SALINITY TOLERANCE AND MANAGEMENT FOR ALFALFA

[1]Blake Sanden and Bob Sheesley

ABSTRACT

Vegetative forage production is basically a linear function of plant transpiration. Open stomata with lots of water vapor leaving the plant (transpiration) allows for maximum carbon dioxide uptake to build plant carbohydrates and biomass. Excessive salinity in the crop rootzone creates osmotic stress that reduces root uptake of water and crop transpiration. The added stress then reduces forage yield. At the same time, Class 1 water and land costs have doubled in the last 3 to 4 years; forcing hay growers to more marginal ground. This paper discusses current published salinity tolerance levels for alfalfa, some practical observations from the field and strategies to reclaim salty ground.

Key Words: forage, salinity tolerance, osmotic pressure, reclamation

INTRODUCTION: WATER SUPPLY QUANTITY, QUALITY AND COST

Declining water supply: Allocations of surface water to most California growers have been reduced by 30 to 65% over the last two years, depending on the watershed and irrigation district. The natural drought conditions of reduced precipitation and runoff are made worse by recent legal decisions that impose additional restrictions on the pumping of fresh water from the Sacramento/San Joaquin River Delta. The current forecast for Westside San Joaquin Valley and southern California water allocations from the State Water Project is 15%. Growers face hard choices in selecting rotation crops and finding water for permanent crops. With the downturn in the economy we have also seen hay and grain prices decline. Some hay fields will undoubtedly be retired early (no 4th or 5th year), or left unplanted to maintain permanent crops.

Groundwater-banking schemes, quality/cost concerns: Most Central Valley forage growers overlie groundwater basins of good quality, and depended heavily on pumping during the 2008 season. This trend will continue for 2009, but will certainly become a more expensive proposition as groundwater levels decline. Areas of Kern County have seen a significant decline in quality as pumping water levels have fallen 40 to 80 feet and salinity has increased.

In many areas the pain was lessened by extensive water banking schemes that have been installed in the last 10 years to increase groundwater storage and retrieval capacity. Large water districts, like the Arvin-Edison and Semitropic Water Storage Districts in Kern County, have installed large recharge basins and efficient wells as part of capitalization deals made with the Metropolitan Water District of Southern California. Recharge "banked" water credited to MWD is being exported via the California aqueduct, but the high volume pumping has been pulling in higher salt loads in some area and causing smaller grower wells to lose head and pumping capacity. Without a return to 100% levels of water exported from the Delta we will continue to see groundwater levels decline and water costs increase.

[1]B. Sanden, University of CA Cooperative Extension Kern County, 1031 S. Mt Vernon Ave, Bakersfield, CA 93307. Email: blsanden@ucdavis.edu. B. Sheesley, S&W Seeds, P.O. Box 235, Five Points, CA 93624 Email: swseedco@pacbell.net. **In**: Proceedings, 38th California Alfalfa & Forage Symposium, December 2-4, 2007, San Diego, CA. Published by: UC Cooperative Extension, Agronomy Research and Extension Center, Plant Sciences Department, University of California, Davis, CA 95616. (See http://alfalfa.ucdavis.edu for this and other alfalfa symposium Proceedings.)

For the 2008 season, there was a significant amount of water sold for $200 to more than $300/ac-ft for “surplus” water purchased for Westside SJV permanent crops. This is too high a water cost for profitable forage production. Growers planting field and forage crops to the more than ½ million acres on the Westside with marginally saline soils overlying brackish groundwater must sometimes use this water for forage production. Thus, long-term management strategies for reclamation, leaching and crop rotation are imperative for sustaining production.

FORAGE CROP WATER USE and the IMPACT OF SALINITY

The fuel of forage production is carbon dioxide (CO_2) assimilation through the stomata on the top and bottom of alfalfa leaves. This provides the carbon base for carbohydrate production powered by the engine of photosynthesis and root nutrient uptake. The more open the stomata, the greater the CO_2 uptake and the stomata are most open with maximum crop water use. Stress from dry soil, disease and salinity can all add up to decrease the stomatal or leaf conductance of CO_2. Several studies show that this conductance (and therefore your yield) decreases linearly starting around -10 bars plant water potential down to -25 bars where stomates shut down and growth stops. By comparison, almonds don’t experience serious stress until around -15 bars. The natural internal resistances to water flow in alfalfa are about -4 to -7 bars.

Adding the resistances of water flow in a drying soil and any extra salinity can quickly put you above the -10 bar threshold. Taylor (1952) did some of the first work on soil moisture impacts on yield and found tonnage decreased when the soil water potential (matric or capillary potential) dropped to -1 bar, -100 centibars, or just about the time a tensiometer breaks suction. Figure 1 shows that for every 1 dS/m (or mmho/cm) unit increase in the soil ECe as measured in the lab you add an extra -0.4 bars of osmotic water stress to potential root uptake. **As a rule of thumb, for every 2 point increase in soil EC above 2 dS/m you can expect about a 10% decrease in normal ET and tonnage.**

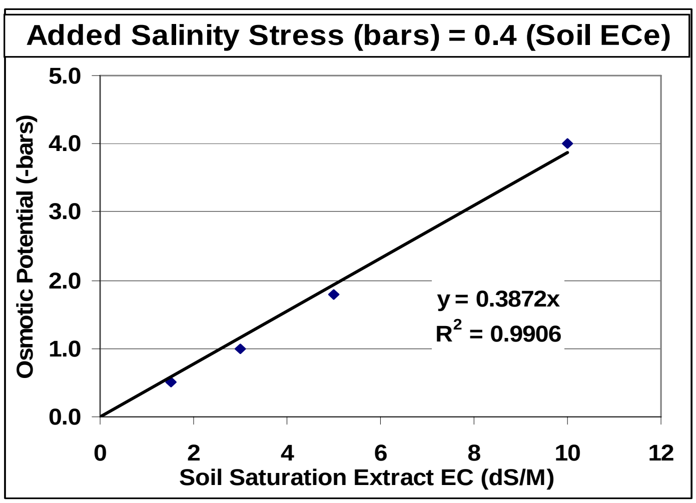

Fig. 1. Soil solution osmotic potential as a function of soil saturation extract salinity. Adapted from, USDA. 1954. “Diagnosis and Improvement of Saline and Alkali Soils. Agricultural Handbook 60.

So the first best step in managing salinity in alfalfa is to review forage ET in the SJV to understand the “normal year”, unstressed water requirement to be supplied by irrigation.

<u>**Evapotranspiration (ET) and “Reference crop” ETo:**</u> The combination of air temperature, humidity, solar radiation and wind provide the energy to evaporate (E) water from the wet soil and to change the liquid water in the plant canopy into vapor that leaves the stomata in the underside of the leaves as transpiration (T). This allows for CO_2 assimilation and cooling the plant to maintain efficient photosynthesis and carbohydrate production. The combination of these two is the total water use for crop production, **evapotranspiration or ET**. The basic crop used to

benchmark all others is a tall, well-watered, non-stressed cool season grass. This is called the "Reference Crop" and its water consumption is defined as Potential ET (ETo).

Crop coefficients (Kc) and average forage ET: Since most forage crops are planted dense and cover the ground like a pasture then it's natural to assume that their ET would be the same as ETo, and as a first guess this isn't too bad. But there are developmental differences due to initial seedling growth, physiology of the particular forage compared to pasture and cutting schedules. Basically, the crop coefficient, Kc, is the ratio of actual crop water use for a particular stage of growth compared to ETo. We have typical Kc values for the developmental stages of most crops. Crop ET is then calculated as follows:

$$\mathbf{ETcrop = ETo * Kc * E_f}$$

ETo = reference crop (tall grass) ET

Kc = crop coefficient for a given stage of growth as a ratio of grass water use. May be 0 to 1.3, standard values are good starting point.

E_f = an "environmental factor" to account for immature permanent crops, salinity, etc. May be 0.1 to 1.1 depending on field. Usually 1 for good ground and water.

Table 1. Crop coefficients and calculated ET for various forage crops in the SJV.

DATE	Pasture *ETo (inch)	[1]Crop Coefficient Values (Kc): [2]Alfalfa	Silage 4/1-8/25	Silage 6/15-10/15	[3]Sudan	Winter Forage	Triple Crop	[4]Normal Year Crop ET (inches): [2]Alfalfa	Silage 4/1-8/25	Silage 6/15-10/15	[3]Sudan	Winter Forage	Triple Crop
1/15	0.54	0.95				0.62	0.62	0.51				0.33	0.33
2/1	0.70	0.95				0.80	0.80	0.67				0.56	0.56
2/15	0.98	0.95				0.95	0.95	0.93				0.93	0.93
3/1	1.26	0.95				1.15	1.15	1.20				1.45	1.45
3/15	1.64	0.95				1.15	1.15	1.56				1.89	1.89
4/1	2.08	0.95	Plant			1.20	1.20	1.98	*1.04*			2.50	2.50
4/15	2.55	0.95	0.14			1.20	Silage90	2.42	0.35			3.06	*1.28*
5/1	3.15	0.95	0.18		Plant	1.15	0.14	2.99	0.55		*1.58*	3.62	0.44
5/15	3.50	0.95	0.31		0.58		0.22	3.33	1.09		2.03		0.77
6/1	3.79	0.95	0.94	Plant	0.80		0.45	3.60	3.55	*1.90*	3.03		1.71
6/15	4.00	0.95	1.14	0.14	0.95		1.00	3.80	4.55	0.55	3.80		4.00
7/1	4.25	0.95	1.18	0.25	1.05		1.10	4.04	5.02	1.06	4.46		4.68
7/15	4.35	0.95	1.18	0.56	1.10		1.20	4.13	5.13	2.45	4.79		5.22
8/1	4.33	0.95	1.15	1.00	1.10		Sudan	4.11	4.98	4.33	4.76		*2.17*
8/15	4.11	0.95	1.06	1.15	0.60		0.60	3.90	4.36	4.72	2.46		2.46
9/1	3.64	0.95	0.98	1.20	1.10		0.90	3.46	3.55	4.37	4.01		3.28
9/15	3.10	0.95		1.20	1.10		1.05	2.95		3.72	3.41		3.26
10/1	2.70	0.95		1.06	0.60		1.10	2.57		2.87	1.62		2.97
10/15	2.20	0.95		0.98	1.10		0.60	2.09		2.16	2.42		1.32
11/1	1.73	0.95			1.10		1.10	1.65			1.91		1.91
11/15	1.20	0.95			1.00	Plant	TriGrain	1.14			1.20	*0.60*	*0.60*
12/1	0.88	0.95				0.25	0.25	0.84				0.22	0.22
12/15	0.70	0.95				0.36	0.36	0.67				0.25	0.25
12/31	0.52	0.95				0.52	0.52	0.49				0.27	0.27
TOTALS	57.90							55.01	34.18	28.12	41.47	15.68	44.45

*Jones, D.W., R.L. Snyder, S. Eching and H. Gomez-McPherson. 1999. California Irrigation Management Information System (CIMIS) Reference Evapotranspiration. Climate zone map, Dept. of Water Resources, Sacramento, CA.

[1]Adapted from Pruitt, W.O., E. Fereres, K. Kaita, and R.L. Snyder. 1987. "Reference Evapotranspiration (ETo) for California." UC Bull. 1922. Pp. 12-13.

[2]Kc of 0.95 takes into account reduced ET during cuttings over season.

[3]Total of 3 cuttings. ET reduced for 1 to 2 weeks after cutting 7/15 and 9/1.

[4]ET numbers in italics are evaporation losses from water at planting.

Table 1 shows the Kc values and "normal year" crop ET estimate for various forages planted at the appropriate date. Obviously, the winter forage uses the least water as it grows only during the winter and spring and the non-dormant alfalfa uses the most. In reality, the ET of alfalfa has a saw tooth type pattern due to the frequent cutting and in the end run, depending on the vigor/nutrition of the stand has an ET from 48 to 60 inches. All of the numbers in Table 1 can easily be +/- 10% depending on many factors – pest pressure, precision of irrigation/fertilizer scheduling, soils, etc. Excessive salinity and poor aeration can decrease these numbers by 20 to 40% before the stand becomes totally unacceptable. Figure 2 compares the San Joaquin Valley ETo curve to what the "model" stand of alfalfa ET would look like over the year.

The real picture of actual ET, even when averaged on a weekly basis is much more complicated and can actually have some Kc values in excess of 1.5, more than 150% of ETo. Alfalfa ET measured from a Buttonwillow field on heavy, cracking black clay irrigated once per cutting showed that mid-season crop ET occasionally ran 115 to 150% (0.33 to 0.45 inches/day) in July and August. The net result was that the average May-October Kc for this field was 1.10 instead of the 0.95 shown in Table 1. **Bottom line: Normal year ET tables are a good guideline for planning irrigations, BUT actual crop ET can be +/-15%. Therefore, you must check soil moisture and irrigation uniformity over the season to maximize yield and efficiency.**

Yield/ET production functions and water use efficiency (WUE): Much research over the last 30 years has examined the WUE, **crop per drop** so to speak, of most field crops. The production function for a given crop predicts the yield as a function of crop ET. The final WUE is a ratio of final yield over total applied water – including irrigation system losses. Figure 3.a. shows the variety of alfalfa production functions that have been developed from many different locations and research trials throughout the West (Hanson et al., 2007).

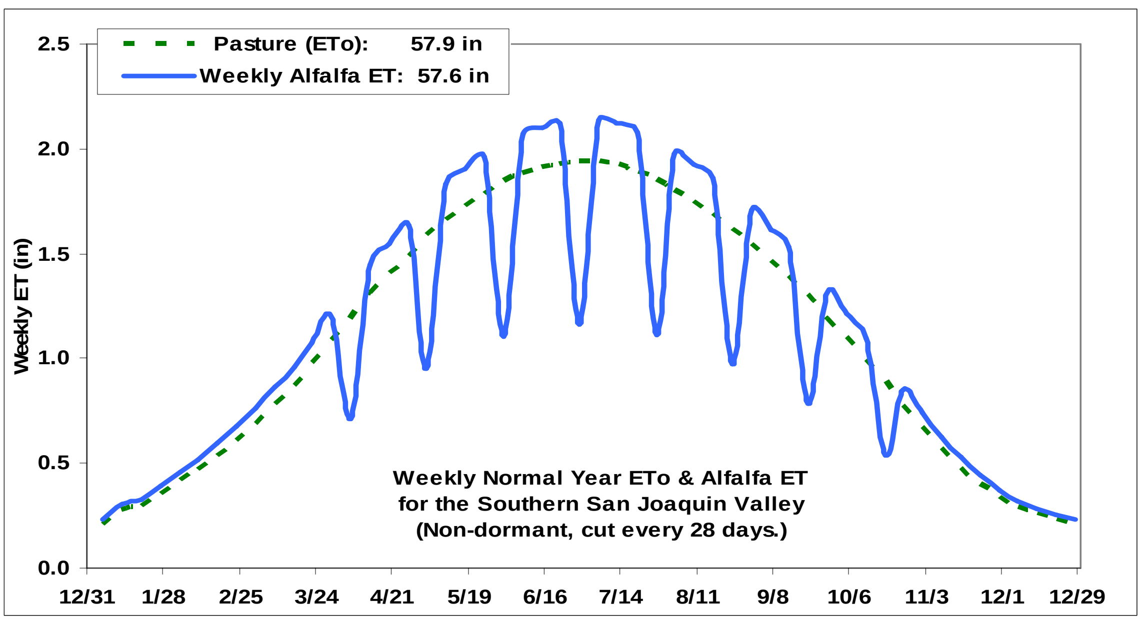

Fig. 2. Weekly ET for an established stand of non-dormant alfalfa in the SJV with 8 cuttings. Crop ET is calculated using peak crop coefficient (Kc) values of 1.1 immediately upon irrigating after bale pickup and a low of 0.6 for one week immediately after cutting as the hay cures prior to baling.

"But wait a minute," says the San Joaquin Valley hay grower, "I've never known anyone to make 14 t/ac on their alfalfa!" Most of this data comes from intensive field station research plots where nearly every leaf goes into the final yield. Figure 3.b. is a more achievable option

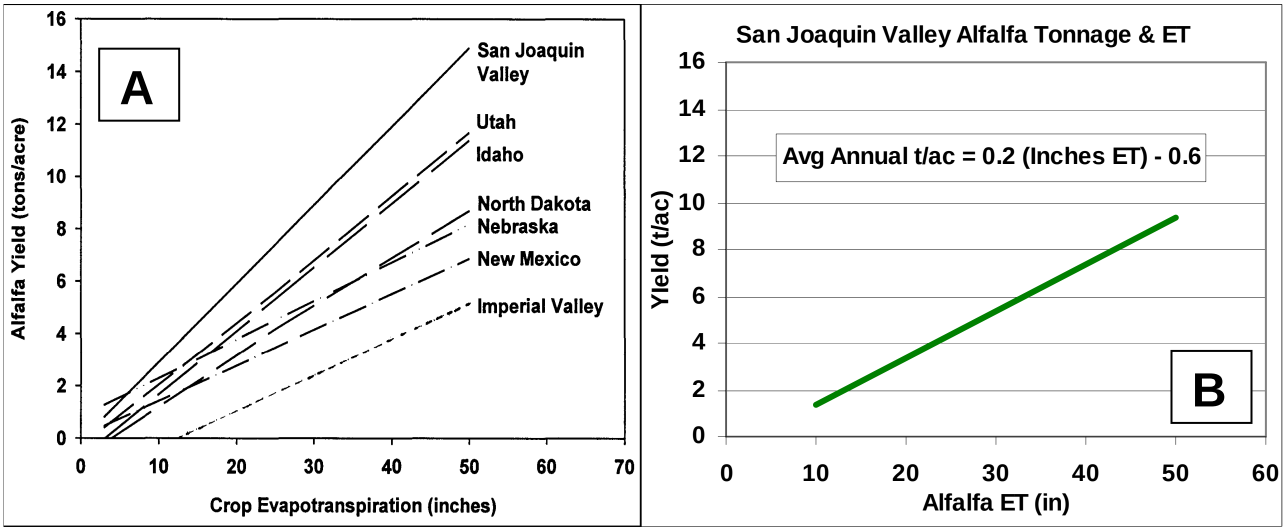

Fig. 3. Optimal alfalfa production functions for various locations in the West (left, Hanson et al., 2007). More realistic field production function for well-managed established alfalfa in the SJV (right, Sanden, personal observation, 3 year trial in Buttonwillow).

from my observation of production conditions (and a 3 year trial measuring ET/yield of alfalfa in Buttonwillow) where leaf loss in the field is unavoidable and top hay yields are around 10 t/ac. What this function says is that it takes about 5 inches of ET to make one ton of alfalfa hay. You'll notice that the lowest production line in Fig. 3a. is for the Imperial Valley. Excessive heat during the day and night result in high "respiration losses" in alfalfa, where the plant actually burns up some stored carbohydrates as it transpires large amounts of water to maintain cooling. CO_2 assimilation is high, but so are metabolic losses. Alfalfa is a C3 plant that prefers cooler temperatures (50-80°F) for the most efficient photosynthesis. So it's not surprising that many research trials find the best WUE in the spring and fall cuttings and areas with cooler nights.

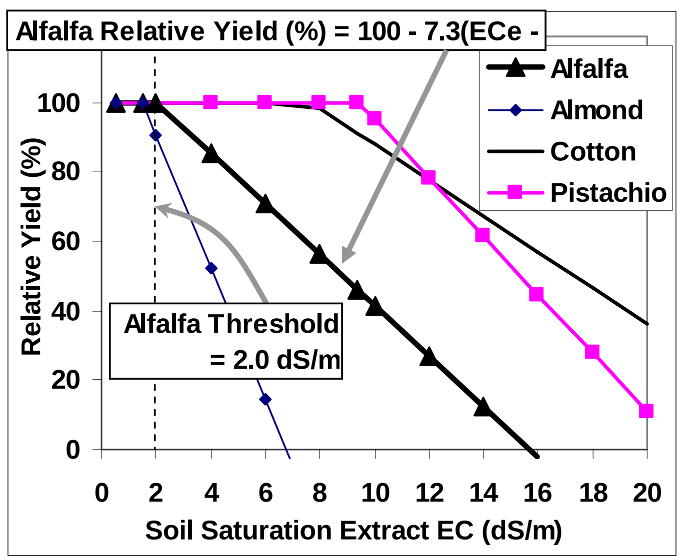

Fig. 4. Salinity tolerance curves for alfalfa, almond, cotton and pistachio. (Ayers and Westcott, 1985. Sanden, et. al., 2004)

CURRENT PUBLISHED SALINITY GUIDELINES FOR ALFALFA AND FORAGES

Figure 4 shows the classic standard salinity tolerance curve for alfalfa, cotton, almonds and pistachios. Many of the published crop tolerance limits we use today were established under tightly controlled conditions in sand tanks, often using saline/nutrient solutions dominated by sodium and chloride. Some of these values (such as the curve for pistachios) were generated under field conditions and others (such as cotton) combine numerous trials.

Table 2 lists most forage crops in order of increasing salinity tolerance with berseem as the most sensitive and tall wheatgrass as most tolerant. What this means is that if you have a source of drain water at an EC of 4 dS/m and you irrigate silage or alfalfa you can lose 25% of the potential yield for that field and the ET will also decrease. On the other hand if you plant

Table 2 Crop tolerance and yield potential of selected crops as influenced by irrigation water salinity (EC_w) or soil salinity (EC_e)[1] (Ayers and Westcott, 1985)

YIELD POTENTIAL[2]

FORAGE CROPS	100%		90%		75%		50%		0% "maximum"[3]	
	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w	EC_e	EC_w
Berseem *(T. alexandrinum)*	1.5	1.0	3.2	2.2	5.9	3.9	10	6.8	19	13
Corn (forage Zea mays)	1.8	1.2	3.2	2.1	5.2	3.5	8.6	5.7	15	10
Alfalfa (Medicago sativa)	2.0	1.3	3.4	2.2	5.4	3.6	8.8	5.9	16	10
Sudan (Sorghum sudanense)	2.8	1.9	5.1	3.4	8.6	5.7	14	9.6	26	17
Wheat, durum grain (Triticum turgidum)	5.7	3.8	7.6	5.0	10	6.9	15	10	24	16
Wheat Red (Triticum aestivum)4	6.0	4.0	7.4	4.9	9.5	6.3	13	8.7	20	13
Barley (forage) (Hordeum vulgare)4	6.0	4.0	7.4	4.9	9.5	6.4	13	8.7	20	13
Sorghum (Sorghum bicolor)	6.8	4.5	7.4	5.0	8.4	5.6	9.9	6.7	13	8.7
Bermuda grass (Cynodon dactylon)7	6.9	4.6	8.5	5.6	11	7.2	15	9.8	23	15
Wheatgrass, tall (Agropyron elongatum)	7.5	5.0	9.9	6.6	13	9.0	19	13	31	21

1 Adapted from Maas and Hoffman (1977) and Maas (1984). These data should only serve as a guide to relative tolerances among crops. Absolute tolerances vary depending upon climate, soil conditions and cultural practices. In gypsiferous soils, plants will tolerate about 2 dS/m higher soil salinity (ECe) than indicated but the water salinity (ECw) will remain the same as shown in this table.

2 ECe means average root zone salinity as measured by electrical conductivity of the saturation extract of the soil, reported in deciSiemens per meter (dS/m) at 25°C. ECw means electrical conductivity of the irrigation water in deciSiemens per meter (dS/m). The relationship between soil salinity and water salinity (ECe = 1.5 ECw) assumes a 15–20 percent leaching fraction and a 40-30-20-10 percent water use pattern for the upper to lower quarters of the root zone. These assumptions were used in developing the guidelines in Table 1.

3 The zero yield potential or maximum ECe indicates the theoretical soil salinity (ECe) at which crop growth ceases.

4 Barley and wheat are less tolerant during germination and seeding stage; ECe should not exceed 4–5 dS/m in the upper soil during this period.

winter wheat for grain you will not lose yield. Again, these values are only guidelines and will go up or down depending on some varietal differences, existing salt levels in the soil and the ratio of sodium to calcium in the irrigation water. Continued plant breeding has improved salinity tolerance in many crops, but the values in Figure 4 and Table 2 are good starting points for doing homework and exercising caution when planting salty fields. As a general rule, field crops will do better and appear 10 to 20% more tolerant of salinity on soils that are dominated by calcium and sulfate salts (gypsiferous) instead of sodium and chlorides (sodic soil).

Maintaining acceptable rootzone salinity: Root zone salinity increases when salts are transported into the field in the irrigation water and, in some Westside soils, previously precipitated soil salts made soluble with irrigation water. The only way of decreasing salinity is transporting salts out of the root zone with deep percolation or tile drainage. This is referred to as leaching, and it is an important function of irrigation.

The ***leaching requirement for maintaining acceptable salinity levels*** is the fraction of infiltrating water that is not used to refill the rootzone or for crop ET but instead percolates below the rootzone. It is expressed as a percentage rather than as a specific quantity, so discussion of leaching fraction can be applied to crops with various water requirements and water qualities. As the quantity of applied water increases, or as the concentration of the salts in the water increases, more salinity is transported into the field. Therefore, more leaching is required to leach salts below the root zone.

Variations in irrigation water quality and soil salinity create the need for different **leaching fractions (LF)** from one field to the next. Table 3 provides leaching fractions required for irrigation water qualities from 0.5 to 6 dS/m to maintain two different rootzone salinity levels.

Table 3. Leaching fraction (% additional water) required to sustain long-term rootzone salinity (ECe, dS/m) for given irrigation water salinity.

Irrigation Water EC (dS/m)	**Desired Average Rootzone ECe**					
	1	**2**	**3**	**4**	**5**	**6**
0.2	2	1	%			
0.5	10	3	2			
1.0	33	10	5	3	2	2
1.5		20	10	7	5	3
2.0		33	17	10	7	5
2.5			24	15	10	8
3.0			33	20	14	10
3.5				26	18	13
4.0				33	23	17
4.5					27	20
5.0					33	24
5.5						28
6.0						33

Adapted from Ayers, R.S., D.W. Westcot. Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29 Rev. 1, Reprinted 1989, 1994. http://www.fao.org/DOCREP/003/T0234E/T0234E0

Leaching Fraction Example (See Table 3)

Alfalfa uses about 50.0 inches of water annually. The irrigation water supply has an **EC_w of 1 dS/m, and the goal is to maintain an average root zone EC_e of 2 dS/m.** Table 3 shows that an **LF of 10% is required**.

Required Irrigation = ET * (1 + LF)
= 50 * 1.10 = 55 inches

If the irrigation water EC_w was instead 1.5 dS/m then, LF = 50 x 1.2 = 60 inches.

(Note: adequate drainage to handle any excess water above ET is imperative. Monitor soil moisture during the season to avoid saturating the rootzone. If you have to irrigate sparingly during the season to avoid scalding and waterlogging, and tonnage declines then do a winter reclamation irrigation. Sample soil salinity in November and use the Reclamation Table 4 to estimate needed winter leaching.)

RECLAMATION EXAMPLE FROM KERN COUNTY USING BIOSOLIDS COMPOST

Reclamation of sodic-saline ground using a combination of flooding, crop rotation, gypsum/sulfur and organic amendments has added at least 250,000 acres of irrigated farmland to Kern County over the last 80 years. The old formula was 3 to 10 ton of dairy manure, 2 ton of gypsum and a foot of water for winter leaching. As the urban area grows and swallows up adjacent Class 1 ground growers have continued development of more marginal areas – some of them with near extreme salinity problems. With the cost of water, fuel and other standard amendments becoming increasingly expensive growers are interested in alternative materials, especially low cost urban-based organics subsidized through mandated waste reduction programs (AB939) that can still make reclamation of these marginal lands economically feasible. Subsidized biosolids (sewage sludge)/manure compost provides a cheap alternative source of organic matter to improve infiltration and provide additional P and K fertilizer.

<u>Procedures:</u> A 53 acre highly alkaline, sodic field in western Kern County was selected for this trial (Figure 4). The USDA NW Kern County Soil Survey classifies the soils in the testplot area as Buttonwillow and Lokern Clay. In reality, there is much more very fine sand and silt and

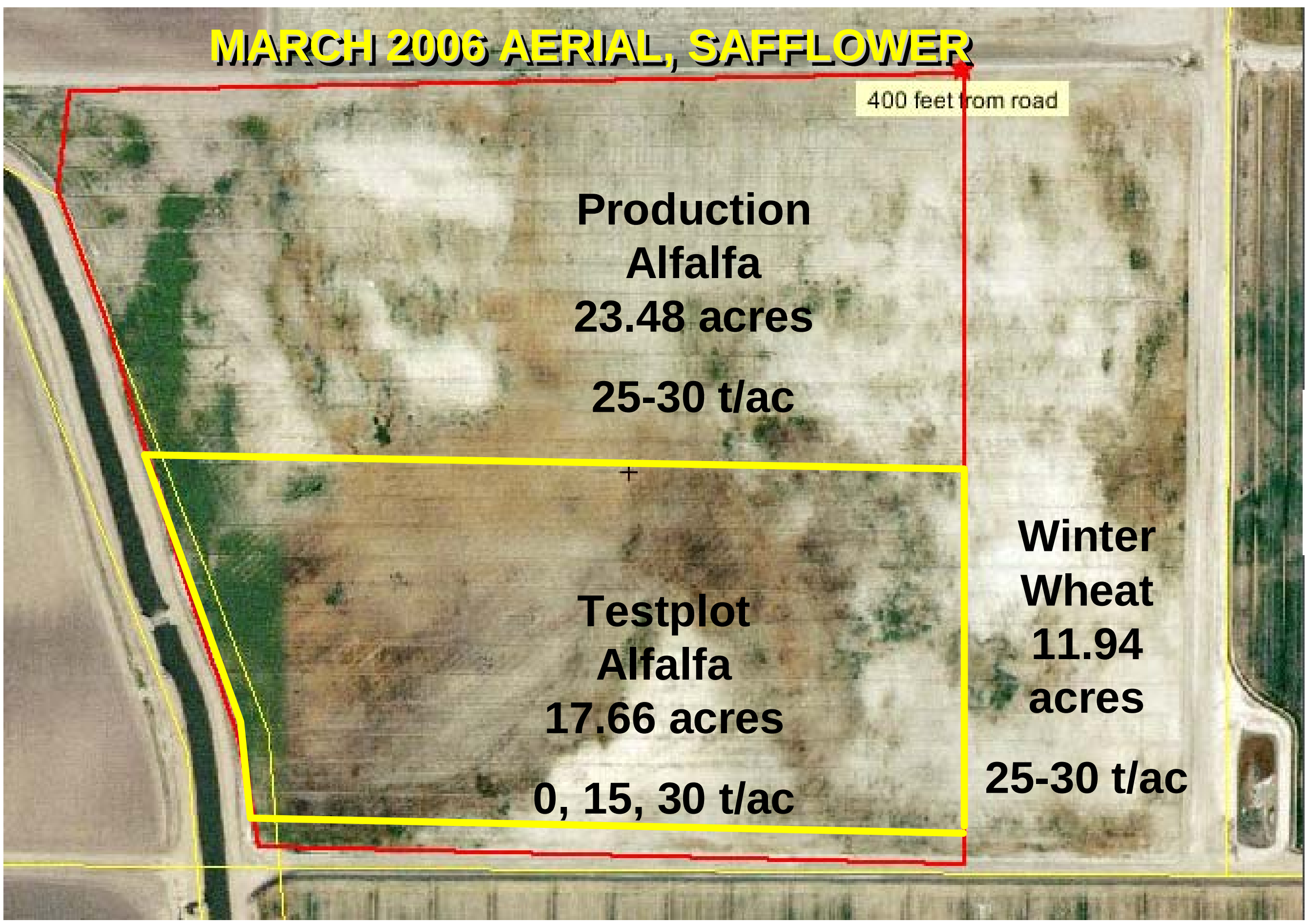

Fig. 4. Aerial view of sodic/alkali field, eastern edge of Buena Vista lake bed, late March 2006. Field was planted to safflower January 2006 and watered once by furrow. Lack of vegetation due to excessive sodicity, salinity and alkali are very evident.

proportionately that much less actual clay at this site than is typical for these soil series; making the soil closer to a sodic Lethent or Garces series. The trial area consists of 12 checks 50 feet wide by 1200 to 1365 feet long (1.38 to 1.57 acres/check) due to an angled western border for a total test area size of 17.66 acres. Testplot checks are arranged in a randomized complete block design with 4 replicates of the three treatments described below. Many newly planted alfalfa fields on alkali fields on the Westside of the San Joaquin Valley receive a standard broadcast treatment of 1,500 lb/ac 98% sulfuric acid immediately before the germination irrigation. The entire production and testplot area received this treatment to provide some benefit to the Control checks after compost application to treated checks and planting the whole field.

Treatments:

1. **Control – no amendment**
2. **15 ton/ac Biosolids/manure compost (usable N-P-K, 127-129-293 lb/ac)**
3. **30 ton/ac Biosolids/manure compost (usable N-P-K, 254-258-586 lb/ac)**

10/5-20/07: chisel, disc 2x, landplane, make borders, take pre-application soil samples
11/12-18/07: broadcast compost, spring tooth/spike harrow to 3 inches
11/21/07: plant S&W9215 salt tolerant variety with Brillion seeder @ 25 lb/ac, cultipack
11/26/07: broadcast 1,500 lb/ac, 98% sulfuric acid over all alfalfa planting with 60 foot boom
12/3/07 - 1/15/08: apply 12 inches of well water (EC 0.5 dS/m), sprinklers in 6 to 12 hour sets
2/8/08: Raptor and 2-4Db aerial application to control fiddleneck, London rocket and safflower
3/4/08: Buctril ground application to control escapes of large fiddleneck

Leaching calculations: Table 4 below gives a simple way to estimate the required leaching for reclaiming a soil when using water <= 1 dS/m. Table 5 are the results from composite soil samples in the "Good" and "Bad" areas of the alfalfa field as of May 2007. The average EC in the GOOD area is about 4. So the germination irrigation will be more than enough to get the starting rootzone down to our EC threshold of 2 for no problems. The BAD area has an EC of 43 dS/m. A precise calculation of required leaching just to get down to 3 dS/m shows 23 inches of water would be needed to reclaim just one foot!

Table 4. Depth of leaching water required per foot of rootzone to be reclaimed given the initial soil salinity and final desired salinity (Hoffman, 1996).

Desired Rootzone Salinity (dS/m)	*Inches of water/foot of rootzone Required to leach initial salinity of: **4** dS/m	**8** dS/m	**12** dS/m	**16** dS/m
2	1.8	5.4	9.0	12.6
4	0	1.8	3.6	5.4
6	0	0.6	1.8	3.0

Table 5. Soil salinity and nutrient analysis from composite samples taken in sodic/alkali safflower field May 2007 from GOOD (G) and BAD (B) areas of safflower growth.

N	% SP	pH	EC dS/m	Ca (meq/L)	Mg (meq/L)	Na (meq/L)	K (meq/L)	Cl (meq/L)	ESP	% $CaCO_3$ QUANT	LIME PRESENCE LP	B	NO_3N	PO_4P	K AA
G 0-9'	31	7.9	6.71	16.5	5.8	50.4	3.9	25.5	17.3	2.42	++++	3.3	21.1	15.3	1002
9-24'	27	8.2	2.28	3.9	0.9	17.5	0.6	6.5	13.3	2.65	++++	2.8	3.8	13.8	864
B 0-9'	32	8.8	46.29	19.4	1.1	537.3	1.7	155.4	71.1	2.34	++++	13.3	126.0	11.2	336
9-24'	36	9.8	41.30	1.2	0.2	461.2	1.3	133.6	88.9	2.32	++++	39.3	80.0	16.4	236
RANGES		6.0-7.5	<4.00 >0.60	Ca > 2x (Mg+Na)			>0.4	<10	<5	<1.5%		>0.2 <1.5	Fertility Optimum Rar	>16.0	>150

In reality, this BAD analysis reflects only 5% of the field. More extensive sampling on 11/8/07 after borders were pulled and just before applying compost showed salinity averaged from 2 to 9 dS/m down to 3 feet depending on the check. Some SAR/ESP values from this analysis (a ratio of sodium to calcium that indicates potential soil sealing problems) were over 200. This value should be no higher than 5x(soil or water EC), say about 10 to 15. This high SAR plus the high silt and fine sand % in this soil makes a large dose of organic matter applied to the soil surface and incorporated in the top inch or two the preferred amendment strategy.

Referring to Table 4, if we want to reclaim a soil EC of 8 down to 2 dS/m we need 5.4 inches of water/foot of soil to leach THROUGH the soil. For this trial the grower could only afford to pump about 12 inches of water and apply with solid-set sprinklers in 6 to 12 hour sets repeated every 2 to 3 days. Irrigations began immediately after planting and acid application.

It took 2.5 inches/foot just to rewet the profile after the safflower. This meant the top foot received 9.5 inches leaching out the bottom, the second foot had 7 inches leaching and the third foot got 4.5 inches leaching. Thus full reclamation was achieved during stand establishment in the top 2.5 feet and most of the salt stopped moving around the 4 to 5 foot depth. This allows enough rootzone to get the hay started with the expectation of further leaching to keep pushing the salt below 5 feet with continued irrigation and deep percolation.

Stand development/yield: As expected, due to the cool temperatures and elevated salinity initial seedling emergence and subsequent growth was slow – especially in the Control plots with no compost. By March, the Control treatment had a few bare spots with few or no plants and overall plant density and growth appeared less compared to the Compost plots. The additional nitrogen in the form of ammonium supplied in the biosolids/manure co-compost along with improved infiltration and leaching of salts improved the vigor in treated checks. However, a salinity saturation extract EC from composite samples taken in March from the top foot for each treatment in Checks 7, 8 and 9 was virtually identical for the Control and Compost treatments at about 0.95 dS/m – well within the tolerance limits for alfalfa. Stand counts on 5/5/08 ranged from 12.6 to 17.3 plants/sq ft, but averaged 15/ sq ft for control and treated checks. Table 6 shows the yield advantage of the compost treatments. About 40 lb/ac of P_2O_5 was applied to control checks in April as water-run 10-34-0 phosphoric acid as the alfalfa had a bluish appearance and the grower used this treatment on an adjacent field as part of his production practice. We will determine if the compost application was economically beneficial after the 3rd or 4th year of production. After 5 cuttings, the compost treatments have a 1.14 and 1.29 t/ac advantage over the control for the 15 and 30 t/ac rates, respectively (Table 6).

Table 6. Cutting dates and yield (t/ac). All Control yields are significantly less ($P < 0.01$) than the Compost treatments.

	4/27	6/4	7/7	8/19	9/21	Total	% of Control
CONTROL	0.71	1.28	1.55	1.84	1.35	6.72	100%
15 TON/AC	1.03	1.54	1.72	2.06	1.51	7.85	117%
30 TON/AC	1.18	1.47	1.76	2.09	1.50	8.01	119%

IMPORTANT NOTE ON ALFALFA BREEDING FOR SALT TOLERANCE: Alfalfa breeders in Arizona and California have worked on increasing alfalfa salt tolerance for more than 20 years. S&W 9720 has been successfully farmed on the Westside of Fresno County for the last

7 years; including a 5 year stand that was irrigated solely with tile drainage water (EC ~3.5 dS/m, 2500 ppm TDS) from the Firebaugh Canal Company, and as part of a sequential drain-water reuse scheme near 5 Points (Sheesley, personal communication). Grattan, et al. (2004) revisited the sand tank studies and found that SW9720 produced just as much tonnage as Jose Tall Wheatgrass (ranked the most salt tolerant in Table 2 up to an irrigation water EC of 15 dS/m (~10,000 ppm TDS), but then quickly crashed as the EC went up to 25 dS/m. SW9720 and its later generation, 9215 used in this trial offer greater tolerance than the classic guidelines, but in the final analysis, you only get good tonnage when nutrition is good and the plant is not stressed.

REFERENCES

Ayers, R.S. and D.W. Westcot. 1985. *Water Quality for Agriculture.* FAO Irrigation and Drainage Paper 29 Rev. 1, Reprinted 1989, 1994.

Grattan, S.R., C. M. Grieve, J. A. Poss, P. H. Robinson, D. L. Suarez and S. E. Benes. 2004. Evaluation of salt-tolerant forages for sequential water reuse systems : I. Biomass production. Agricultural Water Management 70:2:109-120.

Hanson, B.R., K.M. Bali, B.L. Sanden. 2007. *Irrigated Alfalfa Production in Mediterranean and Desert Climates.* Technical manual companion to *Arid Land Alfalfa Manual.* Univ. California, Davis, Dept. Land, Air and Water Resources, UC ANR Publication to be announced. 36 pp.

Hanson, B. S.R. Grattan, and A. Fulton. 1993. “Agricultural Salinity and Drainage”. Univ. of CA Irrigation Program, Davis, CA.

Hoffman, G.J. 1996. “Leaching fraction and root zone salinity control.” Agricultural Salinity Assessment and Management. ASCE. New York, N.Y. Manual No. 7:237-247

Sanden, B.L., L. Ferguson, H.C. Reyes, and S.C. Grattan. 2004. Effect of salinity on evapotranspiration and yield of San Joaquin Valley pistachios. Proceedings of the IVth International Symposium on Irrigation of Horticultural Crops, Acta Horticulturae 664:583-589.

Additional Irrigation Management Resources

Determining Daily Reference Evapotranspiration (ETo). UC Publication 21426.

Drought Tips for Vegetable and Field Crop Production. UC Publication 21466.

Grattan, S.R., Bowers, W., Dong, A., Snyder, R., Carroll, J. J. and George, W. 1998. New crop coefficients estimate water use of vegetables, row crops. California Agriculture, Vol 52, No. 1.

Irrigation Scheduling: A Guide for Efficient On-Farm Water Management. UC Publication 21454.

Jones, D.W., R.L. Snyder, S. Eching and H. Gomez-McPherson. 1999. California Irrigation Management Information System (CIMIS) Reference Evapotranspiration. Climate zone map, Dept. of Water Resources, Sacramento, CA. http://wwwcimis.water.ca.gov/cimis/images/etomap.jpg

Using Reference Evapotranspiration (ETo) and Crop Coefficients to Estimate Crop Evapotranspiration (ETc) for Agronomic Crops, Grasses, and Vegetable Crops. UC Publication 21427.

Using Reference Evapotranspiration (ETo) and Crop Coefficients to Estimate Crop Evapotranspiration (ETc) for Trees and Vines. UC Publication 21428.