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Anjugramam - Kanyakumari Main Road, Palkulam,Variyoor P.O. - 629 401, Kanyakumari District.

DEPARTMENT OF AGRICULTURAL ENGINEERING

CAI 334 IRRIGATION WATER QUALITY AND WASTE WATER MANAGEMENT

UNIT 2 IRRIGATION WATER QUALITY

2.3 IRRIGATION PRACTICES FOR POOR QUALITY WATER

PREPARED BY

MRS. NITHYA.K

ASSISTANT PROFESSOR/AGRI

ROOT ZONE SALINITY AND AVOIDANCE MEASURES

Root zone salinity refers to the concentration of salts in the immediate vicinity of plant roots within the soil. When soil contains high levels of soluble salts, such as sodium chloride (NaCl), calcium sulfate ($CaSO_4$), or magnesium sulfate ($MgSO_4$), it can lead to elevated salinity in the root zone.

The average root zone salinity can be calculated using the average of five points in the rooting depth.

This accumulation of salts can occur due to various factors, including:

1. **Natural Processes:** Salts may be naturally present in the soil due to factors such as weathering of minerals, geological formations, and the accumulation of salts from groundwater or surface water sources.
2. **Irrigation Practices:** In agricultural settings, improper irrigation practices can contribute to root zone salinity. For example, excessive use of irrigation water without proper drainage can lead to the accumulation of salts in the soil over time.
3. **Poor Water Quality:** The quality of irrigation water can influence root zone salinity. Water sources with high salt content, such as saline groundwater or recycled wastewater, can contribute to salt buildup in the soil if not properly managed.
4. **Climate Conditions:** Arid and semiarid climates with low rainfall and high evaporation rates are more prone to soil salinization. In these environments, salts can accumulate near the soil surface as water evaporates, leading to increased salinity in the root zone.

SALINE WATER IRRIGATION - IRRIGATING WITH POOR QUALITY WATER-FUTURE STRATEGIES

- **Leaching**

The salts that accumulate in the soil can be effectively removed only by leaching. For this to occur, enough water must enter the surface to produce downward percolation and outflow of drainage water from the root zone. The extra amount of this water in addition to the irrigation dose is called the leaching requirement (LR), and can be estimated exactly with the use of the equation:

$$LF = \frac{D_d}{D_a} = \frac{C_a}{C_d} = \frac{EC_a}{EC_d}$$

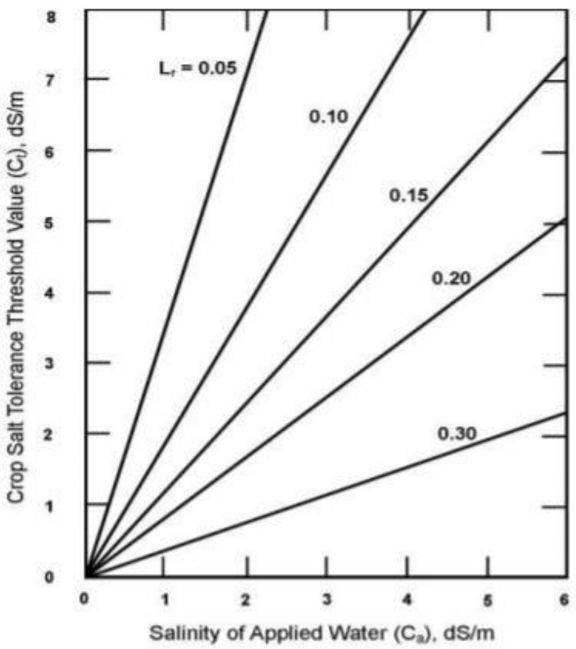
where Dd (mm) and Da (mm) are the depths of drainage water and infiltrating applied water, respectively; Ca (mg/L) and Cd (mg/L) are the salt contents of the applied and drainage water, respectively; and ECa (dS/m) and ECd (dS/m) are the electrical conductivities of the applied and drainage water, respectively.

$$\text{Leaching Fraction (LF)} = \frac{\text{depth of water leached below the root zone}}{\text{depth of water applied at the surface}}$$

Leaching requirement was originally defined as the fraction of water infiltrating the soil that must move beyond the rootzone to prevent soil salinity from exceeding a specified value. The Lr represents the minimum LF that will adequately leach salts in the rootzone to a level that does not measurably reduce crop yield; consequently, the rootzone salinity level is the maximum permissible salinity level of ECdw (i.e., EC* dw) that will still result in optimum plant growth.

Leaching is especially necessary as a soil preparation for crops with high plant density, such as carrots, onions and groundnuts. The salinity over the entire area should be the same with no difference between the wetted and the non-wetted parts of the field during the preceding season.

The leaching of the salts in the top layer is particularly important because crops are sensitive to salinity during the first stages of their growth. For the control of the salinity level in the root zone, frequent observations should be conducted with soil sampling for the laboratory determination of the soil extract EC. The use of soil solutions, extractors and portable metering devices on the spot enables the continuous monitoring, for immediate action, of any significant change in the EC of the soil solution, the chloride and nitrate content, and the soil pH as a result of irrigation and fertilization.



Leaching requirement (L_r) as a function of the salinity of the applied irrigation water (EC_i) and plant salt-tolerance threshold (EC_e^*).

The salinity of the drainage water can be estimated from the equation:

$$EC_{dw} = \frac{EC_w}{LF}$$

where: EC_{dw} = salinity of the drainage water percolating below the root zone (equal to salinity of soil-water, EC_{sw})

EC_w = salinity of the applied irrigation water

LF = leaching fraction

The plant, however, is only exposed to this drainage water salinity at the lowest part of the root zone. The salinity in this lower portion of the root zone tends to be higher than in the upper portion due to its much lower leaching fraction. The crop responds, however, to the average root zone soil salinity and not to the extremes of either the upper or lower zones.

EXAMPLE 1 - CALCULATION OF CONCENTRATION OF DEEP PERCOLATION FROM THE BOTTOM OF THE ROOT ZONE

A crop is irrigated with water of an electrical conductivity (ECw) of 1 dS/m. The crop is irrigated to achieve a leaching fraction of 0.15 (assumes that 85 percent of the applied water is used by the crop or evaporates from the soil surface).

Given: EC_w = 1 dS/m

LF = 0.15

Explanation:

The concentration of the soil-water percolating below the root zone (ECsw) is equivalent to the concentration of the drainage water (ECdw) accumulating below the root zone. The salinity of the deep percolation from the bottom of the root zone (drainage water) can be estimated by using equation (3):

$$EC_{dw} = EC_{sw} = \frac{EC_w}{LF}$$

$$EC_{dw} = \frac{1}{0.15} = 6.7 \text{ dS/m}$$

The salinity of the soil-water that is percolating from the bottom of the root zone (EC_{dw}) will be approximately 6.7 dS/m.

- **Drip Irrigation**

  Drip irrigation has the potential of increased yield under saline soil conditions. Factors affecting root zone soil salinity under drip irrigation include the salinity of the irrigation water, amount of applied water, soil hydraulic characteristics, placement of drip lines relative to plant rows, subsurface vs. surface drip lines, and under saline, shallow ground water conditions, the ground water depth and salinity. The salt pattern reflects the water flow patterns under drip irrigation. The key to profitable drip irrigation under saline conditions is adequate salinity control by leaching salts from the root zone. Under drip irrigation, highly concentrated leaching, called localized leaching, occurs near drip lines. Leaching decreases with horizontal distance from drip lines. Larger amounts of applied water increase the volume of leached soil near drip lines. Salts accumulate above subsurface drip lines, which requires rainfall or sprinkle irrigation for leaching. The water balance method of estimating leaching fractions is inappropriate for drip irrigation and underestimates the actual leaching fractions. Water applications equal to crop evapotranspiration provide adequate localized leaching.

- Use of poor quality waters requires three changes from standard irrigation practices: (1) selection of appropriately salt-tolerant crops; (2) improvements in water management, and in some cases, the adoption of advanced irrigation technology; and

(3) maintenance of soil-physical properties to assure soil tilth and adequate soil permeability to meet crop water and leaching requirements (LR).

Management strategies for safe use of poor-quality water

- In details various management practices are as follows:
- **Crop management Practices are**

Selection of crops

The uses of poor-quality water harmful effects are affecting by crop management option/practices. Every crop has its own genetic potential to tolerant the harmful elements present in WW. The saline-irrigated water is affecting the pulse crop germination; blackgram, peas, lentil, and pigeon pea are tolerate exchangeable sodium percent (ESP) 10–15, cowpea 20–25, whereas rice and barley crops tolerate higher ESP.

Growth stages

Most of the crop growth stages are not equally performed in poor-quality water like saline, alkaline, or heavy metal-contaminated water. The early growth stages are more sensitive than later stages. Therefore, application of poor-quality water should not be applied on the germination phase of crops.

Cropping sequence

It is one of the important management practices followed to minimize the effect of marginal quality water on crop cultivation. In this system cereal crops are grown in one season, and in next season, pulse crops may be cultivated, *i.e.* pearl millet-gram, mungbean-wheat, etc. The crops irrigated with saline water, presence of various cations and anions affected the growth of pulse crops and finally reduced the crop yield. The chloride ions are more toxic than the sulphate ions, because this application of sulphate ion rich water in mixing is reduced the adverse effect of chloride

Use of horti-crop sequence

The effect of salinity and heavy metal(s) is less effective on tree species. Planting of horticultural plants rows is in between the cereal crop fields. In one way it will minimize the adverse effect of metal toxicity, and in other side, it will give the added income to farmers. It acts as crop insurance in adverse climatic conditions. Some of the medicinal plants are well grown in saline water-irrigated fields, *i.e*. isabgol, aloe, kalmegh, etc.

Farmyard Manure (FYM) application

Poor-quality water affected the nutrient uptake pattern of crops and also reduced the soil fertility levels. The addition of SOC through external application of Farmyard Manure (FYM) in crop field enhanced the crop growth .The FYM not only provides the plant nutrient to plant but also structural improvement in soil. Addition of organic matter through crop residue reduced the salinity, trace metal toxicity in crops and improved the soil health. (.Application of organic matter increased the soil biodiversity properties, *i.e.* microbial population and types. That microbial population are reduced the trace metal effect on the plant by degradation and conversion of toxic metal to non-toxic metal. Different types of microbial biomass released various types of soil enzymes which also helped to reduce the salinity and adverse impact of metal toxicity in soil and plant growth.

The application of FYM in poor-quality irrigated soils, mediated the rhizospheric micro-climate and enhanced the different types of organic acids, which enhanced plant nutrient. In response of these effect plant roots also released various types of low molecular organic acid (LMOA) in the soil, which enhanced the soil microbial biomass and nutrient transformation rate. Soils irrigated with high chloride water reduced the P availability to plant and 50% additional application of P is needed. Application of inorganic fertilizers with FYM effectively countered the poor water effect in pulse crops. Addition amount of N fertilizers in higher organic matter irrigated soils, promotes higher rate of mineralization and improves the soil mineralization rate and crop yield. Application of biofertilizers with compost also reduces salinity and toxicity of heavy metal under WW-irrigated crop production systems.

Soil amendment

Utilization of marginal quality water for crop cultivation regarding its effect on crop is also affected by the soil type and texture. High permeability soils have more chances to contaminate the GW in sewage-irrigated areas. Due to lower organic matter in the soils of sandy or arid regions, there is less binding capacity of metals and they are leached down to a lower profile of the soils. These metals are again pumped out and used for the cultivation of crops and show their harmful effect on crop productivity and quality. Light-texture soils are good in drainage compared to heavy-textured soils. In soils of high clay content there is resistance to metal transfer in the lower zone of soils due to humus metal complex. Apart from this, the chances of moving the metals after few centimetres from soil surface to lower zone are fewer. An application of high Na containing poor-quality water reduced the soil fertility and soil productivity. After analysis of physico-chemical properties of WW was formed counter-management strategies, the higher concentration of heavy metals in effluent, addition of absorbent in soil, or WW channel reduces the availability of metal in irrigation water. Different types of absorbent are available in the market like bentonite, bioabsorbent, nanoclay, chitosan-based biosorbents. Long-term application of higher Na concentration effluent during crop production causes alkalinity in soil. For this, the use of gypsum in a cultivated field reduced the alkalinity effect, whereas lower pH effluent-irrigated field application of lime improves the crop's germination rate. In sandy soil condition, addition of FYM and organic residues reduces the toxic metal leaching and improves the soil health. Addition of MSW compost in soil improves the plant nutrient concentration and labile part of the sulphur. Microbial population and diversity enhance the secretion of low molecular organic acids in soil and improve the plant nutrient dynamics during crop growth stages. **Nanotechnology** is a cutting-edge technology for reducing metal toxicity. Different types of nanoparticles are being created and used to remove trace metals from water bodies all over the world. In comparison with traditional treatment procedures, magnetic microparticles provide target selectivity and cost-effectiveness. Many other organic soil amendments also reduced the adverse effect of heavy metals in soils. The hydrogel formed from animal waste and reduced the salinity or water loss from soil. These results showed that addition of animal waste-formulated hydrogel improves the moisture availability in soil and plant wilting symptoms are appeared on later period. These organic amendments enhanced the plant nutrient concentration in soil.

- **Crop response to water and salinity**

Determination of appropriate crops for irrigation is done on the bases of the salt tolerance of the crop and the salinity of the irrigation water. The objective of the selection process is to identify crops for which achievable levels of leaching will result in soil salinities that do not reduce crop yields. The optimal leaching is usually thought to depend only on the salinity of the irrigation water, the salt tolerance of the crop, and the amount of water required to maximize yields. However, maximum yields may not correspond to maximum profits because of the costs of reusing or disposing of the resulting drainage water. n. Crop growth and evapotranspiration (ET) are linked: ET increases with crop growth.