Food and Agriculture Organization of the United Nations

International Network of Salt-Affected Soils

Nutritional imbalances in salt-affected soils

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In this talk

- Salt-affected soils
- Na toxicity in Salt-affected Soils
- Cl toxicity in Salt-affected Soils
- N interactions in Salt-affected Soils
- P & K interactions in Salt-affected Soils
- Ca & Mg interactions in Salt-affected Soils
- Micronutrient interactions in Salt-affected Soils
- Nutrient management in Salt-affected Soils

Salt-affected Soil: Saline vs sodic/alkali soils

Saline soils

– having high soluble salts

– $ECe \geq 4$ dS m^{-1} , $SAR < 13$ $(mmol\ L^{-1})^{1/2}$, $ESP < 15$, $pH < 8.5$

Sodic/alkali soil

– having high exchangeable sodium concentrations

– $ECe < 4$ dS m^{-1} , $SAR \geq 13$ $(mmol\ L^{-1})^{1/2}$, $ESP \geq 15$, $pH \geq 8.5$

Saline sodic/alkali soils

– having high soluble salts and exchangeable sodium

– $ECe \geq 4$ dS m^{-1} , $SAR \geq 13$ $(mmol\ L^{-1})^{1/2}$, $ESP \geq 15$, $pH \geq 8.5$

Nutritional imbalances in salt-affected soils

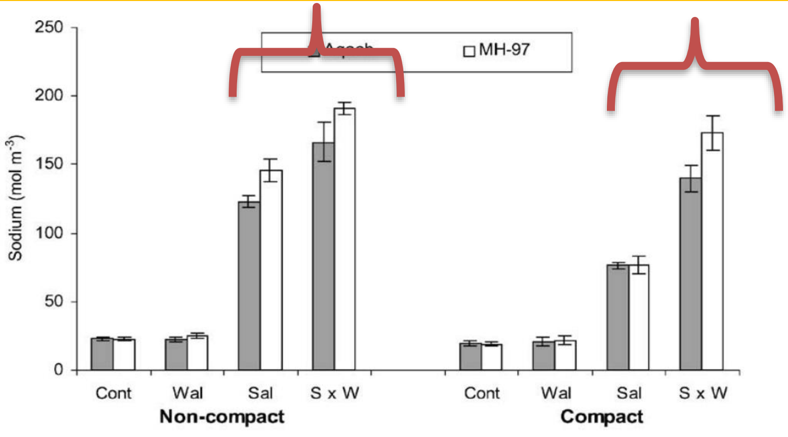
Salinity-nutrient interactions are complex:

Increase, decrease, no effect

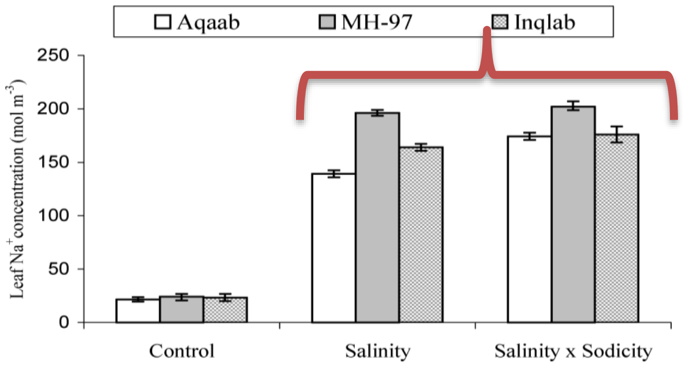
Plant nutrition in salt affected soils depends on

- Composition of salts
- Level of salinity, ion competition
- Nutrient concentrations in the soil
- Plant factors including species, genotypes, transport and partitioning in plant
- Climatic conditions

Na toxicity in Salt-affected Soils



Effect of soil compaction on Na^+ contents (mol m^{-3}) of wheat leaves under saline and waterlogged conditions.



The leaf Na^+ concentration (mol m^{-3}) of the three wheat genotypes in response to salinity (ECe 15 dS m^{-1}) and salinity x sodicity (ECe 15 dS m^{-1} and SAR 35). The columns represent the mean values and the bars show ± standard error (n = 5).

Shoot and root Na^+ concentrations, root-to-shoot Na^+ translocation and Na^+ uptake per gram plant of four wheat genotypes under salinity (125 mM NaCl)

Genotypes	Shoot Na^+ (mmol g^{-1} dry wt)	Root Na^+ (mmol g^{-1} dry wt)	Root-to-shoot Na^+ translocation	Normalized root-to-shoot Na^+ translocation	Na^+ uptake per g plant (mmol)
SARC-1	1.3 ± 0.1 b	1.7 ± 0.1 a	1.4 ± 0.1 c	2.0 ± 0.1 c	1.5 ± 0.01 a
Inqlab-91	1.8 ± 0.2 a	1.3 ± 0.1 b	4.5 ± 0.4 a	4.8 ± 0.3 a	1.7 ± 0.13 a
MH-97	1.5 ± 0.1 b	1.1 ± 0.1 b	3.3 ± 0.2 b	4.4 ± 0.1 b	1.4 ± 0.05 a
7-Cerros	1.6 ± 0.1 a	1.1 ± 0.1 b	4.1 ± 0.1 ab	4.3 ± 0.2 ab	1.5 ± 0.05 a

(Saqib et al. 2004, 2005, 2008)

Na-Si interaction in Salt-affected Soils

Shoot Na^+ concentration, plant Na^+ content, root-to-shoot Na^+ distribution and plant Na^+ uptake in two wheat genotypes as affected by salinity (125 mM NaCl) and silicon (1 mM)

The data show means ± s.e. ($n = 4$). Plants were 14 days old when treatments were applied for 21 days. *df*, degrees of freedom; NS, not significant; *, $P \leq 0.05$; **, $P \leq 0.01$ and ***, $P \leq 0.001$

Treatment/genotype	Shoot Na^+ concentration (mmol g^{-1} dry weight)	Plant Na^+ content (mmol $plant^{-1}$)	Shoot : root Na^+ distribution (shoot Na^+ content/ root Na^+ content)	Plant Na^+ uptake (mmol g^{-1} root dry weight)
		Salinity		
SARC-1	1.62 ± 0.04	2.19 ± 0.02	3.65 ± 0.08	2.50 ± 0.05
7-Cerros	2.07 ± 0.21	3.17 ± 0.18	5.65 ± 0.11	3.38 ± 0.2
		Salinity + silicon		
SARC-1	1.13 ± 0.02	1.72 ± 0.06	1.41 ± 0.22	1.83 ± 0.13
7-Cerros	1.30 ± 0.07	2.83 ± 0.08	1.68 ± 0.27	3.02 ± 0.06

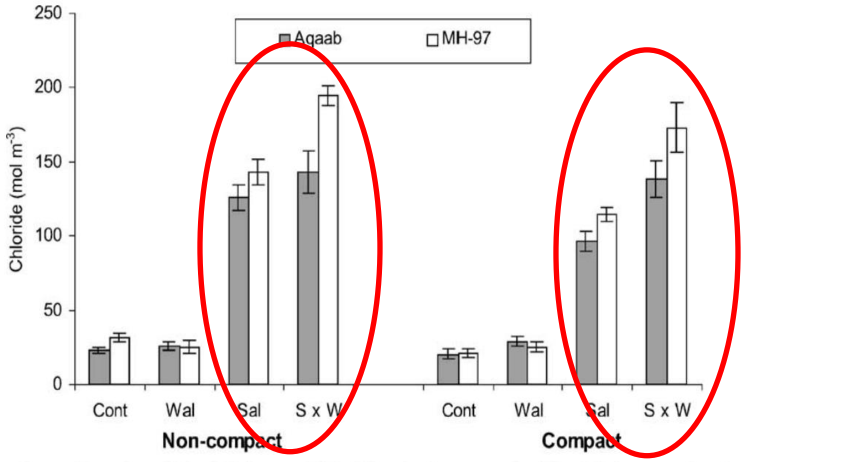
Cell wall-bound Na^+ of two wheat genotypes as affected by salinity (125 mM NaCl) and silicon (1 mM)

The data show means ± s.e. ($n = 4$). Plants were 14 days old when treatments were applied for 21 days. NS, not significant; *, $P \leq 0.05$

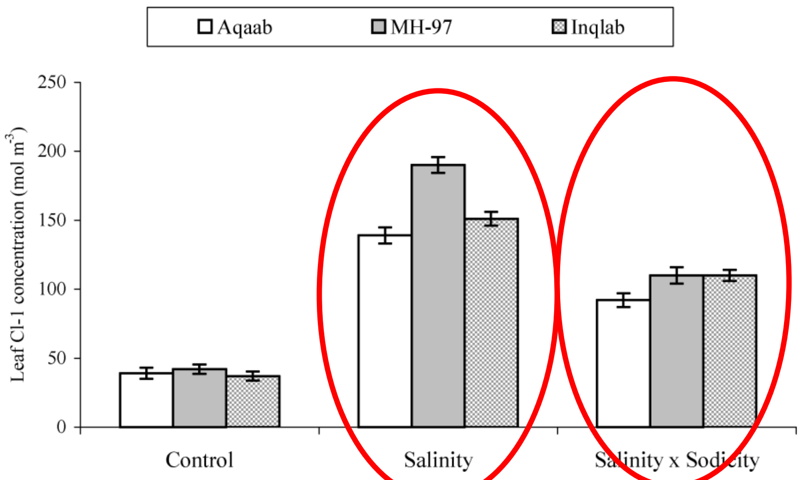
Genotype	Cell wall Na^+ (mmol g^{-1} dry weight)		Cell wall Na^+ as % of shoot Na^+	
	Salinity	Salinity + silicon	Salinity	Salinity + silicon
SARC-1	0.79 ± 0.06	0.98 ± 0.02	49	87
7-Cerros	0.77 ± 0.02	1.03 ± 0.05	37	79

(Saqib et al. 2008)

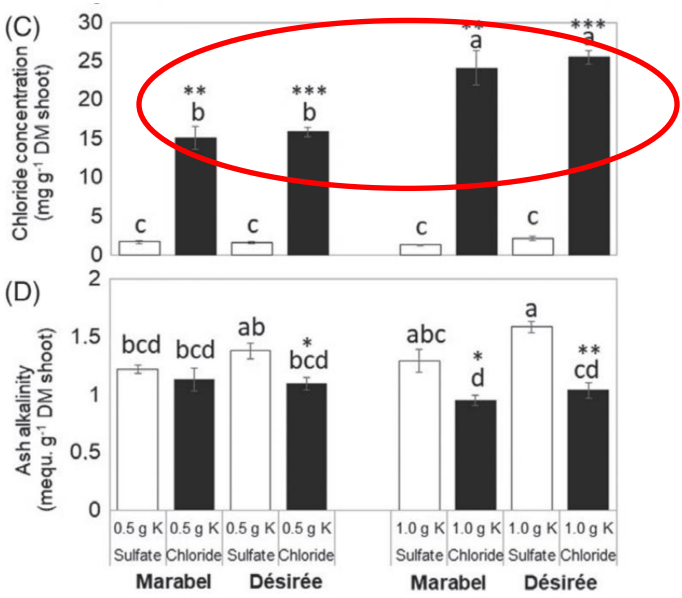
Cl toxicity in Salt-affected Soils



Effect of soil compaction on Cl^- contents (mol m^{-3}) of wheat leaves under saline and waterlogged conditions.



The leaf Cl^- concentration (mol m^{-3}) of the three wheat genotypes in response to salinity (ECe 15 dS m^{-1}) and salinity x sodicity (ECe 15 dS m^{-1} and SAR 35). The columns represent the mean values and the bars show ± standard error (n = 5).



(Saqib et al. 2004, 2008; Huetsch et al. 2018)

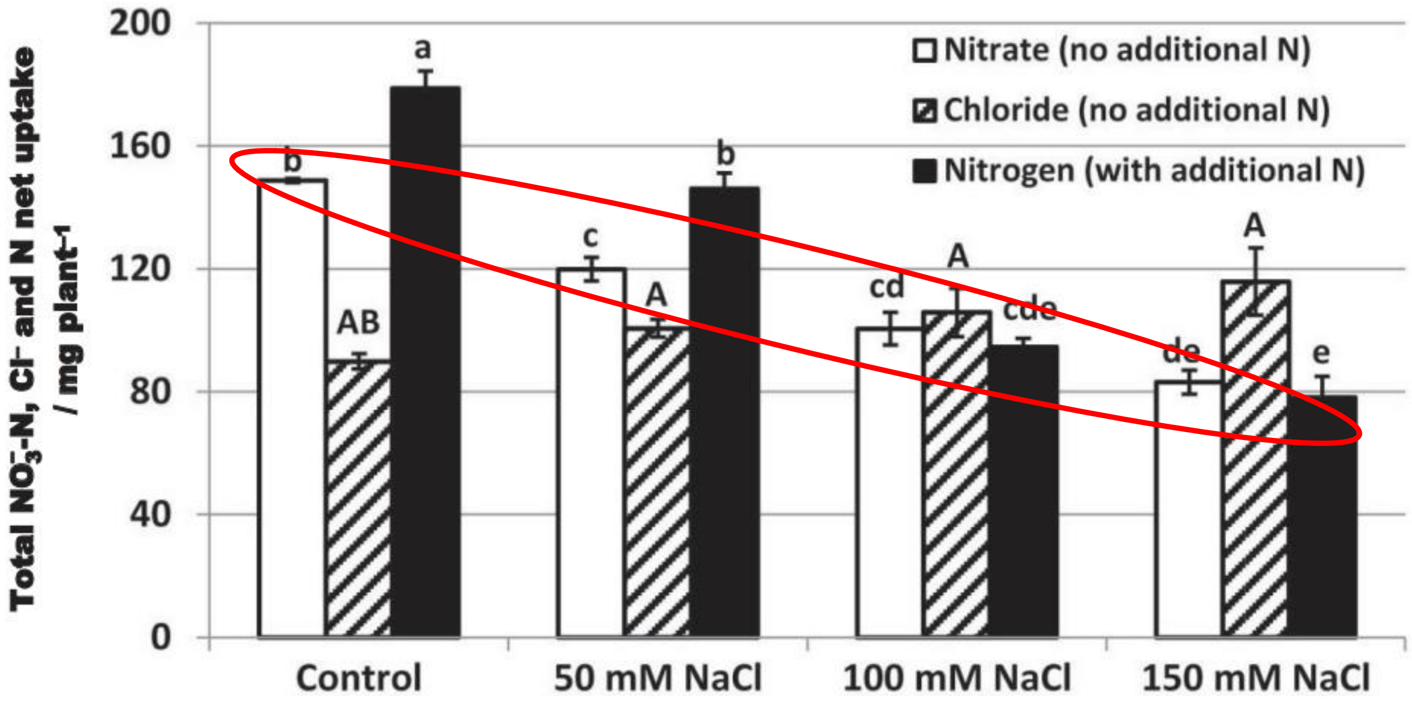
Nitrogen interactions in Salt-affected Soils

Nitrogen nutrition is compromised in salt-affected soils

- High concentrations of Cl^- competes and reduces NO_3^- uptake
- High concentration of Na^+ competes and reduces NH_4^+ uptake (Huetsch et al. 2016; Gratten and Gireve, 1999)

Symbiotic N_2 fixation is reduced in salt-affected soils because of reduced nodulation, Rhizobium number and efficiency, and reduced supply of photosynthates to nodules (Fageria, 1992)

Nitrogen interactions in Salt-affected Soils



"Although total nitrate uptake and root-to-shoot translocation of N were markedly decreased by NaCl application, the smaller plants nevertheless received enough N to meet their demand pointing to other growth-limiting factors than N nutrition. In maize, Cl^-/NO_3^- antagonism is only of minor importance for the overall uptake of both ions". (Huetsch et al. 2016)

P and K interactions in Salt-affected Soils

- **Phosphorous** availability is either decreased or increased or remained unaffected in salt-affected soils.

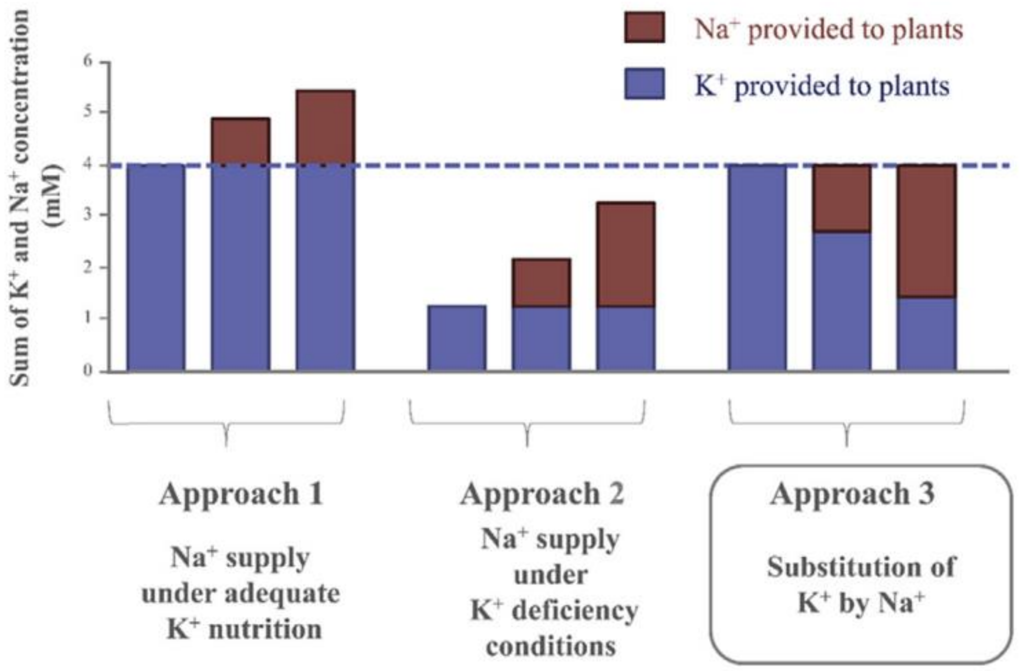
(Abbas et al., 2013; Fageria, 1985; Grattan and Grieve, 1999)

- **Potassium** availability and uptake is reduced in salt-affected soils as a result of high soil Na^+ concentration and disrupted membranes.

- **Improved Ca^{2+} nutrition** improves K^+ uptake and reduces its leakage as a result of improved membrane integrity.

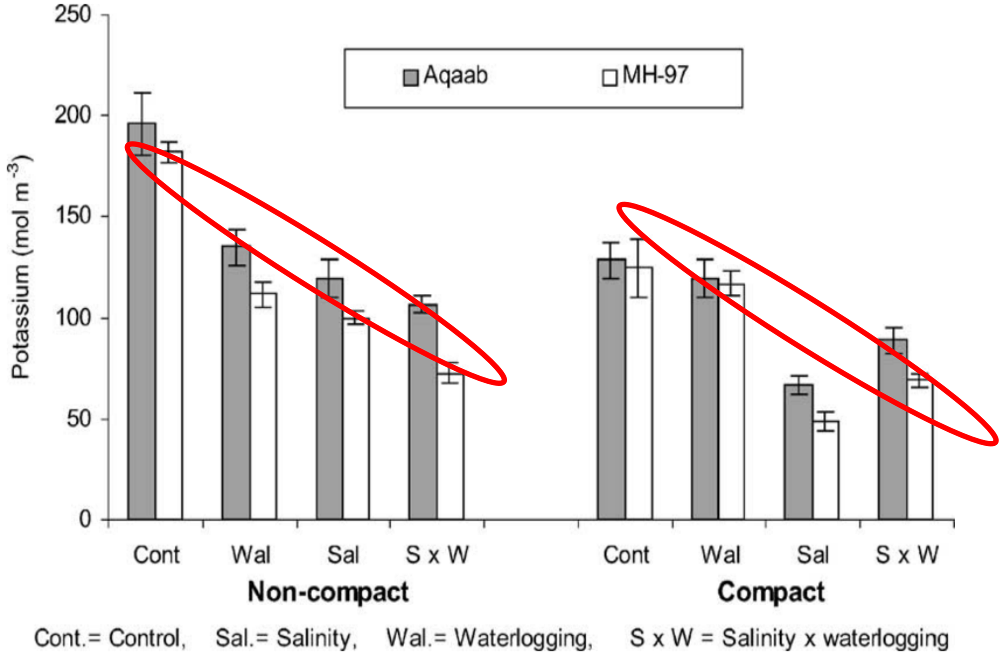
(Faust and Schubert, 2016; Grattan and Grieve, 1999; Saqib et al., 2004)

K interactions in Salt-affected Soils



Schematic illustration of experimental approaches dealing with the interaction of K^+ and Na^+ under non-saline conditions. Horizontal line indicates the level of adequate K^+ concentration.

(Faust and Schubert, 2016)



Effect of soil compaction on K^+ contents (mol m^{-3}) of wheat leaves under saline and waterlogged conditions.

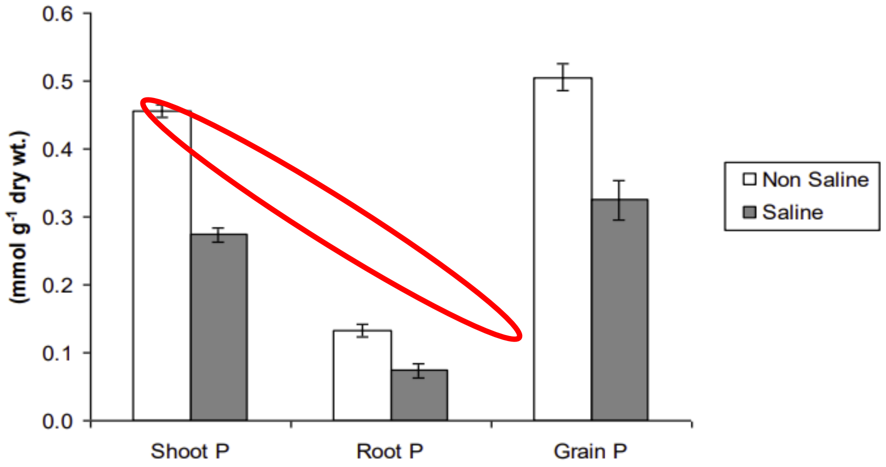
(Saqib et al., 2004)

P interactions in Salt-affected Soils

Influence of soil salinity on concentration of phosphorus and potassium in two lowland rice genotypes

Salinity level ($ds\ m^{-1}$ at 25 °C)	Genotype CNA 810098 P Conc. ($g\ kg^{-1}$)	Genotype CNA 810098 K conc. ($g\ kg^{-1}$)	Genotype CNA 810162[1] P conc. ($g\ kg^{-1}$)	Genotype CNA 810162[1] K conc. ($g\ kg^{-1}$)
0.29 (control)	2.9	35.5	2.5	34.0
5	2.7	32.5	2.0	32.8
10	2.4	25.7	2.1	24.3
15	1.5	22.5	—	—

(Fageria, 1985)



Effect of salinity on phosphorous concentration (mmol g^{-1} dry wt.) of shoot, root and grain of wheat

(Abbas et al., 2013)

Ca and Mg interactions in Salt-affected Soils

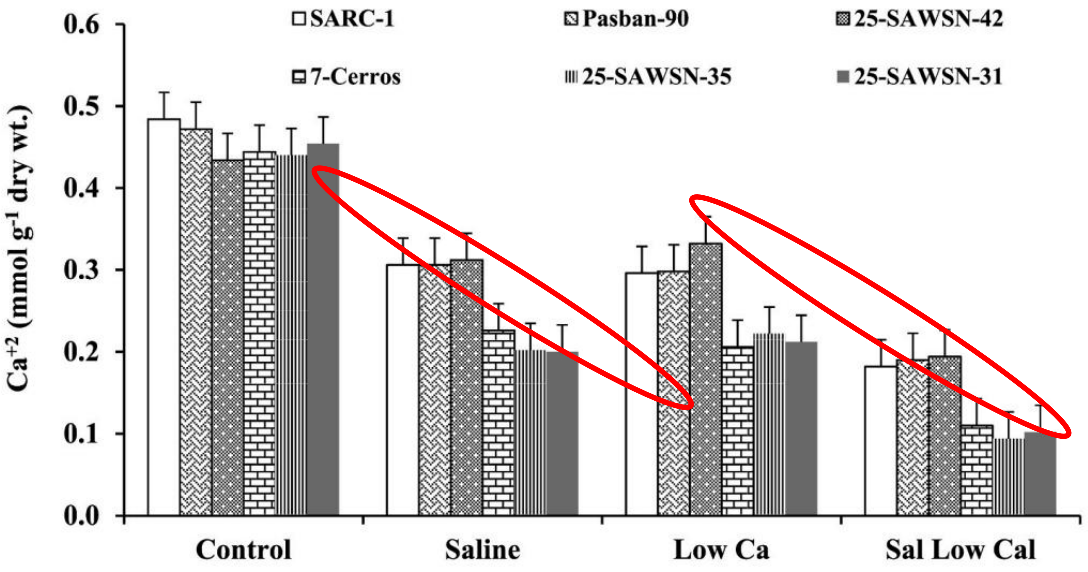
- **Calcium availability** and uptake is decreased in salt-affected soils because of ion interactions. (Saqib et al., 2020)

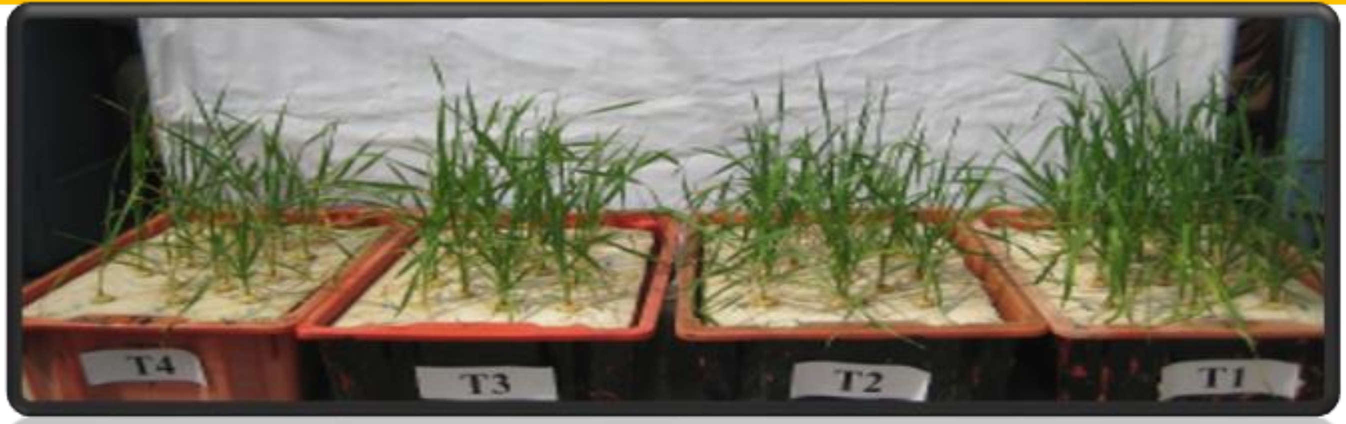
- **Addition of calcium** under salt-affected soils improves membrane integrity, reduces leakage of NO_3^- and $H_2PO_4^-$, and reduces Na^+ toxicity. (Saqib et al., 2020; Cachorro et al. 1994)

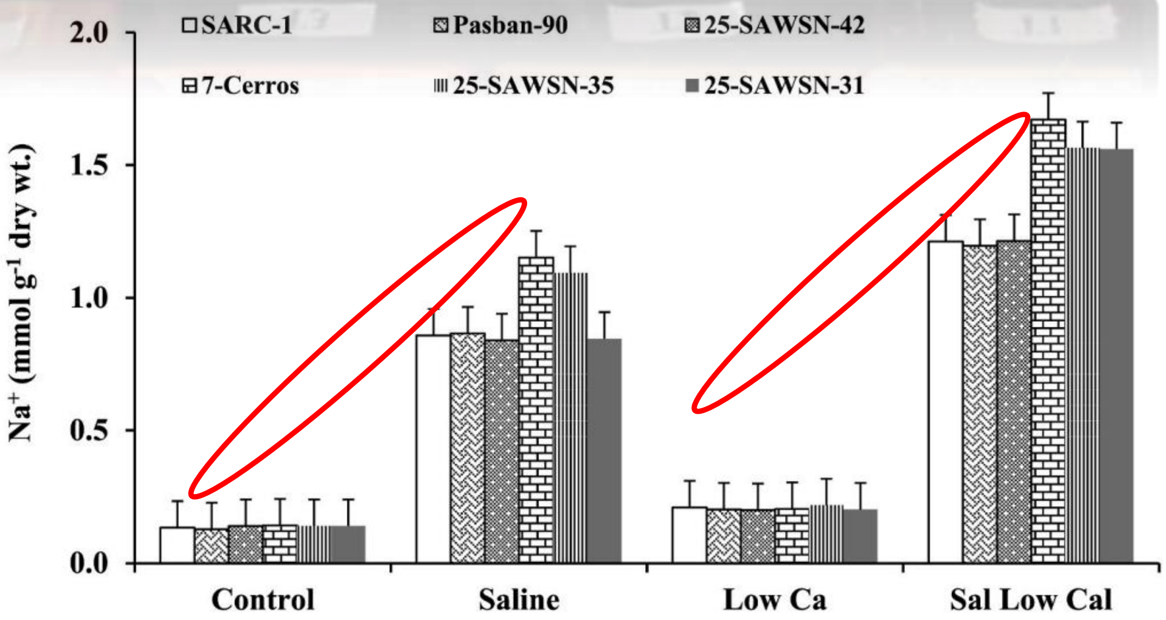
- **Magnesium uptake** and accumulation in plants is either reduced or not affected by salinity.
- However, **Ca^{2+} and Mg^{2+} competes** and Mg^{2+} deficiency because of high calcium has been reported.

(Grattan and Grieve, 1999; Bernstein and Hayward, 1958)

Ca interactions in Salt-affected Soils







(Saqib et al., 2020)

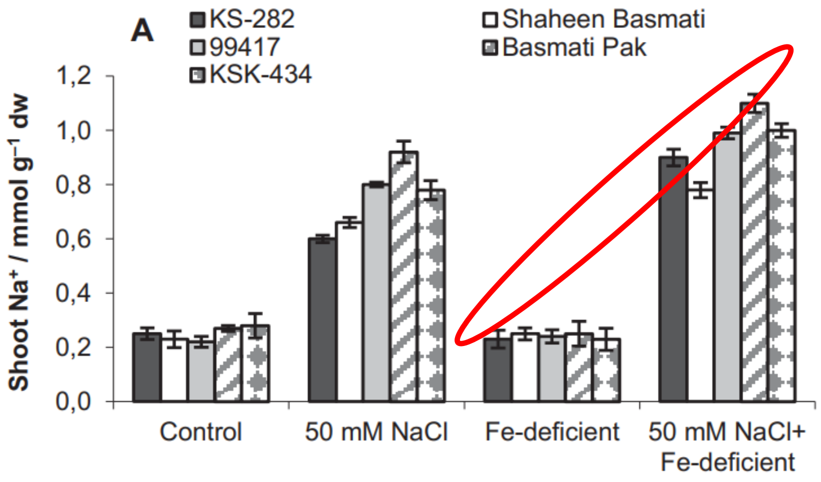
Micronutrients interactions in Salt-affected Soils

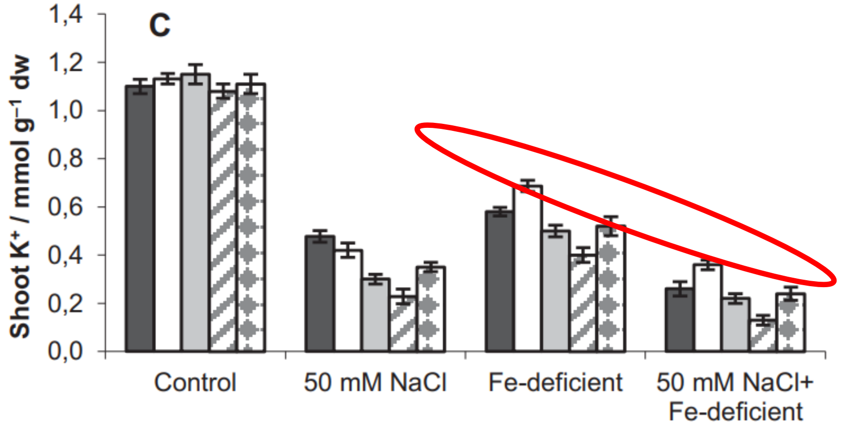
- Salinity reduced **Mn** uptake in corn (Rahman et al. 1993).
- Salinity decreased **Zn** accumulation in maize (Batool et al., 2015).
- However, in rice an increase in **Zn, Cu and Mn** has been reported under saline conditions which was suggested to be due to decreased pH (Fageria, 1985).
- Salinity decreased **Fe** concentration in rice (Abbas et al., 2015; Batool et al., 2015).

Micronutrients interactions in Salt-affected Soils

- An increase in **Mo** concentration due to salinity (Rahman et al. 1993)
- A decrease in **Cu** concentration in corn (Rahman et al., 1993) and an increase in **Cu** concentration in tomato has been reported under salinity (Grattan and Grieve, 1999)
- Salinity and **B** interactions have been found in wheat, maize and sunflower. (Saqib et al., 2009; Riaz, 2012; Ahmed, 2012)
- A decrease in uptake of **B** under high Ca^{2+} and SO_4^{2-} has been reported. (Saqib et al., 2009)

Fe interaction in Salt-affected Soils





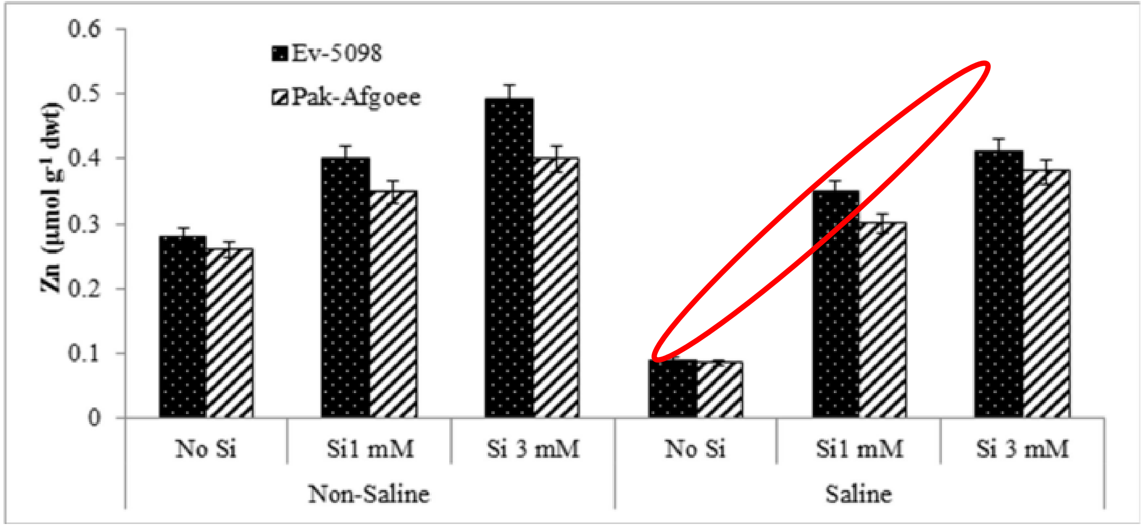
Abbas et al. 2015

Influence of salinity on the concentration of Zn, Cu and Mn in the tops of two lowland rice genotypes

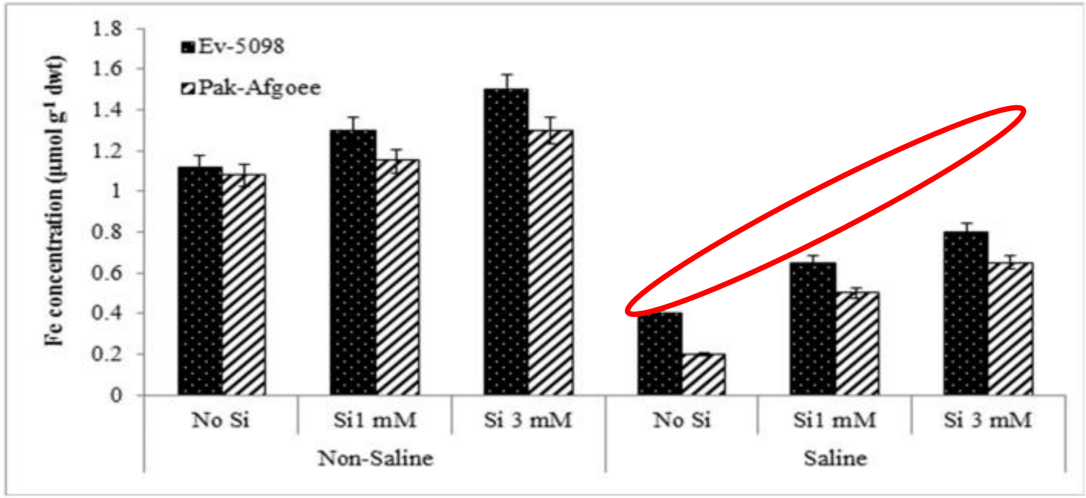
Salinity level ($ds\ m^{-1}$)	Genotype CNA 810098 Zn ($mg\ kg^{-1}$)	Genotype CNA 810098 Cu ($mg\ kg^{-1}$)	Genotype CNA 810098 Mn ($mg\ kg^{-1}$)	Genotype 810162[1] Zn ($mg\ kg^{-1}$)	Genotype 810162[1] Cu ($mg\ kg^{-1}$)	Genotype 810162[1] Mn ($mg\ kg^{-1}$)
0.29 (control)	28.5	25	683	25.5	15.0	680
5	32	30	943	37	25.0	915
10	45.5	35	773	35	22.5	903
15	60	30	1150	—	—	—

Fageria, 1985

Zn and Si interactions in Salt-affected Soils



Effect of Si application on zinc concentration of Maize genotypes under non- saline and saline conditions



Effect of Si application on iron concentration of Maize genotypes under non- saline and saline conditions

Batool et al., 2015

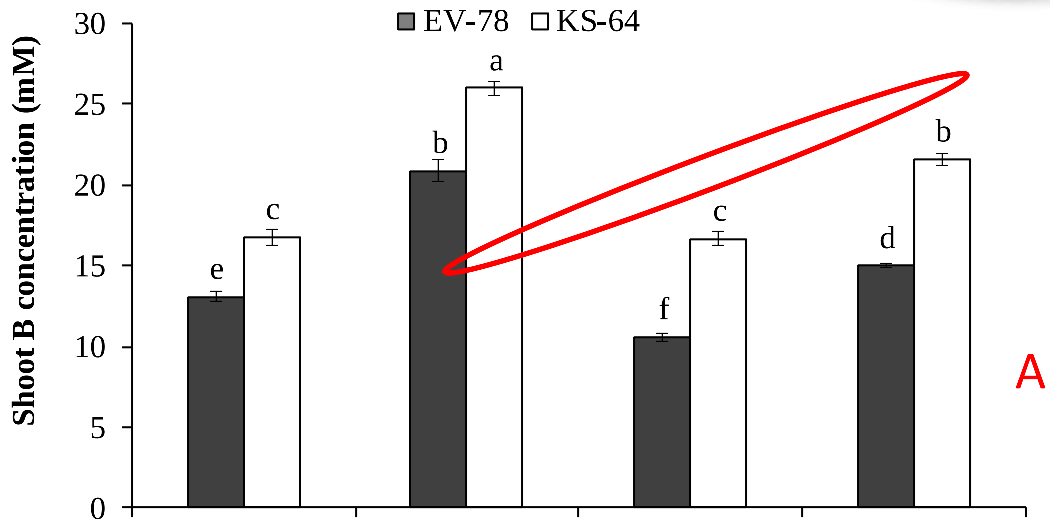
B interactions in Salt-affected Soils

Effect of NaCl and boron on shoot and root growth (g per plant) of wheat

Growth parameters	Control	Salinity (100 mM NaCl)	Boron (2.5 mM B)	Salinity x Boron
Shoot fresh weight	2.84 A	1.73 C (61)	2.12 BC (75)	0.88 D (31)
Shoot dry weight	0.331 AB	0.252 C (76)	0.281 BC (81)	0.155 D (47)
Root fresh weight	1.39 AB	1.19 BC	1.07 C	0.69 D
Root dry weight	0.215 A	0.163 B	0.13 C	0.064 D

(Saqib et al. 2009)

Salinity x B interaction in maize



Ahmed, 2012

Nutrient management in salt-affected soils

- Soil, water and crop management
- Use of soil amendments-reduces salt effects
- Addition of organic matter
- Use of salt-tolerant plant species and genotypes
- Addition of fertilizers

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THANKS

International Network of Salt-Affected Soils

Crop nutrition in salt-affected soils

24 April, 2024

GLOBAL SOIL PARTNERSHIP