Departamento de Engenharia Agrícola
Centro de Ciências Agrárias
Universidade Federal do Ceará

Instituto Nacional de Ciência e Tecnologia em Salinidade
(INCTSal)

Saline water: sources, possibilities and strategies for use in irrigation

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General Outline

1. Saline water sources and possible uses for irrigation

2. Strategies for use of saline water in irrigation

   2.1 Salt tolerant plants (glycophyte and halophyte)
   2.2 Crop rotation
   2.3 Cyclic use of saline water and during the salt tolerant plant growth stages
   2.4 Denser crops
   2.5 Drainage and leaching of salts
   2.6 Mixing of different irrigation water
   2.7 Hydroponics
   2.8 Use of biofertilizers

3. Conclusions

1. Saline water sources and possible uses for irrigation

- Sea water
- Continental surface water
- Groundwater
- Waste water

Sea water

- Electrical conductivity (EC) – 45 to 55 dS m^{-1}
- High availability but low quality for irrigation
- Irrigation of halophyte plants
- Mixed with other water sources

Continental surface water

- Electrical conductivity (EC) – 0.05 to 1.5 dS m^{-1}
- Salinity of small dams can vary in time
- Availability varies over time and space
- Use in industry, domestic consumption and irrigation

Groundwater

- Electrical conductivity (EC) – in general is higher than surface water
- Brackish water
- Crystalline basement > alluvial formations > sedimentary rocks
- Wells drilled in Ceará - 63% - crystalline basement
  29% - sedimentary rocks
  8% - alluvial formations
- Salinity and water availability vary in according to location, season and depth
- Use in industry, domestic consumption and irrigation

Water samples from different localities in the Brazilian semiarid

Characteristics	S1	S2	S3	S4	S5	S6	S7
EC (dS m^{-1})	1.3	0.5	3.2	0.6	1.9	15.5	8.0
pH	6.9	7.5	7.1	7.4	7.3	7.5	7.1
Ca^{2+} ($mmol_c$ L^{-1})	3.5	15	13.4	1.8	16.0	130	6.0
Mg^{2+} ($mmol_c$ L^{-1})	2.8	1.6	3.8	1.8	1.5	16.8	5.0
Na^{+} ($mmol_c$ L^{-1})	5.7	1.7	15.9	2.9	1.4	93.4	50.0
K^{+} ($mmol_c$ L^{-1})	0.1	0.2	0.1	0.5	0.5	1.8	0.7
HCO_3^{-} ($mmol_c$ L^{-1})	5.8	2.3	6.6	3.1	2.8	2.7	1.8
Cl^{-} ($mmol_c$ L^{-1})	6.0	2.9	25.9	1.7	2.0	227.5	90.0
SO_4^{2-} ($mmol_c$ L^{-1})	-	-	-	-	15.6	2.5	-
RAS	3.2	1.4	5.4	2.2	0.5	31.0	11.4

S1 = Água de poço tubular em aluvião (Pentecoste, CE)
S2 = Água de canal de irrigação proveniente do Açude General Sampaio (General Sampaio, CE)
S3 = Água de poço do Aqüífero Calcário Jandaíra, profundidade de 80 m (Porto Filho et al., 2006)
S4 = Água de poço do aqüífero Arenito-Açu, profundidade de 1000m, RN (Porto Filho et al., 2006)
S5 = Água de poço do Aqüífero Serra Grande (Simplício Mendes, PI)
S6 = Água de poço amazonas no município de Choro Limão, CE
S7 = Amostra proveniente de rejeitos de dessalinizador, no município de Pentecoste, CE

Wastewater

a. Wastewater produced by industrial activities and domestic sewage

- moderate salinity
- presence of chemical and biological contaminants
- potential use for irrigation (ornamental plants, wood, biofuels, etc.).

Wastewater

b. Desalinization wastes

- High salt concentrations
- About 70% of the water entering the process of desalination
- Brazilian Semiarid – more than 3000 desalination equipments installed
- Use in irrigation of halophyte

Wastewater

c. Drainage water

- Variable salinity
- High availability in some irrigated areas
- Few studies and experiences of reuse in Brazil

2. Strategies for use of saline water in irrigation

2.1 Salt tolerant plants

- Glycophyte – Salt sensitive???

Many glycophyte are moderately tolerant or tolerant to salinity

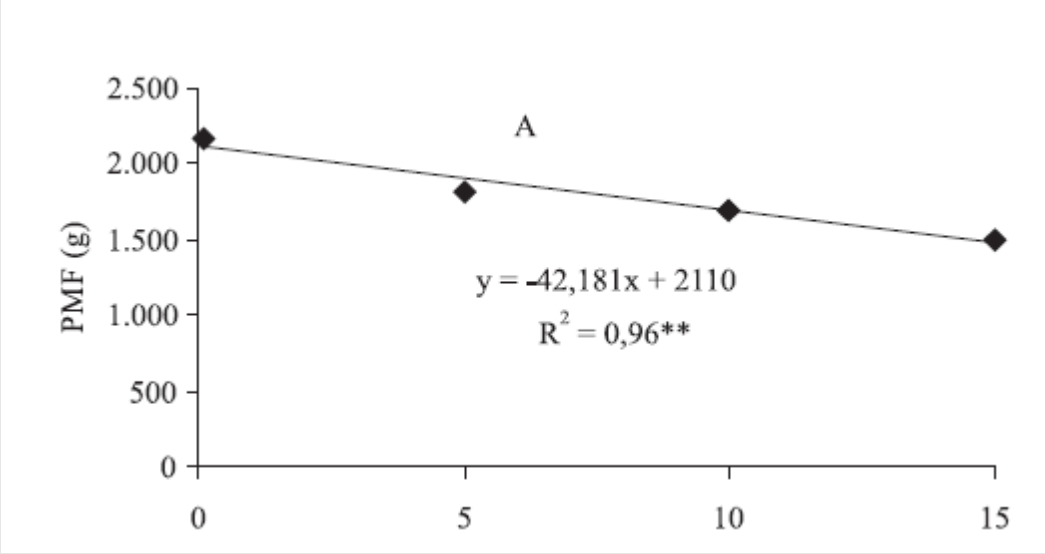
Examples: cotton, sorghum, cowpea, sunflower, etc.

- Halophyte – can be irrigated with high salinity irrigation water, examples desalinization wastes and sea water

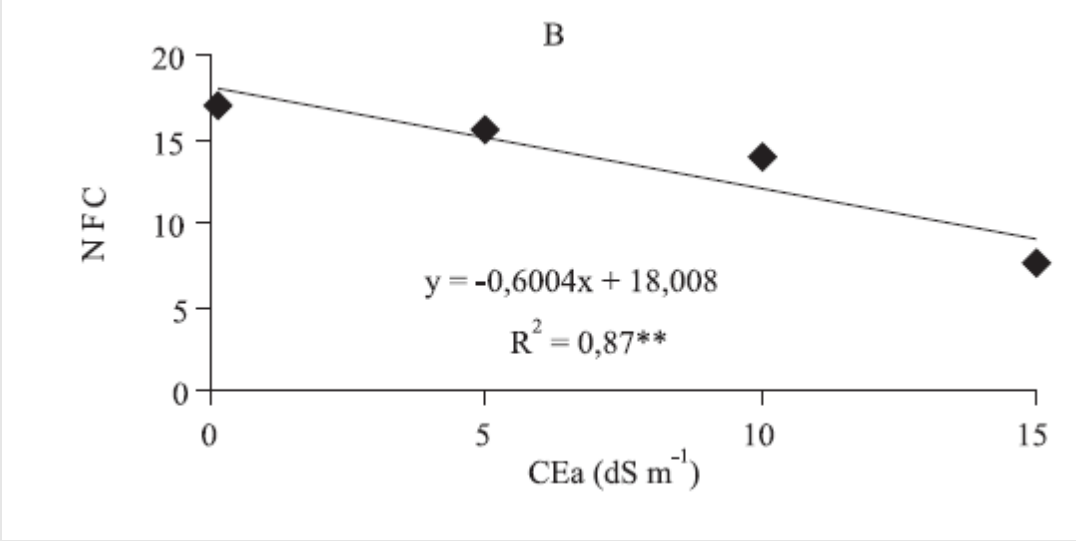
Examples: *Salicornia, Atriplex*, etc.

Coconut irrigated with saline water

Fruit weight

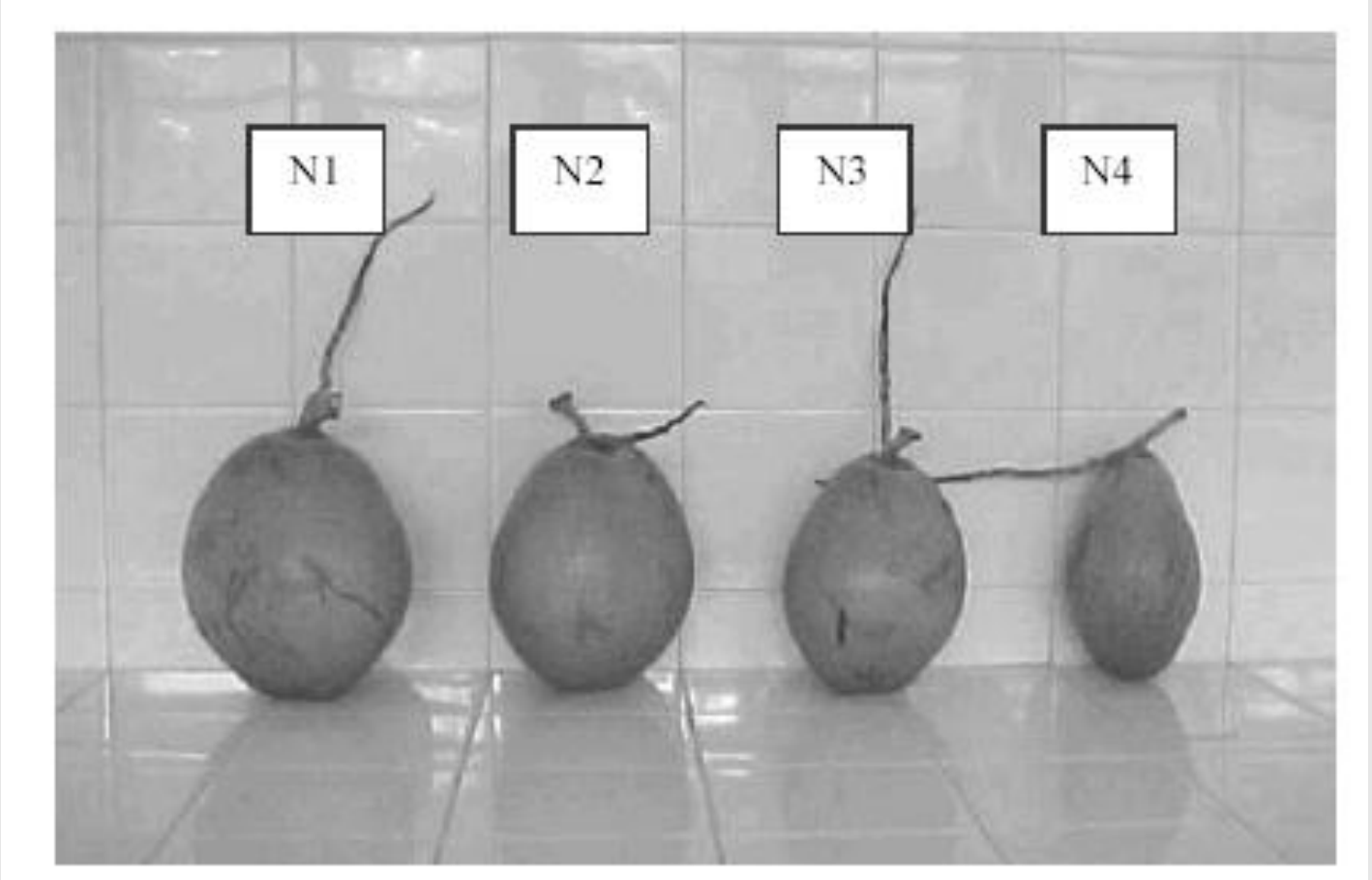


Number of fruits



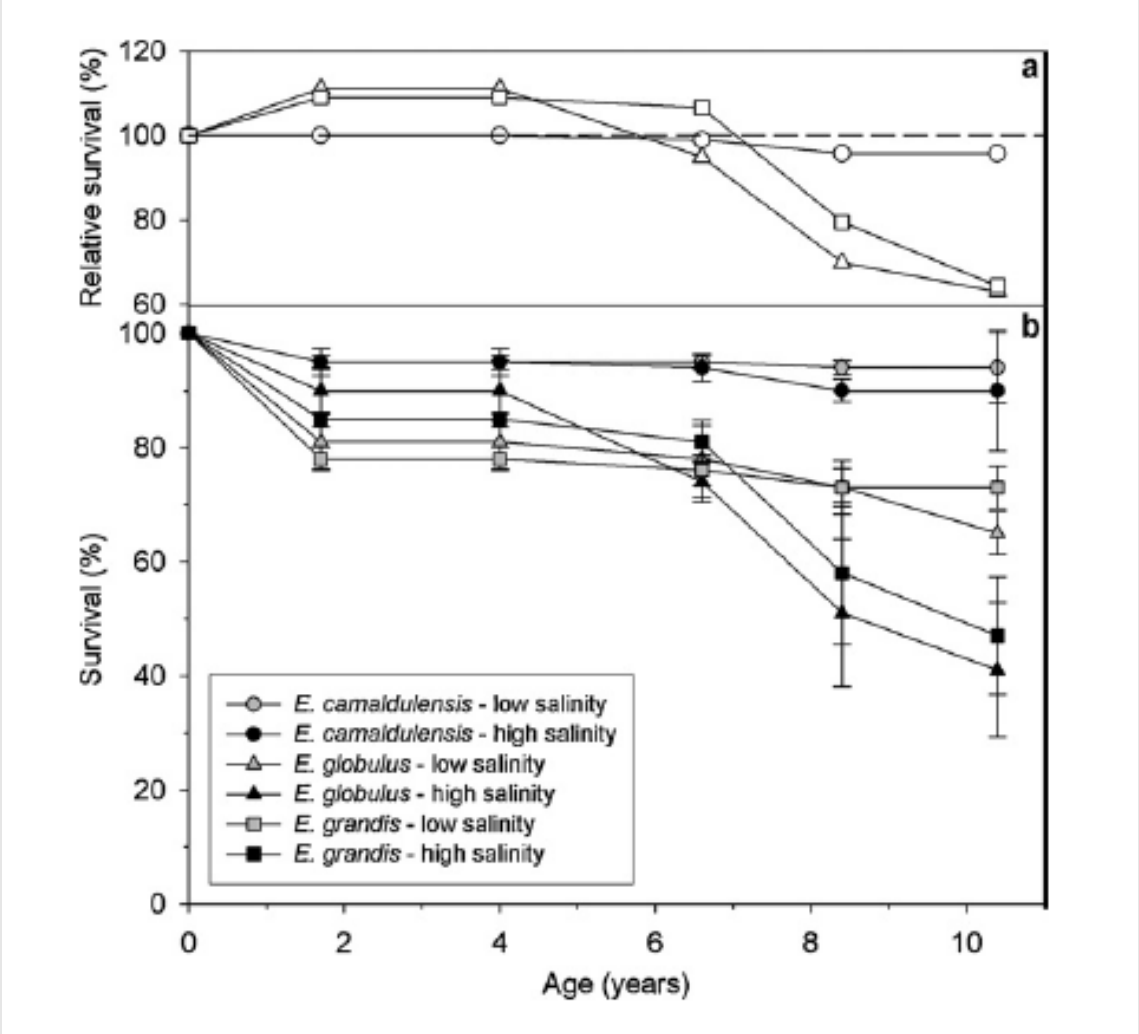
(Marinho et al., 2006)

ECw between 0.1 and 15 dS m^{-1}



(Ferreira Neto et al., 2001)

Effect of salinity on growth of irrigated plantation *Eucalyptus* in south-eastern Australia



(Feikema & Baker, 2011)

Atriplex nummumaria irrigated with desalinization wastes

(Porto et al., 2001)

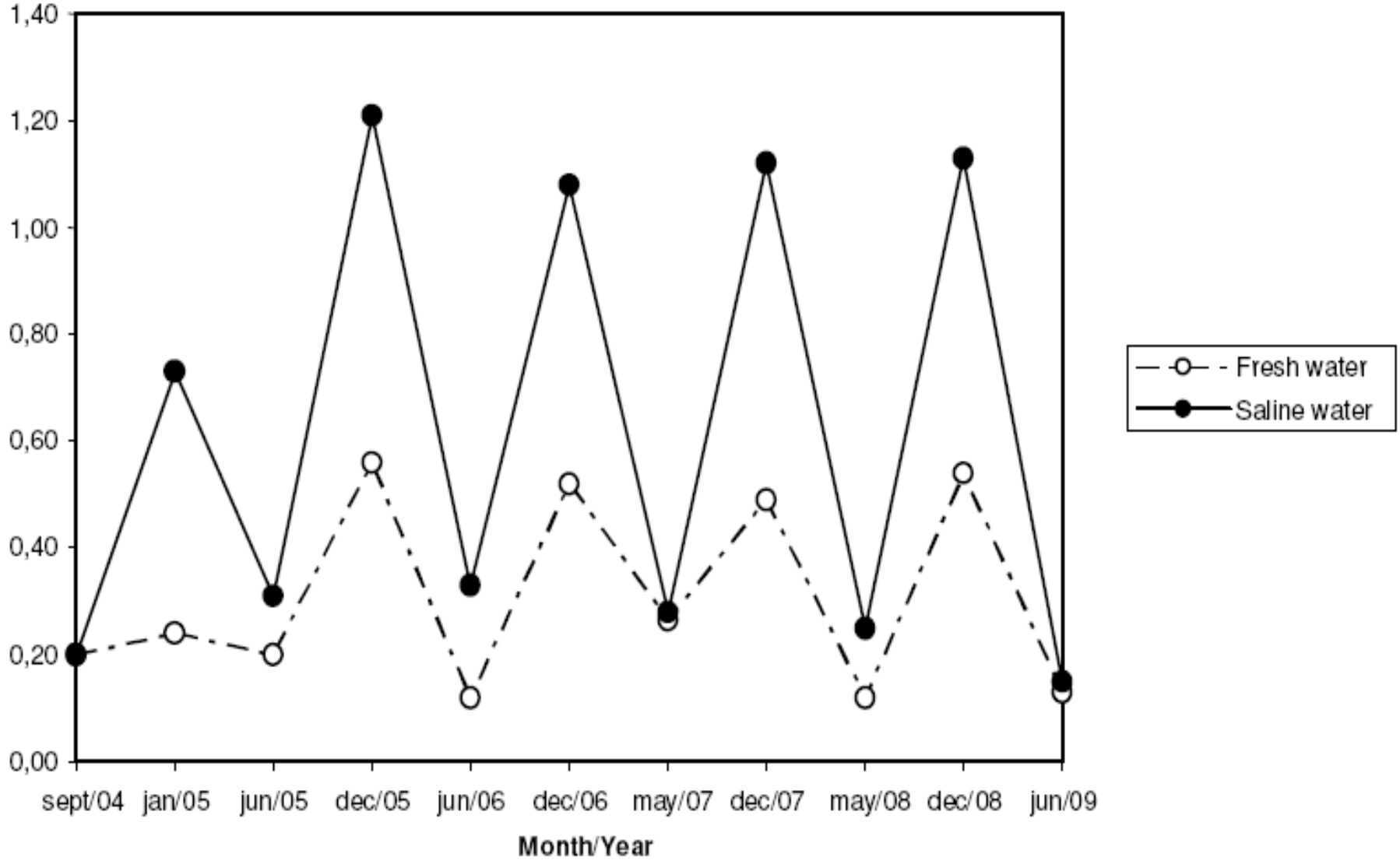
Forage quality of *Atriplex*

Characteristics	%
Ash in the stems	10.4
Ash in the leaves	25.5
Protein in the stems	8.8
Protein in the leaves	15.5

2.2 Crop rotation

- Use of saline water for irrigation during dry season – more salt tolerant plants
- Leaching of salts and crops more salt sensitive during the rainy season
- The planting in the rainy season should only be done after the first rains
- The results can be altered by environmental conditions, especially at the beginning of the rains of the wet season

Average contents of Na^+ in the layer from 0.0 to 0.6 m



Mean values of temperature (T). relative humidity (RH). and totals of insolation and rainfall (PPT) obtained during the dry season and during the subsequent rainy season

Months	T(°C)	RH(%)	Insolation (h)	PPT (mm)
sept/07	27.0	67	308.1	**14**
oct/07	27.2	67	313.6	**0.9**
nov/07	27.7	70	332.5	**5.0**
dec/07	27.7	73	254.5	**87.5**
jan/08	26.6	83	141.8	**287.7**
feb/08	27.8	75	257.6	**75.3**
mar/08	27.0	79	211.8	**282.7**
apr/08	26.6	85	113.4	**521.5**

Source: Federal University of Ceará's Weather Station

Cowpea/maize crop rotation systems utilizing waters of different salinities

Treatments ECa (dS m^{-1})	Yield (kg ha^{-1})	
	Crop Rotation 1	Crop Rotation 2
	Maize	**Cowpea**
0.8	4362.0	1758.0
2.2	4366.0	1458.0
3.6	3606.0	1358.0
5.0	3110.0	1266.0
	Cowpea	**Maize**
0.8 (residual)	160.0	5212.0
2.2 (residual)	181.0	5181.0
3.6 (residual)	168.0	5093.0
5.0 (residual)	169.0	5350.0

Bezerra et al. (2010) Lacerda et al. (2011)

Other examples of crop rotation systems used in our studies

Sunflower/maize

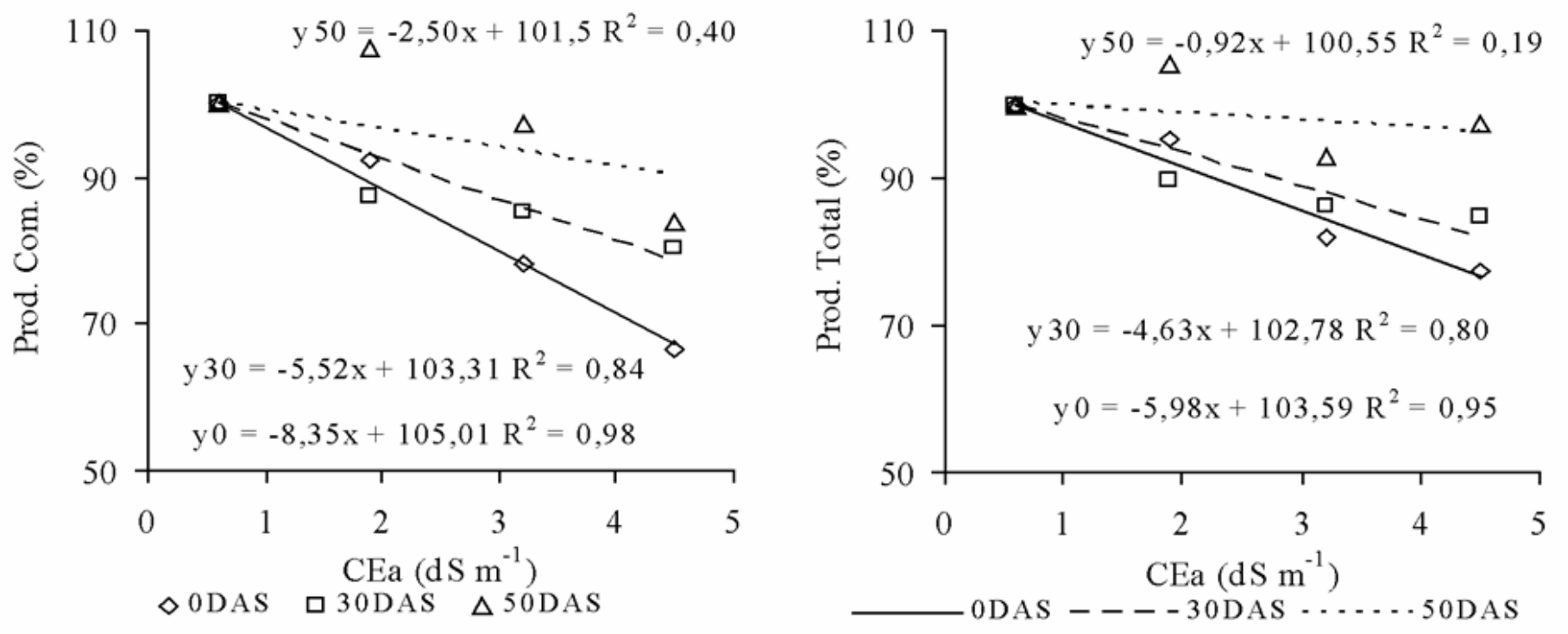
Cowpea/sunflower

Cotton/sunflower/cowpea

Sorghum/cowpea

2.3 Cyclic use of saline water and during the salt tolerant plant growth stages

Use of saline water at different growth stages of melon plants



(Porto Filho et al., 2006)

Contribution of the fresh and saline water in the total irrigation depth and cowpea yield of the different treatments of irrigation management

Treatments	Fhesh water (mm)	Saline water (mm)	Irrigation depht (mm)	Yield (kg ha-1)
FW	**326.3 (100)[1]**	**0.0 (0)**	**326.3**	**1864.5 a**
SW	25.9 (7.9)	300.4 (92.1)	326.3	984.8 b
SW (0 a 22 DAP)	239.2 (73.3)	87.1 (26.7)	326.3	1241.4 b
SW (23 – 42 DAP)	215.8 (66.1)	110.5 (33.9)	326.3	1827.3 a
SW (43 a 62 DAP)	**197.6 (60.6)**	**128.7 (39.4)**	**326.3**	**1877.4 a**

FW = 0.8 dS m^{-1}; SW = 5.0 dS m^{-1}

(Lacerda et al., 2009)

Contribution of the fresh and saline water in the total irrigation depth and cowpea yield of the different treatments of irrigation management

Treatments	Fhesh water (mm)	Saline water (mm)	Irrigation depth (mm)	Yield (kg ha-1)
FW	**375.7 (100)**	**0.0 (0)**	**375.7**	**1281.8 a**
SW - continue	**0.0 (0.0)**	**375.7 (100)**	**375.7**	**853.0 c**
FW-SW (cyclic)	**247.6 (65.9)**	**128.1 (34.1)**	**375.7**	**1246.5 a**
SW – last stage	198.6 (52.9)	177.1 (47.1)	375.7	1061.7 ab

FW = 0.5 dS m^{-1}; SW = 5.0 dS m^{-1}

Neves et al. (2012)

Contribution of the fresh and saline water in the total irrigation depth. leaf Na+ contents, and relative maize yield of the different treatments of irrigation management

Treatments	Fhesh water (mm)	Saline water (mm)	Leaf Na^+ (mmol kg^{-1})	Relative Yield (%)
FW	**589.5 (100)**	**0.0 (0)**	**66.6 b**	**100**
SW - continue	**0.0 (0.0)**	**589.5 (100)**	**104.5 a**	**71**
FW-SW (cyclic)	**315.7 (53.6)**	**273.8 (46.4)**	**68.5 b**	**100**
SW-FW (cyclic)	**273.8 (46.4)**	**315.7 (53.6)**	**66.6 b**	**84**

FW = 0.8 dS m^{-1}; SW = 4.5 dS m^{-1}

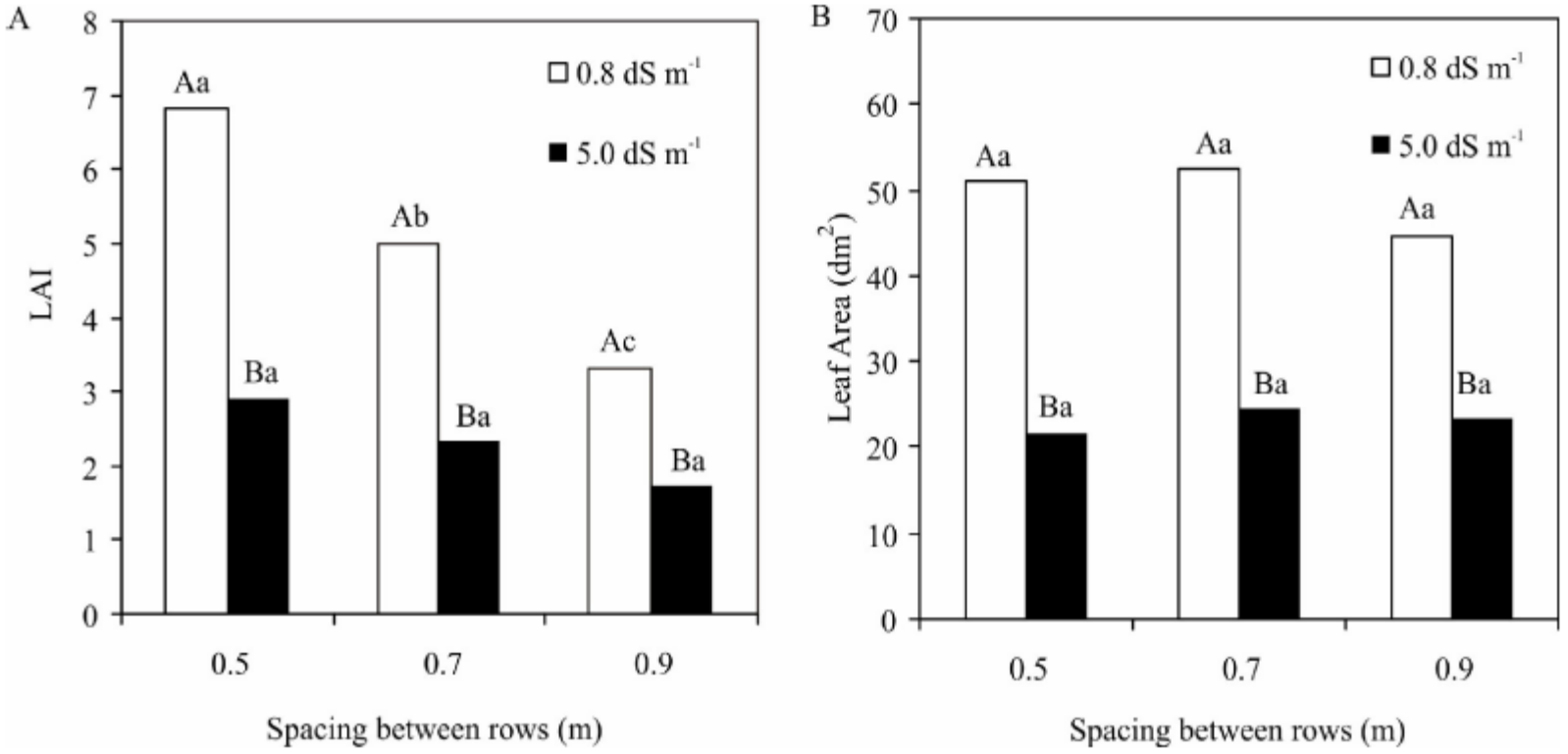
Barbosa et al. (2012)

2.4 Denser crops

- **Plants under salt stress**

- Reduction in plant growth
- Reduction in nutrient uptake
- Reduction in LAI
- Minor shading of leaves
- Increased rate of photosynthesis of all leaves

Leaf area index-LAI (A) and leaf area per plant (B) of **cowpea** plants grown at different spacings and irrigated with low and high salinity water



(Lacerda et al., 2011)

Net photosynthetic rates (A) and photosynthetically active radiation (PAR) levels measured at 36 DAS on cowpea leaves from plants grown with different plant spacing (S) and irrigated with low- and high-salinity water (ECw)*

ECw ($dS\ m^{-1}$)	Spacing (m)	A ($\mu mol\ m^{-2}\ s^{-1}$)	PAR ($\mu mol\ m^{-2}\ s^{-1}$)
		2nd leaf from the base	
0.8	0.5	**5.4 Bb**	**275.5**
0.8	0.7	**7.8 Bb**	**350.3**
0.8	0.9	**13.1 Ba**	**471.5**
5.0	0.5	**18.3 Ab**	**1004.8**
5.0	0.7	**21.5 Aab**	**1974.0**
5.0	0.9	**23.4 Aa**	**1939.5**
		1st mature leaf from the apex	
0.8	0.5	**33.7 Aa**	**2061.0**
0.8	0.7	**31.9 Aa**	**2025.5**
0.8	0.9	**32.0 Aa**	**1963.0**
5.0	0.5	**20.5 Bc**	**2020.8**
5.0	0.7	**27.9 Ba**	**2039.8**
5.0	0.9	**24.5 Bb**	**1994.0**

(Lacerda et al., 2011)

Yield of cowpea plants grown at different spacing (S) and irrigated with low- and high-salinity waters

ECw	S	Yield	
(dS m^{-1})	(m)	**g $planta^{-1}$**	**(kg ha^{-1})**
0.8	**0.5**	17.30	**2307.3 Aa**
0.8	**0.7**	22.56	**2148.9 Aa**
0.8	**0.9**	28.46	**2108.0 Aa**
5.0	**0.5**	14.44	**1925.6 Ba**
5.0	**0.7**	17.55	**1671.0 Bab**
5.0	**0.9**	17.19	**1273.6 Bb**

(Lacerda et al., 2011)

Conclusions??

Use of different strategies in a study conducted in Pakistan (Murtaza et al., 2006)

FW = fresh water; SSW = saline sodic water; FM = farm manure; G = gypsum

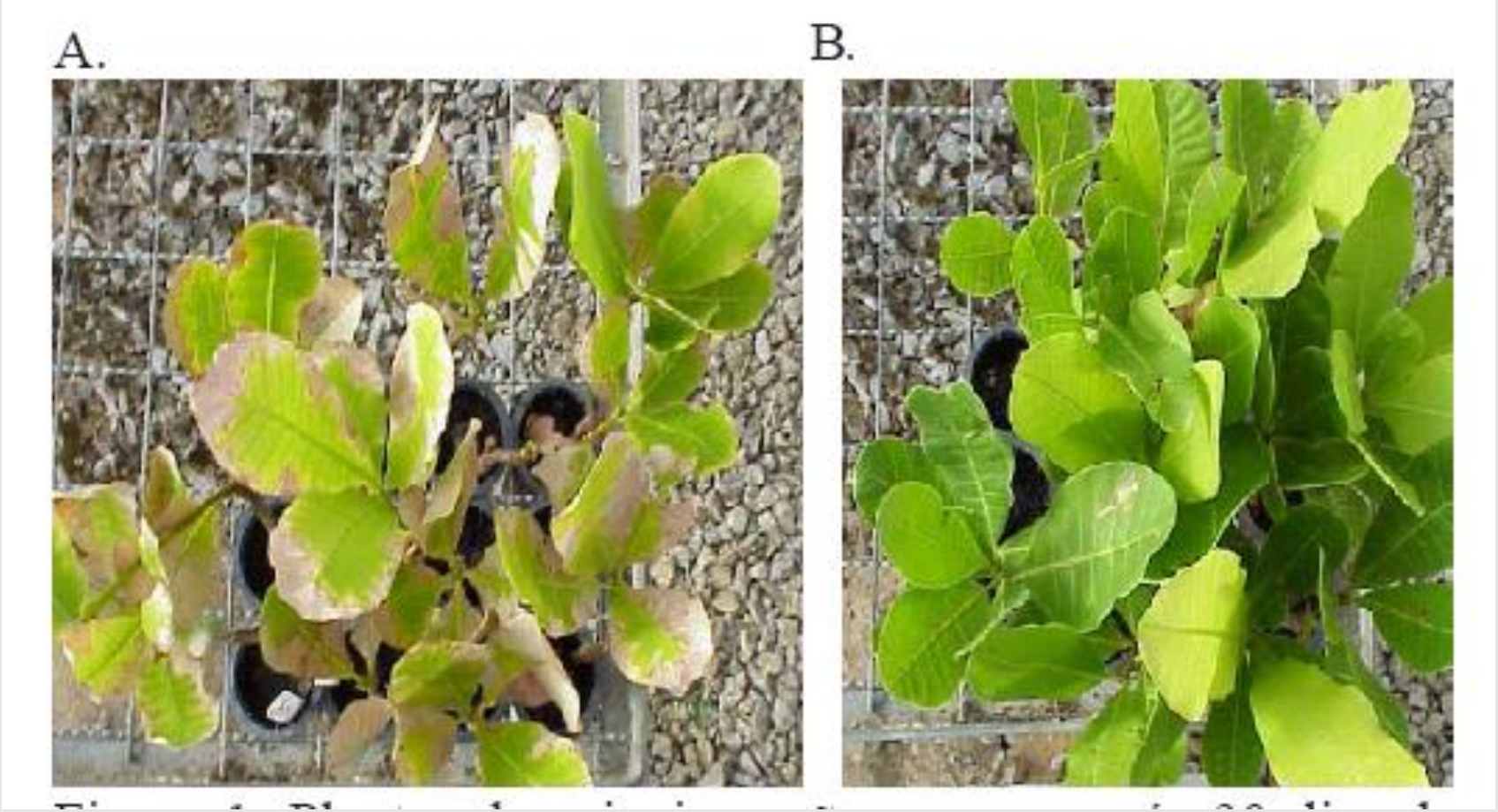
Table 6
Economics of treatments for cotton and wheat crops

Treatment	Cotton I	Wheat I	Cotton II	Wheat II	Cotton III	Wheat III	Total
Total cost (US$ ha^{-1}) including uniform and variable inputs							
FW	305	187	248	177	179	159	1255
SSW	304	177	235	167	171	151	1205
Cyclic use (FW – SSW)	315	184	244	180	176	162	1261
FM + SSW	340	181	273	172	207	162	1335
G + SSW	337	220	284	210	214	197	1462
Gross income (US$ ha^{-1})							
FW	852	586	311	443	526	391	3109
SSW	838	521	126	369	352	287	2493
Cyclic use (FW – SSW)	998	562	250	471	465	411	3157
FM + SSW	876	547	186	411	422	408	2850
G + SSW	846	577	348	447	574	413	3205
Net income (US$ ha^{-1})							
FW	547	399	63	266	347	232	1854
SSW	534	344	−109	202	181	136	1288
Cyclic use (FW – SSW)	683	378	6	291	289	249	1896
FM + SSW	536	366	−77	239	215	246	1515
G + SSW	509	357	62	237	360	216	1743

To finish...

The importance of Drainage

Method of irrigation



Just my opinion

The success of an irrigation method is a function of the techniques employed in its management, *Ceteris paribus*

Institutions that participate in projects

- Departamento de Engenharia Agrícola/UFC
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Manejo e conservação de bacias hidrográficas no semiárido

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