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Salinity in rice fields

In the past few weeks I have received several calls from growers facing salinity problems. Several fields in the west side of the valley have this problem, so let's review some of the concepts about salinity and information specific to California rice.

Salinity refers to the presence of soluble salts (in the soil or irrigation water) in amounts that can negatively impact productivity of a crop. The most common soluble salts encountered are ions and include calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), bicarbonate (HCO_3^{-}), chloride (Cl^{-}), nitrate (NO_3^{-}), sulfate ($SO^{2-}{}_4$) and borate ($BO^{2-}{}_3$).

The salinity of a solution is determined by measuring its conductivity to an electrical current. As the content of salts in the solution increases, its electrical conductivity (EC) increases. Usually, the EC of the soil solution or irrigation water is expressed in decisiemens per meter (dS/m); however, you will probably find several other units of EC measurement, for example milimhos per centimeter (mmhos/cm). Decisiemens/m and mmhos/cm are equivalent. Some EC meters measure total dissolved solids and use parts per million (ppm) as units. To convert ppm to dS/m, divide by 640. Some EC meters use other units and the conversions can get quite confusing. Table 1 shows some of these units and their respective equivalence to dS/m (for more information, go to the May 2009 issue of Rice Briefs, available at http://cecolusa.ucdavis.edu/rice/Newsletter/).

Table 1. Electrical conductivity units and their equivalence to dS/m

Unit	Symbol	Equivalence to dS/m
microSiemens per centimeter	µS/cm	1 dS/m = 1000 µS/cm
milliSiemens per centimeter	mS/cm	1 dS/m = 1 mS/cm
millimho per centimeter	mmho/cm or m Ω^{-1}/cm or m ℧/cm	1 dS/m = 1 mmho/cm
parts per million	ppm	1 dS/m = 640 ppm
milligrams per liter	mg/l	1 dS/m = 640 mg/l

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Fields become affected by salinity through the accumulation of soluble salts through time. Some soils are naturally high in salts as a result of the weathering of primary minerals present in the soil. However, in the majority of rice soils, the most common source of salt is irrigation water. All irrigation water contains salts, but the concentration will vary depending on the origin of the water and the kinds of soils the water has been in contact with. When more salts are added to the field than what can be "washed", salts will accumulate. Experiments in California rice during the mid 1990s showed that soil salinity significantly increased as the salinity of the flood water increased.

In some areas of the Sacramento valley, drainage water and well water can have high concentrations of soluble salts. Typically, river water has a low concentration of salts; however, as water passes through fields and evaporates, salts concentrate and the EC increases. This is why users of drain water face salinity problems. Additionally, holding water to comply with pesticide degradation requirements or to reduce costs can intensify the problem. When holding water, evaporation concentrates salts, especially in bottom basins. Groundwater can have high concentration of salts, and can affect fields directly through its usage or by its movement to nearby fields when river or canal levels are high.

A soil is considered saline when the soil solution (the water solution near the root zone) has an EC higher than 4 dS/m. In the case of rice, because the field is flooded during most of the crop's development, one can measure the salinity level of the field by measuring the EC of the flood water. In rice, negative impacts on plant development and yield have been observed when the seasonal average salinity of the floodwater is greater than 1.9 dS/m. The most susceptible stages of rice to salinity are seedling emergence and from 3 leaf to panicle initiation. Salinity reduces seedling survival and growth, tiller production and growth, root growth and yield; delays maturity; and can induce panicle sterility (Fig. 1).

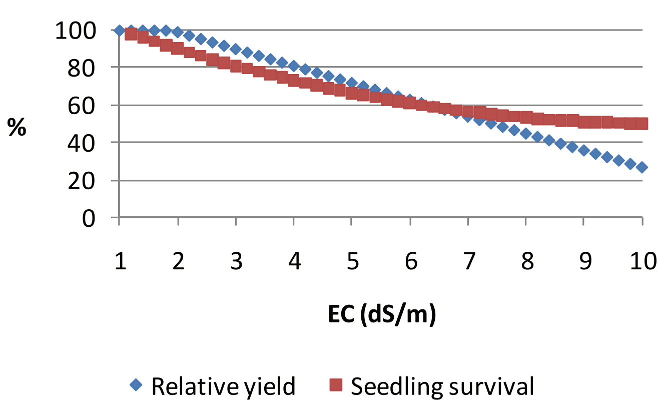

Figure 1. Yield and seedling survival reduction with increasing flood water salinity. From Zeng and Shannon (2000a) and Grattan et al. (2002).

Experiments conducted under greenhouse conditions showed that increasing the seeding rate does not compensate for yield reductions due to salinity, even though higher seeding rates increase plant stand and panicle density (Figs. 2 and 3). Actually, salinity sensitivity increased with increasing seeding density, reducing seed weight and increasing floret sterility. Other studies have shown that under moderate flood water salinity levels (EC<1.9 dS/m), shallow water

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(4 inches) produces better seedling establishment and grain yields than deep water (more than 4 inches).

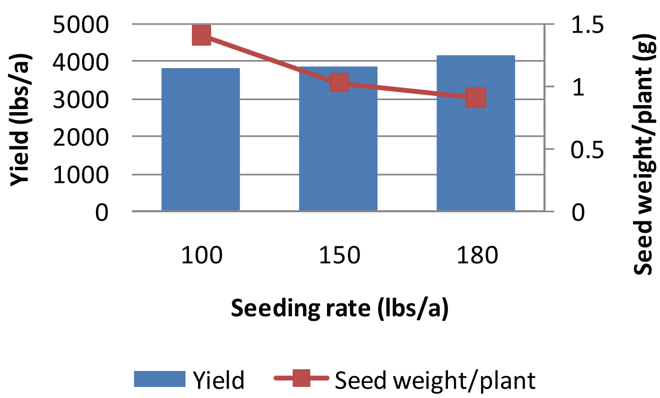

Fig. 2. Effect of seeding rate on yield and seed weight per plant in rice grown with saline flood water (average EC=3.8 dS/m). From Zeng and Shannon (2000b).

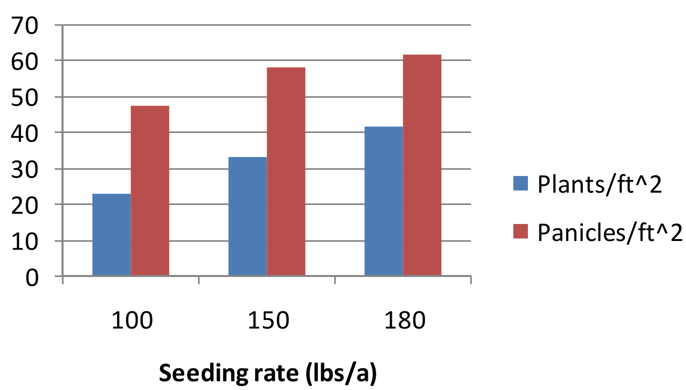

Fig. 3. Effect of seeding rate on number of plants and panicles per square foot in rice grown with saline flood water (average EC=3.8 dS/m). From Zeng and Shannon (2000b).

How do salts affect the rice plant? One mechanism involves a change of the osmotic pressure in the root zone. The high concentration of salts near the roots prevents the plant from absorbing water. This is remarkable, considering that plants are surrounded by water. The result is that plants need to use more energy to take water, consuming energy that could be otherwise used in photosynthesis and respiration processes. Nutrient uptake can also be affected, producing nutrient imbalances. For example, excessive Na^+ reduces K^+ uptake. In the case of seedlings, accumulation of Cl^- seems to be the cause of injury.

Visual symptoms of salinity injury include chlorotic leaf tips that turn white with time. Older leaves are affected first, but as salinity becomes more severe the growing leaf can show symptoms. In the field, symptoms are usually observed in a patchy pattern.

The most common way of dealing with saline soils in most crops is to "flush" the salts from the root zone using a water source of low EC. In rice, this is an impractical way to reduce salt accumulation due to the low permeability of rice soils. Instead, salinity can be managed by diluting the salt content in the flood water by adding low salinity irrigation water. This requires constant monitoring, especially during the rice stages most susceptible to salt injury. Using an EC meter, you can determine the salinity of the flood water in your basins and of the irrigation water

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sources available. Continued water flow will not let salts accumulate in the field. Water holding requirements may render continued flow difficult. If using saline water, avoid using herbicides that require long term water holding periods. During hold periods, minimize salinity build up, especially in lower basins, by recirculating the water.

References:

Grattan, S., L. Zeng, M. Shannon and S. Roberts. 2002. Rice is more sensitive to salinity that previously thought. California Agriculture 56: 189-195.

Zeng, L. and M. Shannon. 2000a. Salinity effects on seedling growth and yield components of rice. Crop Science 40: 996-1003.

Zeng, L. and M. Shannon. 2000b. Effects of salinity on grain yield and yield components of rice at different seeding densities. Agronomy Journal 92: 418-423.

Difficult start for 2011

The 2011 season started with warm, dry weather. However, the good conditions didn't last long. After a period of normal temperatures in early May, cool wet weather set in. The low temperatures affected many fields that were planted during early and mid May, reducing nutrient uptake, stunting and delaying plant growth.

Many factors affect rice seedling growth, but temperature is probably one of the most important ones. A way to measure the effect of temperature on plant growth and development is to calculate the amount of heat units, or degree days (DD), that accumulate over a

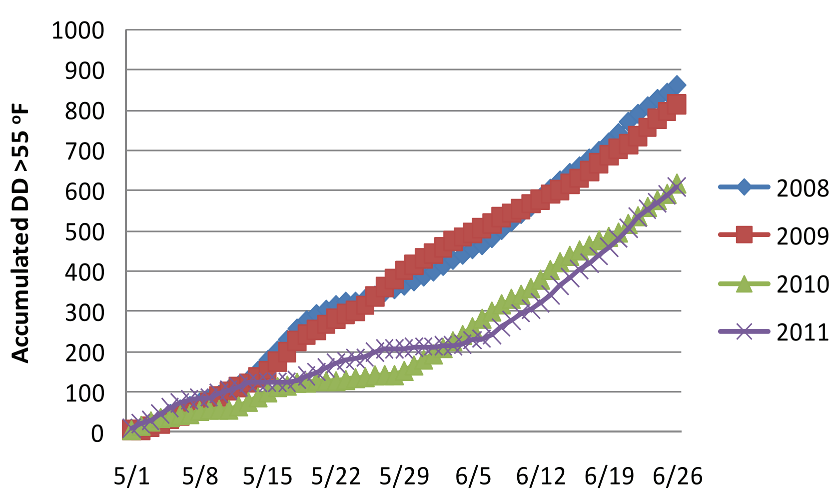

Figure 4. Degree day accumulation over 55° F from May 1st. Temperature data from CIMIS station # 32, Colusa.

Difficult start for 2011

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developmental threshold. In the case of California rice, 55° F is the threshold temperature below which growth and development are greatly reduced.

Figure 4 shows DD accumulated at Colusa from May 1^{st} to June 26 for 2008-2011. In 2011, during early May, DD accumulation was similar to 2008 and 2009, and higher than 2010, a cool year. By mid May, DD accumulation slowed down substantially and became more like 2010. By the end of May, DD accumulation was almost nil and lower than 2010 (note that the line for 2011 is almost flat during this period, when temperatures dropped drastically). During June, DD accumulation picked up and reached 2010 levels; however, you can see that we are way below 2008 and 2009 DD accumulation levels.

Expect to see delayed growth in your fields. In a normal year, fields planted during early May should be in full tillering by mid June; however, because of the lack of heat units, these fields are only beginning to tiller at best. Like last year, schedule your practices according to the stage of growth of the crop, not the calendar days from planting. Evaluate weed and rice plant growth before spraying herbicides. Topdresssing should be done when plants reach panicle initiation (PI). This year, if you go by the calendar days from planting, you might be topdressing too early, before PI. Early topdress nitrogen applications are not as effective as applications at PI because plants have not developed their root system fully. Also, evaluate the nitrogen need of the crop and topdress accordingly.

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