SDSU Extension

gardens

APRIL 2020

SOUTH DAKOTA STATE UNIVERSITY®
AGRONOMY, HORTICULTURE & PLANT SCIENCE DEPARTMENT

# Salt/Salinity Tolerance of Common Horticulture Crops in South Dakota

Review and Revision: Rhoda Burrows | Professor & SDSU Extension Horticulture Specialist Lance Stott | former SDSU Lecturer

Original Publication: 1999 - John Bischoff, Assistant Professor, Water Resources Research Institute and Hal Werner, Professor, Extension irrigation specialist, SDSU Agricultural Engineering Department

## Salt Tolerance

Plants vary tremendously in their ability to tolerate salt in water. Their growth can be restricted by the stress of "pulling" water away from the salt. Soil salt level–salinity–is one of several stresses that limit plant growth.

The salinity stress referred to in this fact sheet is the osmotic stress that limits the availability of water stored in the soil. This publication does not consider the permeability problem caused by sodium that reduces the amount of water put into storage. The publication Salinity & Sodicity Management from Montana State University available at http://landresources.montana.edu/swm/documents/SW%202%20updated.pdf gives more information about salinity and sodicity problems.

Separating salinity stress from other plant stresses is difficult because increased salts alter the ionic chemical balance in plants and affect water availability to plants. Therefore, salinity problems may contribute to other classes of plant stress. A relationship of relative crop yield compared to the salinity of the soil solution (electrical conductivity of a soil solution extract) is shown in Figure 1. The classes are sensitive (S), moderately sensitive (MS), moderately tolerant (MT), tolerant (T), and unsuitable for crops.

To use Figure 1, read the value of the soil salinity on the horizontal axis and follow it upward until it intersects the upper right hand line of the SALT TOLERANCE CLASS for the crop that interests you. Then draw a line horizontally left to intersect the vertical "relative yield" axis and read the number. This would be the percent yield obtainable with these salt conditions.

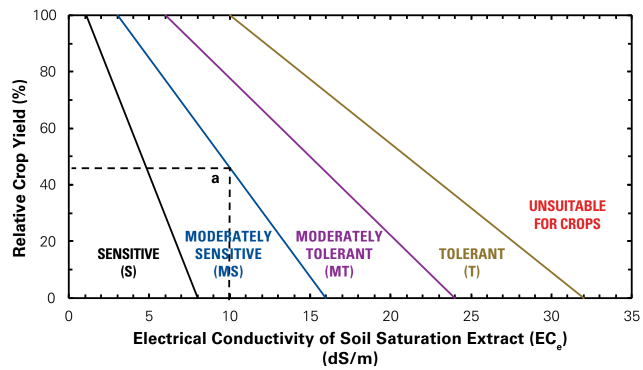


**Figure 1. Relative crop yield compared to the salinity of the soil solution. Maas and Hoffman, 1977.**

If your line does not intersect an upper right line for the salt tolerance class, there would be no yield reduction from salinity. An example of a moderately sensitive crop and a soil salinity value of 10.0 dS/m is shown as a line in Figure 1. Follow up from 10.0 (on the horizontal axis) to the MS line, then draw a line to the left to get about a 45% relative crop yield. This yield would be the highest you could expect for a moderately sensitive crop at this level of soil salinity.

## Factors Influencing Salt Tolerance

**Growth stage** of the plant is very important when considering salt tolerances. Many plants are extremely sensitive to soil salt during germination or in the early seedling stage. Most experiments have evaluated salt tolerance only on more mature plants.

**Varieties and rootstocks** of specific crops can be quite varied in their sensitivity to salt. Some varieties are known to be much more tolerant than others within the same species. Be sure to read the footnotes in the tables regarding salt tolerances and variety differences.

**The nutrition level** of the plant (i.e. soil fertility) when under stress may affect the plant's ability to tolerate salt. Fertilization usually improves a plant's ability to tolerate salt. Fertilization beyond the plant's needs, however, does very little to improve salt tolerance. Excessive fertilizer, which can be salt-based, may even contribute to soil salinity.

Climatic environment has much to do with a plant's ability to tolerate salt. High temperature, low humidity, and high winds increase evaporation and make the plant more susceptible to salinity; this can cause symptoms similar to water stress. High air humidity benefits salt-sensitive crops more than salt-tolerant plants. High temperatures decrease any plant's ability to tolerate salt.

Chemical ion toxicity affects plants that may be sensitive to specific individual ions. It may affect the plant either by climatic air or water carriers or through the soil. Boron is an ion that some plants are very sensitive to in low concentrations. In South Dakota, aquifers with high concentrations of sodium also may have high concentrations of boron.

Nutritional imbalance as a result of too much salt may occur if some salts are in a certain proportion. For example, high concentrations of calcium sulfate ($CaSO_4$) may tie up some phosphates into complexes that are too insoluble for plants to use.

## Soil and Water Analyses

Salinity (soil salt levels) can be determined by testing. Sample soil depths by layers to help determine if and where salts occur in the greatest concentrations. Shallow soil depths can be sampled with a spade during moist conditions. Deeper root zones can be sampled easier with a hand soil probe or truckmounted soil sampler. Collect composite samples throughout the field to get a representative average of the field. If there are trouble spots that you suspect are caused by salt conditions, sample them separately from the rest of the field. South Dakota State University no longer analyzes soil samples commercially. For a list of labs that can analyze your soil sample visit: https://extension.sdstate.edu/soil-testing-labs.

To determine how much salt is in the water you are using to irrigate, collect a representative pint of water and have it analyzed for types and levels of salts. The testing facility will also usually interpret the compatibility of the water with general soils. South Dakota State University no longer analyzes these types of water samples. For a list of facilities that can analyze your irrigation water visit: https://www.sdstate.edu/water-sample-analysis-and-interpretation.

## Tolerant Horticultural Crops

The salinity level of the soil at which reductions in yield could be expected for individual South Dakota horticultural crops, assuming all other stresses are not limiting, is shown in Tables 1 and 2. This is the "threshold" salinity level or the 0% yield reduction column. The columns indicate the expected yield reduction if the salinity is at a given level over the growing season.

The MAXIMUM column signifies the soil salinity level of the root zone – rooting depth associated with various crops – at which little to no yield can be expected. The root zone for alfalfa may be up to 10-12 feet deep, whereas for strawberries it may be only 10-18 inches deep and for blackberry only 2-3 feet deep. Implement reclamation procedures before this level of salinity is approached, or grow more salt tolerant crops.

### Garden and Vegetable Crops

Asparagus, beets, and squash are the most salt-tolerant, common vegetable crops grown in South Dakota. Onions, peas, carrots, okra, and strawberries are among the most salt-sensitive garden crops in this state (see Table 1).

Consider strawberries as an example. If the average soil salinity of the root zone for the entire growing season for strawberries was around 2.7 dS/m, potential yield would probably be reduced about 50% (50% yield reduction column for strawberries is 2.5 dS/m). If your production goal for strawberries was 10 quarts per unit, salt levels of 2.7 dS/m would reduce the maximum yield to only 5 quarts per unit (100% - 50%) x 10 = 5. The root zone for strawberries may be only 1 to 1.5 feet deep.

### Woody Fruits

Most woody fruits are very sensitive to salts in soils. These include apples, apricots, blackberries, boysenberries, cherries, currants, gooseberries, oranges, peaches, pears, plums, and raspberries (see Table 2).

Consider grapes as an example. If the average soil salinity of the root zone for the entire growing season for grapes was around 4.2 dS/m, you could anticipate

Table 1. Salt tolerance for garden crops. Salinity level (dS/m) for different yield loss columns of various crops.

| CROP | ROOTING DEPTH[@] | RATING[b] | Yield decrease to be expected for certain crops due to soil salinity[a] | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0% $EC_E$[1] | 10% $EC_E$ | 25% $EC_E$ | 50% $EC_E$ | MAXIMUM $EC_E$ |
| Asparagus | D | T | 4.1 | 9.1 | 16.6 | 29.1 | 54.1 |
| Bean | M | S | 1 | 1.5 | 2.3 | 3.7 | 6.3 |
| Beet, red | M | MT | 4 | 5.1 | 6.8 | 9.6 | 15.1 |
| Broccoli | S | MS | 2.8 | 3.9 | 5.5 | 8.3 | 13.7 |
| Brussel sprouts | S | MS* | --- | --- | --- | --- | --- |
| Cabbage | S | MS | 1.8 | 2.9 | 4.4 | 7 | 12.1 |
| Carrot | S | S | 1 | 1.7 | 2.8 | 4.6 | --- |
| Cauliflower | S | MS* | --- | --- | --- | --- | --- |
| Celery | S | MS | 1.8 | 3.4 | 5.9 | 9.9 | 17.9 |
| Corn, sweet | D | MS | 1.7 | 2.6 | 3.8 | 5.9 | 10 |
| Cucumber | S-M | MS | 2.5 | 3.3 | 4.4 | 6.4 | 10.2 |
| Eggplant | M | MS* | --- | --- | --- | --- | --- |
| Lettuce | D | MS | 1.3 | 2.1 | 3.2 | 5.2 | 9 |
| Muskmelon | S-M | MS* | --- | --- | --- | --- | --- |
| Onion | S | S | 1.2 | 1.8 | 2.8 | 4.3 | 7.5 |
| Parsnip | D | S* | --- | --- | --- | --- | --- |
| Pea | M | S* | 0.9 | 2 | 3.7 | 6.5 | --- |
| Pepper | M | MS | 1.5 | 2.3 | 3.3 | 5.1 | 8.7 |
| Potato | S-M | MS | 1.7 | 2.6 | 3.8 | 5.9 | 10 |
| Pumpkin | D | MS* | 3.9 | 4.9 | 5.9 | 7.9 | --- |
| Radish | S | MS | 1.2 | 2 | 3.2 | 5.1 | 8.9 |
| Spinach | S-M | MS | 4 | 3.3 | 5.3 | 8.6 | 15.2 |
| Squash, scallop | D | MT | 3.2 | 3.8 | 4.8 | 6.3 | 9.5 |
| Squash, zucchini | M | MT | 4.7 | 5.8 | 7.4 | 10 | 15.3 |
| Strawberry | S | S | 1 | 1.3 | 1.8 | 2.5 | 4.1 |
| Sweet potato | D | MS | 1.5 | 2.4 | 3.8 | 6 | 10.6 |
| Tomato | D | MS | 2.5 | 3.5 | 5 | 7.5 | 12.6 |
| Turnip | M | MS | 0.9 | 2 | 3.7 | 6.5 | 12 |
| Watermelon | D | MS* | 2 | 2.5 | 3.5 | 4.5 | --- |

[a]These data are applicable when rootstocks are used that do not accumulate Na+ or Cl- rapidly or when these ions do not predominate in the soil.
[b]Ratings are S=sensitive; MS=moderately sensitive; MT=moderately tolerant; T=tolerant to salts.
*Ratings with an * are estimates.
[1]$EC_E$ = Electrical conductivity of the saturation extract of the average root zone (dS/m).

approximately a 25% reduction in potential yield (25% yield reduction column for grapes is 4.2). If your yield goal for blackberries was 500 lbs per unit, salt levels of 4.2 would reduce the maximum yield to only 375 lbs per unit (100% - 25%) x 500 lbs = 375. For grapes, the root zone may be about 2 to 3 feet deep.

## Salt Management

### Drainage

Salt problems often occur in soils of poor internal drainage. Low permeability soil layers may restrict the flow of water "out the bottom" "causing deep percolation to be" then continue with "much slower than evapotranspiration (ET)" removes water "out the top." In such situations, choose crops that can tolerate the salt without much yield reduction, and/or, install artificial drains to allow the removal of leaching water and salts from soils. If artificial drain lines are installed, do it according to county, district, or state drainage laws to prevent passing a salt/water problem from one landowner to another.

Table 2. Salt tolerance for woody fruit crops in South Dakota. Salinity level (dS/m) for different yield loss columns of various crops.

| CROP | RATING[b] | Yield decrease to be expected for certain crops due to soil salinity[a] | | | | |
|---|---|---|---|---|---|---|
| | | 0% $EC_E$[1] | 10% $EC_E$ | 25% $EC_E$ | 50% $EC_E$ | MAXIMUM $EC_E$ |
| Apple | S | --- | --- | --- | --- | --- |
| Apricot[C] | S | 1.6 | 2.0 | 2.65 | 3.7 | 5.8 |
| Blackberry | S | 1.5 | 1.95 | 2.65 | 3.8 | 6.05 |
| Boysenberry | S | 1.5 | 1.95 | 2.65 | 3.8 | 6.05 |
| Cherry, sweet | S* | --- | --- | --- | --- | --- |
| Cherry, sand | S* | --- | --- | --- | --- | --- |
| Currant | S* | --- | --- | --- | --- | --- |
| Gooseberry | S* | --- | --- | --- | --- | --- |
| Grape[C] | MS | 1.5 | 2.55 | 4.1 | 6.7 | 12.0 |
| Peach | S | 1.7 | 2.2 | 2.9 | 4.1 | 6.5 |
| Pear | S* | --- | --- | --- | --- | --- |
| Plum; Prune[C] | MS | 1.5 | 2.1 | 2.9 | 4.3 | 7.1 |
| Raspberry | S | --- | --- | --- | --- | --- |

[a]These data are applicable when rootstocks are used that do not accumulate Na+ or Cl- rapidly or when these ions do not predominate in the soil.
[b]Ratings are S=sensitive; MS=moderately sensitive; MT=moderately tolerant; T=tolerant to salts.
[c]Tolerance is based on growth rather than yield.
*Ratings with an * are estimates.
[1]$EC_E$ = Electrical conductivity of the saturation extract of the average root zone (micromhos/cm).

**Fruit Crops –** For smaller plantings, management techniques such as mulching, using rainwater instead of groundwater, improved drainage, etc. may be feasible. If drainage is an issue on larger planting, drain tile may help decrease salt accumulation.

## Irrigation

Irrigation management can be used to decrease the level of salts in the root zone of the crop. As the salinity of irrigation waters increases and seasonal rainfalls decrease, the window of management for salt becomes smaller and smaller.

Permeability of the subsurface soils is important for salt management. There is a battle between moving sufficient salts downward beyond the root zone and evapotranspiration bringing water and salts back toward the surface.

The balance of salts can be better monitored if the soil moisture content and dynamics are known, since the salts move with the water during the irrigation season. Tensiometers or moisture blocks can be used to monitor the soil water at different depths. Refer to Extension publications FS 876, Irrigation Management: Measuring Soil Moisture, and FS 899, Irrigation Management: Using Electrical Resistance Blocks to Measure Soil Moisture, for more information on monitoring soil water. These publications are still accessible and contain relevant information. However, newer soil moisture measurement technologies are also now available. For more information, refer to the Soil Water Sensors section of Irrigating Corn in South Dakota available here: https://extension.sdstate.edu/igrow-corn-best-management-practices-corn-production

When you manage irrigation water to reduce salts, remember that other mobile chemicals can move with the water as well. The publication Reducing Nitrate Losses from Drained Lands available at https://extension.sdstate.edu/igrow-corn-best-management-practices-corn-production gives more information on the movement on nitrate and the potential effects on ground and surface water.

Salts in the root zone are dynamic and tend to change with climatic changes. For well-drained soils, wetter periods tend to push salts further down in the root zone, whereas drier periods bring salts nearer to the surface. In poorly drained soils, wetter periods tend to bring the water table closer to the surface. In wetter conditions, the salt moves with the water (upward) as the water table rises. Poorly drained soils usually have higher salinity in wetter periods than during a drought. If these facts are known, selection of crops for planting according to their salt tolerance can be used according to climate cycles and soil drainage classification. Obviously, planning for annual crops is easier than for perennials.

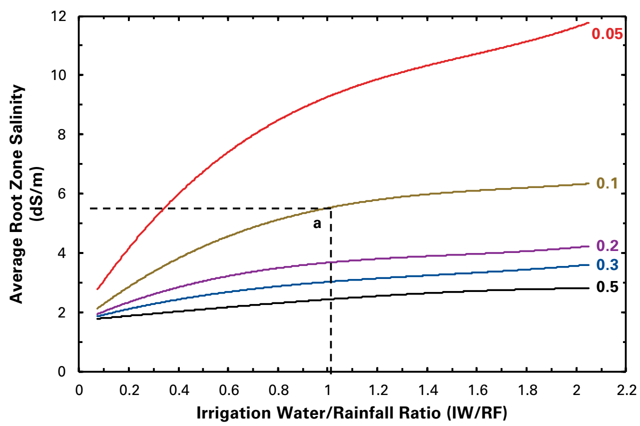


Figure 2. Relationships of average root zone salinity, leaching, irrigation, and rain depths.

When irrigation water is used to replenish soil profiles during the growing season, salt is associated with both surface and ground water. Even water considered good for irrigation in South Dakota of 0.81 dS/m electrical conductivity (600 milligrams per liter) would have 0.82 tons of salt for every acre-foot of water. The publication Irrigation Water Quality Standards and Salinity Management Strategies from Texas A&M provides more information on irrigation water quality and its potential effects on soil salt levels. http://soiltesting.tamu.edu/publications/B-1667.pdf

Irrigation adds salt to the soil with the water. The more soluble salts such as sodium sulfate ($NaSO_4$), sodium bicarbonate ($NaHCO_3$), sodium chloride (NaCl), and magnesium chloride ($MgCl_2$) cause more plant stress than less soluble salts such as calcium sulfate ($CaSO_4$), magnesium sulfate ($MgSO_4$), and calcium carbonate ($CaCO_3$). Therefore, some of these salts may need to be managed more carefully to prevent buildup in the root zone.

If natural leaching does not occur, leaching with irrigation water on better drained soils can help move salts downward where they do less harm to growing crops. The "leaching fraction" is defined as the amount of water pushed past the bottom of the root zone DIVIDED by the total amount of water received into the soil. Unfortunately, the leaching fraction is very much controlled by the existing subsurface soils and geology, and finer-textured soils are more difficult to manage for salts because the response time to leaching may span years compared to only weeks for outwash (coarse subsoils).

Figure 2 shows the relationship between average root zone salinity, irrigation water and rainfall depths, and leaching fractions for a given irrigation water salinity of 2.0 dS/m (high salinity). The average root zone salinity is based on a weighted crop water use of 40% from the top quarter of the root Zone, 30% from the second quarter, 20% from the third quarter, and 10% from the bottom quarter of the root zone (Figure 3).

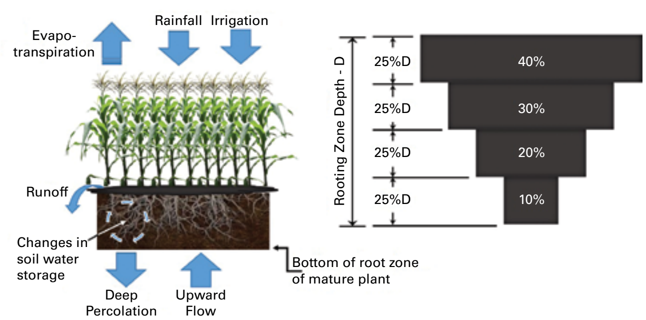


Figure 3. Soil water balance (after Cassel, 1984) and the percent water extraction from a basic crop root zone (after Pair, 1975).

As the amount of irrigation water applied increases and rainfall decreases, the irrigation water/rainfall ratio (IW/RF) increases, the average root zone salinity increases, and a higher leaching fraction is needed to keep salt levels below a certain point. Figure 2 is based on receiving 15 inches of frost-free rainfall during the growing season. This is a good average number to use for central South Dakota (see Figure 4).

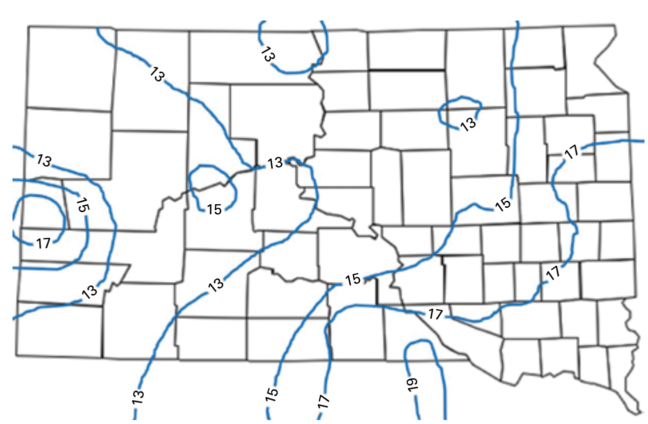

Figure 4. Average normal growing season precipitation in South Dakota (April 1 - October 31) for 1961-1990.

There is considerable salt removal over the winter months as vapor moves up through the soil profile during freezing conditions leaving the salts behind. The quantitative extent of the "distilling" depends upon the water table position, the soil moisture content, depth of snow cover, and soil texture. Not much is known about the salt exclusion phenomenon in areas where soils become frozen, but something happens that keeps salts below the root zone in many cases of long-time irrigated fields in South Dakota. Rarely do soils reach the higher levels of salts as shown in Figure 2 when irrigated with high-salinity waters. Salt precipitation and freezing conditions appear to account for much of the reduction in salinity levels in soil root zones in South Dakota.

Frost-free rainfall varies considerably over the state from a high of 20 inches in the southeast to 10-14 inches in the northwest. Therefore, the IW/RF ratio for the southeast for corn may be around 0.6, whereas, it may be closer to 2.0 in the northwest. Two reasons account for a tremendous difference in potential soil salinity:

- More water applied contributes to more salt.
- There is less dilution of soil water from salt-free rainwater.

Average leaching fractions under non-irrigated conditions will vary from almost zero in northwest South Dakota with tight subsoils, to as much as 0.4 in eastern South Dakota under high spring rains over shallow soils with coarse subsoils and deep water tables.

Figure 5 shows the relationships of average root zone salinity and irrigation water salinity for various salt levels in irrigation water for a constant leaching fraction of 0.10. Figure 5 is based on 15 inches of frost-free rainfall. The rainfall amount is constant in the IW/RF ratio. This graph shows how low salt waters are much easier to manage than higher salt waters. For example, an irrigation water of 0.25 dS/m changes very little in average root zone salinity over the ranges of IW/RF, whereas, a water of EC of 3.0 dS/m varies by more than three times (from 3.0 to about 10.0) over the IW/RF range.

Use Figures 2 and 5 to consider example "a" for a garden or fruit crop in central South Dakota. Assume that the crop needs 30 inches of water to obtain expected yields. If 15 inches of IW with a water quality of 2.0 dS/m is applied and 15 inches of frostfree rainfall is received, the IW/RF ratio is 1.0. If a leaching fraction of 0.10 is assumed (for every 10 inches of water applied at the surface, 1 inch is lost below the root zone), then an average soil salinity of approximately 5.4 dS/m is approached for steady state conditions. This assumes no precipitation of salts, no uptake by plants, no horizontal flow, or no "distilling" of the water by freezing conditions during winter months.

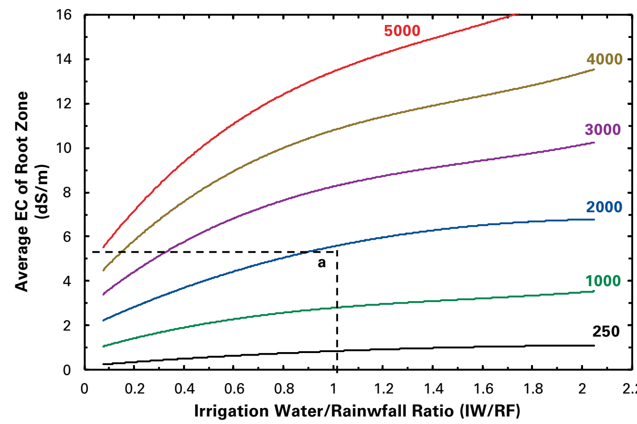


**Figure 5. Relationships of average root zone and irrigation water salinity and irrigation and rainfall depths.**

As can be seen from Figure 2, for high salinity waters (2.0 dS/m, or 2.0 tons of salt per acre-foot of water), the average soil salinity can go up rapidly even when 10% of the water is lost out the bottom of the root zone.

Generally, the average soil salinity values in Figure 2 can be considered as a maximum for South Dakota. Many of the salts in the state are gypsum ($CaSO_4$) that precipitate out at lower concentrations, and upward movement of water as the soil freezes in the winter "distills" some of the soil water.

## Reducing Salt Stress in the Garden

Here are some ways to reduce salt stress for crops grown in the garden:

**Test soil and water salinity to determine the extent of the problem.**

**Mulch around the base of garden crops.** Liberally apply any mulch to minimize evaporative water loss. Many times garden crop root zones are shallow and lose water more quickly than deep rooted crops.

**Develop a lower-salt water source, if available.** If more than one water source is nearby, determine the salt load in each, and determine which will least affect the plants you are growing in your garden. If you have limited supplies of each source, you may want to use the better quality water on sensitive crops (i.e. strawberries) and poorer quality water on tolerant crops (i.e. asparagus).

**Harvest rainwater from nearby buildings.** Rainwater harvested from a 25′ x 40′ building will provide about one additional inch of salt-free water to the garden for a 10′ by 20′ area. (Assuming 75% collection efficiency, and a 0.25″ rainfall). You can either use a storage tank to collect the water and pump the water to the garden, or, if the slope permits, route water from the down spouts to gravity irrigate your garden. If the latter method is used, good residue and/or mulch used on the garden surface will help reduce erosion. Harvested rainwater should not be used on crops where it will contact the harvestable portion of the crop, as it may carry contaminants from bird droppings, etc. that could carry food-borne illnesses.

**Install subsurface artificial drainage.** This allows for removal of excess salts and water in the soil. This would help in reclaiming a severe salinity problem, and, also, would be helpful in maintaining salinity problems below a certain level. A place to gravity drain the water and salts is essential when this measure is used, and should be planned in advance of the installation of the drains.

**Water frequently but thoroughly.** If soils are kept moist, salinity stress will be reduced, because salts concentrate as the water is used by evapotranspiration and the salts are left behind. Watering too often in shallow amounts will contribute to growth of diseases and fungus on plants, and concentrate root growth near the surface.

**Water the garden early in the day** to reduce salinity stress during the heat of the day, and to reduce the likelihood of disease development during the night.

**If reclamation of soil salinity cannot be accomplished by the above procedures, consider moving the garden** area to a new location that has much less salt in the soil.

**If the surface and internal soil drainage is good (medium to coarse textured soils), try overwatering to leach salts below the root zone.** This is best done in the autumn of the year after most plants have been harvested. Care must be taken to reduce erosion on sloped gardens.