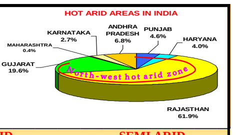


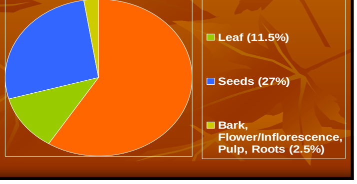
	ARID	SEMI ARID
Rainfall (mm)	< 500; cv. > 40%	500 – 850; cv. 25-40%
ET (mm)	1500 – 2100	1000-1500
Moisture Index	< - 66.6%	- 33.3 to -66.6
Aridity	Severe; Scarcity of drinking water	Moderate;Water shortage for crops
Drought	Chronically drought-prone 1 in 2.5 yrs	Drought-prone 1 in 5 yrs
Cropping	One in normal yrs	Potential for double cropping
Watershed	Limited scope of runoff harvesting, use	Adequate scope
Issues	Survival, Livelihood	Sustainability, Productivity

RAJASTHAN (“Marusthal”)

One of the largest states of India.

- Area – 3,42,274 sq. km i.e. nearly 11% of total area of India.
- The total arid area in Rajasthan is about 1,96, 150 sq. km and occupies about 62% of the total area of the state.
- Soil : containing 90-95% sand and 10-5% clay.
- High % of soluble salts and relatively high pH.
- Annual rainfall 25 cm or less.
- Annual diurnal temperature 32 degree Celsius or more coupled with low relative humidity i.e. 35-60% and high wind velocity i.e. 10.7 km/hr average annual in hot summer season and during monsoon (Pramanik & Ghose, 1952).

Percentile schematic representation of Horticultural plants of Rajasthan



Layout, digging and plantation for establishment of date orchards

Land preparation and planting operation

- Availability and quality of irrigation water;
  - Field selection;
  - Mechanical actions to be implemented;
  - Tools and equipment needed for date cultivation;
  - Labour needs;
  - Irrigation design and installation;
  - Hole preparation;


Layout of orchard

Planting operation

Plant spacing

- It is difficult to prescribe a definite plant spacing but there are specific factors influencing the spacing such as:
- - to allow for sufficient sunlight when palms are tall;
  - to allow for sufficient working space within the plantation; and
  - to provide sufficient space for root development.
- Previously, the general assumption for a commercial date plantation was to use a plant spacing of 10 m x 10 m (100 palms/ha). It has, however, changed over time and a plant spacing of 9 m x 9 m (121 palms/ha; Israel) or 10 m x 8 m (125 palms/ha;).

- The planting density also depends on ecological factors (mainly humidity) and on varieties.
- In general, commercial plantations use 10 m × 10 m,
- 9 m × 9 m or 10 m × 8 m, for all varieties except for Khadrawy (dwarf variety with a small canopy) which could be planted at a higher density.
- The tendency to plant more closely is found when the prevailing wind is dry and extremely hot and strong. The 10 × 10 is desired in areas where humidity during the date ripening period is high.
- This wider spacing is to allow sun and wind to counteract the humidity's influence.
- wide spacing is also recommended whenever there is considerable danger of rain damage to dates during the ripening season.

Lay-out of a date plantation with 10 m × 8 m spacing

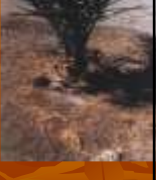


Digging of pits

- The actual digging of the hole is one of the last actions before planting takes place, but it must be emphasised that this is not the final preparation for the planting operation itself.
- This is the point where the required inputs such as gypsum and organic materials are worked into the soil
- It is recommended that a hole of 1 m^3 be prepared and that the soil from the hole be mixed with the organic material and gypsum.
- The soil mix is then put back into the hole, whereafter the site is clearly marked for positioning of the small date palm plants.
- In most soils, the early and rapid growth of the date plant is better when the holes are prepared one to two months before planting.
- Well-rotted manure can also be used in holes prepared and irrigated shortly before planting, but extreme care must be taken to put the manure (and fertilisers) deep enough to allow a layer of soil at least 15 to 20 cm thick to be placed between the manure and the roots of the date plant.

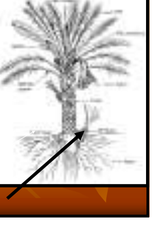
Time of planting

- The critical factor is to transplant the young tissue culture date palms or offshoots at that time of the year that will ensure a good survival rate and proper establishment before the beginning of a "hard" season.
- Spring avoids the cold of winter and takes advantage of the warm weather that encourages rapid growth, while autumn gives the young shoot a longer time to establish itself before the heat of summer. The best time of establishment is during autumn (In areas without extreme dry, hot summers and with severe frost during winter it is recommended to plant during August/September.



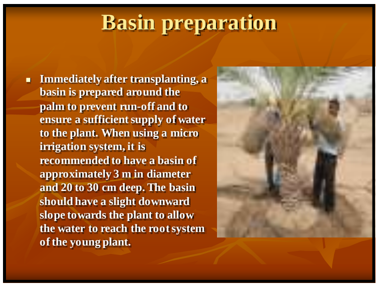
Planting time and depth

- Planting should always be initiated early in the morning to limit stress on the date plantlets and also to allow sufficient time for adaptation (from the plastic bag to the soil). Bags are to be removed with care and the plant, with most of its surrounding substrate, to be planted carefully.
- The planting depth is critical because the "heart" of the plant should never be covered with water. Once the plant is covered with water the growing point rots and the plant dies off. If a date plant is planted too shallow, its roots will desiccate and die.
- The golden rule is to ensure that the greater diameter of the bulb of the plant is at the same level as the soil surface after transplanting and to ensure that water does not go over the top of the date plant.

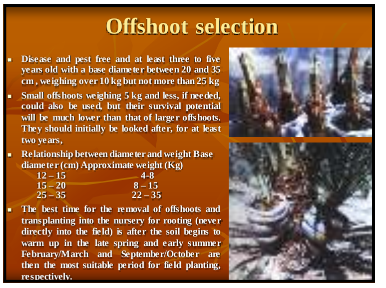


Transplanting stage

- Best field survival rate, as well as early plant development, is obtained when the date tissue culture plantlets are transplanted at the four (4) plus leaf stage.. This results in the young plants being kept in the farm nursery for a period (approximately 8-12 months), until the sufficient number of leaves have developed before transplanting takes place.
- Regarding offshoots, it is highly recommended to ensure their rooting in the nursery after separation from the plant mother (at least 10 to 12 months). It is not recommended to plant an offshoot directly after its separation.


Basin preparation
Immediately after transplanting, a basin is prepared around the palm to prevent run-off and to ensure a sufficient supply of water to the plant. When using a micro irrigation system, it is recommended to have a basin of approximately 3 m in diameter and 20 to 30 cm deep. The basin should have a slight downward slope towards the plant to allow the water to reach the root system of the young plant.


Date orchard


Offshoot selection
Disease and pest free and at least three to five years old with a base diameter between 20 and 35 cm, weighing over 10 kg but not more than 25 kg
Small offshoots weighing 5 kg and less, if needed, could also be used, but their survival potential will be much lower than that of larger offshoots. They should initially be looked after, for at least two years,
Relationship between diameter and weight Base diameter (cm) Approximate weight (Kg)
12 – 15 4-8
15 – 20 8 – 15
25 – 35 22 – 35
The best time for the removal of offshoots and transplanting into the nursery for rooting (never directly into the field) is after the soil begins to warm up in the late spring and early summer February/March and September/October are then the most suitable period for field planting, respectively.


PLANTS USED AS FRUITS
Cordia gharaf
Ephedra ciliata
Grewia tenax
Prosopis cineraria
Prosopis juliflora
Salvadora persica


PLANTS USED AS LEAF
PLANTS USED AS BARK
Amaranthus viridis
Euphorbia caducifolia
Acacia nilotica subsp. indica
Prosopis cineraria
PLANTS USED AS SEED
Acacia nilotica subsp. indica
Acacia senegal
Achyranthes aspera
Aerva javanica

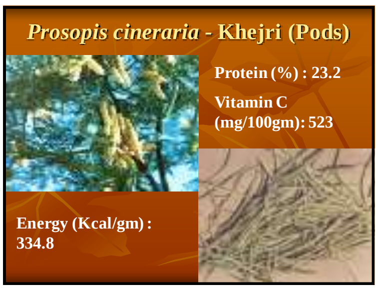

OTHER ARID PLANTS
Lasiurus scindicus
Tribulus terrestris
Calligonum polygonoides
Cenchrus ciliaris
Citrullus colocynthis
Indigofera cordifolia
Indigofera linifolia

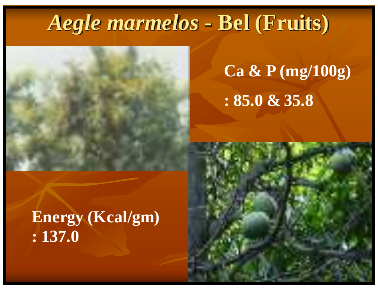

Some Important Fruit Trees from Forests of Arid Zone


Salvadora oleoides – Jal (Fruits)
Carbohydrates (%) : 76.0
Energy (Kcal/gm) : 346
This plant occurs widely in the arid regions of Rajasthan and Gujarat and also in some part of Punjab. In Pakistan, it commonly occurs in Sind and Punjab and extends to part of Baluchistan It grows in the rainfall zone ranging from 180 to 760 mm and proper medium and fine textured soil. Particularly sandy loam sandy clay loam and high clay of good depth.


Ziziphus mauritiana –Ber (Fruits)
Vitamin C : 76 mg/100g
Energy (Kcal/gm) : 73.9


Capparis decidua – Ker (Fruits)
Ca & P (mg/100g) : 55 & 57
Fibre (%) : 12.3
Energy (Kcal/gm) : 41.9


Prosopis cineraria - Khejri (Pods)
Protein (%) : 23.2
Vitamin C (mg/100gm): 523
Energy (Kcal/gm) : 334.8


Aegle marmelos - Bel (Fruits)
Ca & P (mg/100g) : 85.0 & 35.8
Energy (Kcal/gm) : 137.0


Feronia limonia – Kaitha (Fruits)
Vitamin A & C : 170µg /100g & 2 mg/100g
Energy (Kcal/gm) : 98.6

Nutrient content of forest fruits from arid zone

Species	Protein (%)	Carbohydrate (%)	Fat (%)	Fibre (%)	Vit A (mg/100g)	Vit B2 (mg/100g)	Vit C (mg/100g)	Ca (mg/100g)	P (mg/100g)	Fe (mg/100g)	Energy
B.aegyptiaca	4.9	69.9	0.1	3.5	-	0.07	46	147	58	4	300.1
C. decidua	8.6	1.8	-	12.3	-	-	7.81	55	57	-	41.6
C. dichotoma	2.0	92.0	2.0	2.0	-	-	-	55.0	275.0	6.0	394.0
P. cineraria	23.2	56.0	2.0	20	-	-	523.0	414.0	400.0	19.0	334.8

Nutrient content of forest fruits from arid zone

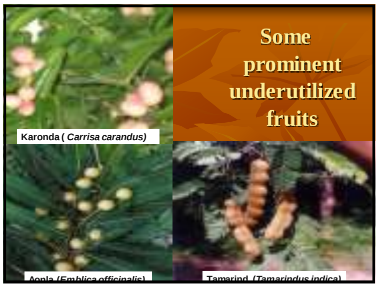
Species	Protein (%)	Carbohydrate (%)	Fat (%)	Fibre (%)	Vit A (mg/100g)	Vit B2 (mg/100g)	Vit C (mg/100g)	Ca (mg/100g)	P (mg/100g)	Fe (mg/100g)	Energy
S.oleoides	6.0	76.0	2.0	2.0	-	-	-	6.0	76.0	8.0	346.0
Z.mauritiana	0.8	17.0	0.3	-	0.02	0.02	76.0	4.0	9.0	1.8	73.9
A.marmelos	4.7	22.3	0.3	2.9	0.055	1.2	213.8	117.6	151.8	52.2	210.8
F.limonia	7.3	15.5	0.6	5.2	-	0.17	2.0	0.13	0.11	0.6	96.6

Other important fruit species from arid zone

Botanical Name	Local Name	Family	Habit	Fruit	Fruiting Period
Grewia tenax	Gangerun	Tiliaceae	Most common shrub or undershrub growing amongst Euphorbia bushes	Fruit is a drupe, deep orange in colour, sold in the market.	September-December
Cordia gharaf	Goondi	Ehretiaceae	Shrub or small tree found in arid areas	Berry is orange or reddish brown when ripe, eaten and sold in the market	May-June
Citrullus lanatus	Matiro	Cucurbitaceae	Trailing hispid annual found in open fields	Globose or ellipsoid, Dark green bands or uniform	August-December

Ephedra foliata	Lana	Gnetaceae	Dioecious much branched climbing shrub, common on sand or gravel or rocks	Fruits ovoid-globose, milky white, semi-transparent, are eaten in scarcity	January - April
Cucumis melo	Kachro	Cucurbitacae	Common annual much branched prostate herb	Usually cylindrical, quite smooth, yellow or orange with blotches in irregular lines	November-December
Cucumis callosus	Kachri	Cucurbitaceae	Much branched very common prostate , perennial herb	Fruits are ellipsoid, ovoid, green variegated stripes, sold in the market	August-November
Rhus mysurensis	Dasan	Anacardiaceae	Much branched spiny shrub, not very common in arid areas, found in hilly tracts	Fruit is a drupe and is eaten.	July-September

Some prominent underutilized fruits



Drumstick orchard under drip

Citrus orchard under drip irrigation


Dried and processed U. U. Fruits


Processed products of Underutilized fruits
Chutney
Jelly
Candy
Jam
Pickle
Jelly


Fruit Toffee
Jam and Honey
Squash


Processed products from UUF


Fruit balls and pickles


Branded Industry products
Small Scale Industry Processed products

CONCLUSIONS

- Fruits from saline environment provide more protein & energy apart from being rich in minerals and vitamins.
- Many unripe fruits find use as vegetables.
- They possess medicinal properties.
- Most fruit trees are multipurpose species.
- Play very important role in stress times.

Sustaining production of horticultural crops with poor quality water

DR. Anshuman Singh
ICAR-CSSRI, Karnal-132001

Introduction

➢Energy intensive agriculture, supported by the use of high-yielding varieties irrigation and heavy use of fertilizers, has significantly contributed to increases in food production in the second half of 20th century.

➢Nevertheless, these practices have altered the ecosystem services in such a fundamental way that world is facing serious consequences in terms of biodiversity loss and the degradation of natural resources (Matson *et al*., 1997).

➢Development and spread of salt-affected soils, a major form of land degradation, is a cause for concern (Gupta and Abrol, 1990). In addition, the problem of poor quality water is fast emerging a serious constraint in the way of sustainable agricultural development (Qadir *et al*., 2007).

➢The problem is of particular concern to the arid and semi-arid regions where irrigation is essential to sustain crop production. Given this state of affairs, the productive utilization of salt-affected soils and poor quality water remains a challenge for the researchers, farmers and policy makers (Abrol *et al*., 1988; Qadir et al., 2007).

Contd….

✓Given the fact that fresh water is increasingly becoming scarce and that agriculture accounts for a major chunk of fresh water use, it becomes imperative to explore the strategies for optimizing cost-effective, environment-friendly and sustainable use of available water resources in crop production (Chapagain and Hoekstra, 2004).

✓Available evidence shows decreasing availability of good quality irrigation water due to increasing population in urban areas and industrialization in many developing countries (Yadav *et al*., 2002). The problem may aggravate in near future and changing scenario would necessitate appropriate water management strategies, restricted irrigation and even use of poor quality water for sustaining crop production (Oster, 1994).

✓Poor quality water (PQW), also referred to as marginal quality water, is a collective term for wastewater, saline and sodic water and agricultural drainage water (Qadir *et al*. 2007).

Categories of poor quality water

➢Wastewater (domestic and industrial effluent)

➢Saline and sodic water and

➢Agricultural drainage water.

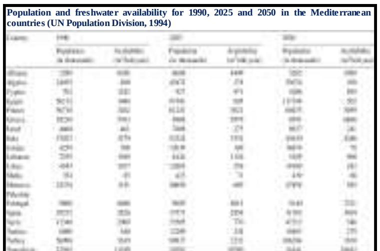
❑In majority of the cases, wastewater used in crop production is not treated and this may have adverse environmental and health implications as untreated wastewater often carries heavy metals, pathogens, residual drugs and other organic compounds which could prove harmful to the environment and human health.

❑Contrary to wastewater, saline and sodic water contains toxic salts that often restrict plant growth and result in reductions in yield and quality. Continuous use of saline and sodic water may also cause waterlogging and secondary salinization which could impair soil health and productivity.

❑Agricultural drainage water, which often contains salts, agro-chemicals, nutrients and amendments such as gypsum is also used to irrigate crops.

(Qadir et al. 2007)

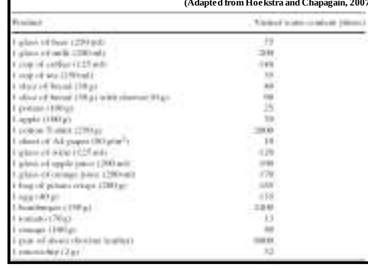
Population and freshwater availability for 1990, 2025 and 2050 in the Mediterranean countries (UN Population Division, 1994)



Majority of Mediterranean countries including Egypt, Libya, Tunisia, Algeria, Morocco, Syria, and Lebanon exhibit severe water scarcity and per capita water availability is mostly near/below the threshold of 1000 m^3/person/year.

Global virtual water content of some products

(Adapted from Hoekstra and Chapagain, 2007)



Effects of treated and untreated wastewater in horticultural crops.

Crop	Effects	Reference
Treated wastewater		
Citrus	Citrus trees did not exhibit any detrimental effect under wastewater irrigation as growth and fruit quality remained unaffected in spite of high Na, Cl and B concentrations in wastewater.	Reboll *et al*. (2000)
Grape	Drip irrigation with municipal wastewater did not cause any yield or quality reduction in Okanagan Riesling vines planted in a sandy soil. Observations over a 4-yr period revealed no horticultural limitations to the use of wastewater.	Neilsen *et al*. (1989)
Tomato	Combined application of reclaimed wastewater and normal water resulted in partial translocation of heavy metals from the soil to the fruit, yet concentrations of these heavy metals in fruit were below the standard limits. Besides no apparent impairment in fruit quality, wastewater application enhanced plant growth and reduced fertilizer application rates and thus seems to be practically feasible in tomato.	Al-Lahham *et al*. (2007)
Gerbera	Fertigation with treated wastewater decreased the total number of marketable flowers by 21% as compared to fertigation with nutrient solution.	Maloupa *et al*. (2009)
Untreated wastewater		
Olive	Application of saline wastewater (4.3-6 dS m^{-1} and 73-90 SAR) from a table olive industry caused significant decrease in photosynthetic parameters, leaf N concentration and yield in olive trees and thus was not found suitable for use.	Murillo *et al*. (2000)
Vegetables	Application of untreated wastewater effluent caused *Salmonella* contamination in harvested vegetables. Differences were observed with respect to crop (lettuce and parsley were more affected as compared to tomato) and season (summer grown crops such as tomato were less affected while winter grown lettuce and parsley recorded higher *Salmonella* count).	Melloul *et al*. (2001)
Cole crops	Cauliflower and red cabbage gave highest yields when irrigated with untreated wastewater as compared to both normal and treated wastewater, but heavy metal concentrations were significantly more in both the vegetables with untreated wastewater use.	Kiziloglu *et al*. (2008)
Potato	Irrigation with untreated sewage water significantly increased concentrations of Fe, Mn, Zn, Al, Ni, Cu and Cr in potato leaves and tubers and the increase was generally higher in leaves than in tubers.	Brar *et al*. (2000)

Factors responsible for increasing wastewater use in irrigation

✓Increasing scarcity of fresh water for irrigation.

✓Growing recognition of the importance and value of wastewater reuse.

✓High cost of artificial fertilizers (as wastewater is a potential source of crop nutrients).

✓the evidence that environmental and health risks can be minimized with certain precautions.

✓Socio-cultural acceptance of the practice.

Organisms usually determined in wastewater treatment and use

Recommended microbiological quality guidelines for wastewater use in agriculture

Category	Reuse condition	Exposed group	Intestinal nematodes[b] (arithmetic mean no. of eggs per litre[c])	Faecal coliforms (geometric mean no. per 100 ml[c])	Wastewater treatment expected to achieve the required micro-biological quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks[d]	Workers, consumers, public	? 1	? 1000	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees[e]	Workers	? 1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent helminth and faecal coliform removal
C	Localized irrigation of crops in cat. B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sedimentation

[a] In specific cases, local epidemiological, socio-cultural and environmental factors should be taken into account, and the guidelines modified accordingly.
[b] *Ascaris and Trichuris species and hookworms.*
[c] During the irrigation period.
[d] A more stringent guideline (? 200 faecal coliforms per 100 ml) is appropriate for public lawns, such as hotel lawns, with which the public may come into direct contact.
[e] In the case of fruit trees, irrigation should cease two weeks before fruit is picked, and no fruit should be picked off the ground. Sprinkler irrigation should not be used.

Source: WHO (1989)

Concentration of some trace elements(mg kg^{-1}) found in some vegetables under wastewater irrigation (Bigdeli & Seilsepour, 2008)

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Values of the soil pH, electrical conductivity (ms cm) and heavy metals concentrations (mg/kg) at three depths (0–20, 20–40 and 40–60 cm) in the soil measured prior to planting and after the last harvest following irrigation with treated wastewater (Al-Lahham et al., 2007)

[illegible]	Prior to planting			After harvest			Significance
	0-20	20-40	40-60	0-20	20-40	40-60	
pH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cd	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cu	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fe	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mn	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Zn	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ni	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[a] Means are the average of 12 samples.
[b] Significant at $P \leq 0.05$.

Heavy metal concentrations in four treatments (control 1:0; 1:1; 1:3 and 0:1, potable water to treated wastewater) Al-Lahham *et al.*, 2007

Treatment	Heavy metals[a]						
	Cd	Cu	Fe	Mn	Zn	Ni	Pb
1:0 (control)	0.000	0.330	4.130	0.180	2.460	0.300	0.000
1:1	0.000	0.670	11.980	0.160	3.970	0.550	0.000
1:3	0.000	0.930	12.220	0.260	10.150	0.760	0.000
0:1	0.000	1.340	12.220	0.530	11.790	0.230	0.000
Significance	ns	*	*	ns	*	*	ns
LSD	–	0.199	2.778	–	2.828	0.504	–

[a] Means are the average of six samples.
[*] Significant at $P \leq 0.05$.

Heavy metal accumulation in tomato fruits following four irrigation treatments (control 1:0; 1:1; 1:3 and 0:1 potable water to treated wastewater) Al-Lahham et al., 2007

Treatment	Heavy metals[a]						
	Cd	Cu	Fe	Mn	Zn	Ni	Pb
GS							
1:0 (control)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1:1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1:3	0.000	0.000	0.000	0.013	0.000	0.000	0.000
0:1	0.000	0.000	0.000	0.025	0.025	0.000	0.000
RS							
1:0 (control)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1:1	0.000	0.025	0.007	0.000	0.000	0.300	0.000
1:3	0.000	0.050	0.020	0.000	0.050	0.100	0.000
0:1	0.000	0.075	0.035	0.013	0.100	0.300	0.000

[a] Means are the average of 60 fruits.

Different risks involved with wastewater irrigation in food crops

- **Low(est) risk to consumer but field worker protection still needed**
  - Crops not for human consumption (e.g. cotton).
  - Crops normally processed by heat or drying before human consumption (grains, oilseeds).
  - Vegetables and fruit grown exclusively for canning/processing that effectively destroys pathogens.
  - Fodder crops and animal feeds that are sun-dried before use.
  - Landscape irrigation in fenced areas without public access (nurseries, forests, green belts).
- **Increased risk to consumer and handler**
  - Pasture, green fodder crops.
  - Crops that do not come into direct contact with wastewater (on condition that none must be picked off the ground and that spray irrigation must not be used as in tree crops).
  - Crops normally eaten only after cooking (potatoes, eggplant, beetroot).
  - Crops in which peel is not eaten (melons, citrus fruits, bananas).
- **Highest risk to consumer, field worker and handler**
  - Any crops eaten uncooked and grown in close contact with wastewater effluent (fresh vegetables such as lettuce or carrots, or spray-irrigated fruit).2. Landscape irrigation with public access (parks, lawns, golf courses).

Major considerations/precautions in wastewater use in irrigation

- Use of treated wastewater to eliminate/overcome probability of human/animal and environmental risks.
- Development and popularization of low-cost, user friendly wastewater treatment devices.
- Periodical monitoring to ensure that soil health is not endangered with prolonged use.
- Preferable use of drip system to control microbial and heavy metal loads. Sprinklers should not be used.
- Promotion of mechanized cultural and harvesting practices.
- No application of wastewater one-two weeks before harvesting.
- Appropriate processing/treatment of harvested produce before human/animal consumption.
- Relatively longer periods between wastewater irrigations through irrigation scheduling and/or alternate use of fresh water and wastewater.

Categorization of ground waters on the basis of EC, SAR, and RSC Standards (ICAR-CSSRI, India)

Water Quality	Electrical Conductivity (dSm^{-1})	SAR ($m\ moL^{-1})^{1/2}$	RSC ($me\ L^{-1}$)
1. Good	< 2	< 10	< 2.5
2. Saline			
a. Marginally saline	2-4	< 10	< 2.5
b. Saline	>4	< 10	< 2.5
c. High SAR saline	>4	>10	< 2.5
3. Alkali			
a. Marginally alkali	<4	< 10	2.5-4.0
b. Alkali	<4	< 10	>4
c. Highly alkali	Variable	>10	>4

Fig. 1. Salinity tolerance in fruits and vegetable crops (FAO)

Besides the fruit crops listed here, many others such as bael (*Aegle marmelos*), aonla (*Emblica officinallis*), ber (*Zizyphus mauritiana*), phalsa (*Grewia subenqualis*), sapota (*Achras sapota*) and jamun (*Syzigium cumini*) do well in moderately saline and sodic soils.

Salinity tolerance in turf grasses

[illegible]

Marcum KB (1999a). Salinity tolerance in turfgrasses. In 'Handbook of Plant and Crop Stress' (Ed. M. Pessarakli) 2nd ed., pp. 891-906. (Marcel Dekker, New York).

Effects of saline water irrigation in horticultural crops

Crop	Effects	Reference
Mango	Drip irrigation with low salinity water (1, 1.5, 2 or 2.5 dS m^{-1}) in 12 year trees for 4 years indicated that rootstock Gomera-1 was relatively tolerant to salinity than Gomera-3. Gomera-3 exhibited higher Na and Cl concentrations in leaves and fruits, smaller fruits and lower fruit yield as compared to Gomera-1.	Zuazo *et al*. (2010)
Date palm	In cultivars Khalas, Khunaizy and Abunarinjah, planted in a sandy soil with good drainage, significant decline in growth occurred when EC_{IW} exceeded 9 dS m^{-1} and it was up to 50% with use of high salinity (EC_{IW} 18 dS m^{-1}) water.	Alrasbi *et al*. (2010)
Olive	Cultivars 'Manzanillo' and 'Uovo de Piccione' (~18 months old), planted in Negev desert (Israel) and drip irrigated initially with good quality water (~1.2 dS m^{-1}) and subsequently with saline (5.5-6.5 dS m^{-1}) water exhibited only occasional reduction in fruit size but significant increase in percent dry weight, percent oil and oil yield per unit fruit weight.	Klein *et al*. (1994)
Grape	In Cabernet Sauvignon vines (grafted on Roggeri), drip irrigation with moderately saline (3.3 and 4.8 dS m^{-1}) water caused reductions in green area index, leaf conductance and gas exchange parameters but berry yield did not decrease.	Ben-Asher *et al*. (2006)
Tomato	Highest yield (3.2 kg/plant) in cv. Floradade was obtained when plants were drip irrigated with saline (4.2-4.8 dS m^{-1}) and fresh water (0.55 dS m^{-1}) blended in 60:40 ratio.	Malash *et al*. (2010)
Gladiolus	Pre-treatment of corms with 100 ppm gibereelic acid and application of 5% magnetically treated seawater increased the number of leaves, plant height, corm volume and dry weight in gladiolus cv. Sancerre as compared to control.	Khattab *et al*. (2000)
Rose	Rose rootstocks [*Rosa×fortuniana*, *R. multiflora* and *R. odorata*) irrigated with saline (3, 6 or 9 dS m^{-1}) solutions recorded complete mortality in 9 dS m^{-1} and significant growth reduction in 6 dS m^{-1} treatment. Based on overall performance, *R.×fortuniana* was relatively salt-tolerant.	Niu *et al*. (2008)
Aromatic grasses	Alternate irrigation with saline (EC_{IW} 8.5 dS m^{-1}) and canal water in citronella (*Cymbopogon winterianus*), lemon grass (*Cymbopogon citrates*), palmarosa (*Cymbopogon martini*) and vetiver (*Vetiveria zizanioides*) caused 3-21% reduction in biomass yield as compared to 24-29% reduction noted with continuous use of saline water. Vetiver was the least affected.	Tomar and Minhas (2004
Isabgol	Alternate irrigation with low (EC_{IW} 4.0 dS m^{-1}) and high (EC_{IW} 8.6 dS m^{-1}) salinity water gave significantly higher un-husked seed yield of 1159 kg ha^{-1} as compared to lone use of either low salinity (1102 kg ha^{-1}) or high salinity (885 kg ha^{-1}) water. Among different varieties tested, the best performance was shown by JI-4.	Tomar *et al*. (2010)

Tolerance of various crops to exchangeable sodium (ESP) under nonsaline conditions

Tolerance to ESP and range at which affected	Crop	Growth response under field conditions
Extremely sensitive (ESP = 2-10)	Deciduous fruits, Nuts, Citrus Avocado	Sodium toxicity symptoms even at low ESP values
Sensitive (ESP = 10-20)	Beans (*Phaseolus vulgaris.* L)	Stunted growth at these ESP values even though the physical condition of the soil may be good
Moderately tolerant (ESP = 20-40)	Clover (*Trifolium* spp.) Oats (*Avena sativa* L.) Tall fescue (*Festuca arundinacea* Schreb.) Rice (*Oryza sativa L.*)	Stunted growth due to both nutritional factors and adverse soil conditions
Tolerant (ESP = 40-60)	Wheat (*Triticum aestivum* L.) Cotton (*Gossypium hirsutum* L.) Alfalfa (*Medicago sativa* L.) Barley (*Hordeum vulgare* L.) Tomatoes (*Lycopersicon esculentum* Mill.) Beets (*Beta vulgaris* L.)	Stunted growth usually due to adverse physical conditions of soil
Most tolerant (ESP = more than 60)	Crested and Fairway wheatgrass (*Agropyron* spp.) Tall wheatgrass (*Agropyron elongatum* (Host) Beau.) Rhodes grass (*Chloris gayana* Kunth)	Stunted growth usually due to adverse physical conditions of soil

Relative tolerance of fruit trees to soil sodicity

pH_2	Fruit species
>10	Not recommended
9.6-10.0	*Carissa congesta, Zizyphus mauritiana, Psidium guajava, Emblica officinalis*
9.1-9.5	*Phoenix dactylifera, Punica granatum, Achras zapota, Tamarindus indica, Syzygium cumini, Feronia limonia*
8.2-9.0	*Grewia subinequalis, Aegle marmelos, Mangifera indica, Ficus spp., Vitis vinifera*

Sharma *et al*., 2014

Effects of sodic water irrigation in horticultural crops

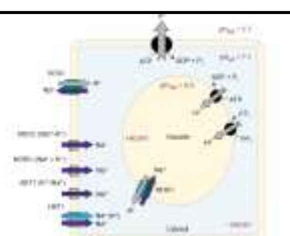
Crop	Effects	Reference
Mango	Irrigation with sodic water (adjusted SAR 22.5) significantly increased (3-5 times) Na concentration in mango leaves as compared to use of normal water (adjusted SAR 1.8) and thus resulted in severe leaf scorch.	Samra (1985).
Pawpaw	Pawpaw seedlings irrigated with non-saline (0.4 dS m^{-1}), high SAR (15.5) water exhibited significant reductions in lateral branch extension, trunk cross-sectional area, dry matter accumulation and net uptake of NPK. Gypsum application, however, significantly enhanced growth and mineral uptake which might be due to ameliorative functions of Ca on both plant and soil physical properties.	Picchioni *et al.* (2004)
Grapefruit	Irrigation with high SAR (10.3 $mol/m^3)^{1/2}$ water caused reduced water uptake and 9% yield reduction. The exchangeable sodium percentage of orchard soil increased due to sodium accumulation.	Bielorai *et al.* (1983)
Grape	Effects of drip irrigation with different salinity (0.37 to 3.47 dS m-l) and varying SAR (2-37) waters for 6-years on own-rooted Sultana grapevines were most severe on vines growing in most heavily textured soil. The yield response on the lightest soil most closely resembled the Maas-Hoffman 'bent-stick' model.	Prior *et al.* (1992)
Lemongrass	Irrigation with high RSC water (8, 12 and 16 meq l^{-1}) caused reduction in total herb yield (46, 58 and 63%, respectively) and total oil yield (39, 48 and 51%, respectively) as compared to control. The plants did not survive 21 months of transplanting which was attributed to very high Na^+ concentrations in foliar parts.	Prasad *et al.* (2001)
Fenugreek	Application of different RSC water (2.5, 5 and 7.5 m mol L^{-1}) significantly reduced plant height, number of pods/plant, number of seeds/pod, test weight, seed yield and straw yield of fenugreek. Zink application (20 mg/kg), however, significantly alleviated salt stress particularly when 2.5 m mol L^{-1} RSC water was used.	Jakhar *et al.* (2013)

Role of osmoprotectants in salt stress (Mahajan and Tuteja, 2005)

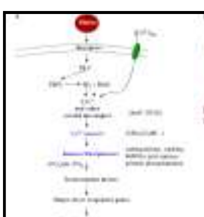
[illegible]

- Osmotic adjustment or osmoregulation can be achieved by several means, e.g., through succulence (of leaves), salt and solute accumulation, or shedding of older leaves, or a combination of these factors. More frequently, however, adjustment involves compatible solutes, classes of compounds that can accumulate in the cytosol without damaging enzymes. Loescher, W., Chan, Z., & Grumet, R. (2011). Options for developing salt-tolerant crops. HortScience, 46(8), 1085-1092.

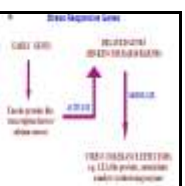
- Compatible solutes are assumed to accumulate to high concentrations without interfering with normal metabolism. The "osmoprotectant" functions include scavenging of free radicals (acting to quench effects of reactive oxygen species) and stabilization of macromolecular and membrane structures.



Schematic representation of NaC transport in plant cells. Electrogenic HC transport (HC-ATPase in the plasma membrane and vacuolar membrane, HC-PPiase in the vacuolar membrane) generates gradients of pH and electrical potential difference across the cell and vacuolar membranes. NaCl ions enter the cell via different channels (AKT1, NORC, NSCC) or carriers (HKT1) and can be translocated out of the cell or into the vacuole by the action of a plasma membrane NaC/HC antiporter (SOS1) or a vacuolar NaC/HC antiporter (NHX1), respectively.



Signaling pathway under stress condition. Stress signal is first perceived by the membrane receptor, which activates different enzymes and up-regulates movements of Ca^{2+} ions from apoplast or from its release from intracellular sources. This change in cytoplasmic Ca^{2+} level is sensed by calcium sensors which interact with their down stream signaling components which may be kinases and/or phosphatases. These proteins affect the expression of major stress responsive genes leading to physiological responses



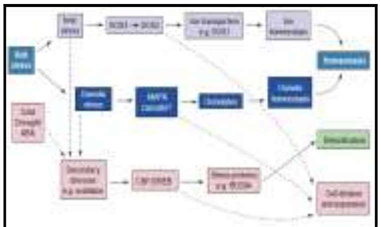
Early and delayed gene expression in response to abiotic stress signaling. Early genes are induced within minutes of stress perception and often express transiently. In contrast, various stress genes are activated slowly, within hours of stress expression and often exhibit a sustained expression level. Early genes encode for the transcription factors that activate the major stress responsive genes (delayed genes). The expression of major stress genes like RD/KIN/COR/RAB18/RAB29B result in the production of various osmolytes, antioxidants, molecular chaperones and LEA-like proteins, which function in stress tolerance.

Salt tolerance in transgenic plants expressing genes involved in ion transporters (Yamaguchi and Blumwald, 2005)

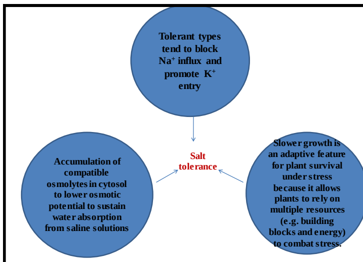
[illegible]

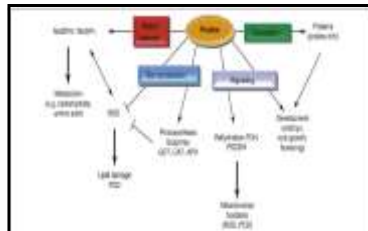
Transgenic tomato plants overexpressing a vacuolar Na+/H+ antiport were able to grow, flower, and produce fruit in the presence of 200 mM sodium chloride. Although the leaves accumulated high sodium concentrations, the tomato fruit displayed very low sodium content. Contrary to the notion that multiple traits introduced by breeding into crop plants are needed to obtain salt-tolerant plants, the modification of a single trait significantly improved the salinity tolerance of this crop plant. These results demonstrate that with a combination of breeding and transgenic plants it could be possible to produce salt-tolerant crops with far fewer target traits than had been anticipated. The accumulation of sodium in the leaves and not in the fruit demonstrates the utility of such a modification in preserving the quality of the fruit.

Zhang, H. and Blumwald, E. 2001. Transgenic salt-tolerant tomato plants accumulate salt in foliage but not in fruit. *Nature Biotechnology* 19, 765–768.



The three aspects of salt tolerance in plants (homeostasis, detoxification and growth control). Homeostasis may be either ionic and/or osmotic. The two primary stresses, ionic and osmotic stresses, cause damage or secondary stresses such as oxidation. Leatype stress proteins are proposed to function in the detoxification or alleviation of damages. CBF/DREB transcription factors mediate some of the stress protein gene expression in response to secondary stresses caused by high salt concentrations, cold, drought or abscisic acid (ABA). The ionic homeostasis, osmotic homeostasis and detoxification pathways are proposed to feed actively into cell division and expansion regulation to control plant growth. (Yamaguchi and Blumwald, 2005).





Multiple functions of proline in plants. Proline is used for protein synthesis, has protective functions as an osmolyte, contributes to the maintenance of the redox balance, can regulate development and is a component of metabolic signaling networks controlling mitochondrial functions, stress relief and development. Abbreviations: APX, ascorbate peroxidase; CAT, catalase; PCD, programmed cell death.

(Szabados and Savoure, 2009)

Genetic improvement- Frontier technology led crop improvement programmes

1. Screening of diverse germplasm including wild relatives and landraces
Different horticultural species exhibit genotypic differences which provide opportunity for selection of tolerant lines.

2. Marker-assisted selection and quantitative trait loci (QTL) mapping
To identify the genes which either control salt uptake and transport or have an osmotic function or those which could hasten plant growth under salinity stress (Munns, 2005).

3. Genetic transformation
Stable expression of transgenes enhances the ability to tolerate salts in the growing medium. Transgenic mulberry line ST30 exhibited greater salt tolerance due to better cellular membrane stability, photosynthetic yield, less photo-oxidative damage and better water use efficiency resulting from the stable expression of transgene hva1 (Lal et al., 2008).

4. Transgrafting
Grafting of a transgenic rootstock with a conventional wild-type scion variety. As wild-type scion will flower and fruit and not the genetically engineered rootstock, there are ample possibilities for addressing the regulatory and consumer concerns over the flow of genetically engineered pollen (Lev-Yadun and Sederoff , 2001).

5. *In vitro* screening
A fast approach for controlled screening for identifying the underlying physiological mechanisms of salinity tolerance in woody species. Rapid screening for salinity tolerance using in vitro platforms has been successfully achieved in almond (Shibli et al., 2003), apple (Shibli et al., 2000), citrus (Pérez-Tornero et al., 2009), cherry (Erturk et al., 2007), grape (Troncoso et al., 1999), mulberry (Vijayan et al., 2003) and pistachio (Chelli-Chaabouni et al., 2010).

6. *In vitro* selection
Identification of somaclonal variants having high salt tolerance. In fruit crops, this has been attempted only in citrus (Kochba et al. 1982, Ben-Hayyim 1987) and cherry (Ochatt and Power, 1989).

Fig. 1. Photographs of a transgrafted tomato seedling (upper left), and walnut sapling (upper right) used in this study (DNA construct of GE rootstocks as described in Escobar et al., 2001). Illustration of a typical transgraft consisting of a conventional or wild-type fruit-bearing scion grafted onto a GE rootstock (bottom left). *Neither gDNA nor mRNA (Fig. 2B) from the transgene expressed in the GE rootstock accumulated in scion leaves, tomato fruits, or walnut kernels at a detection threshold of 4–22 copies of transgene per PCR (Haroldsen et al., 2012)*

Agronomic interventions

1. Selection of salt tolerant fruit crops and varieties
2. Irrigation practices: Drip irrigation
3. Nutrient management: Use of FYM/compost, supplemental application of calcium, use of mycorrhizal inoculants
4. Leaching salts in the root zone
5. Conjunctive use of poor quality and fresh water in alternate or blended mode
6. Use of plant growth substances

Fruiting in different bal cultivars in saline soils

Performance of guava and bael plants in saline soils of Nain Exp. Farm

THANK YOU

Biosaline Agroforestry for Dry Regions

J.C. DAGAR
Ex-ADG (ICAR)
Emeritus Scientist & Fellow NAAS
dagarjc@gmail.com

Some facts

- Worlds' ~7 b population is expected to be 9.1 b in 2050
  By this time another 1 b Mg of cereals (increase by ~70%) and 200 million Mg of extra livestock products will be required
- About 870 m people (14.9%) were undernourished and 11% were without access to adequate drinking water (2010-12)
- World's agricultural production level has grown on an average between 2-4% during last 50 years and cultivated area by 1% only
- The cropping intensity on irrigated land will increase worldwide from 127% to 129% by 2050 (in developing countries from 143 to147%)
- More than 40% of the increase in food production has come from irrigated area
- Out of 13378 Mha available land area only only 1.6 billion (12%) is currently used for crop production-broadly 37.6% is categorized as agricultural land-only 307 Mha is irrigated

- Globally, the availability of freshwater is 813mm annual rains (108831 km^3/yr). Of this, about 3900 km^3 /yr is withdrawn for human uses from rivers and aquifers: some 2710 km^3 (~70%) is for irrigation, 19% for industries, and 11% for municipal sector (FAO 2012)
- Share for irrigation is highest in Asia (87%) and Africa (85%) followed by Americas (81%), Oceania (77%), but much lower (59%) in Europe

- Therefore, the use of poor quality waters in agriculture are inevitable

Saline water

- About 97.5 % of total global water is saline
- Out of 2.5% fresh water
  - 69.0% is locked in glaciers and snow lakes
  - 30.0% as ground water
  - 0.3% in lakes and rivers
  - 0.7% as soil moisture

(Shiklomanov 1993)

EC units of different waters

	Rain water	Tap water	Sea water
• µS/cm (micro Siemens/cm)	20-50	<1500	50,000-60,000
mS/m (milli S/m)	2-5	<150	5,000 – 6, 000
• dS /m	0.02-0.05	< 1.5	50-60
• mg/l (ppm)	10-30	< 1000	33,000 - 40,000

roughly 640-660 mg/l = 1 dS/m

Fresh water (TDS) 0 – 1000 mg/l
Brackish water 1000 – 10, 000 mg/l
Saline water 10,000 – 100, 000 mg/l
Brine > 100, 000 mg/l

Classification of saline water (Rhoades *et al*. 1992)

Water Class	EC ($dS\ m^{-1}$)	Salt concentration ($mg\ l^{-1}$)	Type of water
Non-saline	<0.7	<500	Drinking and irrigation
Slightly saline	0.7-2	500-1500	Irrigation
Moderately saline	2-10	1500-7000	Primary drainage water and ground water
Highly saline	10-25	7000-15000	Secondary drainage water and ground water
Very highly saline	25-45	15000-35000	Very saline ground water
Brine	>45	>35000	Sea water

Ground water

- Ground water surveys indicate that at least 43 countries use saline water for irrigation
- Poor quality waters being utilized in different states of India are 25 to 84%

- Drylands are territories where water income (rainfall) is less than potential water expenditure (evapo-transpiration, runoff, etc)
- Drylands occupy one-third of world's land surface and are inhabited by more than three-quarters of a billion people

Estimated land use-Drylands (Million ha)

Continent	Irrigated area	Rainfed	Range land	Hyper-arid	Total dryland
Africa	10.42	79.82	1342.35	705.36	2137.95
Asia	92.02	218.17	1571.24	187.84	2069.28
Australia & New Zealand	1.87	42.12	657.22	0	701.21
Europe	11.90	22.11	111.57	0	145.57
North America	20.87	74.17	483.14	3.07	581.24
S. America & Caribbean	8.42	21.35	390.91	19.84	440.50
Total	136.50	457.74	4556.42	916.11	6075.75

Global Degraded Lands (FAO 1996, 2011)

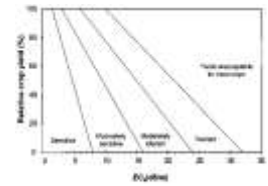
~2 billion ha land is degraded due to anthropogenic factors

Water erosion	56%	(1.12 billion ha)
Wind erosion	28%	(0.56 billion ha)
Chemical degradation	12%	(0.24 b ha)
Physical degradation	4%	(0.08 b ha)

Overgrazing	680 m ha (35%)
Deforestation	580 m ha (30%)
Agricultural mismanagement	550 m ha (27%)
Fuelwood (overexploitation)	137 m ha (7%)
Industry & Urbanization	20 m ha (1%)

Guidelines for saline irrigation waters (RSC < 2.5 me l^{-1}) in India (Minhas and Gupta 1992)

Soil texture (% clay)	Crop tolerance	Upper limits of ECiw (dS m^{-1}) in rainfall region		
		<350 mm	350-550 mm	550-750 mm
Fine soil (>30%)	Sensitive	1.0	1.0	1.5
	Semi-tolerant	1.5	2.0	3.0
	Tolerant	2.0	3.0	4.5
Moderately fine soil (20-30 %)	Sensitive	1.5	2.0	2.5
	Semi-tolerant	2.0	3.0	4.5
	Tolerant	4.0	6.0	8.0
Moderately coarse soil (10-20 %)	Sensitive	2.0	2.5	3.0
	Semi-tolerant	4.0	6.0	8.0
	Tolerant	6.0	8.0	10.0
Coarse soil (<10 %)	Sensitive	-	3.0	3.0
	Semi-tolerant	6.0	7.5	9.0
	Tolerant	8.0	10.0	12.5

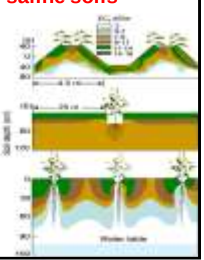


Relative yield compared to the salinity of soil solution (ECe in dS m^{-1}; ECw= 1.5 ECe)

- ECe 4 dS/m or more
- pHs < 8.2
- Dominated by chlorides & sulphates of Na, Ca & Mg
- High osmotic pressure of soil solution
- Associated mainly with arid and semi- arid areas

Plantations on saline soils

- Planting and irrigation in furrows was found most superior and successful method of planting trees on saline waterlogged soils as compared to traditional ridge-trench method



Biomass estimation of trees after 9 years of planting on saline soils

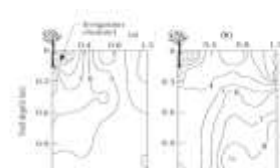
Tree species	Method of planting	Range of soil salinity at 1.2m depth (dS/m)	Range of water table salinity EC (dS/m)	Estimated biomass (t/ ha)
Acacia nilotica	Subsurface Furrow	10.6 - 25.3 11.1 - 21.0	27 - 33 17 - 27	52 67
A. tortilis	Subsurface Ridge	6.8 - 28.1 19.7 - 29.1	12 -33 12 - 33	41 6
Eucalyptus camaldulensis	Furrow	10.0 - 17.9	10 - 35	28
Prosopis juliflora	Subsurface Ridge	10.3 - 24.0 23.5 - 57.5	32 - 36 32 - 36	98 65
Casuarina equisetifolia	Furrow	5.6 - 20.7	10 - 31	28
C. glauca	Furrow	6.5 - 33.9	12 - 19	96
C.obesa	Furrow	9.0 - 19.5	12 - 19	38
Leucaena leucocephala	Subsurface	6.9 - 23.9	10 - 25	30
Tamarix sp.	Furrow	8.2 - 21.3	10 - 32	12

Source: Tomar et al. (1998)

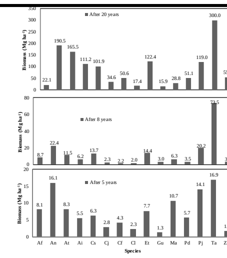
Species suitable for saline soils

Tolerance / (ECe, dS/m)	Trees and shrubs
Very High (> 35)	*Tamarix, Prosopis, Salvadora, Acacia farnesiana*
High salt tolerant (25-35)	*Casuarina ,Terminalia catappa, Thespesia populnea and Cocos nucifera (on specific sites)*
Tolerant (15-25)	*Casuarina (glauca, obesa, equiselifolia), Acacia tortilis, A. nilotica, Callistemon lanceolata, Pongamia pinnata, Eucalyptus camaldulensis, Crescentia alata, Albizia lebbeck, Ziziphus mauritiana, Parkinsonia aculeata etc.*
Moderately tolerant (10-15)	*Casuarina cunninghamiana, Eucalyptus tereticornis, E. rudis, E. microtheca, Acacia catcechu, A. ampliceps, A. eburnea, A. leucophloea, Terminalia arjuna, Samanea saman, Cassia siamea, Albizia procera, Borassus flabellifer, Prosopis cineraria, Azadirachta indica, Dendrocalamus strictus, Butea monosperma, Cassia siamea, Feronia limonia, Leucaena leucocephala, Tamarindus indica, Guazuma ulmifolia, Ailanthus excelsa, Dichrostachys cinerea, Balanites roxburghii, Maytenus emarginatus, Dalbergia sissoo, Salix babylonica, Cordia rothii, Kigelia pinnata.*

Raising trees on calcareous soil with saline irrigation

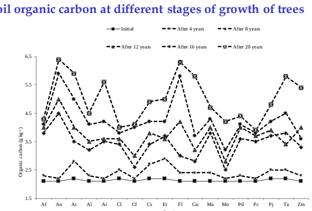


Contour of soil salinity (a) before and (b) after monsoon rains in furrow planted trees (Minhas et al. 1996)



Biomass of trees harvested after 5, 8 and 20 years of growth

Soil organic carbon at different stages of growth of trees



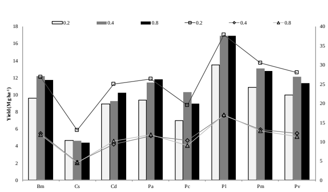
Performance of different forage grasses with saline irrigation

About 30 % of total annual forage may be obtained during lean period when most nomads migrate to the irrigated areas

Gross dry matter yield (t ha^{-1}) of different grasses irrigated with saline water of EC 10 dS m^{-1} (average of 3 years)

Grass species	Irrigation with saline water with Diw/CPE			
	0.2	0.4	0.8	Mean
Brachiaria mutica	9.54	12.15	11.72	11.89
Cenchrus setigerus	4.64	4.57	4.38	4.80
Cynodon dactylon	8.91	9.23	10.20	10.47
Panicum antidotale	9.34	11.41	11.77	11.89
P. coloratum	6.95	10.29	8.93	10.30
P. laevifolium	13.49	16.85	16.88	17.34
P. maximum (cultivated)	10.87	13.04	12.72	13.96
P. maximum (wild)	14.00	14.72	13.72	16.01
P virgatum	9.95	12.10	11.36	12.83
Mean	9.74	11.60	11.30	12.17

Source: Tomar et al. (2003)



Dry biomass yield and water use efficiency of different grasses when irrigated with different Diw/CPE ratio of saline water

Raising fruit trees with saline irrigation

Karonda (*Carissa carandus*) Kaith (*Feronia limonia*)

Yield of karonda after two years

- Karonda produced 910, 927, 840 and 800 kg fruits per ha under different treatments
- 75% plants came to bearings

Yield of Karonda with saline irrigation

Treatment	Plants bearing fruits (%)	Yield (kg/ha)
Traditional (Water with low salinity)	**91**	**1107**
Furrow (Water with low salinity)	**90**	**1156**
Furrow (Water with low/high salinity)	**85**	**829**
Furrow (Water with high salinity)	**76**	**627**
CV (%) LSD (p=0.05/0.01)	3.43 5.85*	3.71 120**

Bael bearing fruits after 4 years

Ber with saline irrigation

Agroforestry with saline water

Barley with karonda (*Carissa carandus*)

Cluster bean with Karonda (*Carissa carandus*)

Anowla with cluster bean after 4 years

Bael with cluster bean after 4 years

Yield (Mg ha^{-1}) of inter-crops grown with fruit trees

Fruit trees	Treatment	Average of five years (2003 to 2007)		Average of four years (2008 to 2011)	
		Barley	Cluster bean*	Mustard	Cluster bean**
-	Control	3.82±0.23	2.22±0.36	3.16±0.29	1.55±0.19
Cc	Low	3.75±0.29	2.10±0.32	2.88±0.16	1.35±0.06
	Low/High	3.63±0.18	1.93±0.30	2.76±0.13	1.30±0.04
	High	3.26±0.15	1.90±0.35	2.61±0.10	1.26±0.02
Eo	Low	3.89±0.25	2.27±0.42	3.61±0.17	1.43±0.13
	Low/High	3.42±0.26	2.09±0.35	3.48±0.12	1.39±0.13
	High	3.16±0.22	1.87±0.30	3.36±0.10	1.33±0.11
Am	Low	3.50±0.22	2.14±0.38	2.68±0.12	1.41±0.22
	Low/High	3.30±0.24	1.99±0.33	2.55±0.15	1.34±0.21
	High	2.99±0.19	1.79±0.28	2.33±0.08	1.26±0.24

*Average of four years; ** Average of 3 years. Cc=*Carissa carandas*; Eo=*Emblica officinalis*; Am=*Aegle marmelos*; Control= Inter-crop raised with low saline water without plantations

Dill (*Anethum graveolense syn. A. sowa*)

Aloe vera

Leaf juice is cathartic, used in liver and spleen ailments, piles & rectal fissures; dried juice in constipation; pulp is given for menstrual irregularity. It is estimated to have about 75 chemical ingredients (lingins, saponins, anthraquinone complex, minerals, vitamins, enzymes, amino acids) useful for body. Used in more than 50 *ayurvedic* drugs.Leaves yield a fibre, leaf & flower stalk pickled. Used in shampoo, cream, lotion & powder industries
Tolerates high salinity, yields 5-7 kg leaves per plant with saline water (EC 12 dS m^{-1}) as compared to 3.2 kg per plant with canal water

Performance of *Aloe vera* under saline irrigation

Irrigation water	*Survival (%)*	*Plant height (cm)*	*Fresh biomass (Mg ha^{-1})*
Canal water	100	48	19
Saline water	88	34	17
Alternate (canal/saline)	100	36	18
Mean	96	36	18
LSD (p=0.05)	NS	NS	NS

Tara-mira (*Eruca sativa*)

Castor (*Ricinus communis*)

Yield performance (Mg ha^{-1}) of dill, taramira and castor grown under different irrigation treatments of saline water of high salinity

Number of irrigations	Dill		Taramira		Castor
	Grain	Straw	Grain	Straw	Seed
3	0.93	7.29	0.97	8.29	3.54
2	0.82	6.91	0.89	6.48	2.77
1	0.68	5.75	0.75	4.63	1.67
LSD (p = 0.05)	0.14	0.59	0.11	0.39	0.65

Dill (*Anethum graveolens*), Taramira (*Eruca sativa*), Castor (*Ricinus communis*)

husked grain yield of isabgol (kg / ha) with different
inity of irrigation waters and their levels

Cultivation of Isabgol with saline water

Unhusked grain yield of isabgol (kg / ha) with different levels of N & P2O5

Nitrogen levels	Phosphorus levels P0	P20	P40	P60	Mean
N0	835	929	1026	962	938
N25	1050	1007	1059	1093	1052
N50	997	1025	949	1018	997
N75	1178	1207	1177	1079	1160
Mean	1015	1042	1053	1038	

CD 5% N – NS ; P_2O_5 – NS ; Interaction - NS

Lepidium sativum

Cassia senna syn.*C. acutifolia* (Senna)

The leaf, flower & pod are household remedy for constipation and as liver-stimulant. Employed as tonic, febrifuge, anthelmintic, in splenic enlargement, anaemia, typhoid, cholera, biliousness, joundice, gout, rheumatism, tumours and amoebic dysentery; externally in eye affections, skin diseases, wounds & burns and to remove pimples.

It can be cultivated successfully in calcareous soils irrigating with saline water up to 12 dS m^{-1} without any yield reduction.

Cultivation of aromatic grasses irrigating with saline water

Vetiver

Lemon grass

Impact of different methods of planting on fresh yield* of lemon grass

Method of planting	Fresh yield (t/ha)
Furrow	7.78
Flat	4.23
Top	2.85
East	3.40
West	3.88
North	3.80
South	3.98
CV	11.67%
LSD (p=0.01)	1.014

* Total of 3 cuttings

Fresh yield*of different varieties of lemon grass under saline irrigation

Varieties	Yield (t/ha)
OD-58	28.3
RRL-16	27.6
Praman	17.4
Krishna	11.7
OD-19	3.3
Pragati	0.9
Nima	0.2
CKP-25	0.1
CV	16.88%
LSD (p=0.01)	3.78

*Total of 4 cuttings

Impact of different irrigation frequency on fresh yield* (Mg ha^{-1}) of lemon grass when irrigated with water of different salinity

Salinity of irrigation (Iw/CPE))	Irrigation schedule				
	0.2 (I_1)	(0.4) I_2	(0.6) I_3	(0.8) I_4	Mean
Low	10.83	11.06	12.95	13.18	12.01
Low/High	8.01	8.26	9.39	10.83	9.12
High	3.39	6.99	8.13	8.11	6.66
Mean	7.41	8.77	10.16	10.71	-

LSD (p=0.05)
Between water of different salinity 2.59;
Between different frequency of irrigation: NS;
Interaction (salinity x frequency) NS

* Total of 4 cuttings

Floriculture with saline irrigation

Chrysanthemum is among the most promising

Evaluation of various flower species

Petro-crops on degraded lands raised with saline water

Jatropha curcas

Euphorbia antisyphilitica

Impact of irrigation schedule on biomass production after 2 years in Euphorbia

Irrigation schedule (days)	Fresh biomass (t ha^{-1})
15	30.05
30	40.63
45	55.65
60	94.38
75	104.45
Rain-fed	68.13
LSD (p=0.05)	11.76

Species for Saline Vertisols

- Among trees *Azadirechta indica* (neem), *Prosopis juliflora, Acacia nilotica, A. eburnea, Butea monosperma, Jatropha curcas, Salvadora persica, Feronia limonia*
- Among grasses *Dichanthium annulatum, Leptachloa fusca, Eragrostis spp., Bothriochloa pertusa, Heteropogon contortus, Chrysopogon aciculatus, Themeda triandra, Tragus biflorus,* **Cymbopogon martinii,* * *C. flexuasus* **Vetiveria zizanioides*, etc.

* Aromatic grasses

Raised and sunken bed technique is ideal for moisture conservation and crop production for vertisols

For Coastal Regions

- Mangroves (*Avicennia, Bruguira, Ceriops, Cynomitra, Exoecaria, Kandelia, Nypa, Rhizophora, Heritieria, sonneratia, Xylocarpus*)
- Associate mangroves (*Terminalia catappa, Thespesia populnia, Casuarina, Salvadora persica, Pandanus, Pongamia pinnata, Borassus flabellifer*, etc)
- *Salicornia, Calophyllum, Pongamia, Nypa, Salvadora, Terminalia*, etc. are of industrial importance
- Skimming of fresh water through improved doruvu for agri-horticultural systems
- Mangrove-based aquaculture having coconut and other trees on bunds of fish ponds

Some important potential under-explored crops

Eel grass-*Zosterra marina*- consumed by Seri Indians
Palmer salt grass- *Distichlis palmeri* -consumed as bread
Pearl millet- *Pennesitum typhoides* coarse grain
Purselane - *Sesuvium portulacastrum* - vegetable
Quinoa- *Chenopodium quinoa, C. alba*- soup, vegetables
Salicornia bigelovii - oil
Sarcocornia spp- salads, vegetables
Tetragonia tetragonioides- frogen like spinach
Sea fennel- *Crithumum maritinum – food*
Palmyrah palm- *Borassus* – radicle and seed eaten roasted
Coastal almond- *Terminalia catappa* – seed oil
Sugar beet – *Beta vulgaris* – vegetable, sugar, salad
Common purslane – *Portulaca oleracea*
Kosteletzkya virginica- rich in protein
Suaeda torreyana - 25% oil
Many more

Other potential halophytes

Nypa fruticans
Calophyllum inophyllum
Citrulus colocynthis -bitter apple
Pandanus spp
Parthenium argentatum – rubber source
Simondsia chinensis
Salvadora persica

Many medicinal & aromatic plants
Forages – *Atriplex, Panicum, Paspalum, Pennesetum, Sporobolus*, ...
Paper material- *Typha, Spartina, Phragmites, Juncus*.........

Sunderbans

(mangrove forest 2125 sq km across 56 islands)

- Form largest Tiger Reserve & National Park
- Part of largest delta
- Home of swimming man eating tigers, estuarine crocodiles, sharks, snakes, birds and pirates.
- Fishing and honey collection main livelihood

Aqua-culture with mangroves. (Coconut cultivation in background)

Way forward

- Developing new halophytic crops through genetic improvement but through adaptation and proper selection is quicker way of finding suitable crops---and energy producing plants
- Research on methodology- amendments, drip, response of climate change
- Identification of proper and competent salt-tolerant root stocks for fruit trees
- Clonal (forest trees) and varietal (fruit trees) trials
- Impact of salinity on quality aspects
- Value addition

Thank you very much

Plantation of Trees with Saline/ Sodic Waters

O.S. Tomar
Ex- Principal Scientist

Central Soil Salinity Research Instiute
Karnal-132 001 (Haryana)

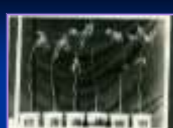
Treatments

EC Levels : 2 and 4 dS/m
RSC Level : 5
(i) 5 me/l
(ii) 10 me/l
(iii) 15 me/l
(iv) Gypsum application to reduce RSC from 10-15 me/l
(v) Gypsum application to reduce RSC from 15-to 5 me/l
Control (Best available water EC 0.4 dS/m, RSC 0.6 me/l
Forest Tree Species : Two
(i) Eucalyptus tereticornis
(ii) Albizzia lebbeck

Effect of irrigation waters of varying EC and RSC levels and of gypsum application on height (cm) of *Eucalyptus tereticornis* at 16 months after transplanting in pots

EC (dS/m)	RSC (me/l) 5	10	15	10→5	15→5	Mean
BAW	-	-	-	-	-	114
2	105	115	37	121	113	108
4	65	67	68	69	57	65

CD 5%
EC – 5.7, RSC – 9.0, EC x RSC- 12.7

Effect of sodic waters (EC2 mmhos/cm) and of gypsum at early



Effect of irrigation waters of varying EC and RSC levels and of gypsum application on the dry weight per plant (g) of Eucalyptus tereticornis at 16 months after transplanting in pots.

EC (dS/m)	RSC (me/l) 5	10	15	10→5	15→5	Mean
BAW	-	-	-	-	-	51
2	45	54	38	56	51	49
4	26	27	28	30	28	28

CD 5%
EC – 1.8, RSC – 2.8, EC x RSC- 4.0

Effect of irrigation waters of varying EC and RSC levels and of gypsum application on height (cm) of Albizzia Lebbeck at 16 months after transplanting in pots.

EC (dS/m)	RSC (me/l) 5	10	15	10→5	15→5	Mean
BAW (0.4)	-	-	-	-	-	70
2	57	49	39	63	64	54
4	20	23	26	25	27	24

CD 5%
EC – 5.6, RSC – 8.8, EC x RSC- 12.4

Effect of irrigation waters of varying EC and RSC levels and of gypsum application on the dry weight per plant (g) of Albizzia Lebbeck at 16 months after transplanting in pots

EC (dS/m)	RSC (me/l) 5	10	15	10→5	15→5	Mean
BAW	-	-	-	-	-	21
2	27	16	14	27	29	23
4	6	8	13	10	14	10

CD 5%
EC – 1.4, RSC – 2.3, EC x RSC- 3.2

Effect of saline water irrigation and fertilizer application on seedling shoot growth (cm) of three tree species

Fertilizers	Saline water (EC-ds/m) 0.4	3	5	7	Mean
	Eucalyptus tereticornis				
Control	29.5	3.7	3.0	X	9.1
N	26.7	4.8	3.3	X	8.7
P	25.0	7.2	X	X	8.1
Mean	27.1	5.2	2.1	X	-
CD 55%	EC-4.2 ; Fertilizer-NS; Interaction-NS				
	Acacia nilotica				
Control	31.9	23.2	8.5	X	16.4
N	30.2	26.0	10.6	4.3	17.3
P	29.6	23.6	8.0	X	15.3
Mean	31.2	24.3	9.0	1.4	
CD 55%	EC-4.2 ; EC-3.9 ; Fertilizer-NS; Interaction-NS				
	Prosopis juliflora				
Control	23.0	21.9	15.9	5.3	16.5
N	23.2	20.8	16.3	5.7	16.5
P	26.9	20.8	16.1	6.4	176
Mean	24.4	21.2	16.1	5.8	
CD 55%	EC-.2.4 ; Fertilizer-NS; Interaction-NS				

Plant survival percent, growth and shoot biomass of different tree species after 9 years of transplanting

Tree species	Survival %	Height (cm)	DSH (cm)	DBH (cm)	Shoot biomass (t/ha)
Acacia auriculiformis	0	-	-	-	0.040
A. farnesiana	83	457	8.8	8.6	25.739
A. nilotica	78	745	15.5	14.3	63.253
A. tortilis	67	663	13.1	10.70	31.638
A. tortilis (Hybrid)	63	690	16.0	15.3	32.957
Albizzia lebbeck	4	276	9.3	7.33	0.000
Azadirachta indica	92	473	11.9	10.4	18.443
Bauhinia variegata	0	-	-	-	0.000
Cassia siamea	63	730	15.3	12.3	33.895
C. javanica	44	390	8.93	5.37	7.823
C. glauca	0	-	-	-	0.000
C. fistula	54	533	11.8	10.3	8.679
Callistemon lanceolatus	54	430	10.2	7.3	6.409

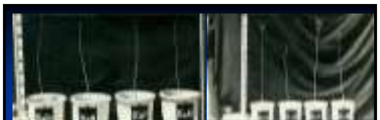
Casuarina equisetifolia	6	387	6.03	3.03	0.385
Crescentia alata	0	-	-	-	0.000
Dalbergia sissoo	0	-	-	-	0.411
Eucalyptus tereticornis	75	10.9	13.3	10.1	37.599
Feronia limonia	77	353	7.3	5.2	4.392
Guazuma ulmifolia	25	580	11.70	8.60	7.504
Melia azedarach	42	630	20.1	16.5	23.518
Pithecellobium dulce	63	470	10.3	8.6	12.915
Pongamia pinnata	15	180	4.27	1.73	0.425
Prosopis cineraria	92	293	6.33	4.4	3.165
P. juliflora	84	670	14.4	11.8	55.123
Samanea saman	0	-	-	-	0.021
Syzygium cuminii	-	-	-	-	0.000
Tamarix articulata	7	12.0	35.7	27.4	167.54
Terminalia arjuna	0	-	-	-	2.350
Tecomella undulata	2	240	4.3	2.7	8.194
Zizyphus mauritiana	63	373	6.67	5.4	14.454
Mean	47	414	9.4	7.6	13.31
CD (P=0.05)	25	187	4.6	3.7	6.62

Effect of N and P on the height increment per plant (cm) of Eucalyptus tereticornis under irrigation with water of varying salinity at 14 months after transplanting in pots

ECiw X 10^3	Fertilizers C	N	P	N+P	Mean
BAW	74	81	82	83	80
5	24	19	32	33	27
10	8	5	18	14	1
Mean	35	35	44	43	11
CD 5 %	ECiw-5.8;	Fertilizers-6.7 Inter-NS			

Effect of saline water irrigation and fertilizers on height growth (cm) at 12 months after transplanting in the field

ECiw X 10^3	Fertilizers PONO	PON1	PIN0	PIN1	Mean	
0.4	360	371	369	434	384	
5.0	355	368	364	413	375	
10.0	357	342	369	404	368	
15.0	264	336	350	423	343	334
Mean	354	363	419			
CD 5%	IW-NS ;	N-34 ; P-21				



Effect of nitrogen and phosphatic fertilizers on the height growth of Eucalyptus hybrid under irrigation with waters of different salinity levels

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Thank You

Plantation of Trees with Saline/ Sodic Waters

O.S. Tomar

Ex- Principal Scientist
Central Soil Salinity Research Instiute
Karnal-132 001 (Haryana)

According to the National Forest Policy of India (1952), at least 33% of the total land area should be under forest for a balanced agrarian economy where as it was about 22.7% as per the land use pattern given by the Government of India in 1982. Thus, extension of forest area requires potentially arable lands presently lying barren to be afforested because the fertile lands can not be spared for the obvious reasons of food scarcities. Substantial portion of the arid regions lies barren for want of water during establishment of tree plantation. Unfortunately, the water quality in 32-83% of the aquifers in such areas, surveyed in different states of the country have been observed to be poor in quality (Minhas and Gupta, 1992). Better quality of irrigation waters are preferably used for cereal crop production and option of irrigating plantation with good quality water is considered less attractive. Mostly, saline waters are not being presently utilized for lack of technology and hesitance of foresters to rehabilitate these areas.

Several workers have earlier reported the effects of saline irrigation on the performance of forest tree species. Tomar and Yadav (1983) observed that plantation of *Eucalyptus tereticornis* can be raised successfully with saline waters upto EC of 15 ds/m provided the build up of soil salinity remains less then ECe 10 ds/m. Ahmad et al. (1985) reported that plants of *Melia azedarach* showed more rapid growth than *Azadirachta indica* when irrigated with saline water (ECiw 4.5-14.0) but both plants could be grown for afforestation on sandy deserts using underground saline water for irrigation where non-saline water in not available. Chaturvedi (1984) observed that plants of *Prosopis juliflora, Acacia nilotica, Terminalia arjuna, Syzygium cuminii, Albizzia lebbeck, Pongammia pinnata, Cassia articulata, Adhatoda vasica* and *Cassia siamea* performed well when irrigated with saline waters ranging from EC 4.0-6.1 ds/m. Wood et al. (1975) suggested local provenances of *Acacia nilotica, A. tortilis, prosopis spi igera* and *zizyphus spina-christi* for irrigated forestry with saline waters. Tamarix spp. has been identified highly salt tolerant by many workers.

With saline irrigation, pre-and post-planting management strategies should be such those minimise the salinity build up and thus its impact effects on transplanted tree saplings (Armitage, 1984; Gupta et al, 1994). Earlier efforts in this direction (Tomar et el, 1994; Minhas et al, 1997) show that furrow planting technique could be adopted as an afforestation practice for arid soils falling with continental monsoon-type climate in view of creation of niches having the favorable water and salt regimes for the better establishment of tree saplings.

Treatments

EC Levels : 2 and 4 dS/m

RSC Level : 5

(i) 5 me/l

(ii) 10 me/l

(iii) 15 me/l

(iv) Gypsum application to reduce RSC from 10 to 15 me/l

(v) Gypsum application to reduce RSC from 15 to 5 me/l

Control (Best available water EC 0.4 dS/m, RSC 0.6 me/l

Forest Tree Species : Two

(i) Eucalyptus tereticornis

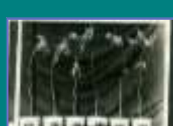
(ii) Albizzia lebbeck

Effect of irrigation waters of varying EC and RSC levels and of gypsum application on height (cm) of Eucalyptus tereticornis at 16 months after transplanting in pots.

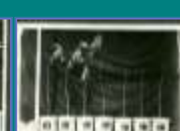
EC (dS/m)	RSC (me/l)					
	5	10	15	10→5	15→5	Mean
BAW	-	-	-	-	-	114
2	105	115	37	121	113	108
4	65	67	68	69	57	65

CD 5%

EC – 5.7, RSC – 9.0, EC x RSC- 12.7



Effect of sodic waters (EC2 mmhos/cm) and of gypsum at early



Effect of irrigation waters of varying EC and RSC levels and of gypsum application on the dry weight per plant (g) of Eucalyptus tereticornis at 16 months after transplanting in pots.

EC (dS/m)	RSC (me/l)					
	5	10	15	10–5	15–5	Mean
BAW	-	-	-	-	-	51
2	45	54	38	56	51	49
4	26	27	28	30	28	28

CD 5%

EC – 1.8, RSC – 2.8, EC x RSC- 4.0

Effect of irrigation waters of varying EC and RSC levels and of gypsum application on height (cm) of Albizzia Lebbeck at 16 months after transplanting in pots.

EC (dS/m)	RSC (me/l)					
	5	10	15	10 5	15 5	Mean
BAW (0.4)	-	-	-	-	-	70
2	57	49	39	63	64	54
4	20	23	26	25	27	24

CD 5%

EC – 5.6, RSC – 8.8, EC x RSC- 12.4

Effect of irrigation waters of varying EC and RSC levels and of gypsum application on the dry weight per plant (g) of Albizzia Lebbeck at 16 months after transplanting in pots.

EC (dS/m)	RSC (me/l)					
	5	10	15	10–5	15–5	Mean
BAW	-	-	-	-	-	21
2	27	16	14	27	29	23
4	6	8	13	10	14	10

CD 5%

EC – 1.4, RSC – 2.3, EC x RSC- 3.2

General Characteristics of the experimental area

- **Climate** : Semi-arid
- **Soil** : Calcareous Saline Soils
- **Texture** : Sandy loam
- **Land form** : Plain
- **Ground water** : Saline ECiw 8.5-10.5 dS m^{-1}
- **Water-table depth** : About 8.0 m
- **Drainage** : Good
- **Moisture conditions** : Slight moist below 20-25 cm depth
- **Erosion** : Slight
- **Visual salts** : Nil

Some initial physico-chemical properties of the experimental soil

Soil depth (m)	silt	clay	sand	pH_2	ECe (ds/m)	$CaCo_3$%	
	%					Mean	Range
0-0.3	18.6	19.5	62.0	8.3	1.0	6.3	1.8-12.1
0.3-0.6	17.5	21.6	61.0	8.3	1.1	6.7	2.4-15.0
0.6-0.9	17.2	21.9	60.9	8.3	0.9	7.6	1.7-12.1
0.9-1.2	18.3	22.1	59.6	8.3	1.0	7.5	1.8-12.2

Survival percentage of different tree species in different years after transplanting of saplings

Tree species	Survival percentage in different years after transplanting of saplings								
	1	2	3	4	5	6	7	8	9
Acacia auriculiformis	97	72	43	10	0	0	0	0	0
A. farnesiana	100	97	97	97	97	97	97	97	83
A.nilotica	99	99	99	97	97	97	97	97	78
A. tortilis	100	97	97	97	96	96	96	94	67
A. tortilis (Hybrid)	100	98	98	98	98	98	96	88	63
Albizzia lebbeck	100	85	82	72	28	7	4	4	4
Azadirachta indica	100	100	100	100	100	92	90	90	90
Bauhinia variegata	89	20	0	0	0	0	0	0	0
Cassia siamea	100	85	84	83	83	81	81	81	63

C. javanica	93	93	93	93	93	92	67	67	44
C. glauca	97	54	0	0	0	0	0	0	0
C. fistula	100	72	72	72	72	71	56	56	54
Callistemon lanceolatus	97	89	89	79	77	67	56	56	54
Casuarina equisetifolia	97	90	73	66	23	9	6	6	6
Crescentia alata	69	66	0	0	0	0	0	0	0
Dalbergia sissoo	97	67	64	26	26	26	26	26	0
Eucalyptus tereticornis	100	98	94	90	88	88	88	88	75
Feronia limonia	83	82	82	82	82	82	77	77	77
Guazuma ulmifolia	75	71	71	59	59	55	41	41	25

Height growth (cm) of different tree species in different years after transplanting saplings

Tree species	Height growth of trees (cm) in different years after transplanting								
	1	2	3	4	5	6	7	8	9
Acacia auriculiformis	58	65	68	-	-	-	-	-	-
A.farnesiana	204	309	329	383	401	401	412	457	457
A. nilotica	197	343	447	552	641	684	689	710	745
A.tortilis	138	239	308	376	506	555	555	663	663
A. tortilis (Hybrid)	145	253	331	411	458	473	473	570	690
Albizzia lebbeck	52	90	112	112	127	127	145	276	276
Azadirachta indica	122	224	265	367	382	395	395	473	473
Bauhinia variegata	65	65	-	-	-	-	-	-	-
Cassia siamea	164	320	395	496	588	649	667	670	730
C. javanica	116	246	246	298	344	344	363	390	390
C. glauca	42	64	-	-	-	-	-	-	-
C. fistula	54	159	262	331	378	433	461	533	533
Callistemon lanceolatus	113	174	227	281	293	320	355	430	430
Casuarina equisetifolia	104	154	154	195	387	387	387	387	387
Crescentia alata	89	162	-	-	-	-	-	-	-
Dalbergia sissoo	66	68	98	128	135	139	162	163	-

Eucalyptus tereticornis	154	393	558	659	782	822	1001	1001	1090
Feronia limonia	35	75	105	168	227	247	320	353	353
Guazuma ulmifolia	114	254	254	330	383	383	383	580	580
Melia azedarach	193	331	386	438	523	591	591	613	630
Pithecellobium dulce	149	299	331	381	406	406	443	443	470
Pongamia pinnata	49	76	104	150	158	164	164	180	180
Prosopis cineraria	72	144	164	198	227	241	241	293	293
P. juliflora	251	352	392	497	585	670	670	670	670
Samanea saman	144	245	245	295	313	313	313	-	-
Syzygium cuminii	-	-	-	-	-	-	-	-	-
Tamarix articulata	186	334	473	769	867	924	1033	1033	1200
Termimalia arjuna	67	67	76	77	77	85	85	-	-
Tecomella undulata	85	124	132	149	159	159	200	240	240
Zizyphus mauritiana	121	182	193	245	282	282	286	373	373
Moringa oleifera*	-	-	-	-	-	367	371	500	500
Mean	115	188	254	321	386	392	396	400	414
CD(P=0.05)	29	56	70	130	150	139	209	226	187

* Planted in 6th year of plantation

Melia azedarach	100	100	100	96	81	75	73	73	42
Pithecellobium dulce	100	99	98	94	92	86	77	77	63
Pongamia pinnata	100	94	89	81	76	57	29	29	15
Prosopis cineraria	100	97	97	97	97	95	92	92	92
P. juliflora	96	96	96	96	96	96	94	94	84
Samanea saman	100	82	78	59	59	49	13	0	0
Syzygium cuminii	0	0	0	0	0	0	0	0	0
Tamarix articulata	92	92	88	67	67	67	67	67	67
Terminalia arjuna	100	97	92	45	36	21	3	0	0
Tecomella undulata	92	86	78	64	53	53	39	39	21
Zizyphus mauritiana	100	100	100	100	96	94	77	77	63
Moringa oleifera	100	100	81	75	72	56	19	19	19
Mean	95	86	78	71	66	61	59	48	47
CD (P=0.05)	8	56	19	26	16	23	26	26	25

Diameter (DSH) growth (cm) of different tree species in different years after transplanting of sapling

Tree species	Diameter growth of trees (cm) in different years after transplanting								
	1	2	3	4	5	6	7	8	9
Acacia auriculiformis	0.9	1.8	1.9	2.1	-	-	-	-	-
A. farnesiana	2.8	4.4	4.9	6.1	6.4	7.1	7.1	7.7	8.8
A. nilotica	3.1	5.7	7.4	10.2	11.9	12.7	13.5	14.6	15.5
A.tortilis	2.2	3.8	5.4	6.1	8.5	9.4	9.7	12.1	13.1
A. cupressiformis	2.7	4.4	5.8	7.3	8.4	9.0	9.7	13.8	16.0
Albizzia lebbeck	0.7	1.7	1.8	1.8	2.4	2.9	4.0	8.5	9.3
Azadirachta indica	2.4	4.7	5.8	7.9	9.5	10.9	11.6	11.8	11.9
Bauhinia variegata	0.8	1.1	2.1	-	-	-	-	-	-
Cassia siamea	2.8	5.1	6.4	8.3	13.1	13.1	13.1	14.6	15.3
C. javanica	1.7	4.1	4.5	6.3	7.3	7.9	8.5	8.9	8.9
C. glauca	0.7	1.6	-	-	-	-	-	-	-
C. fistula	0.6	2.4	5.1	6.4	8.2	9.6	10.7	11.7	11.8
Callistemon lanceolatus	1.2	2.3	3.6	5.	5.7	6.7	7.8	9.1	10.2
Casuarina equisetifolia	1.5	2.4	2.7	2.7	4.4	4.9	4.9	6.0	6.1
Crescentia alata	1.7	2.4	-	-	-	-	-	-	-
Dalbergia sissoo	0.6	1.4	1.6	2.1	2.1	2.4	2.7	2.8	-
Eucalyptus tereticornis	1.8	4.3	6.8	7.8	9.5	10.7	11.9	12.7	13.3

Feronia limonia	1.4	2.2	2.7	3.2	3.7	4.8	5.9	7.1	7.3
Guazuma ulmifolia	2.7	5.2	5.2	7.3	8.5	8.5	8.5	11.7	11.7
Melia azedarach	3.9	6.7	9.2	10.6	13.7	16.4	16.4	17.6	20.1
Pitecellobium dulce	2.0	4.1	5.1	6.3	7.1	8.3	8.8	9.9	10.3
Pongamia pinnata	0.9	1.7	2.1	2.9	3.1	3.4	3.4	4.3	4.3
Prosopis cineraria	0.9	2.3	2.9	3.8	4.3	5.1	5.1	6.3	6.3
P. juliflora	2.6	5.5	6.1	8.4	10.1	11.8	12.9	13.9	14.4
Samanea saman	2.6	4.3	4.3	6.4	7.1	7.1	7.1	-	-
Syzygium cuminii	-	-	-	-	-	-	-	-	-
Tamarix articulata	2.9	6.7	11.1	19.1	22.4	24.5	24.5	29.9	35.7
Termimalia arjuna	1.3	1.9	1.9	1.9	1.9	1.9	1.9	1.9	-
Tecomella undulata	1.2	2.1	2.2	2.6	2.7	3.1	3.3	4.2	4.3
Zizyphus mauritiana	1.5	2.6	2.8	3.6	4.1	4.5	5.0	6.7	6.7
Moringa oleifera (Only 1 replication)	-	-	-	-	-	8.6	9.9	10.8	8.9
Mean	1.8	3.4	4.5	6.0	7.4	8.0	8.1	8.3	9.4
CD(P=0.05)	0.7	3.2	1.4	2.5	3.4	3.1	3.9	5.5	4.6

Plant survival percent, growth and shoot biomass of different tree species after 9 years of transplanting

Tree species	Survival %	Height (cm)	DSH (cm)	DBH (cm)	Shoot biomass (t/ha)
Acacia auriculiformis	0	-	-	-	0.040
A. farnesiana	83	457	8.8	8.6	25.739
A. nilotica	78	745	15.5	14.3	63.253
A. tortilis	67	663	13.1	10.70	31.638
A. tortilis (Hybrid)	63	690	16.0	15.3	32.957
Albizzia lebbeck	4	276	9.3	7.33	0.000
Azadirachta indica	92	473	11.9	10.4	18.443
Bauhinia variegata	0	-	-	-	0.000
Cassia siamea	63	730	15.3	12.3	33.895
C. javanica	44	390	8.93	5.37	7.823
C. glauca	0	-	-	-	0.000
C. fistula	54	533	11.8	10.3	8.679
Callistemon lanceolatus	54	430	10.2	7.3	6.409

Casuarina equisetifolia	6	387	6.03	3.03	0.385
Crescentia alata	0	-	-	-	0.000
Dalbergia sissoo	0	-	-	-	0.411
Eucalyptus tereticornis	75	10.9	13.3	10.1	37.599
Feronia limonia	77	353	7.3	5.2	4.392
Guazuma ulmifolia	25	580	11.70	8.60	7.504
Melia azedarach	42	630	20.1	16.5	23.518
Pithecellobium dulce	63	470	10.3	8.6	12.915
Pongamia pinnata	15	180	4.27	1.73	0.425
Prosopis cineraria	92	293	6.33	4.4	3.165
P. juliflora	84	670	14.4	11.8	55.123
Samanea saman	0	-	-	-	0.021
Syzygium cuminii	-	-	-	-	0.000
Tamarix articulata	7	12.0	35.7	27.4	167.54
Terminalia arjuna	0	-	-	-	2.350
Tecomella undulata	2	240	4.3	2.7	8.194
Zizyphus mauritiana	63	373	6.67	5.4	14.454
Mean	47	414	9.4	7.6	13.31
CD (P=0.05)	25	187	4.6	3.7	6.62

Ranking of tree species for their suitability to site conditions

Tree species	Survival %	Rank	Height (cm)	DSH (cm)	HXD cm^{3}	Rank	Biomas	Rank	A+B+C	Over all rank
A. auriculiforimis	0	18	-	-	00	25	00.04	24	67	22
A.farnesiana	97	1	457	7.7	3519	15	17.08	9	25	7
A. nilotica	97	1	710	14.6	10366	4	39.82	2	7	1
A.tortilis	94	2	663	12.1	8022	7	20.11	7	16	3
A. tortilis (Hybrid)	88	5	570	13.8	7866	8	22.19	5	18	5
Albizzia lebbeck	4	17	276	8.5	2346	19	00.00	25	61	21
A. indica	90	4	473	11.8	5581	11	12.21	10	25	7
B. variegata	0	18	-	-	00	25	00.00	25	68	23
Cassia siamea	81	6	670	14.6	9782	5	20.20	6	17	4
C. javanica	67	9	390	8.9	3471	16	05.53	13	38	11
C. glauca	0	18	-	-	00	25	00.00	25	68	23
C. fistula	56	10	553	11.7	6236	10	06.51	12	32	9
C. lanceolatus	56	10	430	9.1	3913	14	04.38	16	40	13
C. equiosetifolia	6	16	387	6.0	2322	20	00.26	21	57	18
Crescentia alata	0	18	-	-	00	25	00.00	25	68	23
Dalbergia sissoo	26	13	163	2.8	456	24	00.21	22	59	20
E. tereticornis	88	5	1001	12.7	12713	2	22.79	4	11	2
Feronia limonia	77	7	353	7.1	2506	17	02.22	17	41	14

G. ulmifolia	41	11	580	11.7	6786	9	04.47	15	35	10
Melia azedarach	73	8	613	17.6	10789	3	17.22	8	19	6
P. dulce	77	7	443	9.9	4386	13	09.45	11	31	8
P. pinnata	29	13	180	4.3	774	23	00.23	22	58	19
P. cineraria	92	3	293	6.3	1846	21	01.67	18	42	15
P. juliflora	94	2	670	13.9	9313	6	34.89	3	11	2
Samanea saman	0	18	-	-	00	25	00.02	25	68	23
Syzygium cuminii	0	18	-	-	00	25	00.00	25	68	23
T. articulata	67	9	1033	29.9	30887	1	90.00	1	11	2
T. arjuna	0	18	-	-	00	25	0.00	25	68	23
T. undulata	39	12	240	4.2	1008	22	1.22	19	53	17
Z. mauritiana	77	7	373	6.7	2499	18	5.06	14	39	12
Moringa oleifera	19	15	300	10.8	5400	12	1.13	20	47	16

Ranking of tree species for their suitability to site conditions

Tree species	Ranking of tree species to site based on			
	Survival (A)	Ht.x DSH (B)	Biomas (C)	Overall (A+B+C)
A. auriculiforimis	18	25	24	22
A.farnesiana	1	15	9	7
A. nilotica	1	4	2	1
A.tortilis	2	7	7	3
A. ctortilis (Hybrid)	5	8	5	5
Albizzia lebbeck	17	19	25	21
A. indica	4	11	10	7
B. variegata	18	25	25	23
Cassia siamea	6	5	6	4
C. javanica	9	16	13	11
C. glauca	18	25	25	23
C. fistula	10	10	12	9
C. lanceolatus	10	14	16	13
C. equiosetifolia	16	20	21	18
Crescentia alata	18	25	25	23
Dalbergia sissoo	13	24	22	20
E. tereticornis	5	2	4	2

Feronia limonia	7	17	17	14
G. ulmifolia	11	9	15	10
Melia azedarach	8	3	8	6
P. dulce	7	13	11	8
P. pinnata	13	23	22	19
P. cineraria	3	21	18	15
P. juliflora	2	6	3	2
Samanea saman	18	25	25	23
Syzygium cuminii	18	25	25	23
T. articulata	9	1	1	2
T. arjuna	18	25	25	23
T. undulata	12	22	19	17
Z. mauritiana	7	18	14	12
Moringa oleifera	15	12	20	16

Soil salinity (down to 120 cm depth) under different tree species at different periods

Tree species	After 1 Years	After 5 years	After 8 years	Mean
Acacia auriculiformis	7.63	5.82	3.86	5.77
A.farnesiana	7.25	.93	4.54	5.58
A. nilotica	5.27	5.44	5.68	5.46
A.tortilis	7.60	5.94	5.85	6.46
A. tortilis (Hybrid)	7.10	7.10	4.44	6.21
Albizzia lebbeck	7.82	6.18	3.22	5.74
Azadirachta indica	7.23	6.11	5.11	6.15
Bauhinia variegata	7.35	-	-	-
Cassia siamea	6.20	5.27	8.38	6.62
C. javanica	7.21	5.41	4.83	5.82
C. glauca	6.09	4.36	4.14	4.86
C. fistula	7.50	5.76	4.38	4.42
Callistemon lanceolatus	6.36	4.89	3.91	5.05
Casuarina equisetifolia	10.56	6.51	5.65	7.57
Crescentia alata	7.52	5.19	4.38	5.70
Dalbergia sissoo	5.78	5.55	5.78	5.70
Eucalyptus tereticornis	7.06	7.25	5.15	6.49

Feronia limonia	5.60	4.66	5.31	5.19
Guazuma ulmifolia	7.06	6.00	5.66	6.24
Melia azedarach	7.27	6.01	3.72	5.67
Pitecellobium dulce	6.38	5.96	3.57	5.30
Pongamia pinnata	5.77	4.88	5.52	5.39
Prosopis cineraria	5.81	4.30	4.37	4.83
P. juliflora	6.51	6.53	5.53	6.19
Samanea saman	6.04	5.08	5.92	5.68
Syzygium cuminii	5.60	-	-	-
Termimalia arjuna	8.30	6.07	5.01	6.46
Tecomella undulata	6.40	4.93	5.73	5.69
Zizyphus mauritiana	6.81	6.10	5.65	6.19
Mean	6.86	5.64	5.04	-

Weighted mean of organic carbon % in 30 cm depth under some forest tree species* after 3 and 8 years planting

Tree species	3 years	8 years	Mean
Acacia. farnesiana	0.24	0.38	0.31
A. nilotica	0.23	0.45	0.34
A.tortilis	0.29	0.33	0.31
A. tortilis (Hybrid)	0.24	0.37	0.31
Azadirachta indica	0.23	0.41	0.32
Cassia siamea	0.28	0.36	0.32
C. fistula	0.22	0.26	0.24
Callistemon lanceolatus	0.25	0.35	0.30
Eucalyptus tereticornis	0.28	0.37	0.33
Feronia limonia	0.23	0.30	0.27
Guazuma ulmifolia	0.23	0.29	0.26
Melia azedarach	0.22	0.43	0.33
Pitecellobium dulce	0.24	0.37	0.31
Prosopis cineraria	0.22	0.38	0.30
P. juliflora	0.25	0.36	0.31
Zizyphus mauritiana	0.23	0.32	028
Mean	0.24	0.36	0.30

* Initial organic carbon % in 30 cm depth was 0.22

Ionic composition of leaves of different tree species

Tree species	Na	K	Ca	Mg	Zn	Fe	Mn	Total
	(%)				(ppm)			(%)
A. farnesiana	0.71	0.90	2.87	0.38	53	732	86	5.78
A. nilotica	0.71	0.82	2.77	2.08	50	768	77	4.04
A.tortilis	0.76	0.75	3.77	0.46	49	900	90	5.16
A. tortilis (Hybrid)	0.85	1.05	3.4	0.49	38	993	83	5.37
Albizzia lebbeck	0.57	0.60	4.34	1.14	20	553	92	6.20
Azadirachta indica	0.87	2.02	3.93	0.70	23	344	73	6.79
Cassia siamea	0.65	0.82	3.05	0.27	28	375	81	5.16
C. javanica	0.58	0.75	3.66	0.35	36	466	179	4.88
C. fistula	0.70	1.20	2.45	0.12	48	643	136	3.92
Callistemon lanceolatus	2.01	0.52	1.57	0.36	21	258	81	2.79
Casuarina equisetifolia	0.67	0.67	3.66	0.59	48	878	77	5.09
Dalbergia sissoo	0.70	0.90	4.23	0.55	32	508	251	5.83
Eucalyptus tereticornis	3.37	0.75	1.65	0.31	25	764	206	3.15
Feronia limonia	0.61	0.90	3.45	0.97	17	250	109	5.42
Guazuma ulmifolia	1.25	1.12	3.34	0.78	53	582	100	5.45
Melia azedarach	0.70	0.97	4.98	1.06	26	366	85	7.13

Pithecellobium dulce	0.90	1.35	3.04	0.57	42	567	104	5.12
Pongamia pinnata	0.80	0.90	4.38	0.68	47	564	186	6.12
Prosopis cineraria	0.62	0.75	3.10	0.45	61	714	145	4.46
P. juliflora	0.76	1.95	3.98	0.64	48	693	189	6.74
Tamarix articulata	3.56	.27	3.65	0.86	34	397	70	6.19
Termimalia arjuna	0.75	0.67	3.38	0.73	44	827	119	4.96
Zizyphus mauritiana	0.78	1.20	3.36	1.07	39	493	197	5.77
Mean	1041	9946	34457	6047	38	593	122	52879

Effect of saline irrigation schedules with saline and canal waters on the performance of D. Sissoo and A. nilotica at 7 ½ years after transplanting

Treatments	Survival (%)	Height (m)	DSH (mm)
Tree species			
A. nilotica	97	5.54	98
D. sissoo	87	2.78	50
LSD(p=0.05)	7	0.45	7
Water Quality			
Canal water	93	4.56	80
Saline water	90	3.75	68
LSD(p=0.05)	NS	0.36	8
Irrigation schedules			
Diw/CPE=0.1	91	3.97	70
0.2	95	4.17	73
B. channel0.2	90	4.32	77
LSD (p=0.05)	NS	0.17	4
Interaction	All NS		

Effect of various irrigation schedules with canal and saline water on cut biomass production (t/ha) by Dalbergia and Acacia nilotica

Tree spp./ Water quality	Jan. 1993				Jan. 1999			
	0.1	0.2	0.2*	Mean	0.1	0.2	0.2	Mean
Acacia nilotica								
CW	11.3	14.0	14.6	13.3	32.9	36.8	32.6	34.1
SW	10.2	12.0	11.4	11.2	19.0	25.7	33.2	26.0
Mean	10.7	13.0	13.0	12.2	25.9	31.3	32.9	30.0
Dalbergia sissoo								
CW	2.61	2.87	2.98	2.82	2.92	3.48	4.48	3.62
SW	1.10	1.21	1.35	1.22	0.94	1.02	1.19	1.04
Mean	1.86	2.04	2.16	2.02	1.92	2.26	2.84	2.32
Grand mean	6.29	7.51	7.57	-	13.9	16.9	17.9	-
LSD (p=0.05)								
Tree spp.	0.5							
Water quality	NS							
Irrigation levels	0.28							
Tree spp. x W.Q	0.71							
Other interactions	NS							

*Broader channel

Effect of irrigation with canal and saline water for different periods on biomass production and water use by D. sissoo and A. nilotica at Hisar.

Particulars	D. sissoo			A. nilotica		
	1 yr	2 yr	3 yr	1 yr	2 yr	3 yr
Biomass yield (dry wt. Tons/ha)						
CW	0.9	1.4	1.8	1.8	6.5	9.3
SW	-	2.1	3.1	-	5.4	7.9
Mean	0.9*	1.7	2.4	1.8	5.9	8.6
CD5%	Tree Spp.-1.5; Irrig. period-1.7; Water quality-NS					
Evaporation (E,mm)						
	1392	1567	1611	1481	1618	1720
Water use efficiency (MG ha-m^{-1})						
	0.7	1.1	1.5	1.2	3.7	5.0

*Canal water only

Effect of saline water irrigation and fertilizer application on seedling shoot growth (cm) of three tree species

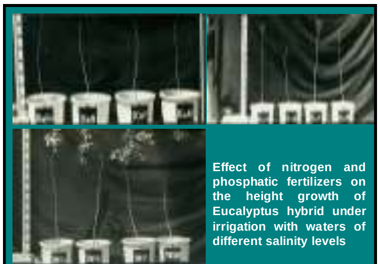
Fertilizers	Saline water (EC-ds/m) 0.4	3	5	7	Mean
	Eucalyptus tereticomis				
Control	29.5	3.7	3.0	X	9.1
N	26.7	4.8	3.3	X	8.7
P	25.0	7.2	X	X	8.1
Mean	27.1	5.2	2.1	X	-
CD 55%	EC-4.2 ; Fertilizer-NS; Interaction-NS				
	Acacia nilotica				
Control	31.9	23.2	8.5	X	16.4
N	30.2	26.0	10.6	4.3	17.3
P	29.6	23.6	8.0	X	15.3
Mean	31.2	24.3	9.0	1.4	
CD 55%	EC-4.2 ; EC-3.9 ; Fertilizer-NS; Interaction-NS				
	Prosopis juliflora				
Control	23.0	21.9	15.9	5.3	16.5
N	23.2	20.8	16.3	5.7	16.5
P	26.9	20.8	16.1	6.4	176
Mean	24.4	21.2	16.1	5.8	
CD 55%	EC-.2.4 ; Fertilizer-NS; Interaction-NS				

Effect of N and P on the height increment per plant (cm) of Eucalyptus tereticornis under irrigation with water of varying salinity at 14 months after transplanting in pots

ECiw X 10^3	Fertilizers C	N	P	N+P	Mean
BAW	74	81	82	83	80
5	24	19	32	33	27
10	8	5	18	14	1
Mean	35	35	44	43	11
CD 5 %	ECiw-5.8;	Fertilizers-6.7 Inter-NS			

Effect of saline water irrigation and fertilizers on height growth (cm) at 12 months after transplanting in the field

ECiw X 10^3	Fertilizers PONO	PON1	PIN0	PIN1	Mean
0.4	360	371	369	434	384
5.0	355	368	364	413	375
10.0	357	342	369	404	368
15.0	264	336	350	423	343
Mean	334	354	363	419	
CD 5%	IW-NS ;	N-34 ; P-21			



Effect of nitrogen and phosphatic fertilizers on the height growth of Eucalyptus hybrid under irrigation with waters of different salinity levels

Recommendations

Based on the information generated from these experiments, the following recommendations were drawn :

- In the case of sodic water application of Gypsum was found useful in counteracting the harmful effect of RSC. The growth of Eucalyptus tereticornis and Alibzzia lebbeck can be expected to be quite satisfactory on a soil having ECe of about 8.5 dS/m and SAR 60 and Ece 7.0 dS/m and SAR of of about 40 respectively. These are the safest limits of ECe & SAR of the soil which should not affect the growth of these two forest species.
- Use of nitrogenous and phosphatic fertilizers was found useful in counteracting the harmful effect of saline water irrigation on the performance of forest tree species
- Many tree species such as *Tamarix articulata, Acacia nilotica, A. farnesiana, A. tortils, Prosopis juliflora, Eucalyptus tereticornis, Azadirachta indica* and *Cassia siamea* seem promising for saline irrigation in calcareous soils of arid and semi-arid zones. *Feronia limonia* also seem promising. These species can be grown successfully with application of saline waters up to EC 10.5 dS/m in furrows.
- *Bauhinia variegata, Cassia glauca, Acacia auriculiformis, Syzygium cuminii, Crescentia alata, Casuarina equisetifolia, Samanea saman, Terminalia arjuna* and *Albizzia lebbeck* performed very poor and thus saline irrigation should be avoided for raising such species.
- *Cassia javanica* and *Crescentia alata* were observed very sensitive to frost.

- Irrigation seemed necessary for a minimum initial period of two years after transplanting. The performance of *A. nilotica* in terms of plant survival, tree growth and biomass yields was better than *Dalbergia sissoo*.
- The results also indicate beneficial effects of enhanced irrigation quantities and the better quality canal water. A reduction of 16 % in biomas of *Acacia* due to saline irrigation, however, seems tolerable but not that of *Dalbergia* where reduction in biomass yield was 57%. Again the reduced production could be compensated with enhanced quantities of saline irrigation in *Acacia* but these showed little impact in *Dalbergia*. Scheduling irrigation at Diw/CPE ratio of 0.2 showed better results in broader channels.

- **As the irrigations were applied only to fill the furrows planted with trees, most of the salts accumulated in the zone below the sill of furrows and only a few moved laterally towards inter-row spaces. The rain water from inter-row area comes as run-off to furrows resulting in major washing of the soil below.**

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Thank You

Prospects of growing industrial and non-conventional crops with poor quality water

Parveen Kumar, Anshuman Singh, RK Yadav and RL Meena
ICAR-Central Soil Salinity Research Institute, Karnal
E-mail:pkumarcssri@gmail.com

Outline of the Presentation

- Overview and importance of MAP
- Physiological and biochemical changes in plants under saline environment
- Results of work done on MAP in India (CSSRI, CIMAP, RRL) and other countries under saline environment
- Major uses of MAP
- Soil reclamation through MAP

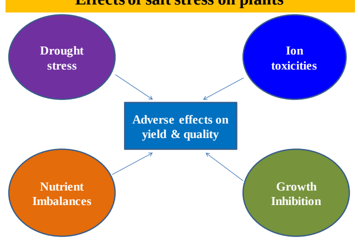
Salt-affected environments- An Overview

- About 25 percent of the earth's lands are degraded spanning soil and water resources and biodiversity (FAO, 2011).
- Global climate change endangers global food production and the developing countries are likely to be the most affected
- In India, soil and water salinity are fast emerging as serious problems and 6.73 million hectare soils are salt affected.
- Development of strategies for the sustainable management of our natural resources is vital.
- The ever-increasing demand for the herbal drugs has necessitated their cultivation in salt-affected environments.
- MAPs can be successfully grown in marginal salt-affected environments.

Importance of MAP

- Extremely valuable in socio-cultural and health-care needs of rural masses world over.
- In developing world, vast population relies on traditional systems of medicine for their health-care needs
- Increasingly being seen as safe and effective option for the treatment of human diseases in developed countries.
- Inextricably linked to the Indian culture and tradition
- About 25% of the modern drugs are derived from plants
- Ideal candidates for crop diversification, processing and value addition
- Emphasis must be on their sustainable utilization

Effects of salt stress on plants

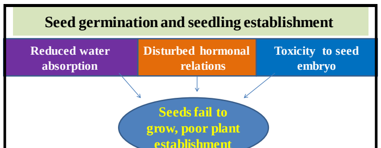


Water salinity and MAPs

Salinity stress adversely affects

- ✓ Seed germination and seedling establishment
- ✓ Membrane stability
- ✓ Leaf water content
- ✓ Leaf chlorophyll
- ✓ Mineral nutrition
- ✓ Plant growth and survival

Seed germination and seedling establishment



- 40 mM NaCl decreased seed germination and early seedling growth in *Withania somnifera* (Jaleel *et al*., 2008).
- Seed germination tended to decrease with increasing NaCl concentrations in *Perilla frutescens*, a Chinese medicinal plant (Zhang *et al*., 2012).

Then what to do?

- Inhibition of seed germination under salt stress is not universal in MAPs.
- NaCl solutions (0 to 10 dSm^{-1}) did not significantly reduce seed germination percentage in basil (*Ocimum basilicum* L.) and rocket (*Eruca sativa* L.; Miceli *et al*., 2003).
- Isabgol seeds showed complete germination at 5000 ppm salt concentration (Dagar *et al*., 2006).
- Seed priming with GA_3 can partially alleviate the salinity induced injury by suitably modifying the plant metabolism and thus improved seed germination and seedling establishment (Sedghi *et al*., 2010).

Membrane stability under salt stress

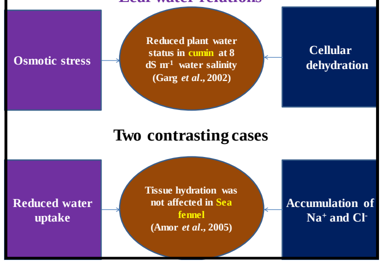
- Membranes are made of mainly lipids and proteins, under stress conditions, plasmalemma and lipid membranes are damaged. Leads to increased cell permeability and electrolyte leakage from the cell (Blum and Ebercon, 1981).
- Under salinity stress, lipid peroxidation (It refers to the oxidative degradation of lipids. It is the process in which free radicals "steal" electrons from the lipids in cell membranes, resulting in cell damage) and the associated membrane injury has been observed in many MAPs.

1. *Catharanthus roseus* at 80 mM NaCl showed lipid peroxidation and membrane injury (Jaleel *et al*., 2007a).
2. *Artemisia annua* plants subjected to 160 mM NaCl exhibited oxidative stress and enhanced lipid peroxidation (Qureshi *et al*., 2005)

Contd.

- As with seed germination, not all MAPs exhibit membrane injury under salt stress.
- Sometimes mild salt stress seems favorable to the membrane stability.
- *Crithmum maritimum* (sea fennel) plants exhibited better lipid peroxidation at 50 mM NaCl as compared to the control ones (Amor *et al*., 2005).
- In order to play a role in salt tolerance, the cell membrane should be less susceptible and maintain its permeability under high salt conditions.
- Enhanced activity of antioxidant enzymes (superoxide dismutase, catalase and peroxidase) protects membrane damage.

Leaf water relations



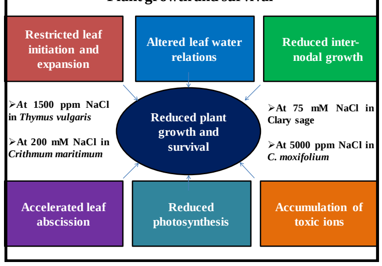
Leaf chlorophyll

- Chlorophyll is membrane bound pigment and its integrity depends on membrane stability.
- As cell membranes are damaged under saline conditions, chlorophyll seldom remains intact (Ashraf *et al*., 1992).
- Reduction in chlorophyll may be due to reduced activity of specific enzymes under saline conditions (Kreps *et al*., 2002).
- Salt stress alters stomatal conductance and photosynthesis in MAPs.
- Damage to photosynthetic apparatus, reduced chlorophyll contents and a decline in photosynthetic rate has been noted in *Withania somnifera* (Jaleel *et al*., 2008) and *Artemisia annua* L. plants (Qureshi *et al*., 2005).

Mineral nutrition

- Salinity affect nutrient uptake; Na^+ reduces K^+ uptake and Cl^- reduces NO_3^- uptake (Grattan and Grieve, 1999)
- In *Mentha pulegium* L. and *Salvia sclarea* L. plants, salinity stress induced restricted K^+ uptake, as well as an increase in Na^+ levels (Ouesalti *et al*., 2010).
- Na^+ and $Cl^−$ in both shoots and roots increased, whereas K^+ and Ca^{2+} decreased consistently with the successive increase in salt level in *Ammi majus* L. plants (Ashraf *et al*., 2004).
- Salinity induced high accumulation of Na and changes in K/Na ratio seem to cause growth reduction in cumin (*Cuminum cyminum* L.) plants (Garg *et al*., 2002).
- For surviving in saline soils, plants must maintain adequate levels of K^+. Under saline conditions, however, high levels of Na^+ interfere with K^+ acquisition by the roots (Grattan and Grieve, 1999).

Plant growth and survival



Biochemical responses

- Under salt stress, certain MAPs accumulate osmoprotectants and antioxidant enzymes (superoxide dismutase, catalase and peroxidase) to overcome osmotic stress and cellular dehydration.
- Under salinity stress, proline acts as an osmoprotectant and a storage source of N.
- Salt tolerant plants accumulate higher proline content.
- Salinity induced accumulation of antioxidant enzymes in *Phyllanthus amarus, Catharanthus roseus* and *Withania somnifera*.

Varietal differences

- The inherent capability of a particular variety or strain in tolerating salt stress has been documented in many MAPs.
- Varieties differ in their ability to salt tolerance which is due to the fact that tolerant types are able to maintain growth and can avoid physiological dysfunctions under salt stress (Sivritepe and Eris, 1999).
- Among the three peril (*Perilla frutescens*) varieties, Suyin 1 was more salt tolerant than Ziye 7 and Ziye 10, whereas Ziye 10 was found to be the most sensitive to salt stress (Zhang *et al*., 2012).
- Two Malaysian accessions of *Andrographis paniculata* (King of bitters) *viz*., 11261 and 11265, exhibited good potential to withstand to salty water environment (Rajpar *et al*., 2011).

Benefits of moderate salt stress

- Moderate salinity may prove beneficial with respect to certain aspects (Levy and Syvertsen, 2004).
- Under salinity stress, plants tend to reduce transpiration leading to reduced accumulation of salts in the root zone (Du Plessis, 1985).
- Mild salinity stress may augment essential oil production and quality by positively affecting certain aroma constituents in parsley (Petropoulos *et al*., 2009).
- Essential oil percentage increased with increasing salinity levels in *Thymus vulgaris* L. The highest essential oil percent was obtained with the application of 4500 ppm NaCl (El-Din *et al*., 2009).
- Irrigation with saline water increased the essential oil content and its main components (α-cadinol, γ- and Δ-cadinene) in *Calendula officinalis* L (Khalid and da Silva, 2010).
- Biosynthesis of oxygenated monoterpenes was stimulated in response to salt levels of 50, 100 and 150 mmol in Lemon grass (*Cymbopogon schoenanthus* L.) plants (Khadhri *et al*., 2011).

Salt tolerance of medicinal plants 1

Plant species	Salinity tolerance (EC dS/m)		Sodicity tolerance	
	Soil (ECe)	Irrigation water	Soil (pHs)	ESP
German Chamomile (*Matricaria chamomilla* L.).	10-12	8-10	9.5	--
Isabgol or Blonde psyllium (*Plantago ovata* Forsk.)	7-8	11-12	9.5	--
Periwinkle (*Catharanthus roseus*)	6-8	8-10	10.0	--
Rye for ergot (*Claviceps purpurea*)	10-12	12-15	9.6	--
E. henbane (*Hyoscyamus muticus*).	7-8	8-10	8.9	--
Wormwood (*Artemisia spp.*)	8-10	8-10	8.4	--

Contd.

Medicinal plants 2

Plant species	Salinity tolerance (EC dS/m)		Sodicity tolerance	
	Soil (ECe)	Irrigation water	Soil (pHs)	ESP
Licorice (*Glycyrrhiza glabra*) or Mulethi	6	10	-	-
Dill (*Anethum graveolens*)	8-9	6-8	8.6	--
Malabar nut (*Adathoda vasica*) or Vasaka	--	8-10	--	--
Aloe (*Aloe vera*)	8-10	10-12	8.4	--
Kair (*Capparis decidua*)	18-20	15-18	8.6	--
Euphorbia (*Euphorbia antisyphilitica*)	12-14	10-12	8.8	--
Jatropha (*Jatropha curcas* Linn.)	6-8	6-8	8.7	--

Contd.

Medicinal plants 3

Plant species	Salinity tolerance (EC dS/m)		Sodicity tolerance	
	Soil (ECe)	Irrigation water	Soil (pHs)	ESP
Holy basil or tulsi (*Ocimum sanctum* Linn.)	--	8-10	8.6	--
Indian senna (*Cassia angustifolia*)	9-10	10-12	8.7	--
Garden cress (*Lepidium sativum*)	10-12	15-17	8.6	--
Asparagus or satavar (*Asparagus racemosus*)	7-8	10-12	8.2	--
Winter cherry or Asawgandha (*Withania somnifera*)	8-10	10-12	8.4	--
Mint (*Mentha citrata*)	4-5	4-5	8.6	--

Salt tolerance of aromatic plants

Plant species	Salinity tolerance (EC dS/m)		Sodicity tolerance	
	Soil (ECe)	Irrigation water	Soil (pHs)	ESP
Palma rosa (*Cymbopogon martinii*)	9-12	14-16	9.5	55
Lemon grass (*Cymbopogon flexuosus*)	8-10	7-8	9.0	50
Citronella (*Cymbopogon nardus*)	4-5	5-6	8.5	25
Jamrosa (*Cymbopogon khasans*)	10-12	9-10	10.0	45
Vetiver (*Vetiveria zizanioides*)	9-10	10-11	9.5	55
Marigold (*Calendula officinalis*)	4-5	5-6	8.8	40

Effect of saline water on medicinal plants

Yield of medicinal plants with saline water irrigation (EC 8.5 dS/m)

Plants	Botanical name	SW	CW	CW/SW	$LSD_{0.05}$
Isabgol (unhusked grain yield, t/ha)	*Plantago ovata*	1.01	1.06	1.09	NS
Sadabahar (flower yield t/ha)	*Catharanthus roseus*	0.12	1.15	0.18	0.69
Tulsi (dry wt. of shoot, t/ha)	*Ocimum sanctum*	0.91	1.06	0.93	NS
Aloe (fresh wt.t/ha)	*Aloe barbadensis*	16.9	19.0	18.1	NS

SW=saline water; CW=canal water

SW= saline water, CW=canal water

Performance of Aloe with saline water

Tolerance up to EC 8-12 dS/m

Effect of quality and number of irrigation water on seed yield (kg/ha) of dill on saline black soils

Water quality EC (dS/m)	One irrigation	Two irrigation	Three irrigation
BAW	784	834	914
4.0	650	815	906
8.0	384	417	567
12.0	209	292	367

LSD(P=0.05) Water quality: 33 No. of irrigation: 30: BAW= Best available water

Effect of saline water irrigation on sennoside content in Indian senna

EC_{iw} (dS/m)	Active principle (%)	Soil EC after experiment (dS/m)
Control	2.40	0.55
4.0	3.35	0.62
6.0	3.32	0.93
8.0	3.30	1.04
10.0	3.28	1.48
12.0	3.27	1.61

Effect of saline water on aromatic plants

Effect of salinity on herb and oil yield of Palmarosa

EC_{iw} (dS/m)	Herb yield (t/ha)	Oil content (%)	Oil yield (kg/ha)
2.4	44.2	0.65	287
4.0	45.6	0.66	301
8.0	45.0	0.65	306
12.0	49.0	0.67	328
16.0	38.0	0.64	243
20.0	35.3	0.65	230
LSD (p=0.05)	2.6	NS	18

Impact of irrigation schedules on fresh yield (t/ha) of lemon grass irrigated with saline water (total of 4 cuttings)

Water Salinity	Irrigation scheduling (IW/CPE)			
	0.2	0.4	0.6	0.8
Low (EC 4 dS/m)	10.86	11.93	13.03	14.28
High(EC 8 dS/m)	4.31	7.12	8.51	10.03
Low/High	7.65	8.63	9.97	11.53

Lemon grass

Growth and yield of palmarosa as affected by saline water irrigation (EC 8.5dS/m)

Water quality	EC_e (dS/m) at harvest	Survival (%)	Shoot biomass (t/ha)	
			Fresh	Dry
Canal water (CW)	3.8	52	92.8a	34.0a
Saline water (SW)	6.8	36	66.3c	24.3c
Alternate CW:SW	5.4	38	79.6b	29.1b
LSD(P=0.05)	-	NS	12.5	4.8

Growth and yield of lemon grass as affected by saline water irrigation (EC 8.5dS/m)

Water quality	EC_e (dS/m) at harvest	Survival (%)	Shoot biomass (t/ha)	
			Fresh	Dry
Canal water (CW)	3.8	82	69.4a	19.2a
Saline water (SW)	6.8	38	50.7b	14.0b
Alternate CW:SW	5.4	47	54.5b	15.1b
LSD(P=0.05)	-	19	7.7	2.1

Growth and yield of vetiver (mean of three cultivars) as affected by saline water irrigation (EC 8.5dS/m)

Water quality	Survival (%)	Dry shoot biomass (t/ha)	Dry root biomass (t/ha)
Canal water	97	99.9a	1.41
Saline water	94	76.2b	1.36
Alternate CW:SW	96	96.5a	2.08
LSD(P=0.05)	NS	17.3	NS

Performance of medicinal plants in salt affected soils

Performance of Aloe and Asparagus on sodic soils

Aloe and Asparagus perform well at pH 8.5 and 8.2 respectively

Performance of Indian Senna plants on sodic soils

Grows well up to pH 8.7

Performance of Garden cress on saline soils

Performed well up to soil EC 10-12dS/m

Performance of Aswagandha or winter cherry on saline soils

Performed well upto soil EC 8-10 dS/m

Performance of aromatic plants in salt affected soils

Palmarosa in sodic soil (sum of 5 cuts)

ESP levels	Oil yield (g/pot)
16 (control)	2.45
55	2.88
65	1.84
75	1.16
85	0.77
CD at 5%	0.025

Palmarosa in sodic soil

ESP	Oil content	Oil composition	
		Geraniol (%)	Geranyl acetate (%)
5 (control)	0.4	79.4	10.0
16	0.4	78.5	10.5
35	0.5	76.3	12.2
48	0.6	75.1	13.7
65	0.4	78.1	14.9

Yield (herb and oil) and quality of oil of palmarosa varieties under sodic soil (pH 10, ESP 60)

Yield/yield attributes	PRC-1		RRL B77	
	Sodic	Normal	Sodic	Normal
Yield (t/ha) herb of 3 cuts	38.5	47.4	39.3	52.5
Oil content (%)	0.75	0.63	0.65	0.57
Oil yield (kg/ha)	288.8	298.6	255.4	299.2
Geraniol (%)	90.0	89.2	88.5	87.5

Yield (herb and oil) and quality of oil of lemon grass varieties under sodic soil (pH 10, ESP 60)

Yield/yield attributes	Pragati		Jor Lab L_2	
	Sodic	Normal	Sodic	Normal
Yield (t/ha) herb of 3 cuts	29.0	35.9	30.9	37.6
Oil content (%)	0.65	0.52	0.64	0.52
Oil yield (kg/ha)	188.5	186.2	197.8	195.5
Citral (%)	85.0	76.0	89.2	76.2

Influence of soil pH on root and oil yield of vetiver

Soil pH	Oil content	Yield	
		Root (g/pot)	Oil (ml/plant)
7.5 (control)	0.045	172.8	0.78
8.0	0.046	181.2	0.85
8.5	0.045	161.3	0.74
9.0	0.045	159.8	0.72
9.5	0.045	143.5	0.63
10.0	0.046	109.1	0.50
10.5	0.046	91.9	0.42
11.0	0.046	66.7	0.31
$LSD_{0.05}$	NS	15.3	0.14

Yield (root and oil) and economic return from vetiver in sodic soil

Soil	pH	EC (ds/m)	Yield (kg/ha)		Net return (Rs/ha)
			Root	Oil	
I	9.0	2.5	27.2	16.3	20,480
II	10.0	2.6	19.9	11.3	13,427

Yield (herb and oil) and quality of oil of Tagetes minuta (African marigold) in sodic soils

Soil ESP levels	Herb yield (kg/plant)	Oil yield (ml/plant)	Dihydro-tagetone (%)
1.2	25.7	0.18	22.1
6	41.6	0.27	24.7
16	34.6	0.25	30.4
24	33.6	0.25	31.5
45	28.8	0.21	33.2
$LSD_{0.05}$	3.6	0.03	-

Uses of salt tolerant medicinal and aromatic plants

- The information is available and updated regularly in **Indian Pharmaceutical Codex, British Pharmaceutical Codex, United States Pharmaceutical Codex and National Formulary** *etc*.
- Extracts of different medicinal and aromatic crops are used in pharmaceutical, food, flavor and cosmetic industries
- The drugs extracted from medicinal plants found successful in control of cancerous tumors, HIV, hypertension, rheumatoid arthritis, digestive disorders, used as contraceptives and many other ailments

Uses of salt tolerant aromatic plants

Plant species	Important uses
Palmarosa (*Cymbopogon martinii*)	Oil contains geraniol and emit rose like aroma used in perfumes, tobacco, soaps, medicines
Lemon grass (*Cymbopogon flexuosus*)	Contains citral used in vitamin-A, other edible recipes, perfumery, cosmetics
Citronella (*Cymbopogon nardus*)	Oil has mosquito repellant characteristics, also used in cosmetics and perfumery
Vetiver (*Vetiveria zizanioides*)	Oil from roots used in perfumery, cosmetics and flavouring sherbats

Medicinal plants and their uses 1

Plant species	Important uses
German Chamomile (*Matricaria chamomilla*)	Flowers yield essential oil used as expectorant, sedative, perfumery, gastric stimulant
Isabgol (*Plantago ovata* Forsk.)	Mucilage present in husk helps in cure of various intestinal, blood and cough ailments
Periwinkle (*Catharanthus roseus*)	All parts are used for treatment of tumors, menorrhagia, leukemia and antibacterial uses
Rye for ergot (*Claviceps purpurea*)	Dried sclerotium used in contraction of uterus and bladder, controls bleeding. Ergotamine used for migraine
Asparagus (*Asparagus racemosus*)	Roots rich source of minerals and other chemicals used as demulcent, aphrodisiac, diuretic, anti-dysenteric and as tonic

Medicinal plants and their uses 2

Plant species	Important uses
Winter cherry (*Withania somnifera*)	Alkaloids are anti stress, anti-cancer, anti-sleeplessness and immune system motivators
Egyptian henbane (*Hyoscyamus muticus*).	Tropane and hyscine are used in treatment of cold, cough, lever pain and apoplexy
Dill (*Anethum graveolens*)	Essential oil is given to children for flatulence, seeds are used as carminative and stomachic
Vasaka or malabarnut (*Adathoda vasica*)	Bark and leaves extract has antiviral activity, used in cold, cough, bronchitis, rheumatic pain etc.
Aloe (*Aloe vera*)	Extract is cathartic, used in lever, spleen, piles, rectal, menstrual, joint pains, constipation and skin problems
Kair (*Capparis decidua*)	Fruit used in cardiac problems, bark used in cough and asthma. Fruits are used as pickles.

Medicinal plants and their uses 3

Plant species	Important uses
Mint (*Mentha citrata*)	Mint oil has great industrial value and also used in flavors of candies, anta-acids and other mouth fresheners
Euphorbia (*Euphorbia antisyphilitica*)	Extract antisyphlatic and is a potential petro-crop
Jatropha (*Jatropha curcas* Linn.)	Juice relieves toothache, applied in piles, root & leaf decoction in diarrhoea, seed oil in skin diseases
Holy basil or tulsi (*Ocimum sanctum* Linn.)	Oil from leaves has antibiotic properties, juice useful in respiratory and digestive disorders, seeds in urinary problems
Indian senna (*Cassia angustifolia*)	Leaves and fruits laxative, liver stimulant, vermifuge, purgative, tonic, anaemia, typhoid
Garden cress (*Lepidium sativum*)	Oil is anti-inflammatory, volatile products show antibacterial activity

Reclamation of salt affected soils

- Studies have established that Palmarosa, Lemon grass and Vetiver can reduce pH, EC and ESP of salt affected soils.
- The high CO_2 production and accumulation by biological action of roots of these grasses, production of weak acids (carbonic) solubilise native $CaCO_3$ and release Ca which replaces Na from exchange complex.
- Medicinal species like German chamomile accumulate up to 66 meq Na/100g of dry matter and thus improve alkali soils through ion uptake

Amelioration of salt affected soils by medicinal and aromatic plants

Crop	Soil pH (1:2.5)		Soil EC (dSm^{-1})		ESP		Reference
	Initial	Harvest	Initial	Harvest	Initial	Harvest	
Palmarosa (2yrs)	10.62	9.40	4.80	0.64	93.0	43.8	Prasad *et. al* 1995
Lemongrass	9.80	8.95	1.25	1.35	60.0	52.8	Patra *et al* 2002
Vetiver	10.50	9.50	--	--	82.0	--	Anwar *et.al* 1996
Vetiver	9.50	9.00	--	--	56.5	38.7	Anwar *et.al* 1996
Isabgol	10.00	9.70	1.25	0.81	60.0	48.4	Patra *et al* 2002

ESP and Na of sodic soil before planting and after harvesting of vetiver

ESP		$pH_{2.5}$		Na(me/l)	
Before	After	Before	After	Before	After
10	9	8.0	7.5	87.6	83.6
15	14	8.5	8.0	89.9	86.8
30	28	9.0	8.3	108.9	100.1
50	35	9.5	9.0	122.5	114.1
65	42	10.0	9.3	125.4	118.6
80	50	10.5	9.5	135.9	132.1
85	61	11.0	9.6	152.5	147.6

Conclusion and future thrust

- Development of suitable alternate land use plans for these degraded and marginal environments is vital.
- One of the best options is to grow medicinal and aromatic plants in these ecosystems to convert them into productive green lands.
- Reports in literature revealed that many high value medicinal and aromatic crops are fairly tolerant to salinity stress.
- They perform very well in saline soils and irrigation with saline water does not have any adverse effect on yield and quality.
- It is interesting to note that mild salt stress even promotes biomass accumulation and enhances quality by promoting the biosynthesis of secondary metabolites.
- For developing salt tolerant ideotypes in these crops, emphasis should be on interdisciplinary research with focus on frontier sciences such as molecular biology and genomics.

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Drip irrigation in horticultural crops – suitability for saline water use

Satyendra Kumar
Sr. Scientist
Soil & Water Conservation Engineering
skumar@cssri.ernet.in

Division of Irrigation and Drainage Engineering
Central Soil Salinity Research Institute, Karnal -132001

Contents

- Drip irrigation
- Why Saline water irrigation
- Case study
- Maintenance of drip system

Drip system of irrigation

By an large drip irrigation is a term used to cover drip, trickle irrigation systems. These systems use small irrigation outlets placed along or under the plant row on pipes called laterals.

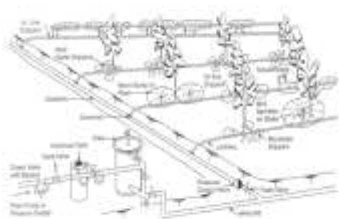
The difference between this type of irrigation and others, is that water is applied to the root zone of the plants only, not the whole field. It is also applied more frequently, but at much lower rates.

Efficient water application

Irrigation Efficiencies under Different Methods of Irrigation (Per cent)

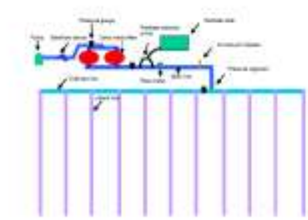
Irrigation Efficiencies	Methods of Irrigation		
	Surface	Sprinkler	Drip
Conveyance efficiency	40-50 (Canal) 60-70 (Well)	100	100
Application efficiency	60-70	70-80	90
Surface water moisture evaporation	30-40	30-40	20-25
Overall efficiency	30-35	50-60	80-90

Source: Sivanappan (1998).

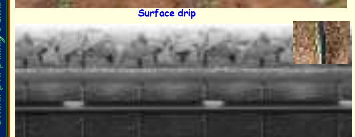


Typical sketch diagram of different micro-irrigation systems

Technical details and lay out of drip system



Surface drip



Subsurface drip

Principles of drip Irrigation

Drip irrigation is the term used to describe the method of irrigation which is characterized by the following features.

- Water is applied at a low rate
- Water is applied over a long period of time.
- Water is applied at frequent intervals.
- Water is applied via a low pressure delivery system

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Drip irrigation system

Drip irrigation makes it possible to grow crop in all types of soils. Even in a light or shallow soil in which water storage is inadequate to supply the crop over an extended irrigation cycle as is the case with furrow or flood irrigation, drip irrigation provides an opportunity to raise good, high yielding crop.

Drip irrigation is a growing technology, which has the potential to enhance crop productivity, conserves soil, water and fertilizer resources while also protecting the environment.

Research activities carried out in India and abroad categorically exhibited that drip irrigation can save precious water with enhancement of yield of different crops under varied agro-climatic conditions.

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Drip irrigation in grapes and tomato

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Drip line between two rows

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Mulching

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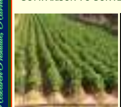
INCREASE IN YIELD AND WATER SAVING THROUGH DRIP IRRIGATION IN COMPARISON TO CONVENTIONAL IRRIGATION METHODS IN VEGETABLE CROPS

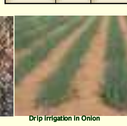


Drip irrigation in potato

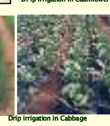
Crop	Increase in yield, %	Water saving, %
Tomato	25-50	40-60
Onion	25-40	20-30
Potato	20-30	40-50
Cabbage	30-40	50-60
Cauliflower	60-80	30-40

Drip irrigation in Cauliflower

Drip irrigation in Tomato



Drip irrigation in Onion



Drip irrigation in Cabbage

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Water use efficiency in drip system for various horticultural crops

Crops	Yield increase (%)	Water saving (%)	Increase in water use efficiency (%)
Water Melon	88	36	195
Pomegranate	45	45	167
Sugarcane	33	56	204
Tomato	50	31	119
Banana	52	45	176
Chilly	45	63	291
Grapes	23	48	136
Groundnut	91	36	197
Sweet Lime	50	61	289

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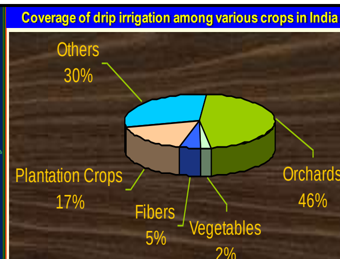
Coverage of drip irrigation among various crops in India



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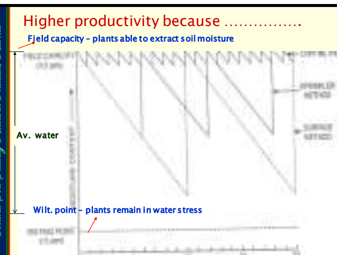
Higher productivity because ....



Moisture availability for crops under different irrigation methods

Central Soil Salinity Research Institute, Karnal saline water for irrigation ?

Shortage of water day by day

When saline water is skillfully used for irrigation, it can be beneficial for agricultural production, particularly in orchards. Saline water use for agricultural production offers several additional benefits

i) Which ultimately would make available some additional fresh water for other purposes other than agriculture.

10% water saving in agricultural sector leads to 20-30% higher availability of water to other sector

Global Freshwater

Year	Population (millions)	Average annual renewable global water resources (km³)	Potential water availability (m³/yr)
1960	3039.7	44800	17532
1980	4454.3	44800	10058
2000	6079.0	44800	7370
2025	7835.9	44800	5717

Water for Agriculture

- Agriculture is the biggest user of water, accounting world wide for about 69% of all withdrawals.
- Domestic use amounts to about 10% and industry uses some 21% (Fao, 2003).
- In 2025, 48 countries with about 3 billion people are projected to face water shortages.
- As climate change exacerbate risks, water users will need to adopt Water Saving approaches.

ii) re-use (instead of disposal) during the entire year with minimal environmental risk of *ground water deterioration*

iii) Quality raw material production for processing industry.

(iv) a premium market price for the fruits and vegetable products because of a high content of total soluble solids and an extended shelf life, due to the adaptation of the plant to the stressful growing conditions.

Classification of saline waters for irrigation

Water class	Electrical conductivity dS/m	Salt concentration mg/l	Type of water
Non-saline	<0.7	<500	Drinking and irrigation water
Slightly saline	0.7 - 2	500-1500	Irrigation water
Moderately saline	2 - 10	1500-7000	Primary drainage water and groundwater
Highly saline	10-25	7000-15000	Secondary drainage water and groundwater
Very highly saline	25 -45	15 000-35 000	Very saline groundwater
Brine	>45	>35 000	Seawater

How does saline water irrigation affect the plant?

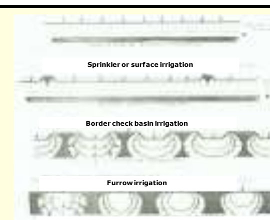
Osmotic

- Decreases soil water potential, harder for the plant to extract water

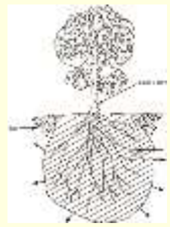
Toxic

- Toxic ions poison plant metabolism, for example increasing leaf chloride decreases photosynthesis, effect internal to plant

If water is sprayed directly on leaves, it can cause salt scorch and leaf damage even at lower salinities.

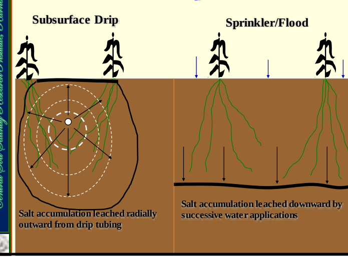


Salt accumulation pattern in soil under different irrigation systems

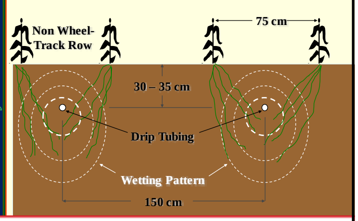


Salt accumulation pattern in soil irrigated with drip system

Salt Movement Under Irrigation with Saline Water



Typical Subsurface Drip Tubing Installation for Row Crops



1.50 meter drip line spacing is satisfactory on silt loam & clay loam soils

Relative Tolerance of Fruit crops

Crop	EC_{iw} (dSm^{-1}) for relative yield		
	90	75	50
Grape	1.7	2.7	4.5
Apricot	1.3	1.8	2.5
Date palm	4.5	7.3	12
Orange	1.6	2.2	3.2
Strawberry	0.9	1.2	1.7

Relative Tolerance of Vegetable Crops

Crop	EC_{iw} (dSm^{-1}) for relative yield		
	90	75	50
Onion	1.8	2.3	3.3
Potato	2.1	4.3	7.8
Tomato	2.4	4.1	6.9
Brinjal	2.3	4.1	7.1
Bitter gourd	2.0	3.4	5.80

WUE as affected by irrigation methods using saline & good quality waters (potato)

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

MAINTENANCE OF SYSTEM

Regular care and timely maintenance of the system ensure that system functions properly in saline environment. Some important maintenance steps to follow for better management and maintenance are

i) Clean or backf lush filters when needed.
ii) Flush lateral lines regularly.
iii) Check applicator discharge often; replace applicators as necessary.
iv) Check operating pressures often; a pressure drop (or rise) may indicate problems.

v) Inject chemicals as required to prevent precipitate buildup and algae growth.

viii) Check chemical injection equipment regularly to ensure it is operating properly.

ix) Check and assure proper operation of backflow protection devices.

Emitters Clogging

The main problem associated with drip irrigation during operation with saline water is clogging of the emitters. Emitters usually have orifice diameters of only 0.5-1 mm and are thus vulnerable to clogging by the formation of chemical precipitates.

Flushing

Routine flushing of pipelines is required to prevent emitter plugging from the gradual accumulation of particles which are too small to be filtered, but which settle out or flocculate at the distal ends of pipelines.

Flushing velocities must be high enough (at least 0.6 m/sec) to transport and discharge heavy particulate matter from the pipelines.

Flushing should be more frequent when large amounts of debris are present, while less frequent flushing may be adequate if only small amounts of debris are flushed.

Sand Filter Back washing

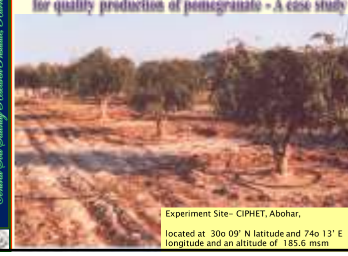
Applying surfactants or dispersing agents such as sodium hexametaphosphate through the micro-irrigation system help in reducing plugging problems by preventing the accumulation of silts and colloidal clays, allowing them to easily pass through the emitters or flushed from pipelines.

Automated flush valves are sometimes used, as at the ends of the laterals to help flush fine particulates at the start of every irrigation.

Periodic manual flushing is still required.

- Iron and manganese precipitating bacteria can be controlled by chlorine treatments, aeration or polyphosphates.

Safe use of saline water through drip system for quality production of pomegranate - A case study



Experiment Site- CIPHET, Abohar,

located at 30o 09' N latitude and 74o 13' E longitude and an altitude of 185.6 msm

Different quality water was prepared by blending good quality water (canal water) with marginal quality water (tube well water) for this experiment. They are as follow

i) Fresh water i.e. canal water (T1)
ii) Blending canal and tube well water in 1:2 ratio (T2)
iii) Blending canal and tube well water in 1:1 ratio(T3)
iv) Blending canal and tube well water in 2:1 ratio (T4)
v) Saline water i.e. tube well water (T5)
vi) Canal water through conventional irrigation system as control (C)

Water application through drip
Peak consumptive period (April, May and June) – 2-3 days
Rest of the year – Once in week
Depth of water will be decided on the basis of evapotranspiration

Set up for preparing different quality water for drip irrigation

Quality of water used under different treatments

Treatment	pH	EC (dS/m)	Ca^{2+} + Mg^{2+} (me/l)	Na^{+} (me/l)	K^{+} (me/l)	SAR
T_1	7.61	0.38	2.40	1.60	0.17	1.46
T_2	7.66	6.30	19.00	12.24	0.49	3.97
T_3	7.77	9.10	29.00	14.40	0.64	3.78
T_4	7.84	14.70	48.80	21.84	0.88	4.42
T_5	7.79	19.50	67.20	29.12	1.09	5.02

Initial soil pH and electrical conductivity of experimental field

Depth of Soil (cm)	pH	Electrical Conductivity (ds/m)
0-30	7.83	0.66
30-60	7.81	0.98
60-90	7.80	1.31
90-120	6.78	0.92

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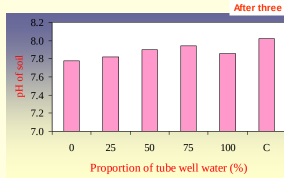
After three months



Soil pH under different irrigation treatments

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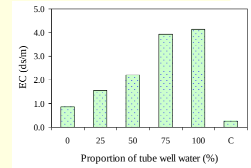
Pomegranate

After three months



Electrical conductivity (EC) under different irrigation treatments

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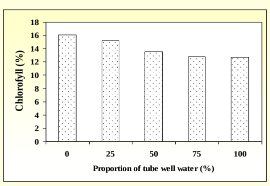
Pomegranate



Percentage of Chlorophyll in pomegranate leaf under different treatments

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Pomegranate leaf under treatment T1 (*before the first rain*)

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Pomegranate leaf under treatment T4 (*before the first rain*)

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Pomegranate leaf under treatment T5 (*before the first rain*)

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After getting 18 cm rain

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After getting 18 cm rain


Central Soil Salinity Research Institute, Karnal
100
After getting 18 cm rain


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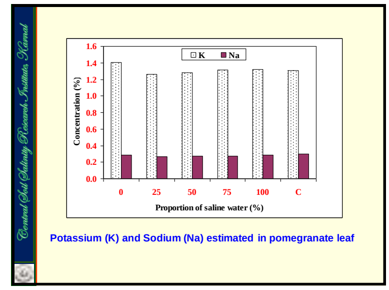
Drip irrigated plant with 25% saline ground water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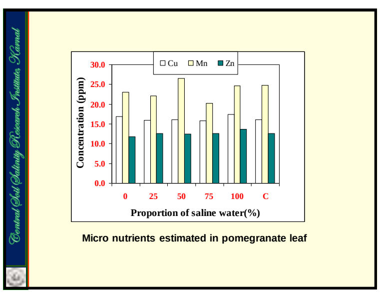
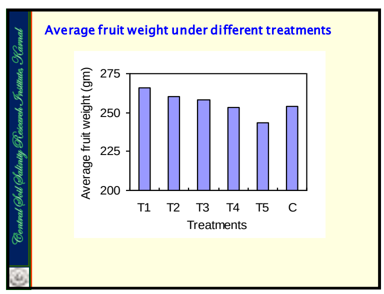
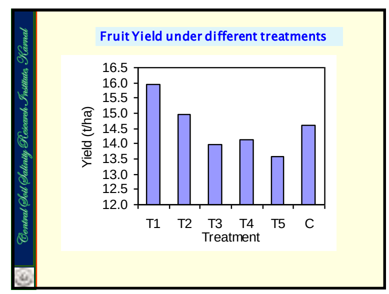
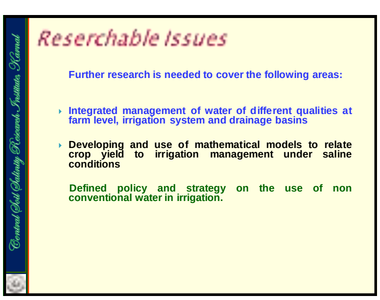
K
Na
Concentration (%)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
25
50
75
100
C
Proportion of saline water (%)
Potassium (K) and Sodium (Na) estimated in pomegranate leaf


Central Soil Salinity Research Institute, Karnal
Cu
Mn
Zn
Concentration (ppm)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
25
50
75
100
C
Proportion of saline water(%)
Micro nutrients estimated in pomegranate leaf


Central Soil Salinity Research Institute, Karnal
Average fruit weight under different treatments
Average fruit weight (gm)
275
250
225
200
T1
T2
T3
T4
T5
C
Treatments


Central Soil Salinity Research Institute, Karnal
Fruit Yield under different treatments
Yield (t/ha)
16.5
16.0
15.5
15.0
14.5
14.0
13.5
13.0
12.5
12.0
T1
T2
T3
T4
T5
C
Treatment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Reserchable Issues
Further research is needed to cover the following areas:
Integrated management of water of different qualities at farm level, irrigation system and drainage basins
Developing and use of mathematical models to relate crop yield to irrigation management under saline conditions
Defined policy and strategy on the use of non conventional water in irrigation.


Thank
you
for your kind attention

Subsurface drip irrigation for sewage and waste waters

R.S.Pandey

Central Soil Salinity Research Institute, Karnal, Haryana

Alarming situation regarding water in the world

International Water Management Institute (IWMI) prediction based on Policy Dialogue (PODIUM) model

- **Acute shortage of water world wide by the year 2025**
- **About 33% of the world population comprising of 45 nations would be most severely affected by this water shortage**
- **India will be one of them**

Water Distribution in the World

Sea and Ocean	-- 97.2%
Ice cap and Glaciers	-- 2.15%
Groundwater till 800m	-- 0.31%
Groundwater after 800m	-- 0.31%
Water in unsaturated zone	--0.005%
Freshwater lake	--0.009%
Saline Lakes and Inland and Sea	--0.0084%
Average Water in Stream and Channel	--0.00014%
Atmosphere	--0.00079%

Availability of water resources and requirement in India

Projection of population and food grain requirement till, 2050

- **150-180 Crore**
- **450 million ton**

Availability of water resources

- **Surface water--- 69 M ha m**
- **Ground water--- 45 M ha m**

Inter Linking of Rivers

- **Surface water ----17.5 M ha m**
- **Groundwater---- 8 M ha m**

Total ------140 M ha m

Problem of Inter Linking of Rivers

- **Social**
- **Political**
- **Environmental**

Latest estimate of water need (m ha m)

Activity	Years		
	1990	2000	2025
Irrigation	46.0	63.0	77.0
Drinking and Livestock	2.5	3.3	5.2
Industrial	1.5	3.0	12.0
Energy	1.9	2.7	7.1
Others	3.3	3.0	3.7
Total	55.2	75.0	105.0

State	Utilizable	Net draught	Potential Available	Low quality ground water	Low quality ground water in use %
Punjab	1.31	0.93	0.36	0.38	41
Harayana	0.88	0.61	0.27	0.38	62
U.P.	9.27	2.68	6.59	1.28	47
Gujarat	2.03	0.69	1.34	0.21	30
Rajsthan	1.83	0.46	1.37	0.39	84
M.P.	5.95	0.79	5.46	0.20	25
Karnataka	1.30	0.18	1.12	0.07	38
Maharastra	3.45	0.66	2.80	------	---
Tamilnadu	2.69	0.99	1.70	------	---
A.P.	3.66	0.74	2.92	0.24	32
Bihar	2.86	0.69	1.34	-----	---
Others	2.15	0.09	2.06	-----	---
Total	41.85	13.50	28.35	-----	---

Extent of use of poor quality ground water

Total ground water development -- 13.5 m. ha. M./ year

Use of poor quality water ---- 3.2 m.ha.m. / year

Use of poor quality water in in different states in arid and semi - arid areas ---- 25--84 % of total of ground water development

Future projection:

After full development of groundwater of 42 m ha m 10 m ha m will be of poor quality groundwater

Underground Poor Quality Waters

------ Saline Waters

----- Alkali Waters

----- Water which may cause specific ion toxicity or element toxicity

waste water

- **Sewage water**
- **Industrial wastewater**

Remedial measures to circumvent water crises

- Additional development of water resources
  - Development of conventional water resources
  - Use of low quality water
    - Poor quality groundwater
    - Return flow from agriculture
    - Waste water
      - Municipal waste water
      - Industrial effluents
- Conservation of water resources
- Precise and efficient use of water resources
  - Adoption of appropriate irrigation methods

Precise and efficient irrigation through drip irrigation achieved in good quality irrigation water

Parameters	Amount %
Application efficiency	90-95
Improved yield	20-70
Reduced evaporation losses	10-25
Water saving	45-75
Fertilizer saving	20-40

Reddy et al., 2004

Advantages:
Higher application efficiency
Reduced evaporation losses
High water use efficiency
May attain high water productivity

Growth of area (Thousand hectare) under drip irrigation

Year	1970	1985	1989	1994	1999	2002
Area (0000), ha	Nil	1.5	12.0	70.9	300.0	355.4

According to Sivanappan (1999) about 28.5 m ha could be covered under drip irrigation till 2020/2025.

Role of drip irrigation in managing saline water

- Frequent irrigation can be applied
- Leaching efficiency is high
- Efficient utilization of good quality water can be done
- Cost on leveling can be avoided

Role of frequent irrigation in managing saline water irrigation

Two stresses in saline soils

----- Stress due to matrix potential

----- Stress due to solute potential

Aim:

Combined effect of these two stresses should be at a such a level that reduction in yield could be minimized

High Leaching efficiency (Drip Irrigation)

Due to:

-------- Less preferential flow

-------- Less Pore Water Velocity

--------- Increase d frontal area

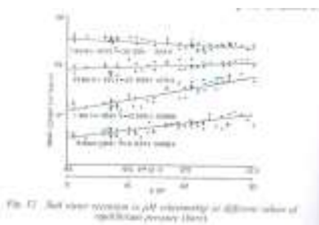
Utilization of Drip Irrigation

(Alkali water and Alkali Soils)

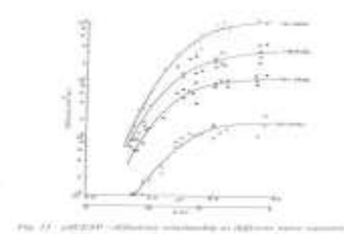
(Over View at CSSRI, Experiments)

- Experiment on RSC waters
- Experiment of Litchi Fruit Crop in Alkali Soil

Drip irrigation and alkali soil



Drip irrigation and alkali soil



Disposal of Sewage Water

- Disposal into surface water body
- Disposal into low lying areas and ponds
- Soak pit disposal
- Sewage treatment plants
- Soil aquifer treatment system
- Oxidation ponds and fish culture
- Sewage for agriculture

Disposal of Sewage Water

Groundwater Pollution

- Disposal into surface water body
- Disposal into low lying areas and ponds
- Soak pit disposal
- Sewage treatment plants
- Soil aquifer treatment system
- Oxidation ponds and fish culture
- Sewage for agriculture

Sewage Water Treatment

(Groundwater Recharging or Surface Water Disposal)

Overview:

No !

--- It contains pathogens i .e. harmful bacteria and Viruses which may cause disease

--- It contains heavy metals i .e. Cd, Cr, As and Pb which may be toxic to human being

--- It contains nutrients, i .e., Nitrate and others which may cause health hazards if it exceed above certain limit

--- Its BOD and COD is high which can cause oxygen deficiency

Benefit of Sewage Water

--- It contain nutrients i . e . Nitrogen and Phosphorous Which may provide fertilizer benefit to plants.

--- It contain organic matter which may increase the fertility of the soil

--- The 99.9 % of the sewage water is water which is a natural resource which may be used for irrigation

Present status of utilization of sewage water in India

- 30% — Untreated sewage water is used for growing vegetable crops with surface irrigation
- 60% — Untreated sewage water is disposed off in rivers and low lying areas causing surface and groundwater contamination
- 10% — To protect the environment, at many places conventional sewage treatment plants have been installed but their treatment level is not up to mark. They are also being used to grow vegetable crops with surface irrigation

Reason for restriction on utilization of raw sewage water for irrigation purpose (Asano et al.,1986)

- To protect public health
  - (1) Due to consumption of infected product
  - (2) Occupational hazard
    - (a) During irrigation
    - (b) During inter culture operation
  - (3) Groundwater contamination
  - (4) Formation of aerosol
- To prevent nuisance condition during storage
- To prevent damage to crops and soils
  - (1) quality of the produce is affected
  - (2) Plants are affected
  - (3) Soils may become unproductive due to excess of heavy metals and other minerals

Options for better solution of sewage water

- Different level of treatments and its utilization in agriculture, disposal in rivers or recharging of groundwater
- Utilization of raw sewage water in agriculture

Intensive Research

- Irrigation methods
  - (1) Surface irrigation
  - (2) Drip irrigation
- Crops
  - (1) Plantation of trees
  - (2) Vegetable production
  - (3) Cereal production

A case study on the disposal of Sewage Water through drip irrigation

Location: Central Soil Salinity Research Institute, Karnal

Type of water: Domestic wastewater

Way of disposal: Water was collected in sump for 24 hours and it was pumped into unlined pond after every 24 hours

Amount of domestic waste water: 83000 liter/day

Distance from residential area: 400 m.

Note: A deep tube well located in the residential area to supply drinking water.

Effect of disposal: · Contamination of groundwater, Foul smell near the pond & Breeding ground for mosquitoes

Composition of Domestic Wastewater

Sr.No.	Parameters	Values
1	pH	7.93
2	EC(dS/ m)	0.98
3	BOD5 (mg/l)	198.00
4	COD (mg/l)	249.00
5	NH4-N (mg/l)	12.90
6	NO3-N (mg/l)	2.43
7	HCO3 (m eq/l)	7.89
8	P (mg/l)	4.06
9	K (m eq/l)	0.29
10	Na (m eq/l)	2.38
11	Ca (m eq/l)	2.19
12	Mg (m eq/l)	3.20
13	Zn (mg/l)	0.20
14	Fe (mg/l)	0.94

Composition of Domestic Wastewater

Sr.No.	Parameters	Values
15	Mn (mg/l)	0.03
16	Pb (mg/l)	0.16
17	Cd (mg/l)	0.01
18	Cr (mg/l)	N.D.
19	Log E.Coli/ ml)	9
20	Total suspended solid (mg/l)	100

EC = 0.98

SAR = 1.45

RSC = 2.50

Hydraulic conductivity of strata and Existence of Aquifers

Sr. No.	Depth range from the surface Of the soil ,m	Hydraulic conductivity of the strata, cm/day
1	0-5	7.26
2	5-10	3.81
3	10-15	17.65
4	15-20	90.00
5	20-25	137.00
6	25-30	181.00
7	30-35	6.00
8	35-40	1.10
9	40-45	0,04
10	45-50	0,04
11	50-55	1.80
12	50-60	0.64

Outcome of utilization of raw sewage Water through Surface Irrigation

- Contamination of Produce
- Possibility of ground water contamination
- soil can be used as an effective means of waste water treatment

- Remedy:
- Repeated Washing
- Exposure of Product to sunlight
- Raising of crops on bed

Utilization of sewage water through drip irrigation

Advantages

- No aerosol are formed
- Deep percolation is negligible
- Contamination of pathogens found in sewage water occurs only when the product to be consumed touches the soil
- It is possible to protect the plant product to be consumed fr the pathogens by subsurface drip irrigation system or using surface drip irrigation system and covering the soil surface plastic sheet
- Farm workers could be prevented from contamination of t pathogens of the sewage water during inter culture operati in the case of subsurface drip irrigation

Art of knowledge and present status of utilization of sewage water through drip irrigation in the world

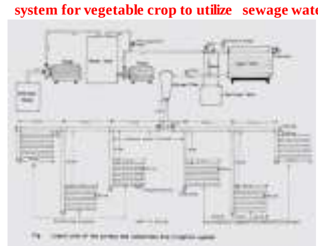
Study on the clogging phenomenon of the emitters

Study on contamination of soil using secondary and tertiary treated waste water

study on contamination of the product using secondary and tertia treated waste water

Use of secondary and tertiary treated sewage water through surface and subsurface drip irrigation in mostly developed countries without any report of adverse effect on health

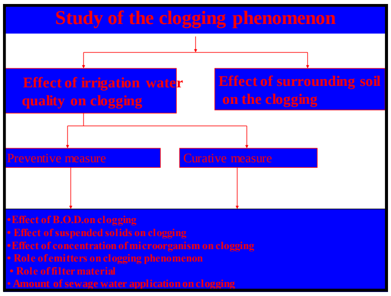
Layout plan of surface and subsurface drip irrigation system for vegetable crop to utilize sewage water



Cabbage crop under surface drip irrigation system

Cabbage crop under subsurface drip irrigation system

Cabbage crop under surface drip irrigation system with control head



Variation in discharge rate and coefficient of variation of emitters flow during three years of experimentation

Mean discharge rate				Coefficient of variation			
Surface drip		Subsurface drip		Surface drip		Subsurface drip	
Initial	After 3 years	Initial	After 3 years	Initial	After 3 years	Initial	After 3 years
3.85	3.83	3.87	3.37	0.077	0.16	0.078	0.23

Variation in mean discharge rate and coefficient of variation with duration in the case of surface and subsurface drip irrigation

Sr. No.	Date of taking observation	Mean discharge rate of the emitters, lph		Coefficient of Variation	
		Surface	Subsurface	Surface	Subsurface
1	3-3-2003	3.85	3.87	0.077	0.078
2	3-10-2003	3.91	3.62	0.080	0.112
3	4-10-2004	3.95	3.40	0.088	0.140
4	24-3-2005	3.88	2.50	0.094	0.254
5	28-3-2005	3.92	3.00	0.093	0.218
6	1-4-2006	3.83	3.37	0.156	0.233

Estimated application efficiency during 3 years of experimentation in drip irrigation methods and its comparison to border irrigation

Surface drip irrigation		Subsurface drip irrigation		Border irrigation
Initial	After 3 years	Initial	After 3 years	
92	85	92	72	60

Estimated deep percolation losses in different irrigation methods

Crop	Surface		Subsurface		Border
	Initial	After 3 years	Initial	After 3 years	
Ladies finger	4.0	8.5	3.0	4.4	35.3
Cabbage	1.5	3.1	1.30	5.0	12.9

Description of Sand and Screen Filters

Sr. No.	Type of the filter	Capacity, m^3/hr	Nominal pressure, Kg/cm^2	Pressure difference, Kg/cm^2	Nominal size (cm)	Mesh size, micron
1	Sand filter	18	2.50	1.0	----	-----
2	Screen filter	25	1.50	0.50	2(6.3)	100

Information on experimental vegetable crop

Sr. No.	Vegetable crop	Duration	Total irrigation water application, cm	Sewage water application, cm
1	Ladies finger	March-September	89	53
2	Cabbage	October-February	27	20

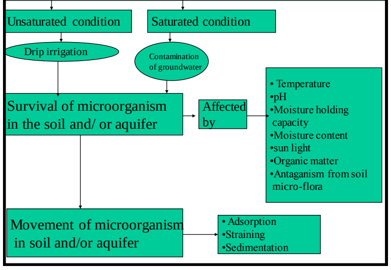
Change in hydraulic conductivity of sand in sand filter with time

Sr. No.	Stage of determination of hydraulic conductivity	Hydraulic conductivity, m/day
1	Initial hydraulic conductivity	109
2	Hydraulic conductivity before back washing	53
3	Hydraulic conductivity after 3 years	60
4	Hydraulic conductivity before back washing after 3 years	45

Energy requirement for drip irrigation system for the discharge of 18 cubic meter per hour, recommend by the firm

Pressure in lateral, Kg/cm^2	Mean discharge rate, lph	Manufacturing coefficient of variation	Application efficiency	Amount of water applied, m^3	Headloss in sand tank filter, m	Headloss in screen filter, m	Headloss in dripper, m	Total headloss, m	Energy requirement in KWH, considering application efficiency
0.60	3.44	0.0514	92	15.65	3.80	2.01	6.00	11.81	0.57
1.0	3.87	0.0827	89	16.17	3.93	2.26	10.00	16.19	0.80
1.5	4.86	0.0928	85	16.94	4.14	2.90	15.00	22.04	1.08
2.0	6.04	0.1037	80	18.00	4.41	3.58	20.00	27.99	1.38

Study of the microorganism behavior in soils



Behavior of micro-organism in ground

Organism	Survival time	Media
E. Coli	63 days	Recharge well
Salmonella	44 days	Water filtering sand column
Shigella	24 days	Water filtering sand column
E.Coli	3 month	Ground water in field
E.Coli	4 month	Groundwater in the lab
Coliform	17 hr/ 50% reduction	Well water
Shigella	28.5 hrs/ 50% reduction	Well water
Viviro cholerate	7.2 hrs/ 50% reduction	Well water

Movement of Bacteria through soil

Nature of pollution	Organism	Media	Maximum observed distance, of travel, ft	Time of travel, days
Wastewater percolation bed	Coliform	Soil	3	12
Treated sewage percolation through per. bed	Coliform	Soil	7	-----
Tertiary treated wastewater	Fecal Coliform	Sand and gravel	200-400	-----
Secondary sewage effluent in percolation beds	Fecal Coliform	Fine loamy sand to gravel	30	------
Surface water	Coliform	Aquifers	----	------
Injection of tertiary treated waste water	Fecal Coliform	Fine to medium sand aquifers	20	------
Injection of primary sewage water mixed with good quality water	Bacteria	Confined aquifers	100	------

Distribution of pathogenic microorganism indicated by E. coli in the soil with surface and subsurface drip irrigation

Sr. No.	Distance from the plant, cm	Depth from the plant, cm	E. Coli/ 100 gm Soil	
			Surface	Subsurface
1	0	0	10000	0
2	0	30	1000	10000
3	25	0	100	0
4	25	30	100	100

Outcome- utilization of sewage water through drip irrigation for vegetable crops

- Survival of pathogens are less compared to surface irrigation
- soil surface can be prevented from the contamination of the pathogens in the case of sub surface drip irrigation.
- Sand filter can reduce B.O.D. and pathogens.
- Cost may be limitation
- Results are encouraging with respect to clogging
- Research on back pressure are required in the case of subsurface drip irrigation

Water use efficiency in the case of ladies finger crop during surface and subsurface drip irrigation

Total water requirement, cm	Sewage water applied, cm	Yield of Ladies finger, t/ha		Water use efficiency, t/ha/cm	
		Surface	Sub-surface	Surface	Sub-surface
89.11	53.07	8.05	14.72	0.089	0.174

Water use efficiency of the Cabbage Crop during surface and subsurface drip irrigation

Total water requirement, cm	Sewage water applied, cm	Yield of Ladies finger, t/ha		Water use efficiency, t/ha/cm	
		Surface	Sub-surface	Surface	Sub-surface
26.83	19.41	33.36	29.00	1.27	1.16

Methodology:

- Treatments → 1. Good quality water 2. Sewage water
- Plant species → 1. Amla 2. Guava
- Irrigation method → Subsurface drip irrigation
- Depth of emitters → 40 cm

Installation of sub-main of subsurface drip irrigation system for fruit crops to utilize sewage water

Installation of lateral pipe of subsurface drip irrigation system to utilize sewage water

Installation of circular lateral pipe along with emitters around the guava tree

Installation of lateral pipe along with the emitters around the guava tree for utilization of sewage water through drip irrigation

Testing of the Backpressure Equipment in the Field

Measurement of the discharge rate of the drippers, volume basis

Measuring observed discharge rate of the drippers

Evaluation of the experimental setup

Sr.No.	Volume basis ,cc	Weight basis, cc	Observed discharge rate, cc	Remarks
1	294	306	320	
2	294	325	320	
3	294	306	320	
4	264	274	280	
5	264	275	260	
6	264	265	260	
7	294	255	242	
8	294	255	260	
9	205	265	260	
10	235	244	250	

Evaluation of the experimental set up

Continued

Sr. No.	Volume basis, cc	Weight basis, cc	Observed discharge rate , cc	Remarks
11	264	234	234	
12	235	244	240	
13	235	244	240	
14	235	255	260	
15	235	224	230	
16	235	224	230	
17	177	224	220	
18	264	224	220	
19	177	214	210	
20	264	244	210	
21	177	183	185	
22	206	255	210	

Significant Achievements cont.

2. Based on the previous project on drip sewage backpressure a new research project proposed.

Contribution in new research Project:

Testing of the system completed with the measurement on pressure and discharge rate: Less discharge rate compared to design discharge rate could be indicator of backpressure

Measuring Discharge rate during testing

Measuring Pressure during testing

Could be Backpressure

Sr.No.	Duration of pump operated , minute	Pressure, Kg/cm²	Flow of the water from the set up, liter	Could be backpressure, Kg/cm²
1	15	1	137.70	0.85
2	20	1	229.50	0.77

Marginal Quality Waters

Definition:

Marginal quality water is defined as " water that possesses certain characteristics which have the potential to cause problems when it used for an intended purpose (F.A.O.,1992)". It is also called low quality water or poor quality waters.

To avoid problems when using the poor quality water supplies, there must be sound planning to ensure that the quality of water available is put to best use.

Applicability of drip irrigation system for wastewater

Each irrigation method has its advantages and disadvantages with specific reference to technical, economic and crop production factors. The selection of a particular irrigation system based upon the situation will depend upon over all performance obtained from a irrigation method compared to other irrigation methods and few such success stories could encourage mission of Drip irrigation in India.

Additional advantages from drip irrigation system

(1) Water saving
(2) Enhanced plant growth and yield
(3) Most suitable to poor soils
(4) Control of weeds
(5) Economy in cultural practices and easy operation
(6) Improve efficiency of fertilizer
(7) Flexibility in operation
(9) No soil erosion
(10) Cost on land leveling can be reduced
(11) Minimum diseases and pest problem

Disadvantages/ limitations

----Persistence maintenance requirements

---- Emitter clogging

Clogging preventive measures are costly

----- Pipe line leak and cracking of tubes(Rodents, rabbits, dogs etc can chew and damage drip line and ants and other insects can occasionally, enlarge opening in drip tubing.

----- Drip lines can be cut during weeding

------ Filters , chemical injectors, pressure regulators, water meters and pumps are also subjected to mal functioning and are liable to theft

Economic -technical limitation

---- Equipment requirement are numerous

----- High initial cost

----- Recurring cost

----- The cost will vary depending upon the type of crops

(Drip irrigation is more suited to widely spaced crops)

------ Life is short varying from 5 to maximum 10 years.

------- Higher level of design, management and maintenance than other irrigation methods.

Conclusion

High potential to solve future water problem. Advancement in technical, and institutional support and few success stories could be a path for Success. Research to encounter STPs, and make effective, both in Rural Environment as well as in urban Environment need attention.

Thanks

Subsurface Drainage for Management of Waterlogged Saline Soils of India

S.K. Kamra
skkamra@cssri.ernet.in

CENTRAL SOIL SALINITY RESEARCH INSTITUTE, KARNAL, HARYANA

OUTLINE

- Introduction
- Salt Affected Soils of India
- Subsurface Drainage
  - Pilot and Large scale Projects in India
  - Impact of SSD
  - Disposal of Saline Drainage Water
- Regional Salinity Management
  - Hydro- salinity Modeling
  - Regional monitoring systems
- Groundwater Recharge

GROUNDWATER PROBLEMS

- Declining watertables
- Drying out of GW dependent water bodies
- Irrigation induced soil and groundwater salinization
- Salt water and sea water intrusion
- Groundwater pollution due to human activities (agricultural, industrial and waste water)
- Geo- genic contamination (arsenic and fluoride)

Source: Groundwater Resources of India, CGWB, 2001

Irrigation Induced Salinity

- 40 % of global food production contributed by areas with irrigation and drainage facilities
- Globally : 20- 30 M ha severally salt affected
  60- 80 M ha slightly to moderately affected
  US $ 10 billion annual losses

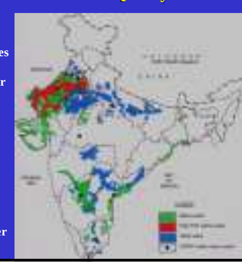
3- 5 M ha area need to be provided with SSD in next 25 years

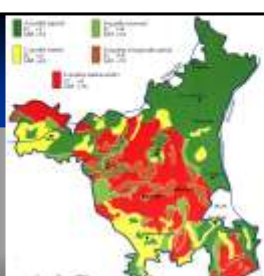
- India: 6.74 M ha salt affected soils
  - 2 M ha severally affected waterlogged saline soils in arid/ semi- arid NW states
  - 1 M ha each in coastal and black cotton vertisols

Projected to be 13 M ha by 2025

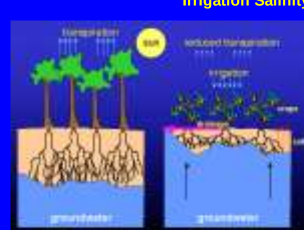
Resource Inventories on Poor Quality Waters

- Use of PQW in some states ranges from 32-84% of total groundwater use
- Saline water use 20%
- Sodic water use 37%
- Saline sodic water use 43%





Irrigation Salinity



WATER LOGGING IN IGNP

Salinity and water logging problems in Gujarat

Water logging is a common feature in the coastal areas of Gujarat state. Prolonged water stagnation results in crop failure and the field remain uncultivated.

Black soils, with the recession of moisture develop deep and wide cracks and concomitant salt build-up pose problems for plant growth.

Need of Drainage

'Irrigation without groundwater control ultimately causes waterlogging and salinity problems… Irrigation can only be sustainable if salts and drainage water are adequately removed from the underground environment and managed for minimal environmental damage'

Herman Bouwer (2000)

Water and Salt Movement

- Tube wells lower the water table to a greater depth, requires to pump much more water to achieve equivalent drawdown than SSD.
- Flow lines in SSD are shorter and originate from shallower less saline layers than in tube well drainage.

- Effluent salinity in SSD improves with time while in tube wells it deteriorates with time.

CSSRI 1983

Cost of Reclamation of Saline Soils with Subsurface Drainage
(2010-11 price level)

Particular	Cost(Rs. /ha)
Land development	5000
Drainage material	25000
Labour charges for system installation	20000
Drainage disposal & operational cost	5000
Total Cost	55000

Particular	Amount
Net Present Worth (Rs. /ha)	55000*
Benefit : Cost Ratio	1.46
Internal Rate of Return (%)	13.0
Pay Back Period (years)	5

Estimated SSD Area in India

- Systematic SSD : 1980 onwards
- Currently : SSD in about 40000 ha area in India

Mechanical Haryana (Western Yamuna and Bhakra command): 8800 ha
Rajasthan (Chambal and IGNP command): 16500 ha
Maharasthra (Sangli): 2500 ha
Karnataka (Belgaum): 1200 ha
South West Punjab : 500 ha , 2000 ha in pipe line

Manual- Small Research projects: 5000 ha
(AP, MP, Gujarat, Haryana, Kerala; Karnataka, Assam, Punjab)

Cost (Rs/ha) : Haryana (Rs. 60000/); Maharashtra (Rs. 75000)

Recommended drain depth - spacing combinations for various agro-climatic regions in India

Agro-climatic region	Drain depth (m)	Drain spacing (m)
Semi-arid coastal plains of Andhra Pradesh Semi-arid Trans-Gangetic plains of Haryana	1.4 1.4-1.75	10-15 60-100
Humid coastal plains of Kerala Semi-arid plains of Gujarat Arid lands of Rajasthan	1.0 1.0 1.0-1.5	30 20-40 30-60
Sub-humid regions of lower Gangetic plains in West Bengal	1.75	15-45

Complied from different sources by Ritzema et. al (2008)

Drainage coefficient (mm/d)			Drainage depth (D_d)		Drain spacing (D_s)	
Climate	Range	Optimal	Outlet	D_d (m)	Soil texture	D_s (m)
Arid	1-2	1	Gravity	0.9-1.2	Light	100-150
Semi arid	1-3	2	Pumped	1.2-1.8	Medium	50-100
Sub Humid	2-5	3			Heavy	30-50

Before drainage (Konanki, A.P.)

After drainage (Sampla, Haryana)

After drainage (Konanki, A.P.)

After drainage (Gohana, Haryana)

IMPACT OF LAND DRAINAGE ON CROP YIELD

State	Crop	Crop yield ($t\ ha^{-1}$)		
		Before drainage	After drainage	Increase over pre-drainage (%)
Haryana (3 locations)	Cotton Wheat Barley Paddy Pearl Millet	0.0 0.0- 3.1 0.0 1.4 0.88	1.4-1.8* 1.9- 4.9* 2.1- 4.2* 1.7 1.23	** 18- 112 ** 21 39
Andhra Pradesh (2 locations)	Paddy	3.6- 3.7	5.2- 5.6	45- 50
Gujarat (1 location)	Sugarcane	78- 104	105- 140	35
Karnataka (7 locations)	Paddy Cotton Sunflower Sorghum Wheat	1.4- 4.0 3.3 3.0 6.8 4.0	3.7- 8.4 10.4 7.4 11.6 6.7	98- 340 215 146 70 68

* Effect of drain spacing during first year
** Increase over pre-drainage zero yield not estimitable

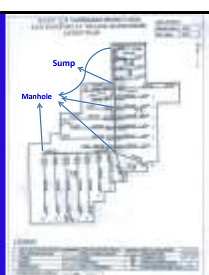
Haryana Operational Pilot Project : Sub- Surface Drainage

CSSRI Research Activities (2013- 2014)

- ❑ Help in Identification of new sites (April- May 2013): 3300 ha (Rohtak, Sonipat, Jhajjar)
- ❑ Approve / Modify proposed design and layout of HOPP (May 2013)
- ❑ Monitoring and evaluation of SSD projects

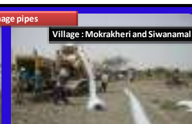
i.Improvement in crop yield
ii.Changes in soil salinity and water quality
iii.Fluctuation in water table depth
iv.Performance of drain
v. Socio economic improvement of livelihood of farmers

- ❑ International Training for Iraqi Engineers (April 2013)
- ❑ Interaction with Fatehabad district authorities and farmers and submission of report (August- September 2013)
- ❑ 2 day Training proposed for Maharashtra Engineers (May 2014)

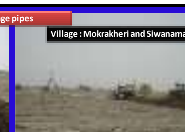


BLOCK F-3	
Area (Ha)	
Gross Area	49.00
Net Area	40.20

Installation of collector and lateral drainage pipes



Installation of collector and lateral drainage pipes



Maharashtra SSD Projects reclaimed – under in Government funding

Sr. No.	Name of Village	Taluka	District	Area	Cost In Lacs
1	Dudhagaon-Reclaim I)	Miraj	Sangli	1100 ha.	458.95
2	Kasabe Digraj-Reclaim II	Miraj	Sangli	592 ha.	331.14
			Total	1692 ha.	790.09

Contributions Pattern for SSD: TDET – 60%; Farmers – 20%; State Govt. – 20%
State Govt. - 100% **for Main Drain.**

Cropping Pattern : Sugar cane
Spacing of Laterals: 30m; Drain Depth : 1 to 1.5m (an average of 1.2m) for laterals and upto 2 m for collectors
Outlets: By Gravity.(No Pumping)
Constrains
Alkalinity: Gypsum or pyrite application
Prosopis juliflora : Clogging of drain by roots

Ongoing SSD projects* in Maharashtra

Sr. No.	Name of Village	Taluka	District	Area	Cost In Lacs
1	Uran Islampur	Walwa	Sangli	362 ha.	217.48
2	Borgaon	Walwa	Sangli	246 ha.	153.14
3	Sakharale	Walwa	Sangli	183 ha.	107.71
4	Kasegaon	Walwa	Sangli	121 ha.	77.15
			Total	912 ha.	555.48

•**Designs approved by CSSRI**
Contributions Pattern for SSD: RKVY – 60%; Farmers – 20%; State Govt. – 20%
State Govt. - 100% **for Main Drain**

Proposed SSD (Survey of villages) under RKVY

Sr. No.	Villages	Area (ha)	Length of main drain (km)	No. of beneficiaries	Necessary Fund (Rs. Lakh)
1	Nilaji (Bamani) and Samdoli Taluka Miraj, Dist. Sangli	1030	10	500	929.66
2	Brahmnal, Vasagade, Dhangaon (Tavadarwadi), Burangwadi and Khatav, Taluka Palus, Dist. Sangli	1200	11	750	1378.00
3	Shedshal Taluka Shirol, Dist.	265	2	300	334.45
4	Kurandwad and Udgaon, Taluka Shirol, Dist.	950	5	400	713.60
5	Baramati, Tal. Baramati (Pune)	950	5	400	713.60
6	Karandwadi, Taluka Walwa, Dist. Sangli	850	5	400	704.80
7	Naigon and Daund, Tal. Daund, Dist. Pune	950	5	400	713.60
8	Karve, Tal. Karad and Phaltan, Dist. Satara	950	5	400	713.60
	Total	7145 H	48 km	3550	6201.31

Contributions Pattern for SSD: RKVY – 85%; Farmers – 15%; State Govt. - 100% for Main Drain.

Ongoing SSD projects* in KARNATAKA

Ongoing projects for SSD work under TDET scheme.

Sr. No.	Name of Village	Taluka	District	Area	Cost In Lacs
1	Ugar Budruk	Athani	Belgaum	925 ha.	479.56

•**Designs approved by CSSRI**
Contributions Pattern for SSD: RKVY – 60%; Farmers – 20%; State Govt. – 20%
State Govt. - 100% **for Main Drain.**

Approximate area in Private sector

Sr. No.	Name of State	Area (Approx)	Cost In Lacs
1	Maharashtra	700 Ha	630
2	Karanataka	1200 Ha	1080
	Total		

Ongoing SSD projects* in Gujarat

Sr. No.	Name of Village	Taluka	District	Area	Cost In Lacs
1	Mullad	Surat	Surat	45 ha.	38.34

•**Designs approved by CSSRI**
Funding From Dist. Panchyat - 100%.

Visit on Dated: 7/10/2013

Disposal Options

- Surface Drains/ River
- Canal system
- In situ disposal for irrigation to agro-forestry/ tolerant field crops
- Evaporation ponds, Aquaculture
- Injection into Deep confined aquifers

DRAINAGE WATER DISPOSAL OPTIONS

Disposal of drainage effluents is of serious environmental concern. Disposal strategies depend upon the volume and quality of effluents and the availability of an outfall.

Disposal to surface drains or sea

- Ideal solution
- Topographical and socio-economic restrictions

Reuse of drainage water for crops/ agro-forestry

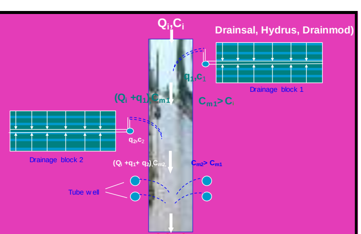
- Drainage water salinity decrease within 1-2 years
- Direct use : Cyclic or blended mode with canal water
- Avoid application at salt sensitive crop growth stages

Allowable subsurface drainage discharge and drainable area into the River Yamuna

Month	Allowable discharge (m^2/s)		Drainable area (ha)	
	Effluent salinity (dS/m)			
	6	10	6	10
June	0.9	0.5	5.000	3.000
July	25.4	14.4	146.000	83.000
August	47.6	27.0	274.000	156.000
September	6.5	3.7	37.000	21.000
October	3.0	1.7	17.000	10.000

Regional Salinity Management

(Modelling and Geo- physical and EM Measurement Systems)



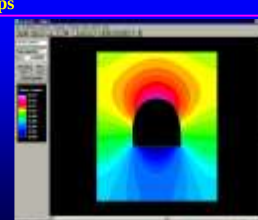
Water and Salt Balance of a canal distributory in an irrigated are of a saline ground water

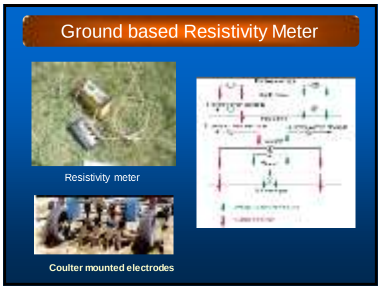
HYDRUS_1D, 2D

Software Packages for Simulating Water Flow and Solute Transport in One- and Two-Dimensional Variably Saturated Porous Media

(Authors: J. Šimunek, M. Šejna and M. Th. van Genuchten, U.S. Salinity Laboratory, USDA-ARS, Riverside, CA)

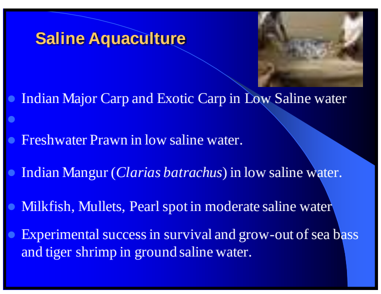
GRAPHICS - Spectral Color Maps




Ground based Resistivity Meter
Resistivity meter
Coulter mounted electrodes


EM Conductivity Meters
EM 31
EM 31
EM 34


Evaporation Tank for Disposal


Saline Aquaculture
Indian Major Carp and Exotic Carp in Low Saline water
Freshwater Prawn in low saline water.
Indian Mangur (Clarias batrachus) in low saline water.
Milkfish, Mullets, Pearl spot in moderate saline water
Experimental success in survival and grow-out of sea bass and tiger shrimp in ground saline water.


SUITABLE TREE SPECIES FOR BIODRAINAGE
Eucalyptus (Eucalyptus teriticornis)
Jamun (S. cumini)
Bamboo
Australian pine (Casurina glauca)


Visit to Fatehabad (21.08.2013)


Iraqi Training (April 15-21, 2013)


Field visit of Iraqi delegates (18-4-2013)


DG and Iraqi delegates visit at HOPP site (Mokhrakheri, Rohtak)- May 2013


Training on SSD for Maharashtra Engineers (April 2014)


Thank you for your kind attention!!!

Groundwater Recharge Tubewells: Prospects and Problems

S.K. Kamra
skkamra@cssri.ernet.in

CENTRAL SOIL SALINITY RESEARCH INSTITUTE, KARNAL (Haryana, India)

INTRODUCTION

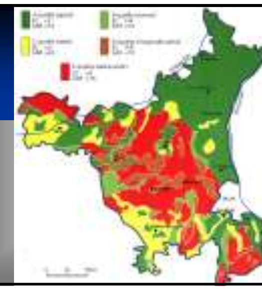
√ Declining watertables: Socio- economic and environmental impacts

•Drying out of GW based water bodies and ecosystems

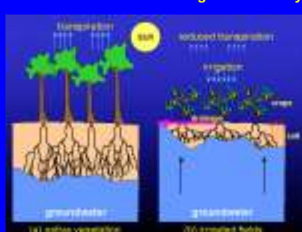
•√ Irrigation induced groundwater salinization, geo-genic salt water and sea water intrusion

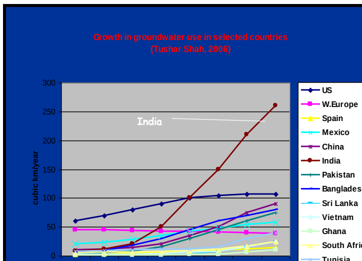
• Groundwater pollution due to human activities (agricultural, industrial and waste water)

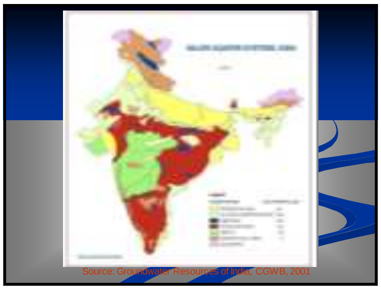
•Geo- genic contamination of groundwater (arsenic and fluoride)

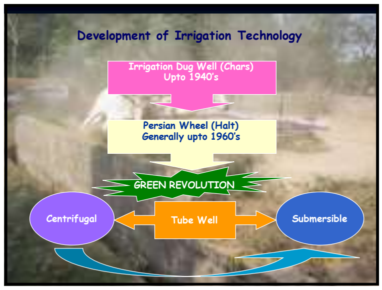


Irrigation Salinity





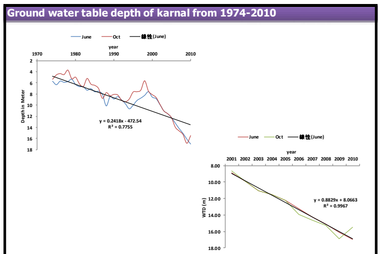




Present water table depths and decline rates in fresh groundwater districts of Haryana

S.No.	District	Water table Depth (June 2012), m	Mean (1974-2012) water table decline (cm/yr)	Stage of groundwater development (%)
1.	Karnal	18.5	35	137
2.	Kurukshetra	31.8	68	166
3.	Kaithal	22.2	49	179
4.	Panipat	17.5	42	156
5.	Gurgaon	26.5	64	209
6.	Mahendragarh	48.7	79	120
7.	Rewari	24.1	44	120

Ground water table depth of karnal from 1974-2010



Narjary *et al.*, 2014

Changes in monthly rainfall during (2001-2010) over average (1972-2010) in Karnal district

Season	Months	Rainfall		
		Average (mm) (1972-2010)	Average (mm) (2001-2010)	% Change over average of (1972-2010) value
Winter	January	26	23	-12
	February	31	40	+29
Summer	March	27	19	-30
	April	14	11	-21
	May	28	37	+32
Monsoon	June	92	101	**+9**
	July	198	137	**-31**
	August	189	131	**-31**
	September	106	150	**+41**
Post Monsoon	October	16	10	-37
	November	6	3	-50
	December	14	8	-43

Narjary *et al.*, 2014

Groundwater recharge is the Key

Surface water dams deliver 150 km3/year; aquifer system delivers 220 km3/year which is far more productive.

India gets 4000 km3 of precipitation; we use 220 km3 of groundwater. Natural recharge of 4-10% of rainfall into aquifers. We need to focus recharge effort at the right places for sustaining groundwater irrigation.

The challenge is to increase recharge in arid areas (north-west) and hard rock aquifers (peninsular India).

Big Groundwater Recharge Structures

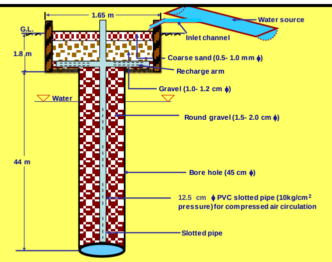
Flood Water Affects Crop Production

- ❖Despite reduction in monsoon rainfall with climate change, runoff gets accumulates at specific locations
- • Low lying fields
- • Close to non-functional surface drains
- ❖Affects paddy crop and sometimes wheat during heavy winter rain
- ❖Small GR structures act as local surface drainage outlets
- • Save crops from water stagnation and improve income
- • Raise watertable
- • Improve groundwater quality (EC, fluoride, nitrate)

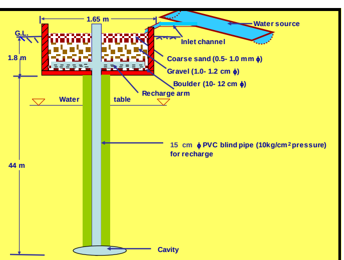
Technologies demonstrated conducted under FPARP

State/ District	Technology/intervention	No. of sites
Haryana		53
Karnal, Kaithal, Jind, Kurukshetra, Yamunanagar, Sonipat	Recharge shaft	21
	Recharge cavity	08
	Laser levelling	19
	Other (abandoned cavity, dry cavity, saline fisheries)	05
Punjab		05
Patiala	Recharge shaft	05
Uttar Pradesh		17
Unnao, Raebareli, Muzzafarnagar	Recharge cavity	03
	Laser levelling and improved irrigation practices	14
Gujarat		15
Bharuch	Recharge well	12
	Renovation of farm pond/IFS	03
Total		93

Location map of technologies demonstration under FPARP



Recharge Shaft for different selected sites of FPARP

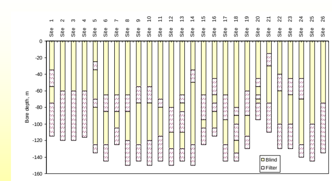


Recharge cavity for different selected sites of FPARP

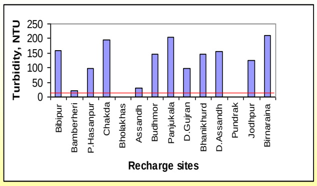
Installation of Recharge Wells

Construction of Recharge Filter

Clogging of filtering media



Permissible limit = 5 – 10 NTU



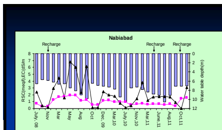
Turbidity of runoff water collected from different sites

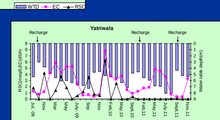
S. No.	Sample	Amount (mL)	Imidacloprid	Endosulfan
1	Jodhpur	380	BDL	BDL
2	P.Hasanpur	410	BDL	BDL
3	Karnal	500	BDL	BDL
4	Bibipur	500	BDL	BDL
5	Assandh	500	BDL	BDL
6	Dussain+	500	BDL	BDL
7	Panjukala	500	BDL	BDL
8	Yatriwala	500	BDL	BDL
9	D.Gujran	500	BDL	BDL
10	Dussain	500	BDL	BDL

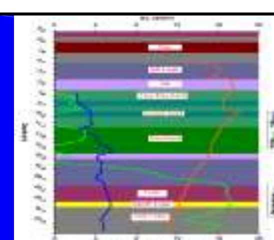
Monitoring of Groundwater at FPARP Sites in Haryana and Punjab

GR structures installed by CSSRI in Bharuch district (Gujarat)

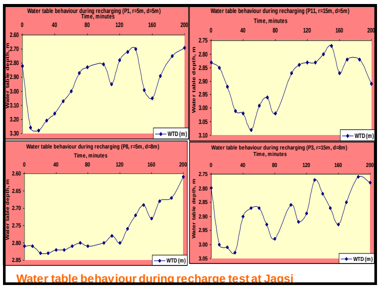
GR Wells installed by CSSRI in Unnao District (UP)

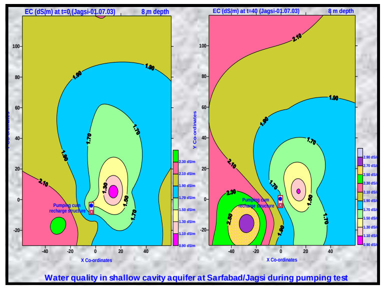


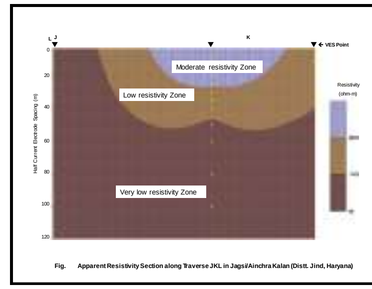




Lithology, EC and Resistivity profile (Site: Jagsi)







Hydraulic and Economic Impact of Groundwater Recharge Structure During 2009

Haryana (Karnal Distt.)

Site	Runoff Area (ha)	Runoff Volume (M^3)	Investment Cost (Rs/m^3 recharge water)	Paddy saved	Net Saving (Rs.)
1	12	12480	3.5	25% in 1ha area	24500
2	20	20800	2.1	30% in 2ha area	58800

- Recharge Rate : 2500-3500 m^3 / weak (4-6 l/s)
- Water table Rise : 0.6-3.3 m
- Reduction in ground water salinity : 0.2-2.4 dS/m

Hydraulic and Economic Impact of Groundwater Recharge Structure During 2009

Gujarat (Bharuch Distt.)

Increase in income (Rs/ha)

Site 1	75000 (Banana)	50000 (Papaya)
Site 2	14,000 (Soyabean)	33,250 (Mango)

U.P. (Unnao Distt.)

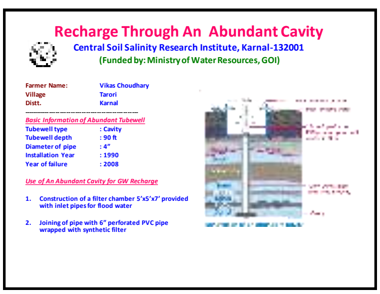
Reduction in fluoride concentration in groundwater

2.5 ppm to 0.6 ppm

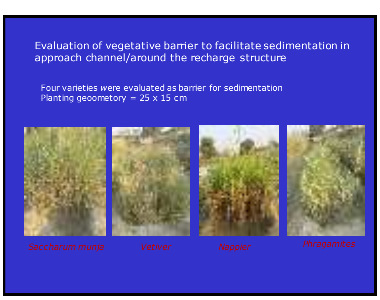
Improvement in Groundwater Quality due to Recharge During 2009

S.N.	State/Village	EC (dS/m)			RSC		
		May/ June	August	October	May/ June	August	October
1	Haryana a) Nabiabad (Karnal) b) Paju Kalan (Jind) Dussain (Kaithal)	1.9 1.2 1.4	1.1 0.9 1.1	0.5 0.5 0.5	6.0 5.6 6.7	2.4 3.4 3.9	0.2 0.62 2.1
2	Punjab Jodhpur (Patiala)	2.0	1.7	1.1	7.1	3.4	3.2
3	Gujarat Borebhete (Bharuch)	1.9	0.3	-	-	-	-

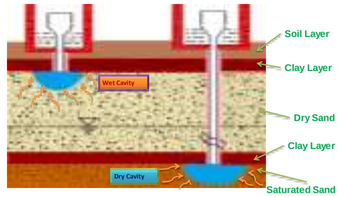

August 27, 2012
August 27, 2012
August 27, 2012
August 30, 2012


Recharge Through An Abundant Cavity
Central Soil Salinity Research Institute, Karnal-132001
(Funded by: Ministry of Water Resources, GOI)
Farmer Name: Vikas Choudhary
Village Tarori
Distt. Karnal
Basic Information of Abundant Tubewell
Tubewell type : Cavity
Tubewell depth : 90 ft
Diameter of pipe : 4”
Installation Year : 1990
Year of failure : 2008
Use of An Abundant Cavity for GW Recharge
1. Construction of a filter chamber 5’x5’x7’ provided with inlet pipes for flood water
2. Joining of pipe with 6” perforated PVC pipe wrapped with synthetic filter


Evaluation of radial filtering unit


Evaluation of vegetative barrier to facilitate sedimentation in approach channel/around the recharge structure
Four varieties were evaluated as barrier for sedimentation
Planting geoometory = 25 x 15 cm
Saccharum munja
Vetiver
Nappier
Phragamites


A view of set up of evaluating vegetative strip



- To reduce cost of structure, may be more expansive due to declining water table
- To avoid environmental issues
- To utilize required amount of cavity for recharging
- Can work as assured drainage for crop diversification with maize

(ii) Supply Augmentation

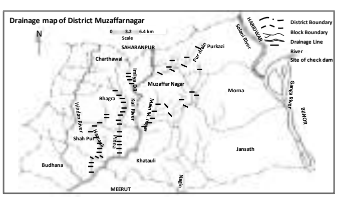
1. Construction of 53 Check dams (1-1.5 m height at 2 km distance) in drainage channels

2. Flood water harvesting and recharge well in Hindon river

- 20 gated check dams of 1 m height. The gates will be closed during monsoon to facilitate recharge but will be opened during remaining period to allow flow of polluted water.
- The check dams will be connected to a recharge well

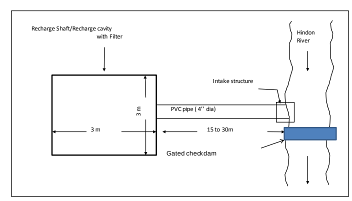
3. Excess canal water recharge through percolation pond - cum- recharge well

Drainage network of Muzaffarnagar district (map showing only few drains selected for construction of series of checkdam)

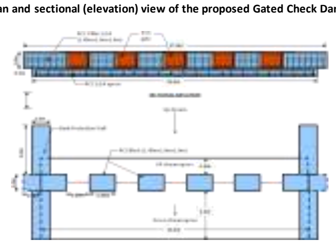


Check dam in drainage line

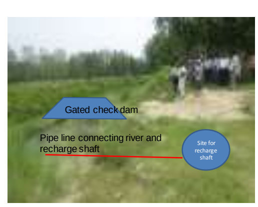
Plan for harvesting flood water from the river for groundwater recharge in monsoon season



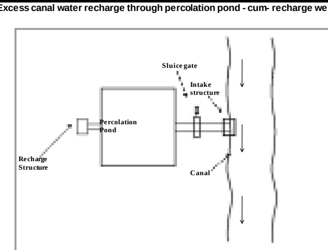
Plan and sectional (elevation) view of the proposed Gated Check Dam

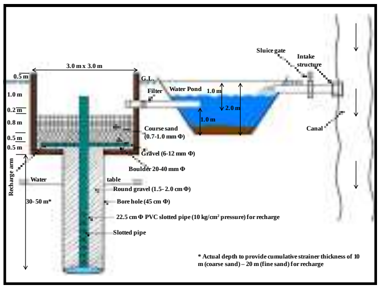


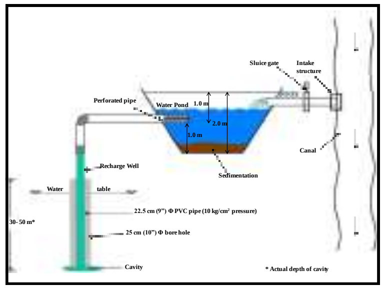
Site for flood harvesting on Hindon river



Excess canal water recharge through percolation pond - cum- recharge well







Conclusions

- Artificial GR through wells is a practical technology to augment groundwater, save crops in submerged areas and improve groundwater quality.
- Effective designs of recharge filters and quality of recharge water need to be taken care of for implementing recharge projects over large areas.
- Small and less costly recharge structures are needed to save wheat crop due to occasional rainfall during February /March.
- GW management must be planned in the context of regional requirements of agricultural, urban and industrial sectors.
- ❖ Regionalization of highly variable GR is constrained due to limited capability to identify/ quantify recharge mechanisms and controlling factors