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Drainage Engineering

(BTAI3103)

Module 2

Drainage for Salt Control

(Lecture-04: Salt problem in Soil and Water_2)

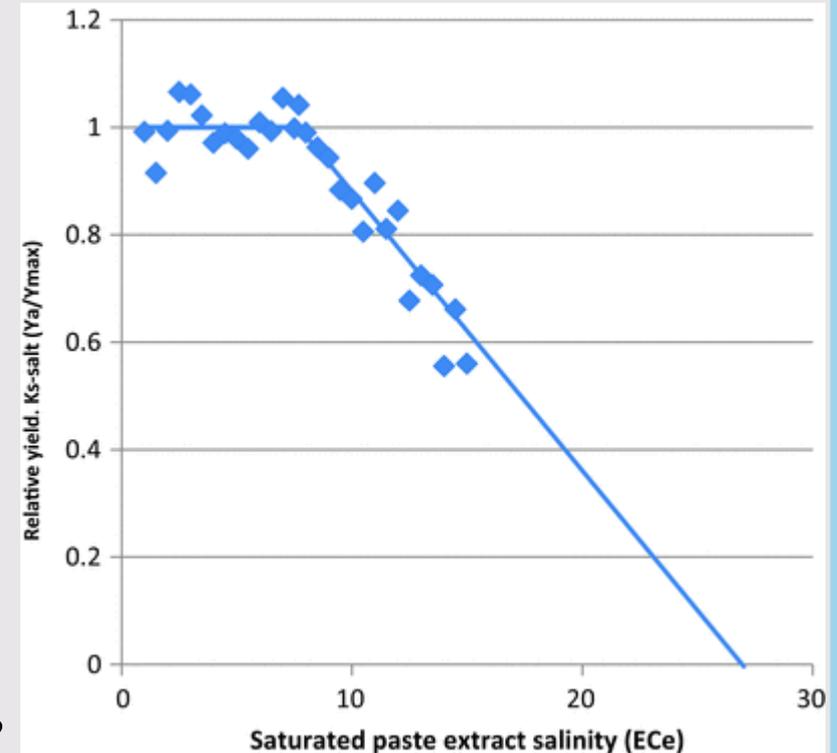
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Salinity Stress Coefficient

- ✓ Increase in soil salinity decreases water uptake, thus, decreases yield.
- ✓ From figure, when EC_e exceeds 7.7, the yield begins to decrease.
- ✓ Crops that are classified as sensitive, moderately sensitive, moderately tolerant, and tolerant to salinity have no reduction in yield at EC_e is 1.0, 3.0, 6.0, and 9.5 dS/m.





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Salinity Stress Coefficient

- ✓ Vegetable crops are generally sensitive to moderately sensitive to salinity.
- ✓ Field crops such as cotton, wheat and barley tend to be less sensitive to salinity.
- ✓ The NRCS classifies irrigation salinity levels as no restriction on use ($EC_{iw} < 0.7$), slight to moderate restriction ($0.7 < EC_{iw} < 3.0$), and severe restriction ($3.0 < EC_{iw}$).



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Salinity Stress Coefficient

The salinity stress coefficient is equal to 1 if $EC_e < EC_{et}$, otherwise

$$K_{s-salt} = 1 - \frac{b}{100 \times K_y} (EC_e - EC_{et})$$

Where b is the slope of EC_e /yield line, %/(dS/m); EC_{et} is the threshold saturated paste extract EC_e With no yield decrease, dS/m; K_{s-salt} is the salinity stress coefficient, varies from 0 to 1; K_y is the crop sensitive to water stress



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Water Stress Coefficient

- ✓ As with salinity stress, the water stress coefficient is generally calculated under the assumption that yield decreases linearly with increased percent water depletion.
- ✓ The threshold percent depletion, θ_t , is the water content at which yield starts to decrease.
- ✓ Thus, K_s -water decreases linearly from 1 at θ_t to 0 at θ_{pwp}

$$K_{s-water} = \frac{\theta - \theta_{pwp}}{\theta_t - \theta_{pwp}} \qquad \theta_t = \theta_{FC} - \left(\frac{p}{100}\right)(\theta_{FC} - \theta_{pwp})$$

p is the point at which yield decreases in contrast to MAD, which may be equal to p or less than p



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Water and Salt Stress Coefficient

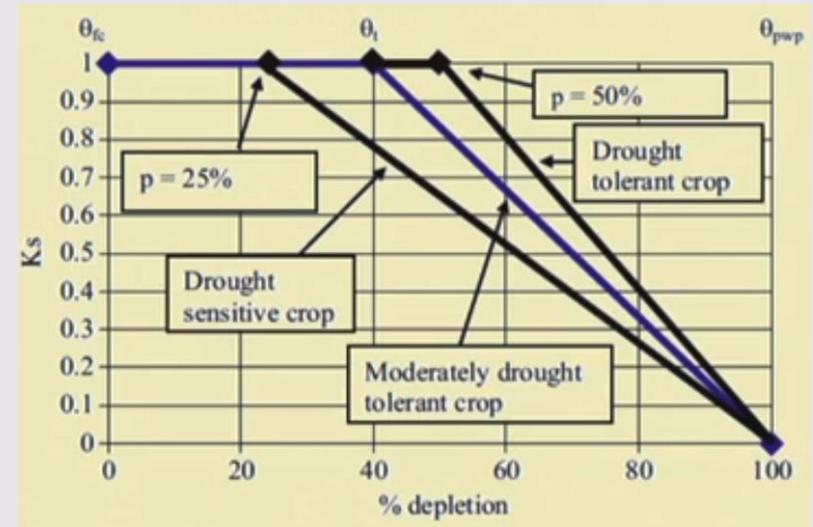
✓ Combined salt and water stress coefficient

$$K_S = K_{S-salt} \times K_{S-water}$$

The relationship between yield decrease and combined stress is:

$$1 - \left(\frac{Y_a}{Y_{max}} \right) = K_y (1 - K_S)$$

Where K_y is the crop sensitivity to water stress, Y_a is the actual yield, kg/ha; Y_{max} is the maximum potential yield, kg/ha.



K_s versus water content curve



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Water and Salt Stress Coefficient

$$\text{Equation, } 1 - \left(\frac{Y_a}{Y_{max}} \right) = K_y(1 - K_s)$$

Can be rearranged to solve for actual yield:

$$Y_a = \left(1 - K_y(1 - K_s) \right) Y_{max}$$

Table: Crop sensitivity to water stress, K_y

Crop	K_y	Crop	K_y
Alfalfa	1.1	Potato	1.1
Banana	1.2-1.35	Safflower	0.8
Beans	1.15	Sorghum	0.9
Cabbage	0.95	Soybean	0.85
Citrus	1.1-1.3	Spring Wheat	1.15
Cotton	0.85	Sugarbeet	1.0
Grape	0.85	Sugarcane	1.2
Groundnet	0.70	Sunflower	0.95
Maize	1.25	Tomato	1.05
Onion	1.1	Watermelon	1.1
Peas	1.15	Winter wheat	1.05
Pepper	1.1		



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Example

Calculate actual yield for cotton for a growing season if average salinity during the growing season is 10.4 dS/m, and average water content is 14%, $\theta_{FC} = 20\%$, $\theta_{pwp} = 10\%$.

$K_y = 0.85$. Max yield = 1285 kg/ha, MAD = 50%. Threshold $EC_{et} = 7.7$ dS/m and $b = 5.2$.

Solution:

$$\begin{aligned}\theta_t &= \theta_{FC} - \left(\frac{MAD}{100}\right) (\theta_{FC} - \theta_{pwp}) \\ &= 20 - \left(\frac{0.5}{100}\right) (20 - 10) = 15\%\end{aligned}$$

$$K_{s-water} = \frac{\theta - \theta_{pwp}}{\theta_t - \theta_{pwp}} = \frac{0.14 - 0.10}{0.15 - 0.10} = 0.8$$



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$$K_{s-salt} = 1 - \frac{b}{100 \times K_y} (EC_e - EC_{et})$$

$$= 1 - \frac{5.2}{100 \times 0.85} (10.4 - 7.7)$$

$$= 0.83$$

$$K_s = K_{s-salt} \times K_{s-water}$$

$$= 0.83 \times 0.80 = 0.67$$

Actual yield $Y_a = (1 - K_y(1 - K_s)) Y_{max}$

$$= (1 - 0.85(1 - 0.67))1285 = 924 \text{ kg/ha}$$



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Example

Calculate the yield reduction for sugar beets. Assume 80 cm is applied and 100 cm is required. $Y_{max} = 40$ t/ha.

Solution:

From Table, K_y for sugar beet is 1.0.

The yield based on the FAO, K_y slope is calculated as follows:

$$\begin{aligned} Y_a &= \left(1 - K_y(1 - K_s)\right) Y_{max} \\ &= \left(1 - K_y \left(1 - \frac{ET_{c,adj}}{ET_c}\right)\right) Y_{max} \\ &= \left(1 - 1.0 \left(1 - \frac{80}{100}\right)\right) 40 = 32 \text{ t/ha} \end{aligned}$$



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Salt Balance at Farm Level

Salt inflow – salt outflow = Change in salt content

$$\begin{aligned} & [\rho_w(V_i C_i + V_r C_r + V_g C_g) + M_s + M_a] \\ & - [\rho_w(V_d C_d + V_{sd} C_{sd} + V_{pw} C_{pw}) + M_p] = \Delta M_{sw} \end{aligned}$$

ρ_w = density of water, 1000mg/L

V_i, V_r, V_g = volume of water added to the same volume of soil by irrigation, rainfall and upward flux (capillary rise), respectively, L.

C_i, C_r, C_g = concentration of salt in irrigation water, rainwater and groundwater, respectively, mg/L

V_d, V_{sd}, V_{pw} = Volume of water removed by deep drainage, surface drainage and plant uptake, respectively, L

C_d, C_{sd}, C_{pw} = concentration of salt in deep drainage, surface drainage and plant uptake, respectively, mg/L

M_s = mass of salts dissolved from soil mineral of a specified soil volume, mg

M_a = mass of salts from agricultural inputs, mg

M_p = mass of salts precipitated (turned into solid), mg

ΔM_{sw} = change in mass of salt in the soil's liquid phase



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Steady-state salt model (Hillel, 1998):

Assumption

- ✓ Salinity concentration during the season and the year is constant ($\Delta M_{sw} = 0$)
- ✓ In-situ precipitation (liquid to solid) and dissolution (solid to liquid) of salt is negligible ($M_s = 0$; $M_p = 0$; $M_a = 0$)
- ✓ Crops remove a negligible amount of salt ($M_c = 0$)

$$(V_i C_i + V_r C_r) = (V_d - V_g) C_d$$

In C_{in} is the average weighted salinity of the precipitation and irrigation water, and V_g is negligible, then

$V_{in} C_{in} = V_{out} C_{out}$ or $d_{in} C_{in} = d_{out} C_{out}$ by replacing water volume with water depth, d



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