MEMO

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From: John Dickey/PlanTierra

To: File

Date: July 25, 2014~~July 24, 2014~~

Subject: **Preliminary discussion of salinity and specific ions in LSJR**

The purpose of this memo is to share some follow up from a conference call on 6/18/2014 with irrigators from the Lower San Joaquin River. Some data were provided during and after the call. I have reviewed them, and looked a bit more at the Hoffman results relative to concerns raised during the call.

Water quality data for the LSJR and for groundwater were shared. I've placed these into tabular and graphical templates I sometimes use to check irrigation water quality against certain criteria. Those are in Table 1 and Figure 1.

Table 1. Sample from 7/11/2014, West Stan ID, A&L Lab 14-192-129, and from 7/9/2014, Patterson ID, Denele Analytical 771900K.

Constituents	WSID GW	WSID River	PID River	Criteria
Chloride (mg/l)	260	236	214	390
Calcium (mg/l)	75	59	83	
Magnesium (mg/l)	71	56	45	
Sodium (mg/L)	133	175	229	115
Sulfate (SO4) (mg/l)	189	178	175	
Boron (B)	**1.25**	0.60	0.71	0.5
Conductivity (dS/m)	1.69	1.67	1.82	1.4
TDS (mg/l)	1082	1,069	1,165	
pH	7.7	8.2	7.9	
SAR	2.6	3.9	5.0	
N (lb/a, 40" water)	-	-	33	
Phosphate (PO4, lb/a)	-	-	-	
Sulfate (lb/a)	1,714	1,614	1,587	

*From Jim Brownell's table for Almonds, minimum precip, 95% maximu relative yield, and 15% LF.

The criteria for sodium and chloride are often used when crops are sprinkled (since these ions can move into tissues from the leaves), and are generic. Almond is noted to be particularly sensitive to chloride, both when sprinkled and in the root zone. One reference (2) indicates levels as low as 245 mg/L in soil saturation extracts can be toxic to stone fruits. This is comparable to concentrations in both irrigation water sources in Table 1, and saturation extract levels will generally be higher than levels in applied water. The thought that chloride may be causing some symptoms currently observed in almonds by WSID is reasonable.

To confirm, we might consider checking:

1. Whether or not the affected trees exhibit leaf tip burn commonly associated with chloride toxicity in almonds, and not necessarily resulting from osmotic (salt) stress. Such burning would support chloride toxicity.
2. Check to see whether impacts due to chloride are more prevalent in sprinkler irrigated orchards, as might be expected.
3. Test leaf tissue, or consult growers about tests that they might have already run.
4. Sample and analyze soil, or assess results that growers provide.

Boron levels in river, and most especially groundwater, are high relative to a standard B threshold. Almonds are sensitive to boron, accumulate a great deal in their roots, and do not reliably express toxicity in leaf tissue concentrations (Ayers & Westcot). Quoting:

Boron toxicity symptoms normally show first on older leaves as a yellowing, spotting, or drying of leaf tissue at the tips and edges. Drying and chlorosis often progress toward the centre between the veins (interveinal) as more and more boron accumulates with time. On seriously affected trees, such as almonds and other tree crops which do not show typical leaf symptoms, a gum or exudate on limbs or trunk is often noticeable.

Most crop toxicity symptoms occur after boron concentrations in leaf blades exceed 250–300 mg/kg (dry weight) but not all sensitive crops accumulate boron in leaf blades. For example, stone fruits (peaches, plums, almonds, etc.), and pome fruits (apples, pears and others) are easily damaged by boron but they do not accumulate sufficient boron in the leaf tissue for leaf analysis to be a reliable diagnostic test. With these crops, boron excess must be confirmed from soil and water analyses, tree symptoms and growth characteristics.

WSID also mentioned concerns about the possible influence of pH on almonds. Figure 2 (from reference 6) shows one aspect of pH interactions with other factors mentioned, namely boron. In the range of observed pH, B is at its maximum levels of sorption to iron oxide. Despite the fact that iron oxide does not predominate in most San Joaquin Valley soils, this is probably a reasonable point of reference. In this case, it is unlikely that pH is having a negative effect by increasing availability of B in the soil solution.

The impact of sodium on infiltration (see discussion below) is significantly exacerbated by elevated pH (e.g., from 7 up to 8; reference 7). This effect is further intensified when soils are subjected to the effects of dilute rainfall. The sodium hazard to soils is therefore higher when irrigating with these (relative to less alkaline) waters, but perhaps less intensively during a drought year such as 2014.

No other likely secondary effects of pH come to mind at this time.

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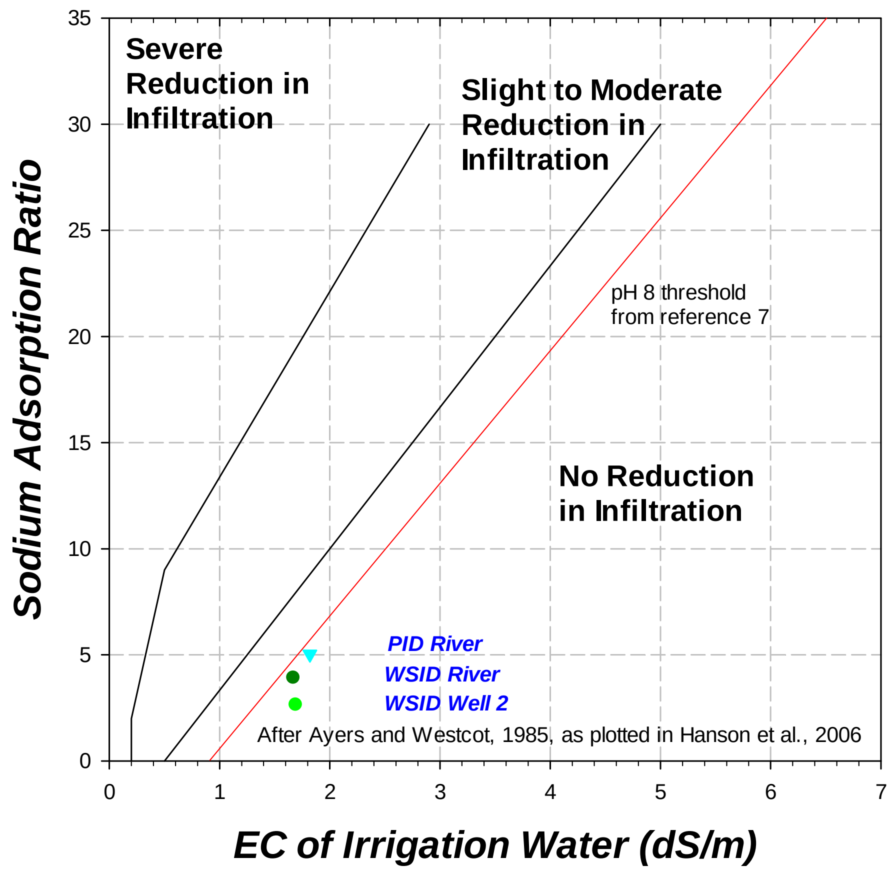

Figure 1. Salinity and SAR data plotted relative to infiltration sensitivity.

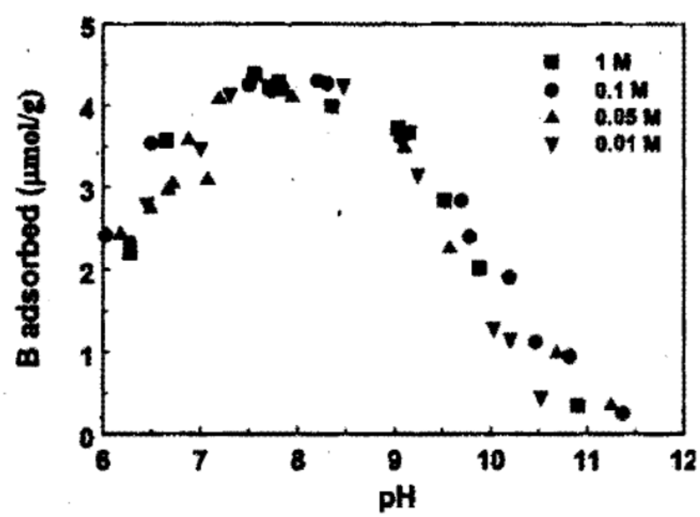

Figure 2. Boron adsorption on the iron oxide, goethite as a function of solution ionic strength and pH. Adapted from Goldberg et al. (1993)

Salinity is also elevated relative to the 1.4 dS/m threshold that Jim Brownell calculated for 95% of maximum yield with the help of the Hoffman model (Table 2). Levels are similar to the 1.7 dS/m level that, in a year with minimum precipitation, should be associated with something closer to 89% of maximum relative yield. An 11% average yield impact is going to be associated with evident signs of stress.

If confirmatory work is desired, some options include:

1. Plant effects of salinity can be measured with a pressure bomb, which assesses osmotic stress directly.
2. Soil salinity measurements in selected areas, made by growers or other interested parties. Conventional soil sampling is one approach. There are remote techniques, such as the EM-38, with which salinity levels (and other soil parameters) can be mapped. These are more costly but provide a much more complete picture of the distribution of salinity in a field.
3. Confirmatory measurements of applied water salinity at irrigator headgate. If thought to vary throughout district, several such measurements may be of use.

Evaluating SAR in the context of these elevated salinity levels suggests no particular risk when using criteria from (3) (Figure 1). However, when more recent work by Suarez (unpublished) is considered, the effect of SAR looks somewhat different. First, at a pH of 8, soils are more sensitive to SAR (see red line on Figure 1 showing that threshold). Second, the influence of precipitation (minmal this year) is to intensify the effect of SAR on infiltration. Third, the "no impact" implication of the labels on Figure 1 represent a more absolute safety than is currently understood relative to long-term effects of SAR. Any increase in SAR represents a likely reduction in infiltration. These reductions pose the greatest inconvenience on heavier (clay dominated) soils. SAR may pose more of a problem in years that are wetter, and when irrigation water salinity is *lower*~~is more likely to become an issue when salinity levels are~~ ~~*lower*~~.

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The remedy most often cited for elevated B, Cl, and salinity is leaching, which requires water. Water being in short supply, this remedy may not be immediately applicable, but rather something to be applied as water supply stress eases. However, even low quality waters, when leached in sufficient quantity, can be helpful. This might be helpful to growers who have access to such supplies, and whose trees are suffering significant stress.

One regulatory issue we have discussed is how best to make adequate leaching water available in a water-short year. One concern is that low salinity standards could be a two edged sword. Any standard would likely prohibit discharge of water above a threshold salinity concentration. On the one hand, such a prohibition may be protective by limiting the influx of saline water. On the other hand, it might constrain wheeling of water volume that could be very useful in a water constrained situation. In particular, low-quality waters useful for leaching to protect crops might become less available. This suggests a need to balance considerations of risks posed by elevated salinity with those posed by highly restricted water supply during drought. Irrigators such as the WSID representatives involved in this discussion may be some of the best resources in considering such questions.

Considering the historic nature of this drought, the unprecedented impact on almonds due to expanded plantings, and the significant regulatory criteria under development, additional diagnostic work might be warranted. In planning such work, consulting with those most knowledgeable about the crop would be indispensible. Resource persons at UC and in the private sector might also be quite interested, given the factors just cited.

Table 2. Irrigation Water EC (dS/m) with 95% Crop Yield (from Jim Brownell June 2014 Hoffman Model results).

	Almond	
LF	Minimum Precipitation	Median Precipitation
10%		
15%	1.4	1.7
20%	>2.0	>2.0

Table 3. Relative Crop Yield (Percent) at 15% Leaching Fraction (from Jim Brownell June 2014 Hoffman Model results).

	Almond	
Irrigation Water EC (µS/cm)	Minimum Precipitation	Median Precipitation
700	100	100
1,000	100	100
1,500	94	99
1,700	89	95

References

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