > alfalfa > sorghum = barley = safflower > cauliflower = sunflower = cotton > sugarbeet (Maas *et al.*, 1982).

#### *Minimising Salt Hazard*

It is possible to minimise harmful effects of sprinkling with saline water on plant leaves and crop yield by reducing absorption of salts. This can be achieved by keeping the foliage away from wetting and if wetting is inevitable, continuous wetting is better than sprinkling as number of sprinklings is more harmful than their duration.

It is preferable to apply saline water below the foliage wherever possible, i.e. in fruit, nut and vine crops. Sprinkling at low angle under citrus trees has been successful and overhead irrigation with saline water be avoided to minimize salt absorption and its harmful effect.

Finally the success of sprinkler irrigation with saline water will depend upon the level of sprinkler in relation to plant height, duration and frequency of irrigation, wind velocity, temperature and humidity at irrigation time, ionic composition of water, total and relative absorption behaviour of dissolved ions in the leaves and salt tolerance limit of the crop at different growth stages.

Amongst drip, furrow and sprinkler methods, all are equally good at low water salinity for moderately salt tolerant crops, However, at higher water salinity, drip is better than furrow flood followed by sprinkler as foliar injury by sprinkler multiplies the adverse effect of salinity on crop growth. And the extent of adverse effect on plant growth and yield is related to the salt tolerance of the plant species and development of soil salinity in the root zone. But the comparative data on development of soil salinity and crop yield by these methods are available for a few crops-including bell pepper, muskmelon, grape, peach and citrus fruit (Goldberg & Shumeli, 1971; Bernstein and Francois, 1973; Natali and Xiloyammi, 1975; Stevens and Rawlins, 1979, Baker *et al.*, 1979 and Bingham *et al.*, 1984).

### SUMMARY AND CONCLUSIONS

Both drip and sprinkler method of irrigation with saline water can be successfully used for most of vegetable, fruit and field crops with low to moderate levels ( $> 4$  ds/m) of salinity in water in sandy to sandy loam soils. Drip saves more water mainly due to less coverage of the cropped area and consequently less area is salinised but it is more at the surface between the emitters than in lower depths. Continuous surface salinisation and annual salt build up under very arid climate is likely to limit the scope of drip irrigation. It is quite useful for wide spaced cash crops and can be operated at low pressure system. On the other hand, sprinkler poses a severe limitation under long dry season due to excessive accumulation of dissolved ions and scorching effect on plant leaves. More salinity can be tolerated under drip than sprinkler by virtue of its point application and less salt and moisture stress developed near the root zone. In dry season, night irrigation with sprinkler is preferable, if feasible and continuous wetting is better than intermittent sprinkling.

Factors affecting both the methods of irrigation with saline water indicate that choice of particular method depends finally on the development of soil salinity in the long run, salt tolerance limit of crop, water quality, soil type, climate, frequency and time of irrigation and salt sensitivity to scorching of leaves by sprinkler.

More quantitative data are needed under varying conditions of soil and water, salinity, irrigation frequency, discharge rate, salt distribution, climatic conditions, crop variety, salt fertilizer interaction, and finally the economic feasibility of both the methods.

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