Fertilization and Fertilizers for High Salt Content Soils

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Salinity and Sodicity in New Mexico and Texas Soils

- Concern on soils with **salinity and sodicity** levels high enough to affect production
- Soils with high amounts of **soluble salts** are called saline soils (exhibit whitish surface crust when dry—Na_2SO_4; NaCl; $CaCO_3$—from 3 types of salts: SO_4, CO_3, and Cl)
- Soils high in sodium (**sodic soils**) may present physical restrictions to plant growth from high amounts of sodium, Na^+)

Factors that can add salts or sodium to soils:

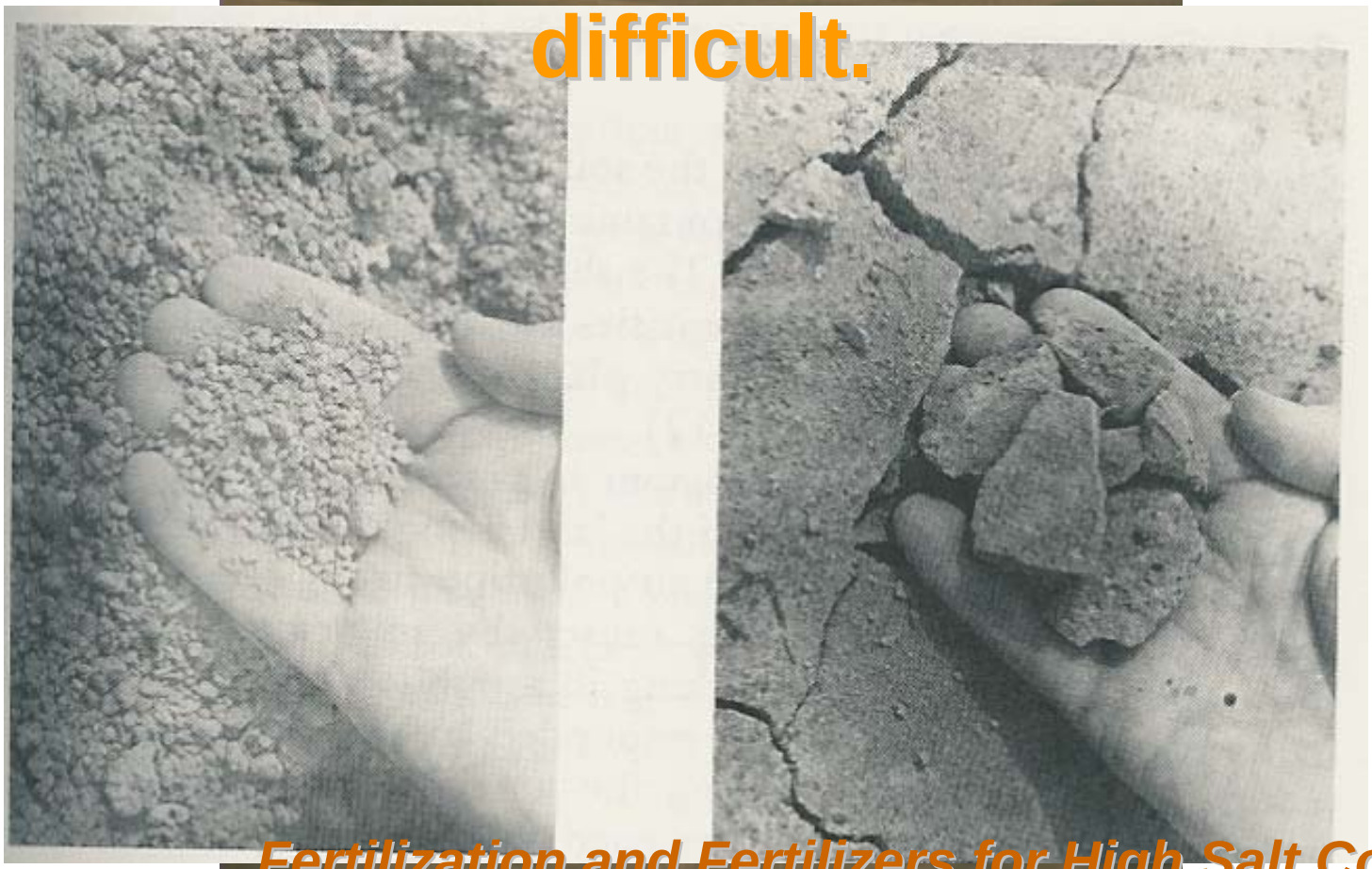
- High pH and sodic soils
- Continuous cropping, especially monocropping
- Slowly permeable claypans (low drainage) and/or limited profile modification once compaction occurs
- Saline seeps
- Salinization along ditches or limited irrigation or no preplant irrigation as well as type of irrigation method
- Wetland areas or ponded areas in fields
- Limited drainage or irrigation water evaporation to soil surface as well as land leveling management
- Low water quality and/or not mixing poor water supply
- Improper crop selection or seed placement
- High salt/sodium fertilizer choice and guessing at rate

Soils high in salts, with high amounts of carbonates of sodium are rare and usually associated with coarse-textured materials.

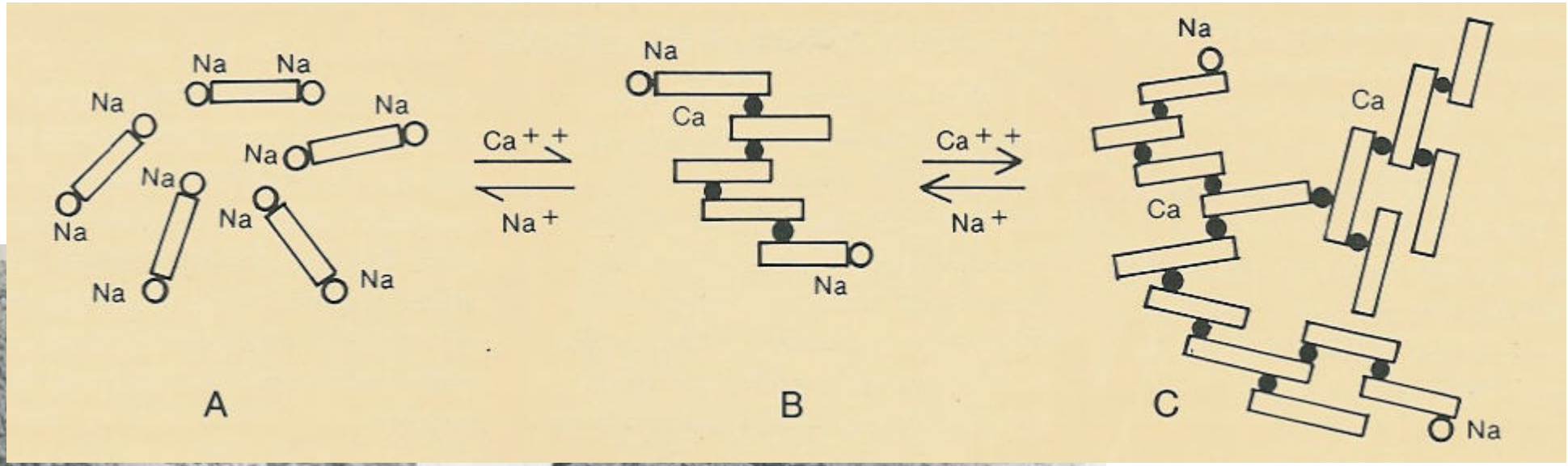
Table 1. Composition and solubility of some common evaporite minerals (salts).

Mineral	Composition	Solubility	Chemical Name
		(moles/liter)	
Calcite (lime)	$CaCO_3$	0.00014	Calcium Carbonate
Gypsum	$CaSO_4 \cdot 2H_2O$	0.0154	Calcium Sulfate
----	$CaCl_2 \cdot 6H_2O$	7.38	Calcium Chloride
Magnesite	$MgCO_3$	0.001	Magnesium Carbonate
Hexahydrite	$MgSO_4 \cdot 6H_2O$	4.15	Magnesium Sulfate
Epsomite	$MgSO_4 \cdot 7H_2O$	3.07	Magnesium Sulfate
Bischofite	$MgCl_2 \cdot 6H_2O$	5.84	Magnesium Chloride
(Washing soda)	$Na_2CO_3 \cdot 10H_2O$	2.77	Sodium Carbonate
(Baking soda)	$NaHCO_3$	1.22	Sodium Bicarbonate
Mirabilite	$Na_2SO_4 \cdot 10H_2O$	1.96	Sodium Sulfate
Thenardite	$NaSO_4$	3.45	Sodium Sulfate
Halite	NaCl	6.15	Sodium Chloride

Soils high in sodium (15% or more of the clay sites are occupied by sodium) have poor physical condition that often restricts root growth and makes tillage difficult.



The Effects of Soil and Water Salinity in Crop Production



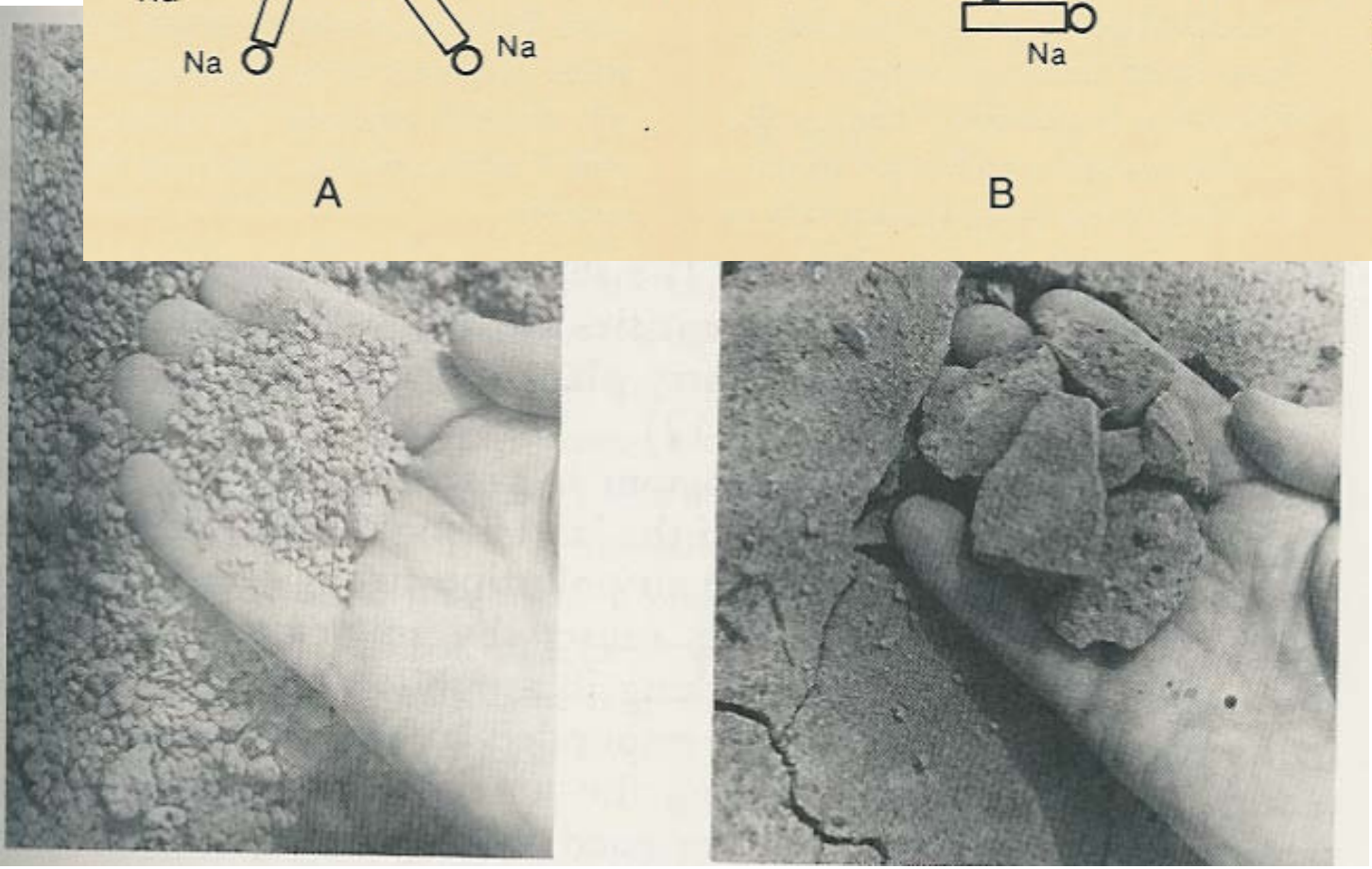


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Table 2. SCS classification of saline and sodic soils.

Saline Soils

class	Non-saline soil series	Saline phase of soil series	Saline soil series
criteria	S.E. EC < 4 dS/m	S.E. EC = 4–16 dS/m	S.E. EC > 16 dS/m

Natric (Sodic) Soils

class	glossic subgroups	typic or udic subgroups	leptic subgroups	aquoll suborder
subsoil criteria	*SAR > 13 weak claypan	*SAR > 13 strong claypan	*SAR > 13 claypan high salinity	*SAR > 13 claypan poorly drained

*Most natric soils meet this chemical requirement; however, some soils are also considered natric with SAR < 13 under certain conditions.
S.E. = saturation extract

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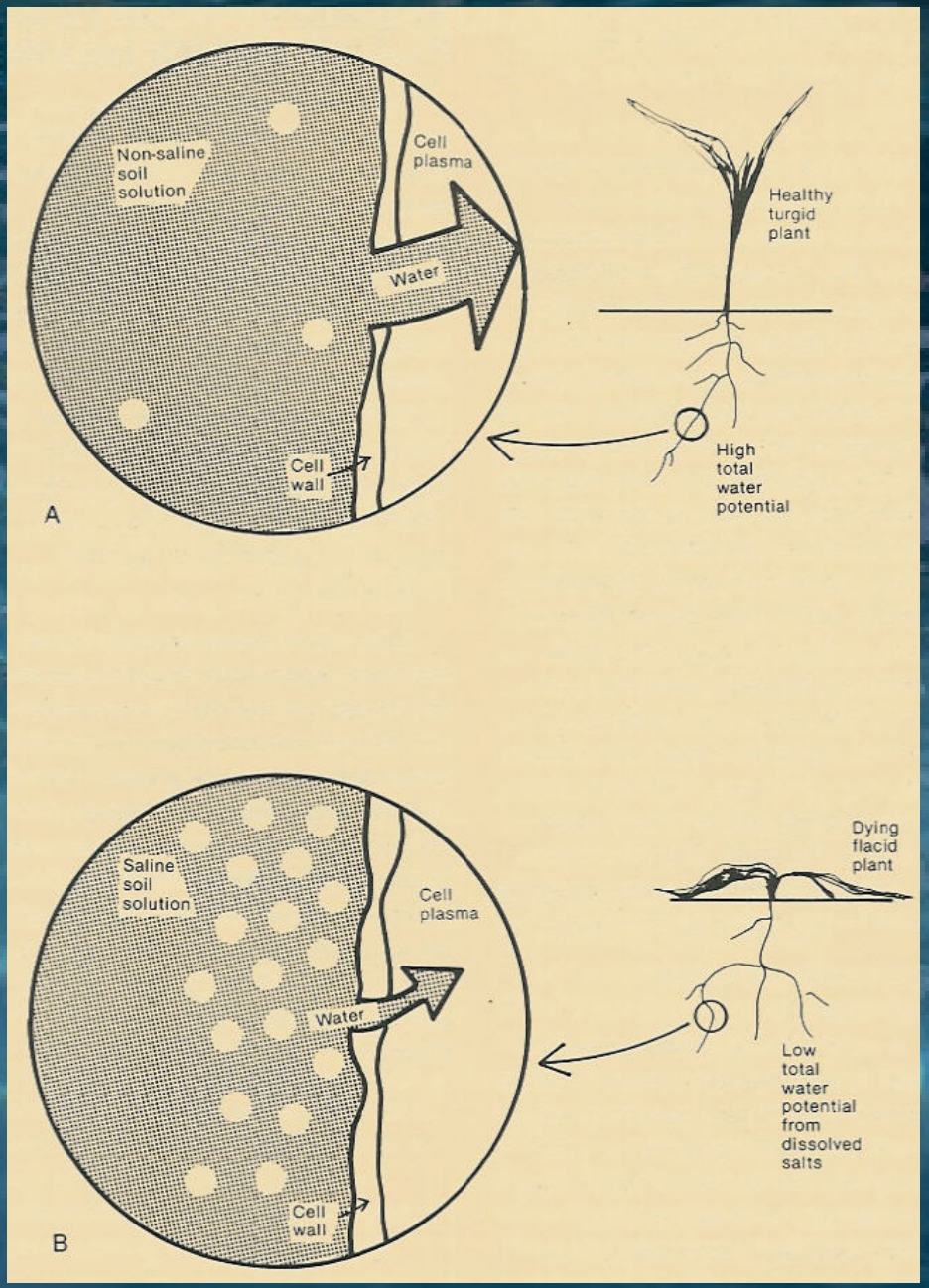
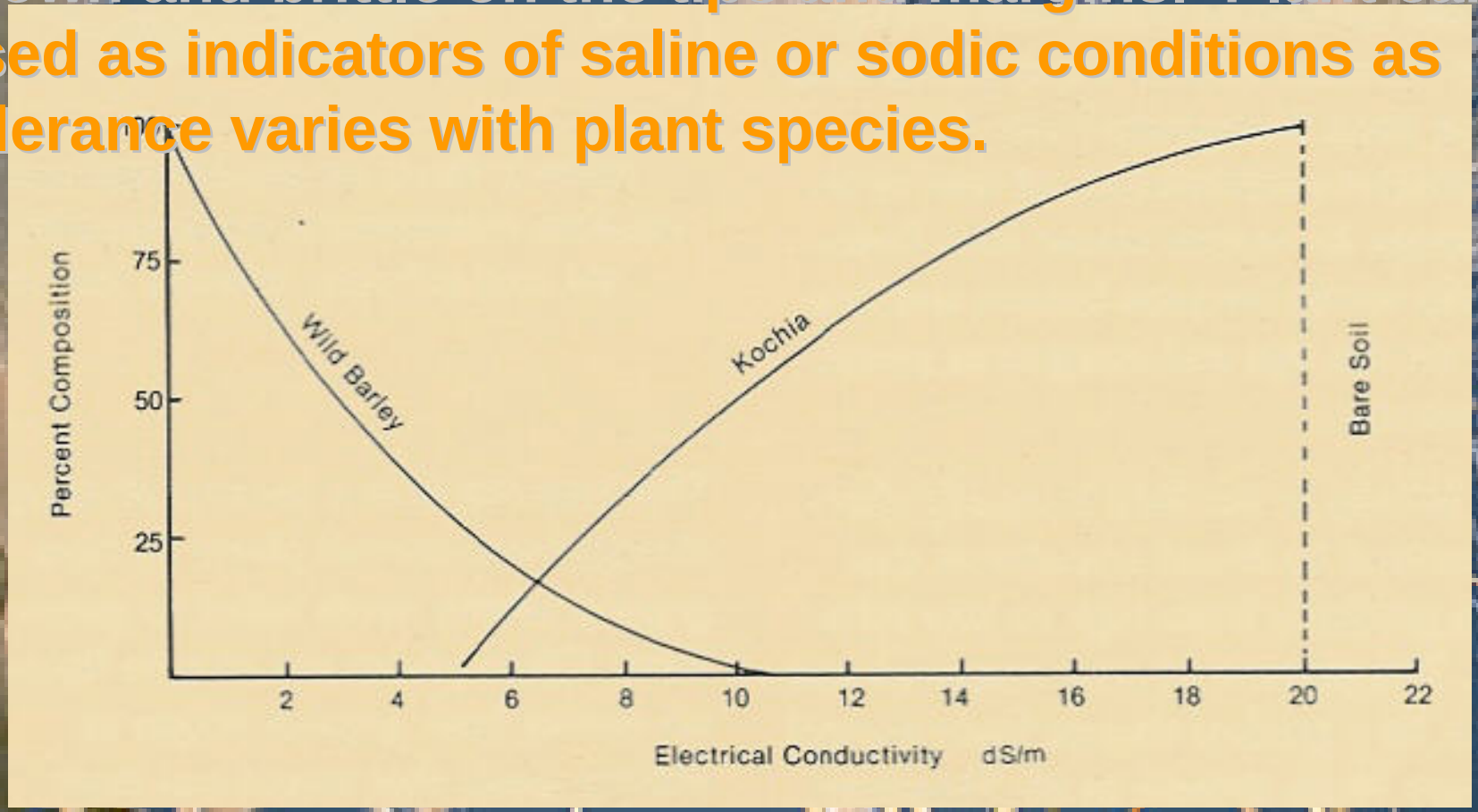
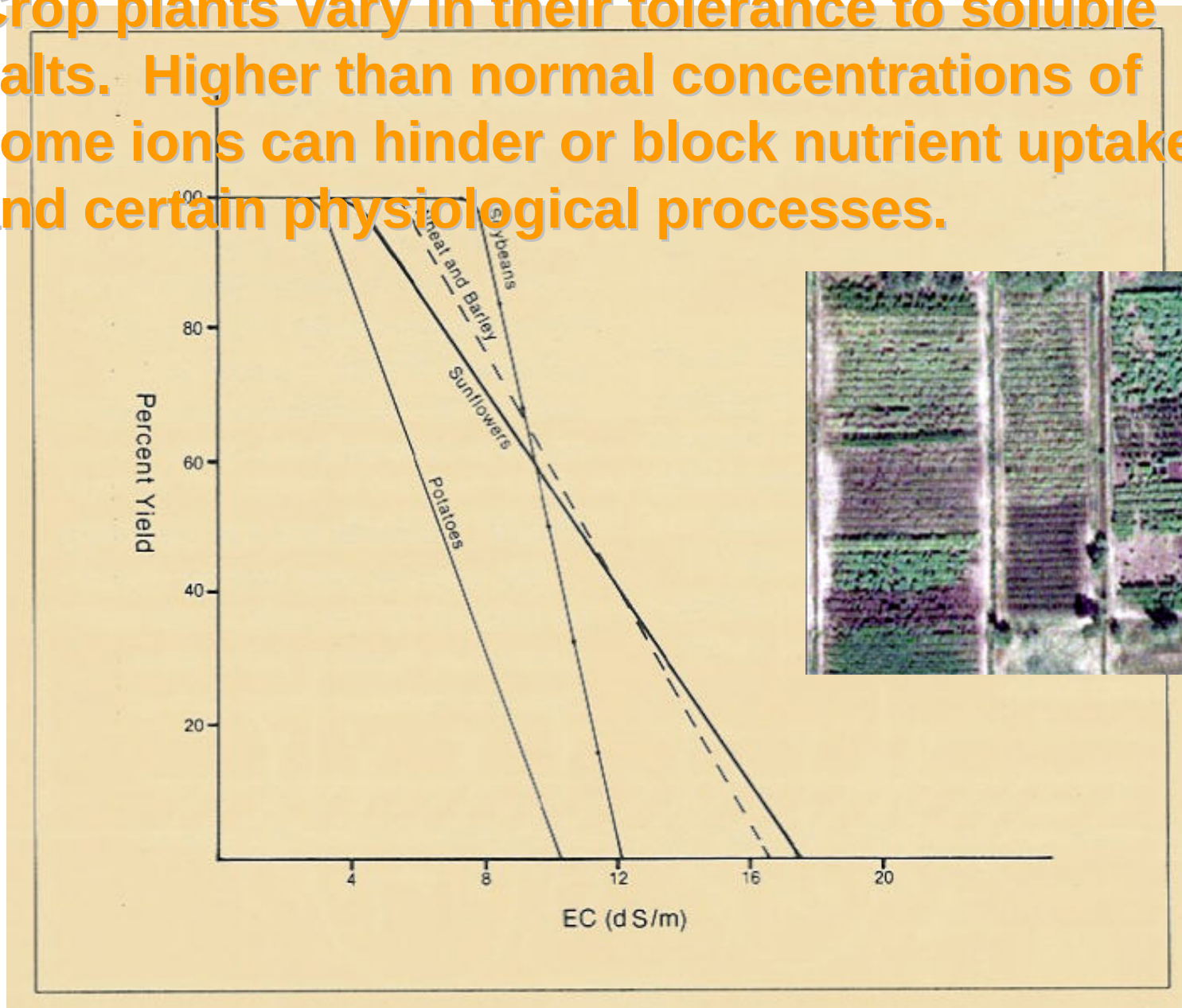


Crop symptoms from high salinity or sodicity are generally the same as symptoms of moisture stress from dry conditions. Plants are stunted, take on a deep blue-green color, with leaves eventually becoming brown and brittle on the tips and margins. Plant can be used as indicators of saline or sodic conditions as tolerance varies with plant species.



Crop plants vary in their tolerance to soluble salts. Higher than normal concentrations of some ions can hinder or block nutrient uptake and certain physiological processes.



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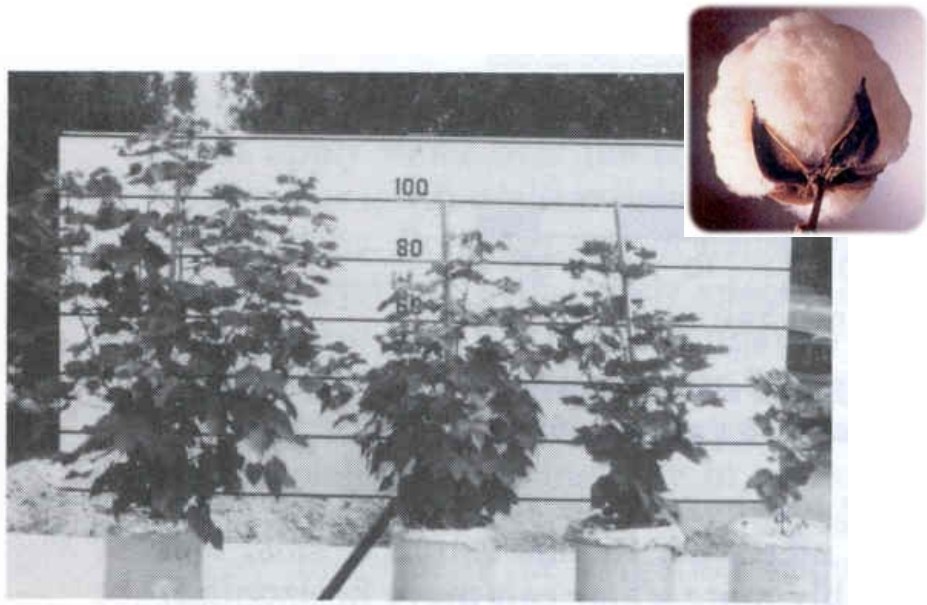
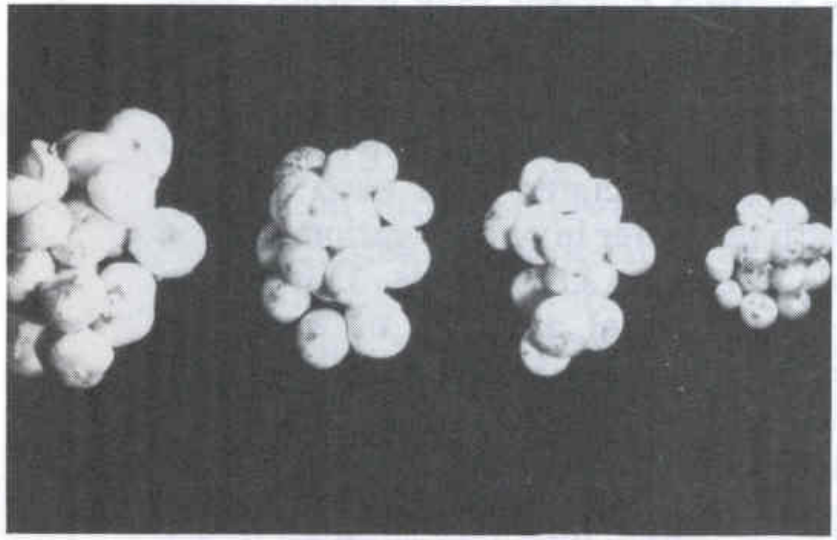
Crop	Salinity* at initial yield decline (threshold) (A)	Percent yield decrease per unit increase in salinity beyond threshold (B)	Qualitative salt tolerance rating†
	dS/m	%/(dS/m)	
Alfalfa *Medicago sativa*	2.0	7.3	MS
Almond *Prunus dulcis*	1.5	19	S
Apple *Malus sylvestris*	—	—	S
Apricot‡ *Prunus armeniaca*	1.6	24	S
Avocado‡ *Persea americana*	—	—	S
Barley (forage)§ *Hordeum vulgare*	6.0	7.1	MT
Barley (grain)§ *Hordeum vulgare*	8.0	5	T
Bean *Phaseolus vulgaris*	1.0	19	S
Beet, garden‖ *Beta vulgaris*	4.0	9	MT
Bentgrass *Agrostis palustris*	—	—	MS
Bermudagrass# *Cynodon Dactylon*	6.9	6.4	T
Blackberry *Rubus* spp.	1.5	22	S
Boysenberry *Rubus ursinus*	1.5	22	S
Broadbean *Vicia Faba*	1.6	9.6	MS
Broccoli *Brassica oleracea botrytis*	2.8	9.2	MS
Bromegrass *Bromus inermis*	—	—	MT
Cabbage *Brassica oleracea capitata*	1.8	9.7	MS
Canarygrass, reed *Phalaris arundinacea*	—	—	MT
Carrot *Daucus Carota*	1.0	14	S
Clover, alsike, ladino, red, strawberry *Trifolium* spp.	1.5	12	MS
Clover, berseem *T. alexandrinum*	1.5	5.7	MS
Corn (forage) *Zea Mays*	1.8	7.4	MS
Corn (grain) *Zea Mays*	1.7	12	MS
Corn, sweet *Zea Mays*	1.7	12	MS
Cotton *Gossypium hirsutum*	7.7	5.2	T
Cowpea *Vigna unguiculata*	1.3	14	MS
Cucumber *Cucumis sativus*	2.5	13	MS
Date palm *Phoenix dactylifera*	4.0	3.6	T



Growth reduction of cotton for salinity levels of 1, 14, 28, and 42 dS/m (left to right)



Decline in onion yields due to salinity levels of 1, 6, 11, and 17 dS/m (left to right)

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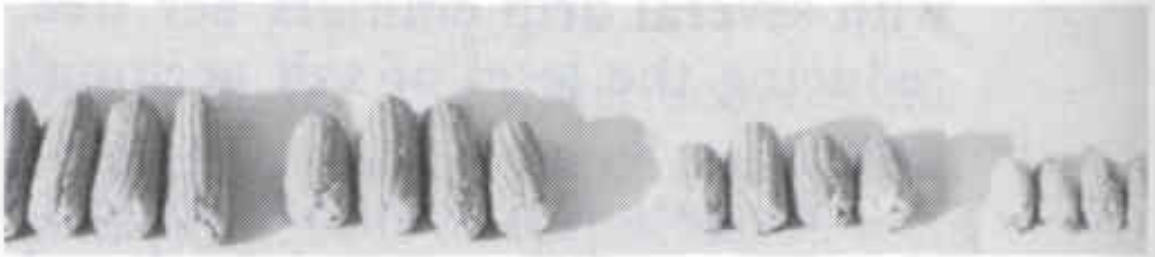
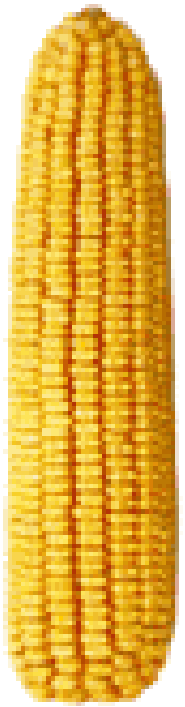
Growth reduction of pea caused by salinity levels of 1, 3, 7, 11, and 14 dS/m (left to right)



Yield reduction of sweet corn caused by salinity levels of 1, 6, 10, and 14 dS/m (left to right)



Corn

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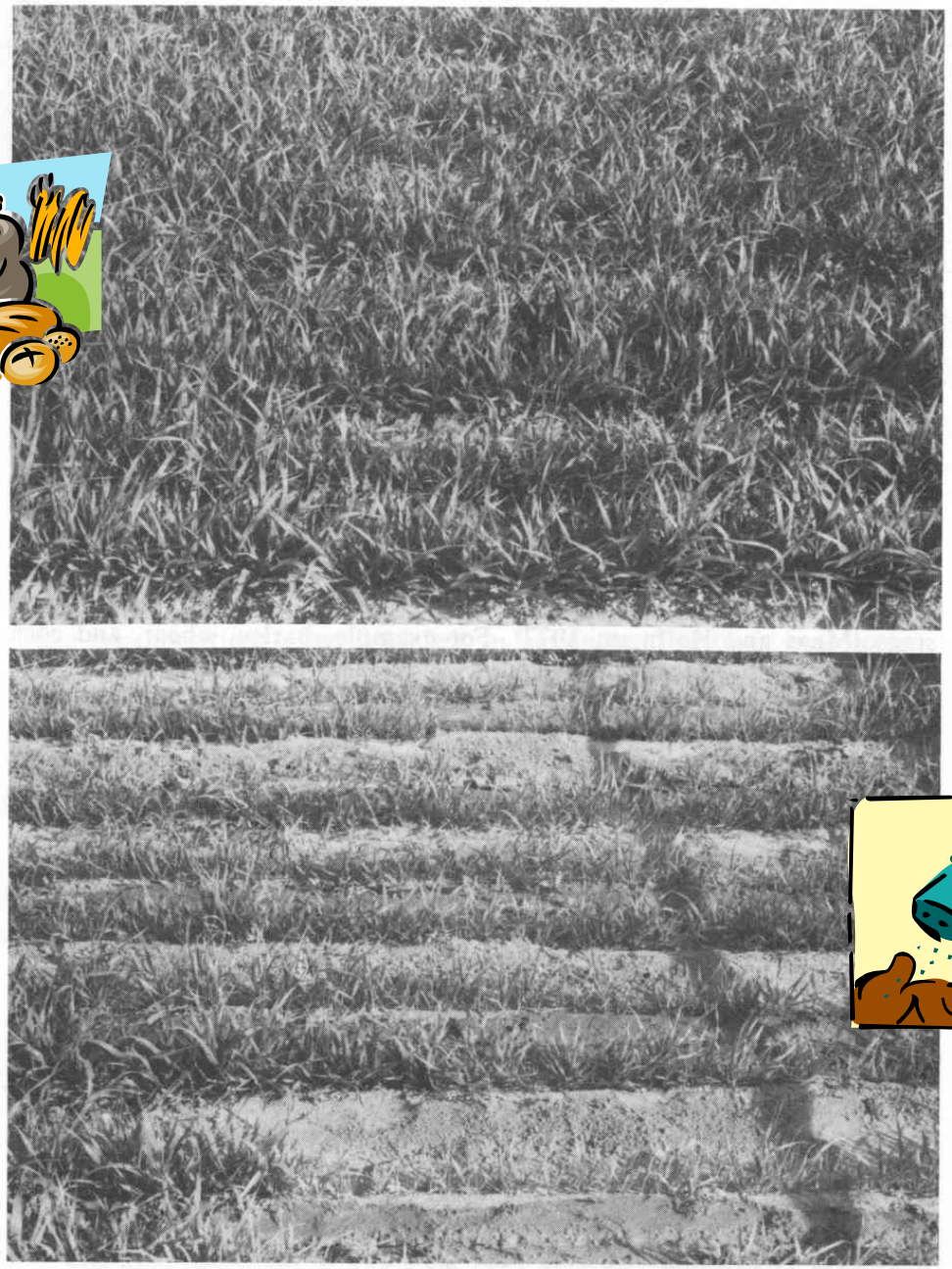

FIG. 5.8 Influence of soil salinity on oat seedlings. Mean root zone salinity (EC_e) is 5 dS/m on the top and 16 dS/m on the bottom.

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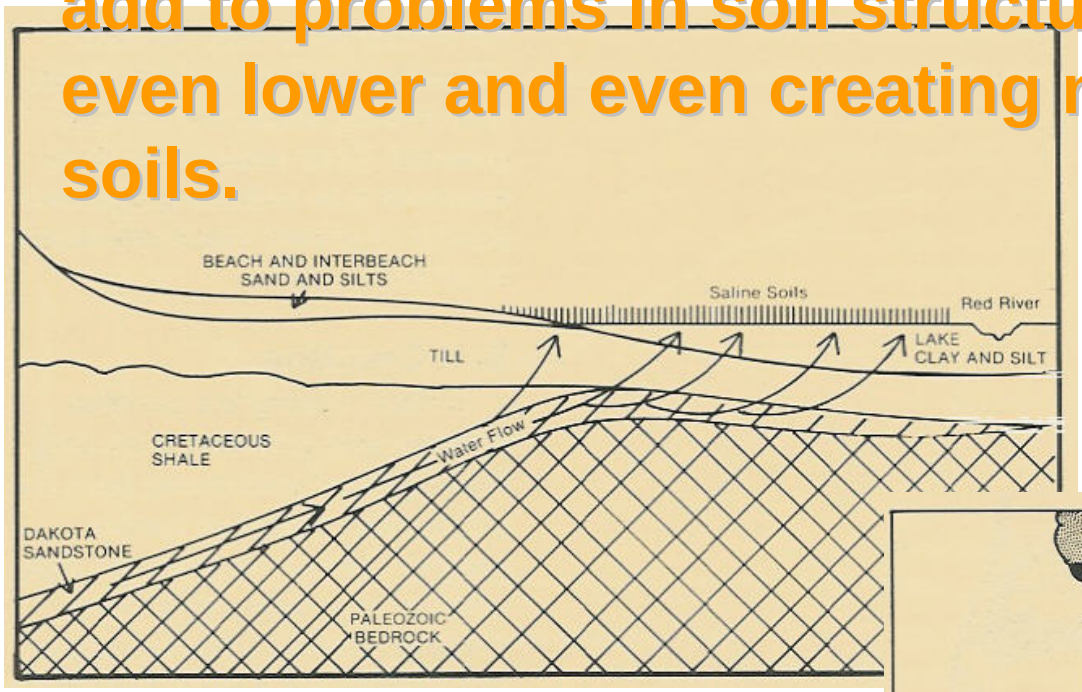
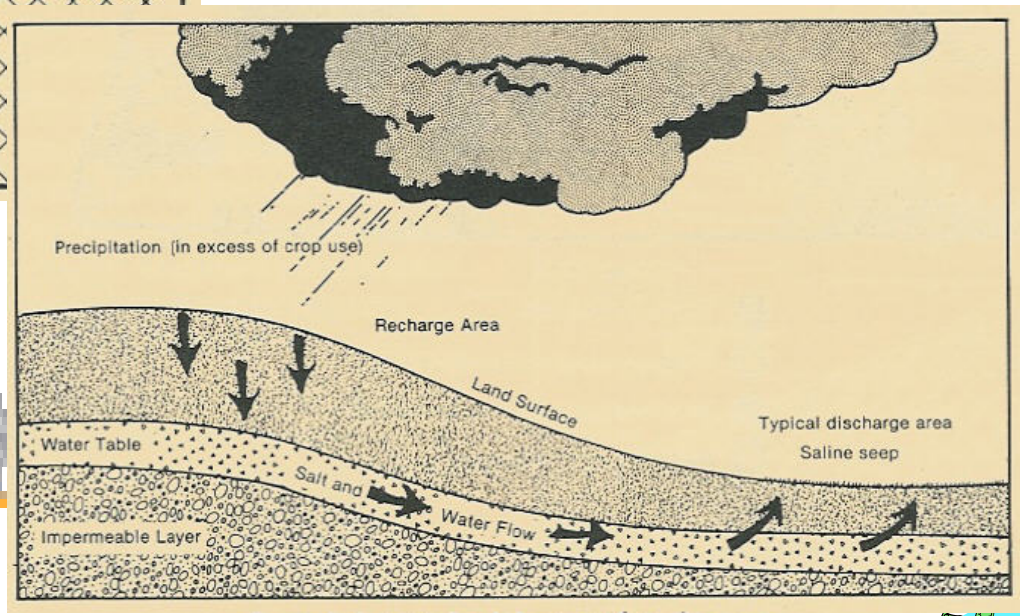
Restrictive subsoils and crusting problems can also add to problems in soil structure, making permeability even lower and even creating more claypans on some soils.





Maximum salinity and crop damage along a drainage or irrigation ditch may vary; however, this effect may be accentuated with certain fertilizers.

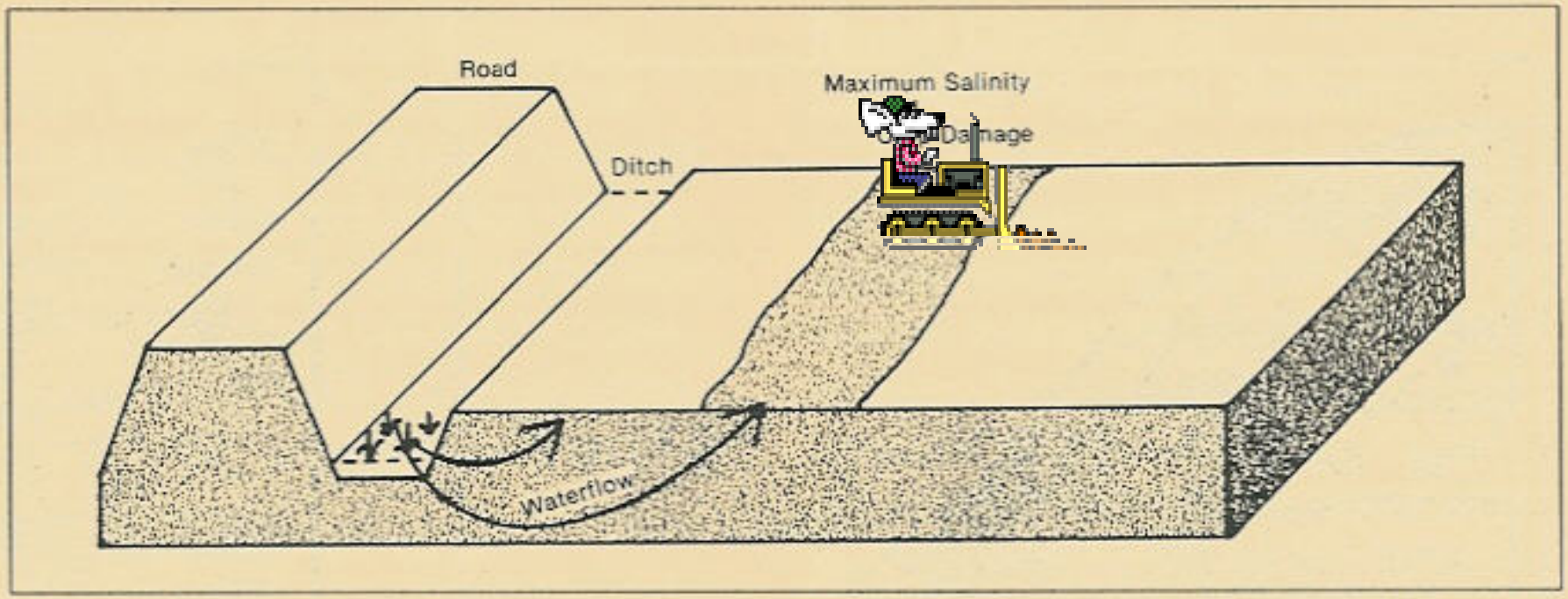


Figure 8. The location of maximum salinity and crop damage along a drainage ditch in the Red River Valley. (After Skarie et al., 1986.)

Careful selection of fertilizers along with drainage or adequate leaching of irrigation salts and eventually fertilizer salts can improve crop growth and yield.

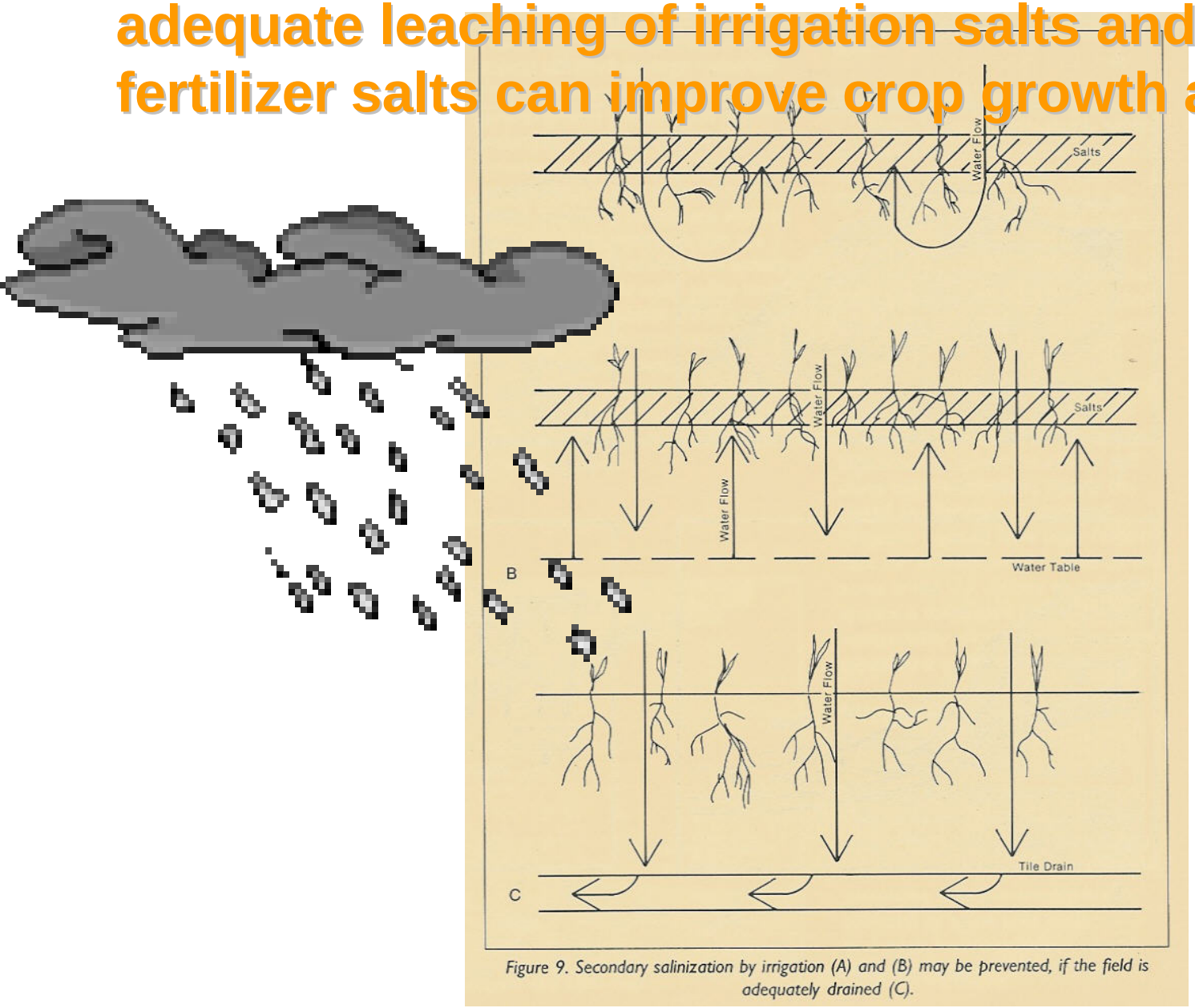
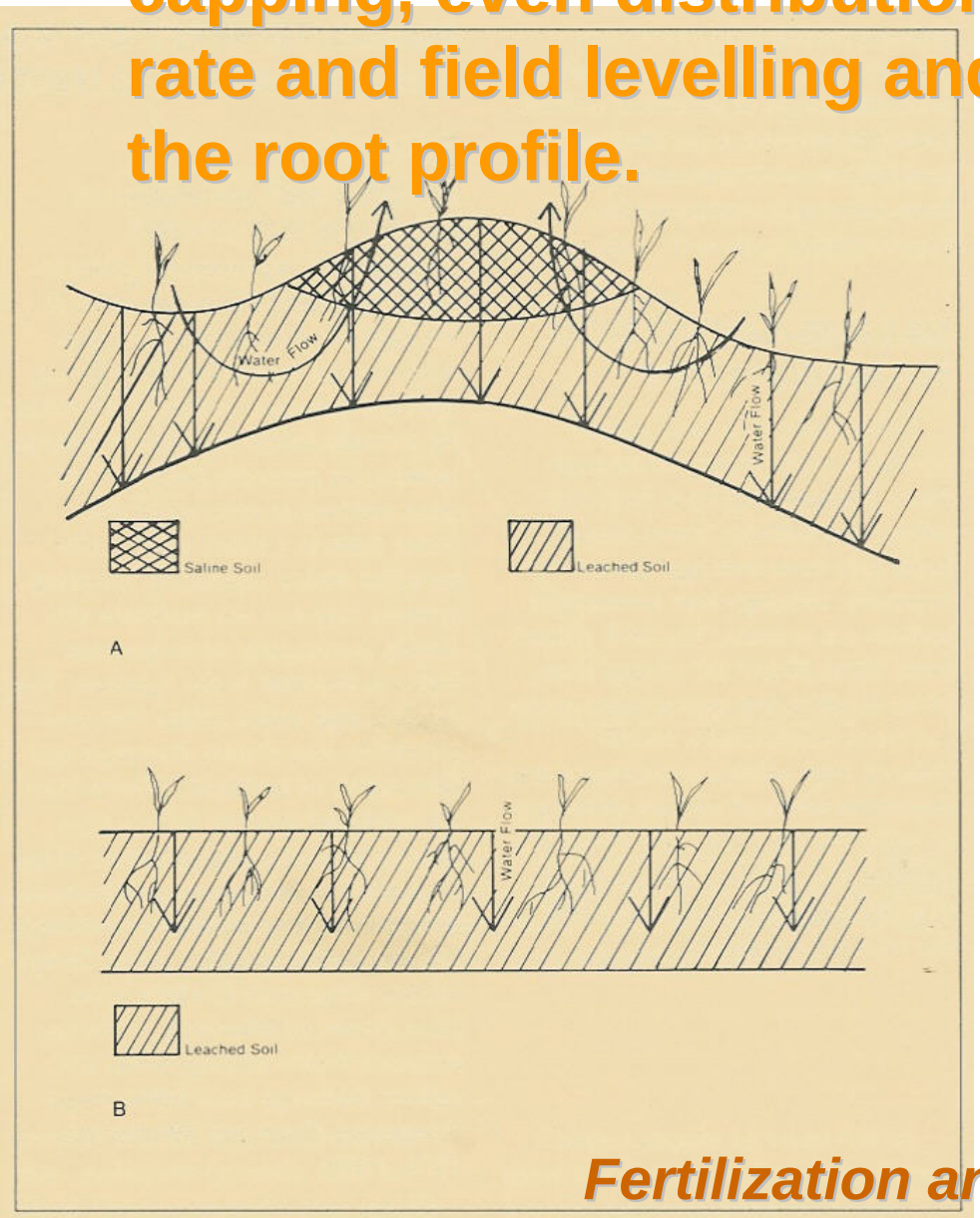


Figure 9. Secondary salinization by irrigation (A) and (B) may be prevented, if the field is adequately drained (C).

Secondary salinization in irrigated fields at points of evaporation can be better managed by planting pattern, capping, even distribution of irrigation water with flow rate and field levelling and drainage through much of the root profile.



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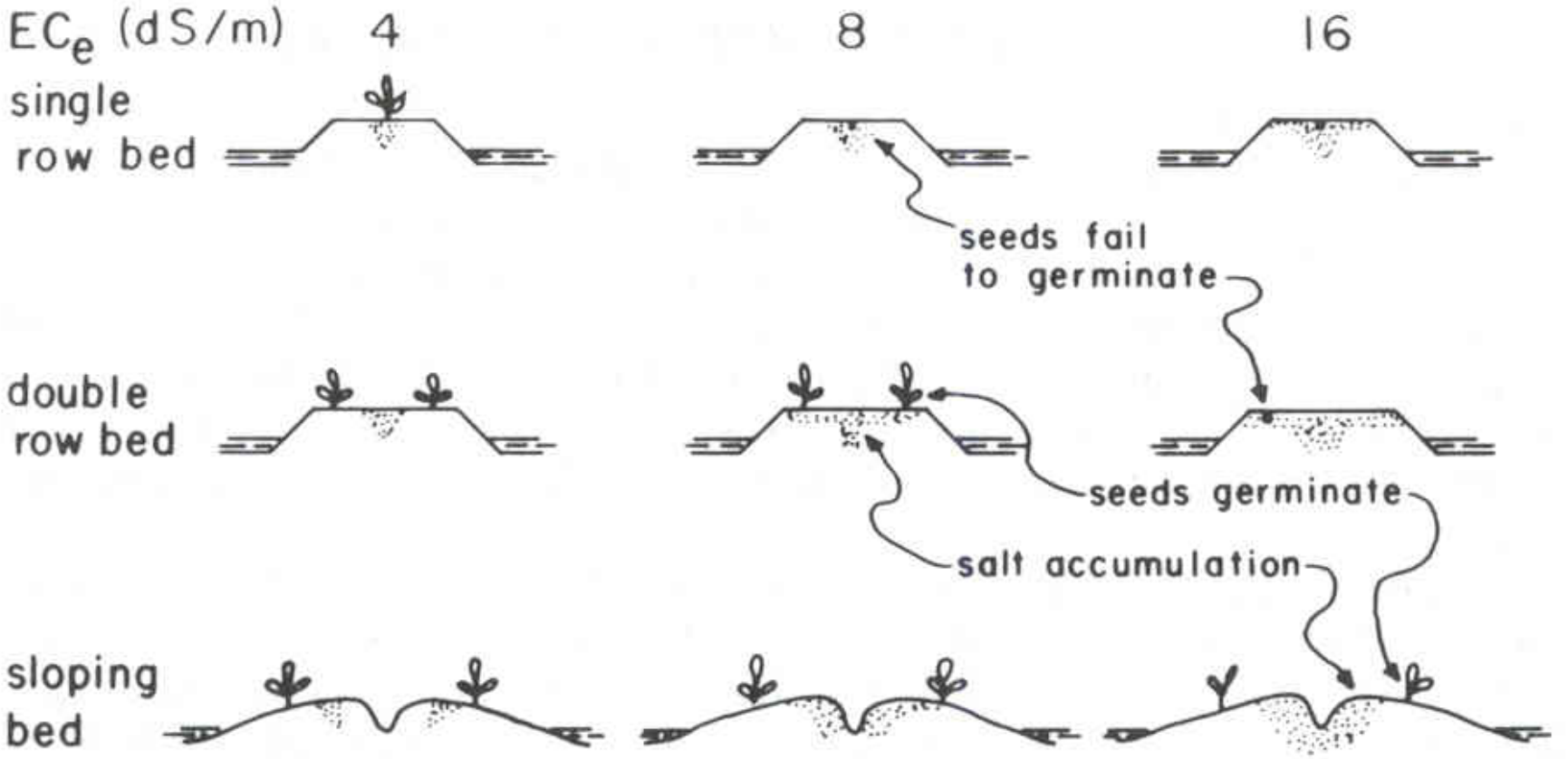

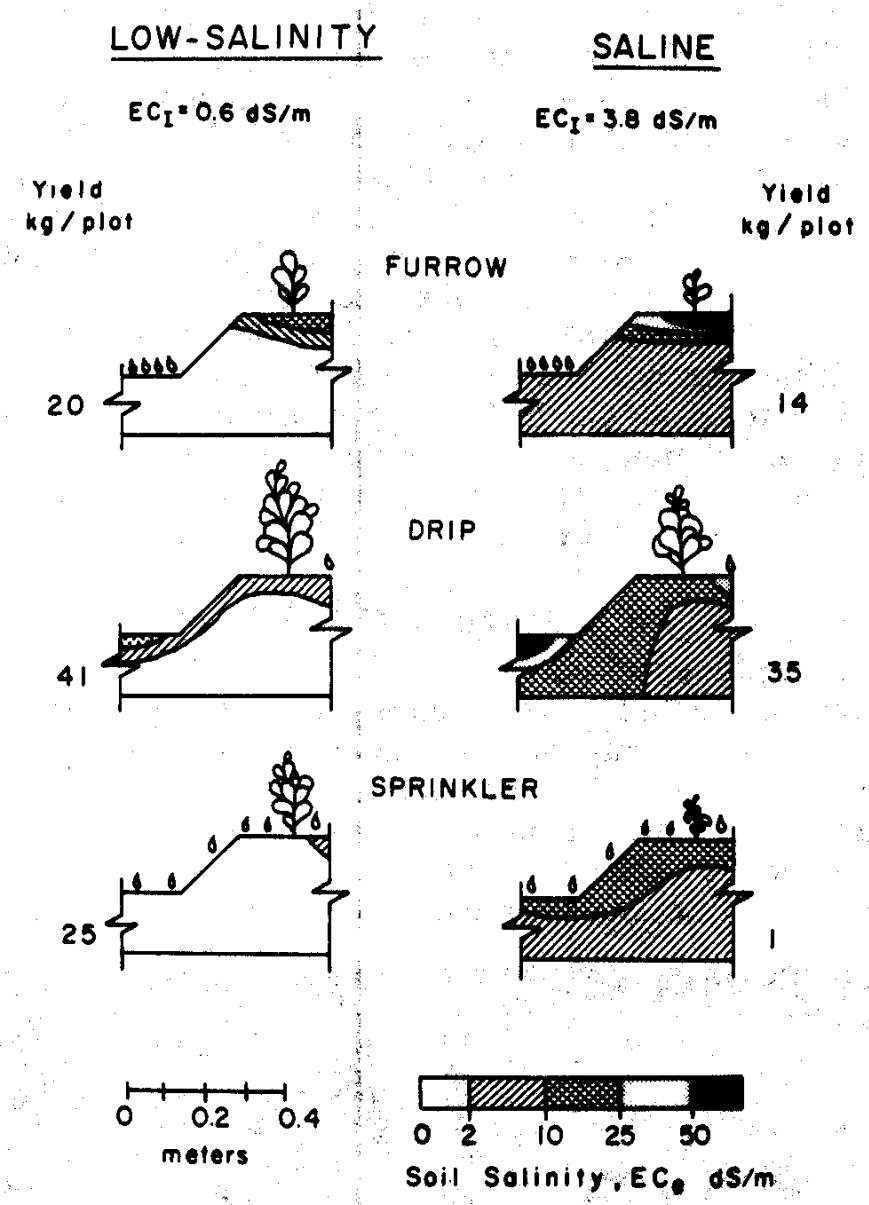

FIG. 5.6 Influence of the irrigation system on the soil salinity pattern and yield of bell pepper at two levels of irrigation water quality (Bernstein and Francois, 1973a).

Fertilizer salinities that can add problems to fields over time.

Salt Index of Fertilizer Materials and Soil Amendments

Material and Analysis	Salt Index: Per equal weights of materials (Basis: sodium nitrate = 100)	Salt Index: Per unit (20 lbs.) of plant nutrients
NITROGEN		
Ammonia, 82% N	47.1	0.572
Ammonium nitrate, 34% N	104.0	3.059
Ammonium sulfate, 21% N, 24% S	68.3	3.252
Urea, 46% N	74.4	1.618
Urea-ammonium nitrate solution		
28% N (39% a. nitrate, 31% urea)	63.0	2.250
32% N (44% a. nitrate, 35% urea)	71.1	2.221
Calcium nitrate, 15.5% N	65.0	4.194
Sodium nitrate, 16.5% N	100.0	6.060
PHOSPHATE		
Ordinary or single superphosphate		
20% P_2O_5	7.8	0.390
Triple superphosphate		
45% P_2O_5	10.1	0.224
Monoammonium phosphate		
11% N, 55% P_2O_5	26.7	0.405
10% N, 50% P_2O_5	24.3	0.405
Diammonium phosphate		
18% N, 46% P_2O_5	29.2	0.456
Ammonium polyphosphate		
10% N, 34% P_2O_5	20.0	0.455
POTASH		
Potassium chloride, 60% K_2O	116.2	1.936
Potassium sulfate		
50% K_2O, 18% S	42.6	0.852
Potassium nitrate		
13% N, 44% K_2O	69.5	1.219
Sulfate of potash-magnesia		
22% K_2O, 11% Mg, 22% S	43.4	1.971
Monopotassium phosphate		
52.2% P_2O_5, 34.6% K_2O	8.4	0.097
Potassium thiosulfate		
25% K_2O, 17% S	68.0	2.720
SULFUR		
Ammonium thiosulfate (12% N, 26% S)	90.4	7.533
Ammonium polysulfide (20% N, 40% S)	59.2	2.960
MISCELLANEOUS		
Dolomite, 12% Mg	0.8	0.042
Magnesium oxide, 60% Mg	1.7	0.002
Gypsum, 23% Ca	8.1	0.247
Calcium carbonate, 40% Ca	4.7	0.083
Magnesium sulfate, 9.8% Mg	44.0	2.687

Salt-affected field in California resulting from insufficient leaching.

Severe soil salinity problem in a Colorado corn field.

Sodic soil in Idaho.

Effect of salinity on cotton in Arizona.

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TABLE 5.10. GUIDELINES FOR INTERPRETATION OF WATER QUALITY FOR IRRIGATION (FROM AYERS AND WESTCOT, 1976)

Water Quality Criterion	Degree of Problem		
	None	Increasing	Severe
Salinity			
EC (dS/m)	< 0.75	0.75-3	> 3
Permeability			
1. Low salt water EC (dS/m)	> 0.5	0.5-0.2	< 0.2
2. Sodium hazard adj. SAR*			
Montmorillonitic soils	< 6	6-9	> 9
Illite-Vermiculitic soils	< 8	8-16	>16
Kaolinite-Sesquioxidic soils	<16	16-24	>24
Specific Ion Toxicity			
Sodium† (adj SAR)	< 3	3-9	> 9
Chloride† (mol/m^3)	< 4	4-10	>10
Boron (mg/L)	< 0.75	0.75-2.0	> 2.0
Miscellaneous Effects			
Nitrogen (mg/L)	< 5	5-30	>30
Bicarbonate (mol/m^3)‡	< 1.5	1.5-8.5	> 8.5
pH	[Normal range 6.5 to 8.4]		

*adj. SAR (adjusted Sodium-Adsorption-Ratio) can be calculated using equation [5.6]. Values presented are for the dominant types of minerals in the clay fraction of a given soil. The higher the salinity of the water, the less likely that permeability problems will occur.

†Values are for sensitive crops such as trees and woody plants. Most annual crops are less sensitive.

‡Overhead sprinkler irrigation with high bicarbonate waters during periods of extremely low humidity may cause white deposits on fruit or leaves.

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TABLE 13–5. Salt Index per Unit of Plant Nutrients Supplied for Representative Materials*

Material	Analysis†	Salt index per unit of plant nutrients
Nitrogen carriers		
Anhydrous ammonia	82.2	.572
Ammonium nitrate	35.0	2.990
Ammonium sulfate	21.2	3.253
Monammonium phosphate	12.2	2.453
Diammonium phosphate	21.2	1.614
Nitrogen solution 2A	40.6	1.930
Potassium nitrate	13.8	5.336
Sodium nitrate	16.5	6.060
Urea	46.6	1.618
Phosphorus carriers		
Superphosphate	20.0	.390
Superphosphate	48.0	.210
Monoammonium phosphate	51.7	.485
Diammonium phosphate	53.8	.637
Potassium carriers		
Manure salts	20.0	5.636
Potassium chloride	50.0	2.189
Potassium chloride	60.0	1.936
Potassium nitrate	46.6	1.580
Potassium sulfate	54.0	.853
Potassium magnesium sulfate	21.9	1.971

* L. F. Rader, L. M. White, and C. W. Whittaker, *Soil Sci.*, **55**:201. Copyright 1943 by The Williams & Wilkins Company.

† By analysis is meant the percentage of nitrogen in nitrogen carriers, of P_2O_5 in phosphorus carriers, and of K_2O in potassium carriers.

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TABLE 13–6. Comparative Salt Index of 5-4.4-8.3 and 10-8.8-16.6

	5-4.4-8.3 (5-10-10)		10-8.8-16.6 (10-20-20)	
	Pounds	Salt index	Pounds	Salt index
Ammoniating solution	148	5.79		
Diammonium phosphate			373	6.37
Urea			260	9.71
Ammonium sulfate	195	6.51		
Treble superphosphate			417	2.10
Superphosphate	1,000	3.90		
Muriate of potash (41% K)	400	21.89		
Muriate of potash (50% K)			667	38.72
Conditioner	100		110	
Filler	157		180	
	2,000	38.09	2,000	56.90

Factors that can LIMIT salts or sodium to soils:

- Lower pH and limit sodium or salts to soils
- Rotational cropping, especially three to five year rotations
- Good drainage and/or profile infiltration

- No saline seeps
- No salinization along ditches or with less irrigation or no preplant irrigation as well as irrigation method
- No wetland areas or ponded areas in fields
- Drainage or irrigation water use and infiltration below soil surface along with land leveling management
- Good water quality and/or mixing water supply when needed
- Good crop selection and seed placement
- Careful fertilizer use and choice

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