AGRO-507 (T)

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Auther:- S.R. Reedy.



In areas where wind velocities exceed 25 to 30 km $hr^{-1}$ during the period when irrigation water is being applied, operational difficulties may arise if the wind direction is opposite to the direction of water flow in the basin. Since wind erosion is also usually a problem in such areas, the basin length should be normal to the prevailing wind direction if practical. If the topography of the field is such that the basin length is parallel to the prevailing wind direction, the water should be applied at the up-wind end of the basin.

Designing sprinkler and drip irrigation systems to deliver water in the amounts and rates required by a farm irrigation plan is an engineering job. A number of books are available for detailed information on these two systems of irrigation.

## 9.8 QUALITY OF IRRIGATION WATER

Irrespective of its source, all irrigation water contains dissolved salts, the type and quantity of which depend on its origin and its course before use. Use of poor quality irrigation water has adverse effect on soil, nutrient availability, crop growth and soil microorganisms.

- High sodium content in irrigation water causes deflocculation of soil leading to reduced permeability and hence low infiltration of water to the root zone. Soil crusting and waterlogging reduce oxygen supply to the root system,
- High concentration of calcium reduces the uptake of potassium by the plant. High concentration of magnesium induces calcium deficiency. High sulphate content reduces uptake of calcium and increase sodium uptake leading to sodium toxicity,
- Soil salinity affects cell division, cell elongation and protein synthesis,
- Excessive soluble salt concentration in the root zone restrict plant water uptake leading to physiological drought,
- High content of boron, chloride, sodium, sulphate and bicarbonate in irrigation water cause toxicity to the plant leading to poor growth and yield,
- Bacteria associated with conversion of unavailable forms of nutrients toavailable forms are sensitive to high salt concentration, and
- Soils with high exchangeable sodium become hard on drying and difficult to work for obtaining good tilth.

### 9.8.1 MAJOR CONSTITUENTS OF IRRIGATION WATER

All minor elements are not found in every source of irrigation water. They appear sporadically, singly or in groups, in different water sources. Bromine, fluorine and iodine may be found when chloride is present. Most fresh water contains less than one ppm bromine and 0.2 ppm iodine. Irrigation water may also contain Li, Ry, Cs, Sr, Ba, Ra, etc. Due to the minute quantities of these elements, they mostly have no influence on water quality. Other minor elements which may appear are selenium, arsenium, antomony, bismuth group and different metals as Cu, Co, Ni, Zn, Ti, Vn, Cr and Mo.

A micro element found in most irrigation water at low concentration is boron. The highest boron concentration in the world in flowing water (1.3 to 1.9 ppm) occurs in Japan. Boron is essential for plant growth. However, it is harmful only slightly in excess of optimum and particularly to citrus and walnut and is toxic to most crops at concentrations only six or eight times the optimum. Selenium, molybdenum and fluorine found in some soils and irrigation waters are absorbed by plants without apparent damage. However, they are harmful to animal life at a relatively low critical level. Animals may obtain these elements from water or from feeds and forage.

### 9.8.2 WATER ANALYSIS

The analysis of irrigation water must include the total salt content, pH, anion and cation composition and content of minor elements of particular importance to the crop involved (USSL 1954).

**Total salt content** : This is determined either by measuring the specific electrical conductivity (expressed in micromhos $cm^{-1}$ at 25°C) or by weight, the total salt content is then expressed in mg $l^{-1}$ or ppm.

**Cations :** The cations generally determined are $Ca^{++}$, $Mg^{++}$, $Na^{+}$ and $K^{+}$ and occasionally also $Cu^{++}$, $Fe^{++}$ and $Li^{+}$. $Ca^{++}$ plus $Mg^{++}$ can be determined by titration with different complex organic compounds (EDTA or CDTA), using Eriochrome Black T or calmagite indicator, then $Ca^{++}$ alone is determined by using ammonium perpurate indicator. $Mg^{++}$ is obtained by subtraction. These two elements may also be determined by using the flame photometer method. $Na^{+}$ may be obtained by the uranyl zinc acetate method, by using the flame photometer method or by the sodium electrode method. $K^{+}$ is determined by the sodium cobalt nitrite method or with the flame photometer. $Cu^{++}$ is obtained by the dithiazone carbonate method, $Fe^{++}$ by the ferrous sulphate zinc soda method; and $Li^{+}$ by ion exchange or flame spectro-photometer methods.

**Anions :** The anions generally determined are $CO_3^{-}$, $HCO_3^{-}$, $SO_4^{--}$, $Cl^{-}$ and $NO_3^{-}$ and in special cases $F^{-}$. $CO_3^{-}$ and $HCO_3^{-}$ are obtained by titration with $H_2SO_4$ or HCl, using phenolphthalein and methyl orange indictors, $SO_4^{-}$ by precipitation as barium sulphate or by cation exchange, $Cl^{-}$ by silver nitrate or mercurium nitrate titration or potentiometrically using a silver chloride electrode. For micro-determination of chloride, a calorimetric method using diphenyl carbazone is recommended. $NO_3^{-}$ is determined by the sulphanilic acid alpha naphthylamine method, and $F^{-}$ by the acid-zirconium alizarin method or spectro-photometrically after prior separation of fluorine by anion exchange.

**Minor elements :** Boron and silica in the irrigation water are also determined occasionally. Boron is usually obtained by the mannitol titration method by carine calorimetric procedure or by electro-titrimetric. Silica is determined by the molybdenum-blue procedure.

### 9.8.3 SUITABILITY OF WATER FOR IRRIGATION

Five factors must be taken into consideration before the suitability for irrigation of a water of a given total salt content is determined. The interaction of these five factors constitutes a water classification.

- Chemical water composition,
- Crop to be irrigated,
- Soils to be irrigated,
- Climate, and
- Management of irrigation and drainage.

**Chemical composition of irrigation water :** Quality of the water is determined by the total salt content and by its ionic composition. Total salt content (expressed in g $l^{-1}$, me $l^{-1}$, ppm) or the electrical conductivity may give a general indication of the water's quality. Also important is the determination of the main cations and anions usually expressed in me $l^{-1}$, as several ion ratios influence water suitability. Under certain conditions, the presence of micro-elements must be taken into account.

**Crops :** Crop is the first and most important factor to be considered. Evaluation of a water must be based on the tolerance of a specific crop or crops in the rotation to the total salt content or specific ion concentration. Tolerance of a crop to salinity is that concentration of the soil solution that will give a certain reduction in yield as compared to non-saline conditions. In the USA, the 50 per cent yield decrement is taken as the tolerance limit for field and forage crops. In Holland and in Algeria, the 25 and 20 per cent decrement is taken. The American 50 per cent decrement is taken for the salinity measured at the bottom of the root zone, whereas in Holland the salinity of the top layer is taken as the criterion. Some crops are specifically sensitive to chloride and sodium ion concentration. The most important of these crops are the deciduous trees, citrus and avocado.

**Soils :** Behaviour of a soil in contact with saline water depends on the initial physical properties and salt content. Clay content of the soil affects the ion adsorption capacity which in turn influences the hydrophysical properties. Furthermore, presence of an impermeable layer or of a groundwater table affects the salt distribution in the profile.

Initial chemical composition of the soil influences the exchange processes during the water-soil contact. Application of saline water to a salt free soil will salinise the soil, but the use of this same quality of water may reduce the salinity of a saline soil if drainage is adequate. As infiltration and percolation of water may differ greatly for different soils, different degrees of salinisation may be expected with the same quantity and quality of irrigation water.

**Climate :** **Evapotranspiration and rainfall** are the two main climatic elements to be considered when evaluating suitability of water for irrigation. Water depth to be applied to a crop during a season depends on the evapotranspiration which, therefore, affects the irrigation regime and consequently the seasonal dynamics of salts in the soil profile. Amount and distribution of rainfall is the second factor of the climate to be paid attention. A given amount of rainfall distributed uniformly over the growing season will dilute the soil solution, but will not bring about a leaching of the profile as the same amount of rain falling during a shorter time would do.

**Management of irrigation and drainage :** **Irrigation method** influences the salt accumulation in the soil and in the plant. Application of amounts of water less than the consumptive use will result in accumulation of salts in the main root zone. Increasing the application will leach the salts out of the root zone and an equilibrium can be reached between the salt contents of the water and of the soil. Lack of proper drainage in an area with a high water table will result in capillary rise of groundwater, increasing the soil salinity. Relatively saline water applied in furrows on a permeable soil will have no harmful effect on plant growth, while the same quality of water applied by sprinkling might cause reduced yields.

### 9.8.4 EVALUATION OF IRRIGATION WATER

The hazards to be considered when evaluating suitability of water for irrigation purposes are salinity, sodium, carbonate alkalisation, chloride and boron.

In the USSAR the evaluation is made as follows:

| *Salt content* ($g\ l^{-1}$) | *Evaluation* |
|---|---|
| 0.2 to 0.5 | Water of the best quality. |
| 1 to 2 | Water causing salinity and alkalinity hazard. |
| 3 to 7 | Water could be used for irrigation only with leaching and perfect drainage. |

## SALINITY HAZARD

The standard set up by the US Salinity Laboratory are shown in Table 9.33.

**TABLE 9.33 US SALINITY LABORATORY'S GROUPING OF IRRIGATION WATER**

| *Classification of water* | | *Electrical conductivity in mhos/cm at 25°C (EC)* | *Salt concentration in $g\ l^{-1}$ (approximate)* |
|---|---|---|---|
| C1 | *Low salinity water* can be used for irrigation with most crops on most soils, with little likelihood that a salinity problem will develop. Some leaching is required, but this occurs under normal irrigation practices, except in soils of extremely low permeability. | $0 < EC \leq 250$ ($0.25\ dS\ m^{-1}$) | < 0.2 |
| C2 | *Medium salinity water* can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most instances without special practices for salinity control. | $250 < EC \leq 750$ ($0.25 - 0.75\ dS\ m^{-1}$) | 0.2 - 0.5 |
| C3 | *High salinity water* cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected. | $750 < EC \leq 2250$ ($0.75 - 2.5\ dS\ m^{-1}$) | 0.5 - 1.5 |
| C4 | *Very high salinity water* is not suitable for irrigation under ordinary conditions but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching and very salt tolerant crops should be selected. | $2250 < EC \leq 5000$ ($2.5 - 5.0\ dS\ m^{-1}$) | 1.5 - 3.0 |

## SODIUM HAZARD

Due to its effect on the soil and plant, sodium is considered to be one of the major factors governing water quality. Several methods were proposed for expressing the sodium hazard. Previously, water quality was defined on the basis of its sodium percentage alone. The soluble sodium percentage (SSP) may be calculated by the formula:

$$SSP = \frac{\text{soluble sodium concentration (me } l^{-1})}{\text{total soluble cation concentration (me } l^{-1})} \times 100$$

Sodium hazard of the irrigation water can also be evaluated through the sodium adsorption ratio (SAR), defined as the ratio for soil extracts and irrigation waters used to express.

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

The ionic concentration are expressed in me $l^{-1}$. As indicated in Fig. 8.10, an empirical relation has been drawn up between SAR and ESP.

The classification of water according to the SAR is also related to the water's electrical conductivity (and therefore its salt concentration). Four groups are indicated: low, medium, high and very high electrical conductivity. For EC = 100 micromhos $cm^{-1}$, the dividing points are at the SAR values, 6, 10 and 18 (Fig 9.14).

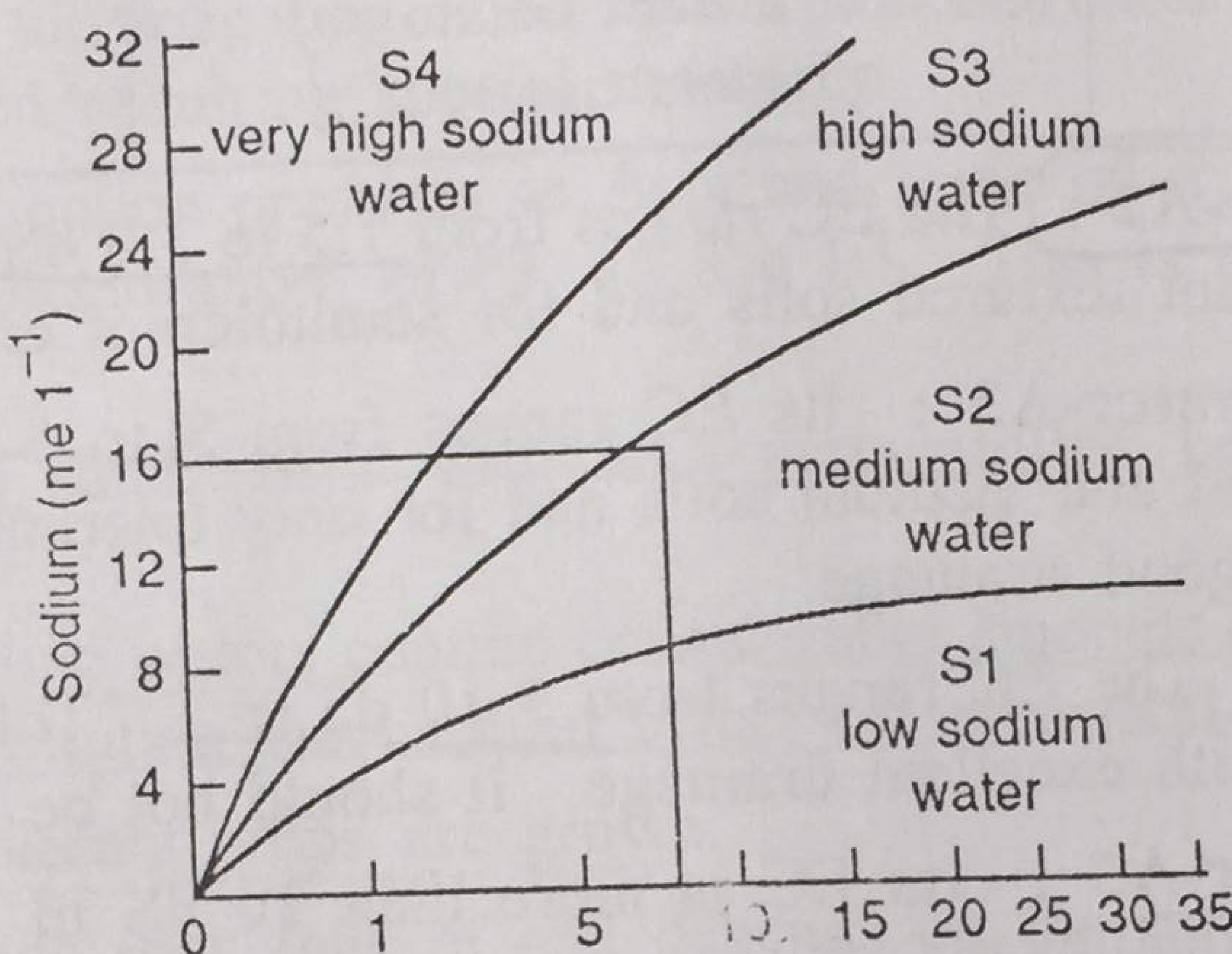


Fig 9.14 Sodium diagram (FAO/UNESCO 1973).

## BICARBONATE HAZARD

The bicarbonate anion is important in irrigation water as regards precipitation of calcium and to a lesser degree, also of magnesium in the soil. This brings about a change in the SSP in the irrigation water and, therefore, an increase of the sodium hazard. The term residual sodium carbonate (RSC) was introduced.

$$RSC\ (me\ l^{-1}) = (CO_3^{--} + HCO_3^{-}) - (Ca^{++} + Mg^{++})$$

## BORON HAZARD

Relative tolerance of crops to boron is given in Table 9.34 Boron content shown at the top of a column may be expected to cause some injury to the more tolerant crops and serious injury to the more sensitive crops of the group. The crops at the top of the column semitolerant would be injured more severely. Probably all the crops listed in the first column could be irrigated with water containing 2.0 ppm boron without serious injury.

**Central Soil Salinity Research Institute** (CSSRI), Karnal classified irrigation water based on EC, adjusted SAR and boron concentration.

**Based on EC,** irrigation water is classified into 5 classes from A1 to A5.

**Normal water-A1 :** Its EC is less than 1.5 dS $m^{-1}$. Water can be used on most soils for most crops.

TABLE 9.34 LIMITS OF BORON IN IRRIGATION WATER FOR CROPS OF DIFFERENT DEGREES OF BORON TOLERANCE

| *Tolerant (2-4 ppm)* | *Semitolerant (1-2 ppm)* | *Sensitive (0.3 - 1.0 ppm)* |
|---|---|---|
| Date palm | Sunflower | Walnut |
| Sugar beet | Potato | Plum |
| Alfalfa | Cotton | Pear |
| Onion | Tomato | Apple |
| Turnip | Radish | Grape |
| Cabbage | Barley | Cherry |
| Lettuce | Wheat | Peach |
| Carrot | Pumpkin | Orange |
| | Sweet potato | Grape |
| | Lima bean | Lemon |

**Low salinity water-A2 :** The EC ranges from 1.5 to 3.0 dS $m^{-1}$. It can be used for most crops on light and medium textured soils and for semitolerant crops on heavy soils.

**Medium salinity water-A3 :** Its EC ranges from 3 to 5 dS $m^{-1}$. It can be used for semitolerant crops on light and medium soils and for only tolerant crops on heavy soils. Soils should have reasonably good drainage.

**Saline water-A4 :** The EC ranges from 5-10 dS $m^{-1}$. Tolerant crops can be grown on light and medium soils with excellent drainage. It should not be used on heavy textured soils.

**High salinity water-A5 :** Its EC is more than 10 dS $m^{-1}$. Water is not suitable for irrigation under normal conditions.

**Based on adjusted SAR,** irrigation water is classified into 5 classes from B1 to B5.

**Normal water-B1 :** The adjusted SAR is less than 10. It can be used on all soils for all the crops.

**Low sodium water-B2 :** Its adjusted SAR ranges from 10 to 20. It can be used on light and medium soils and heavy soils with good drainage. Use of this water leads to problems on black and alluvial soils with clay content more than 30 per cent.

**Medium sodium water-B3 :** The adjusted SAR ranges from 20 to 30. Light and medium textured soils can be irrigated with this water. Not suitable for heavy soils. High calcium carbonate content can minimise the problem.

**Sodium water-B4 :** Its adjusted SAR ranges from 30 to 40. Semitolerant crops can be grown on light soils upto SAR 30 and tolerant crops upto 40. Creates several problems on heavy soils.

**High sodium water-B5 :** Adjusted SAR more than 40 is not ideal for irrigation.

**Based on boron content,** irrigation water is grouped into 5 classes from C1 to C5.

**Normal water-C1 :** Water with less than 3 ppm boron is ideal for tolerant and semitolerant crops on all soils.

**Low boron water-C2 :** Boron content ranges from 3 to 4 ppm. All crops on heavy and medium soils can be irrigated with this water upto 3 ppm boron. Water upto 4 ppm boron can be used on light soils for tolerant crops.

**Medium boron water-C3 :** Boron content ranges from 4 to 5 ppm. It can be used for most crops on heavy soils. Water upto 4 ppm boron can be used on medium textured soils for semitolerant crops and upto 5 ppm for tolerant crops. It creates problems on light soils.

**Boron water-C4 :** Its boron content ranges from 5 to 10 ppm. Semitolerant and tolerant crops on heavy soils can be irrigated with this water. It leads to problems on light soils. Calcium carbonate content may alleviate toxic effect of boron.

**High boron water-C5 :** Water with more than 10 ppm boron is not suitable for irrigation under ordinary conditions.

### 9.8.5 MANAGING WITH POOR QUALITY WATER

Soluble salt concentration of most river water is less than 1.0 g $l^{-1}$ and usually between 0.2 and 0.4 g $l^{-1}$. Under conditions of good drainage this water can be used for practically all crops continuously. If the irrigation water has a concentration of about 0.5 to 1.0 g $l^{-1}$, it may contain sodium, then requiring special measures.

On the other hand irrigation practices in Asia and some other countries shows the use of irrigation water with concentration of 3 to 8 g $l^{-1}$. This is only possible as a result of the following conditions.

- Water is used to sandy soils with high permeability, perfect leaching and natural drainage,
- Many of these saline waters contain considerable amounts of gypsum which precipitate in the soil, thus limiting the harmful effect of saline soil solution, and
- Relatively salt tolerant crops are grown.

Increase of salts in the root zone of soil depends on the salt content of irrigation water, number of irrigations and salts raised by capillarity from ground water. On the other hand, increased use of irrigation water decrease the salt content if the leaching water is removed by drainage. General process of salt accumulation in irrigated soils by saline water is shown in Fig 9.15. Every watering without leaching increases the salinity of irrigated soil. If 1,000 $m^3$ of water containing 1 g $l^{-1}$ salt is put in to the field, 1.000 kg $ha^{-1}$ of salts will be added to the soil, with a concentration of 10 g $l^{-1}$, 10,000 kg $ha^{-1}$ will be added. Consequently, after 20 waterings, the total salinity of irrigated soil will increase upto 20 or 200 t $ha^{-1}$ and the average salinity of soil will increase to 0.4 to 1.0 per cent (FAO/UNESCO 1973). Proper management practices can mitigate the adverse effect of poor quality irrigation water, when it is inevitable to use such water for irrigating the crops. For efficient use of poor quality water, 9.11.6 may be referred.

**Gypsum application :** Use of gypsum creates favourable Ca : Na or Ca : Mg ratio in irrigation water. Improvement in Ca : Na ratio or SAR is due to increase in calcium ion concentration, decreasing the Mg : Ca ratio and precipitating excessive carbonate ions. Gypsum can be applied to the soil if it is alkaline. If the soil is good and water is of poor quality, gypsum should be applied to water.

**Growing tolerant crops :** Tolerant crops and varieties appear to be the most practicable way of crop production with poor quality irrigation water. Barley, sugar beet and rape are tolerant to salinity. Wheat, rice, sunflower, sorghum, etc are semi tolerant. Wheat, oats, sugarcane, cotton, etc are semi-tolerant to sodic soils.

**Methods of sowing :** Seed germination and crop establishment decrease with increasing salinity. In furrow irrigation, salts accumulate in the center of the ridge between furrows and

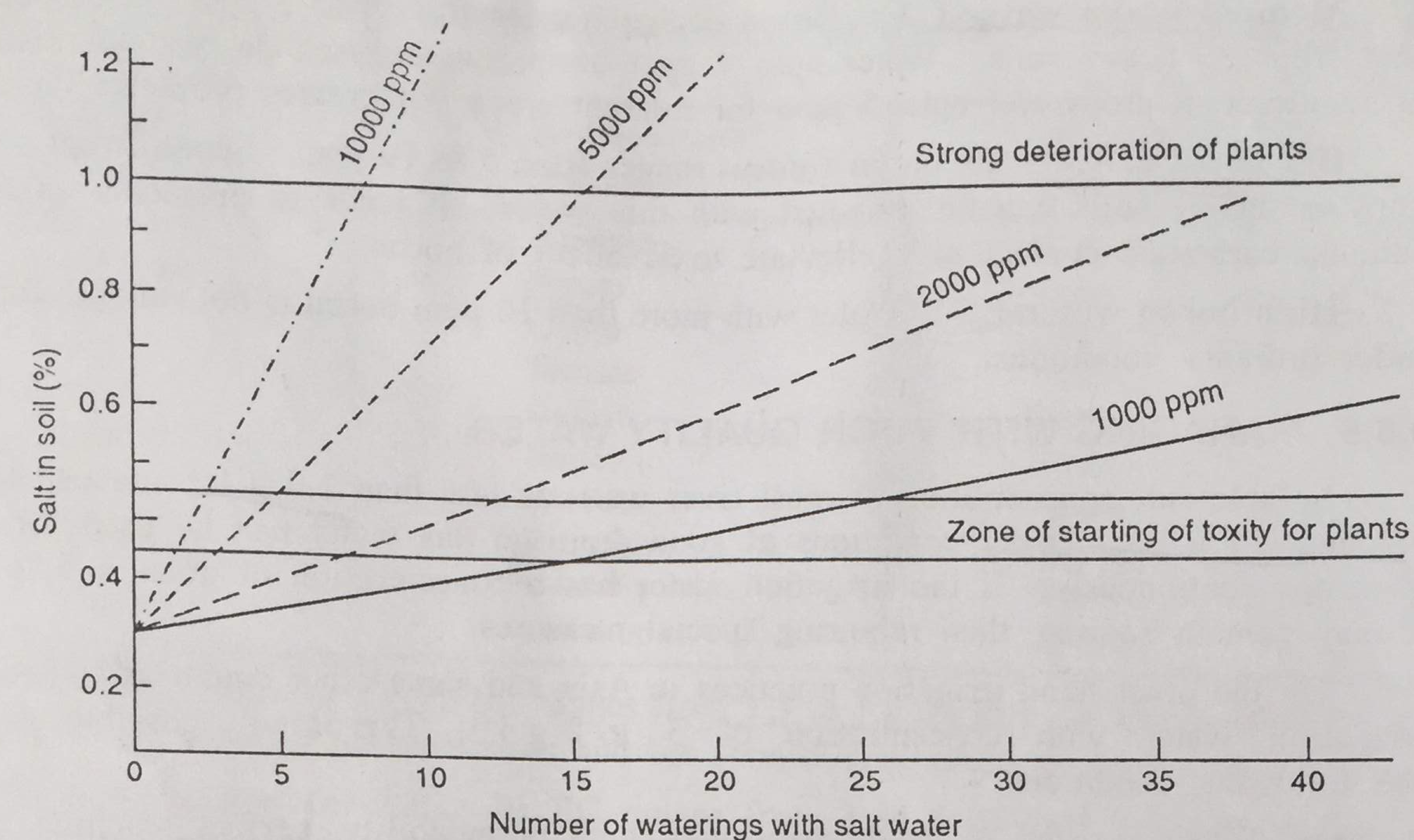


**Fig 9.15** Soil salinisation due to saline water irrigation (FAO/UNESCO 1973).

on the top of the ridge. If the seed is placed on the side of the ridge or at the bottom of the ridge, the problem of salinity can be minimised. Sloping beds either on one side or on both the sides with seeds just above the water line ensure optimum crop stand. Transplanting leads to better crop establishment in fingermillet and pearlmillet. Closer spacing is better than wide spacing.

**Fertiliser use**: Optimum rate and balanced fertiliser use, especially major nutrients, can make the crop to withstand the poor quality of irrigation water considerably. Acidity and basicity of fertilisers should be considered while choosing the fertiliser material.

**Irrigation and drainage**: Poor quality irrigation water application with sprinklers leads to leaf burn. Drip system appears to be better than sprinkler method for such water. Frequent irrigations appears to minimise the adverse effects of poor quality water. Provision of adequate drainage improves the crop growth and yield.

**Soil management**: Any practice aimed at improving soil structure and infiltration reduces salinity hazard. Mulching with organic residues minimise evaporation leading to reduced salt concentration in the effective root zone. Inclusion of lowland rice in crop rotation reduces salinity hazard considerably.

## 9.9 DRAINAGE

The word drainage has multiple meanings. It is used in general sense to denote water outflow from a section of land. More specifically, it can serve to describe the artificial removal of excess water from cropped fields. Drainage aims at maintenance of soil moisture within the range required for optimum crop growth. In humid areas, drainage is needed for the removal of excess rain water. In arid and semiarid areas, drainage is a necessary complement of irrigation. Drainage removes excess water to ensure a favourable salt balance in the soil and a water table optimum for crop growth and development.

cities/towns having supply of water and water consumption of 200 l capita$^{-1}$ day$^{-1}$, the annual estimate of sewage comes to 2.19 M ha-m. If 50 per cent of the sewage water is retrievable, about 1.0 M ha-m will be available for possible recharge.

### 9.11.3 WATER CONSERVATION

Water conservation in irrigated agriculture can be achieved by reducing conveyance losses, efficient canal water management, efficient on-farm water management, rainfall conservation, reducing water demand and reuse of wastewater.

**Reducing conveyance losses :** Conveyance losses account for 40 to 50 per cent of the water delivered into a canal and almost half of these losses occur in field channels. While seepage is a net loss of water in areas with poor quality groundwater, it can be retrieved for irrigation in areas having good quality ground water. This water my be withdrawn by farmers at their conveniences and when needed. In order to reduce these losses, lining of canal network should be done with due importance to economic considerations. However, watercourses, which contribute very little ground water, should be lined for efficient conveyance and distribution of water.

**Canal water management :** Canal irrigation systems were scientifically planned. The water allowance, the capacity factors and the irrigation intensities were designed keeping in view the availability of irrigation water and irrigation demands of the cropping systems prevalent at that time. Since then, a major shift has taken place in cropping pattern, ground water development, cropping intensity, irrigation intensity etc. This has resulted in a mismatch between demand and supply during the crop period. This gap can be minimised by revising the water allowance and the capacity factor, keeping in view the irrigation requirements of existing crops, quality and availability of ground water (Khepar et al 1990).

**On-farm water management :** On-farm water management including improving the conveyance efficiency of irrigation channels/canal water courses (already discussed), application efficiency, scheduling of irrigation and precision land leveling increases the water use efficiency and crop production.

**Reducing application losses :** Application efficiency of surface methods of irrigation is only 30 to 50 per cent as compared to attainable level of 60 to 80 per cent due to the fact that these methods are not designed to match the stream size, soil type, slope etc. By growing row crops such as cotton, sugarcane, soybean, sunflower etc under ridge and furrow irrigation, about 30 to 40 per cent of irrigation water can be saved as compared to border irrigation. Around 30 to 40 per cent of irrigation water can be saved by adopting sprinkler or drip irrigation in water scarcity areas, having conditions conducive to their application.

**Irrigation scheduling :** Irrigation scheduling in relation to water availability is an important aspect of on-farm water management for optimising production. Where irrigation water supplies are plentiful, irrigation must be repeated before a yield or quality reducing water stress develops in the field. In the case of rice, intermittent submergence, which includes rotational and occasional submergence, can save irrigation water up to 50 per cent depending on soil type.

Irrigation scheduling for optimising production with limited water supplies is a bigger challenge. The first step for irrigation scheduling with limited water is to assess the relative sensitivity of different growth periods to water stress. Irrigation with limited water should be so managed that the inevitable stress synchronises with the least sensitive stages.

**Precision land leveling :** Precision land leveling/grading is essential for efficient utilisation, uniform distribution of irrigation water, quick removal of excess rain water in humid and subhumid areas and conservation of rain water in arid and semiarid areas. In surface method of irrigation, land leveling is essential for high application efficiency. The topography index (TI), the difference between average cut and average fill (cm) should be zero for ideally graded field.

### 9.11.4 CONJUNCTIVE USE OF SURFACE AND GROUND WATER

**Conjunctive use management** of multisource/multiquality waters can be defined as the management of multiple water resources in a coordinated operation such that the total water yield of the system over the period of time exceeds the sum of water yields of the individual components of the system resulting from uncoordinated operation (Gupta et al 2000). As a result of conjunctive use of surface and ground water resources, it is possible to have optimum utilisation of water resources as ground water could act and function as a storage reservoir, regularisation agent and conveyance medium. The separate use of surface and groundwater in itself may not always constitute a conjunctive use. Conjunctive use is planned and practiced with the following objectives :

- Mitigating the effect of storage in canal water surplus, often subject to steep variations in river flow during different periods in the year,
- Increasing the dependability of existing water supplies,
- Alleviating the problems of high water table and salinity resulting from introduction of canal irrigation,
- Facilitating the use of high salinity ground water, which cannot otherwise be used without appropriate dilution, and
- Storing water in ground water basins closer to the users to ensure water supply in case of interruption of surface water supply.

### 9.11.5 SAFE USE OF SALINE AND ALKALI WATER

Management practices for optimum crop production with **saline irrigation** must aim at preventing build up of salinity, sodicity and toxic ions in the root zone to levels that limit the productivity of soils, control salt balance in salt-water system as well as minimise the damage effects of salinity on crop growth.

#### 9.11.5.1 CROP MANAGEMENT

**Selection of crops :** Crops differ considerably in their ability to tolerate salinity/ sodicity. The values of salinity for obtaining specific crop yields were computed by Manhas and Gupta (1990) as per response equation: RY = 100 – S (ECe – ECt), where, ECt is **threshold salinity.** Oilseed crops requiring less water can tolerate higher levels of ECiw, where as most pulse crops are very sensitive to salts. Thus, for successful irrigation with saline water in a specific zone, selection of crops should be such as to suit salinity of water, as it may not be possible to change the quality of irrigation water. High water requiring crops like sugarcane and rice should be avoided with brackish waters as these aggravate the salinity problems.

**Growth stages :** During initial stages, plant roots are limited to surface few cm, where most salts concentrate on the evaporating surface. Hence, in most crops, germination and early seedling establishment are the most critical stages requiring strategies for minimising salinity in the root zone. Other critical periods are phase changes from vegetative to reproductive (heading and flowering). Otherwise, tolerance to salinity increases with the age.

**Crop varieties :** There is wide variation in inherent salt tolerance of crop varieties. Usually there is a negative correlation between tolerance and their yield potential. Varieties like Damodar in rice and Kharchia in wheat are tolerant to salinity but have low yield potential. Varieties showing stable yield under saline conditions should be preferred.

**Planting procedure :** Failure to achieve satisfactory germination and thus the required plant population is the major factor limiting crop production with saline waters. Wherever possible, a heavy presowing irrigation with nonsaline water should be given to leach out the salts out of seeding zone. The other technique that seems safe to establish crop is to give a postsowing irrigation. Sowing on northeastern side of ridges or at the side of furrows can also reduce salt accumulation near the seed zone. Relatively higher plant population than the normal appears to be ideal to compensate for poor tillering with saline water.

### 9.11.5.2 IRRIGATION MANAGEMWNT

**Leaching requirement for salt balance :** Areas where highly saline waters are used are usually monocropped. Only salt tolerant crops are grown during winter. In such areas, rainfall received during monsoon is utilised for meeting the **leaching requirements** and thus maintaining the **salt balance.** A leaching strategy that can work well is to apply saline water for boosting the antecedent moisture contents and reducing salinity levels before the onset of monsoon. The refill of the surface soil with water just before the onset of monsoon will enhance salt leaching during *kharif* rains.

In addition to amount and frequency of rains, salt leaching with rains depends on soil texture. Removal of 80 per cent of the salts accumulated during the period preceding monsoon would require 1.85, 0.95 and 0.76 cm of rain water $cm^{-1}$ soil depth in fine, medium and coarse textured soils, respectively. Clay soils irrigated with high SAR – saline/sodic waters become vulnerable to dispersion and movement upon leaching especially with low electrolytic rain water. Thus, salts are held back and such soils have been shown to require almost double the quantity of water (0.7 to 1.2 cm $cm^{-1}$ soil) compared with the structurally stable saline soils (0.4 to 0.5 cm $cm^{-1}$ soil). Therefore, addition of gypsum to prevent surface sealing and enhancing infiltration of rain water is advocated for such situations (Gupta *et al* 2000).

**Irrigation interval :** Under saline conditions, irrigation should meet both crop water requirements and leaching requirements to maintain a favourable salt balance. Therefore, it is usually opined that irrigation in saline soils should be more frequent because it reduces the cumulative water deficits between the irrigation cycles., However, such option is still controversial as small irrigation intervals subsequently induce water uptake from shallow soil layers, increases unproductive evaporative losses from soil surface and with saline irrigations increase the salt load of soils. Experimental results also indicate no advantage of more frequent irrigations than those recommended for normal soils. Depth of applied water should be simultaneously reduced if higher benefits from small intervals of irrigations are to be accrued (Minhas *et al* 1998). As the infiltration rate controls the application depths, it is difficult to apply less than 25 mm water with surface methods and too frequent irrigations may infect aggravate the aeration problem. A shift to sprinkler or drip irrigation is desired for applying small quantities of water at frequent intervals.

**Water table management :** The salts are usually leached down and waterlogging problems alleviated through subsurface drainage for minimising the salinity hazards under high water table conditions. Safer disposal of drainage water is a major problem. Substantial contributions to seasonal water requirements can come from shallow water table. Crops such as wheat require only one irrigation under shallow water table conditions around 1.0 m. Hence, shallow water table is desirable even if the water is saline. Such a practice simultaneously leads to salt accumulation in rooting zone, which levels out following leaching with monsoon rains.

## 9.11.6 INTEGRATED USE OF POOR AND GOOD QUALITY WATERS

When canal water supplies are unassured or in short supply, farmers are forced to use saline ground or drainage waters to meet the crop water needs. Waters from these two sources can be applied either separately or mixed. Mixing of waters to acceptable quality for crops also results in improving the stream size and thus the uniformity in irrigation especially for the surface method on sandy soils. Allocation of two waters, if available on demand, can be done either to different fields, seasons or crop growth stages such that higher salinity water is not applied to sensitive crops or growth stages.

### 9.11.6.1 PREIRRIGATION

**Presowing irrigation** is usually given to facilitate tillage, seedbed preparation and recharge the root zone with water for germination and stand establishment. In saline soils, it also aids in leaching of soluble salts below the seeding zone to mimimise the salt injury to germinating seed and subsequent stand establishment. Crops like sorghum and mustard can tolerate higher salinity once the nonsaline water is substituted for presowing irrigation to leach out the salts of seeding zone.

In saline areas prone to waterlogging, *kharif* crops fail to establish owing to high salinity and temperatures if sown before onset of monsoon and due to excess water after the establishment of monsoon. Crops like sorghum can be successfully raised if they could be established in premonsoon season after leaching the accumulated salts even with saline water (ECe > ECiw) followed by small additions of nonsaline waters as the crop can withstand the excess water from later rains.

### 9.11.6.2 CYCLIC USE OF MULTIQUALITY WATERS

The strategy involves substitution of canal water for saline water at most sensitive growth stages/crops grown in sequence and use of saline water at other stages such that the effects of resultant soil salinity build up can be minimised. In general, crop yields will be high with cyclic use of canal and saline waters when the cropping intensities are less than 200 per cent. Yields can be maintained close to those obtained with good water by delayed substitution of saline water (after two initial irrigations with good quality water). Alternate irrigations with good and saline waters can also be followed if circumstances demand. Irrigation with saline water should not be at critical stages, especially at seeding phase.

Results of experiments are in favour of cyclic use over mixing. The advantage due to cyclic use followed the order; (2C : 1S) > (1C : 1S) > 1C : 2S); canal : saline water use. Multi salinity waters should be used cyclically and the use of canal water at early stages and of saline water should be delayed to later stages (Gupta et al 2000).

### 9.11.7 WATER QUALITY GUISELINES FOR IRRIGATION

It is evident from the above that apart from its composition, determination of suitability of specific water requires specification of conditions (soil, climate, crop etc) of its use and the irrigation and other management practices followed. Therefore, the following broad guidelines, for assessing suitability of irrigation waters, have been suggested from time to time for average use conditions :

- Growing relatively tolerant crops and varieties.
- Sowing on northeastern side of ridges.
- Using around 20 per cent higher seed rate and quick postsowing irrigation (within 2-3 days) for better germination
- Use of gypsum for saline water having SAR > 20 and/or Mg : CA > 3 and rich in silica.
- Fallow during rainy season when SAR > 20 and higher saline waters are used in low rainfall areas.
- Additional phosphorus application when Cl : $SO_4$ ratio is > 2.
- Canal water preferably at early growth stages including presowing irrigation for conjunctive use with saline water.
- When ECiw < ECe (0-45 cm soil depth at harvest of rabi crops), saline water irrigation just before onset of monsoon.

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