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KERN SOIL AND WATER

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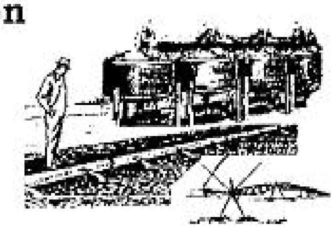


Kern County Sugarbeet Nitrogen Fertilization & Irrigation Scheduling Demonstrations for 2001 & 2002

November 2002

Background: Maximizing Profitable Sugar Yield

Dozens of California sugarbeet trials going back for more than 30 years have proven that maximum sugar yields are dependant on knowing the nitrogen and water dynamics of the particular field you're farming. A "one-size-fits-all" approach for every field does not work. In these past studies, the highest sugar yields were obtained with N fertilizer rates ranging from 0 to 240 lb N/acre. Maximum profit (not always maximum sugar) was obtained with irrigation cutoffs of 30 to 50 days. In the absence of any other field specific information, a 160 lb/ac level of N fertilizer and a 30 day cutoff gave the best average performance. *(For more information on these past trials see the February 2002 Kern Field Crops newsletter or the references given at the end of this newsletter.)*

Table 1. NUTRIENT UPTAKE (lbs/ac) OF SUGARBEET ROOTS

	Tons Roots					
	1	*30*	*35*	*40*	*45*	*50*
Nitrogen (N)	8.5	255	298	340	383	425
Phosphate (P2O5)	2.0	60	70	80	90	100
Potash (K2O)	18.3	550	642	733	825	917

Table 1 gives the amount of N-P-K exported from the field for various tonnages of beet roots (adapted from the *Western Fertilizer Handbook,* California Fertilizer Association, 1985). The K_2O (potash) requirement is probably high (more than twice that given by Hills (1978)) due to the fact that sodium can substitute for a significant amount of potassium in sugarbeets. But everyone agrees that **it takes 8 to 8.5 lbs N/acre to make a ton of roots**. A good chunk of available N cycles naturally, which is why no one applies 350 lb/ac N to make a 40 ton crop. In fact, work by Jack Hills as summarized in the UC Bulletin 1891 titled "Sugarbeet Fertilization", concluded that the average available N in a field under regular rotation practices was good for about 21 tons/ac without any additional N fertilizer. At 8.5 lbs N/ton this is about 180 lb/ac, or an average of 15 ppm NO3-N in the top three feet of soil. The challenge for the grower, then, is to match your applied fertilizer to the additional nutrients needed to make a 40 ton/acre crop. The trick is not to over apply N so that you waste your fertilizer $$ and have excessive nitrates at harvest which depress sugar percentage and make sugar crystallization more difficult.

BOTTOM LINE: Growers should sample field soils to estimate available N-P-K stored in the soil before planting or fertilizer sidedress so as to avoid under or over fertilization and monitor soil moisture to avoid stress or excessive irrigation. Low fertility and drought cost tonnage. Excess N and water depress sugar percentage.

Demonstration Trials for 2001 & 2002

Objective: Determine if soil sampling and soil moisture monitoring can provide fertilizer and irrigation scheduling recommendations to improve the profitability of sugar production in sugarbeets.

Number of fields and soil types

Over the last 2 years we've worked with 4 different growers and six 80 acre fields with coarse to fine textured soils: 3 with Milham sandy loam, 1 with Panoche clay loam and 2 with Buttonwillow clay. Available water holding capacities of these soils range from about 1.2 to 2.5 inches/foot depth of rootzone. All fields were watered up between 10/20 and 11/10 then sampled and set up as described below. Harvest was between 6/25 and 7/15.

Field sampling and monitoring setup

- **Soil samples** February (when beets were no more than 4 inches tall) and post-harvest to 9 feet to determine the N reserves in the rootzone in 4 locations (2 @ 150 feet from the head and 2 @ 800 feet from the head, with one set near the edge of the field and the second near the center). P, K and TKN (total Kjeldahl nitrogen, estimate of ammonium and organic N) determined to 2 feet for 2002.
- **Petiole sampling** every three weeks for nitrate-N content and timing sidedress/water-run N.
- **Watermark® moisture sensors** installed at 150 and 800 feet from the head end at depths of 18, 36 and 60 inches in each location to determine soil moisture "tension". These blocks use a calibrated electrical resistance to give a reading similar to a tensiometer.
- **Data logger automatically storing and graphing** sensor readings every 8 hours to give a 5 week picture of field water storage with the push of one button. Installed at edge of field.
- **Tensiometer and neutron probe readings** from same locations as Watermarks and soil samples.
- **Irrigation schedule** provided to grower weekly over season for optimum water use.
- **Hand-harvest at sampling sites** to correlate tonnage, sugar yield/percent with nutrient uptake.

Preplant soil sampling, fertility and fertilizer application

For this last year of trials, composite preplant soil samples to 3 feet taken on September 3, 2001 showed there was 128 to 168 lb/ac nitrate nitrogen (NO3-N), 161 to 366 lb/ac phosphoric acid equivalent (the common way to express phosphorous as P2O5), and 1205 to 1995 lb/ac potash equivalent (the common term for potassium as K2O) for the three different fields in this year's study. Total N is the sum of the top three feet of soil while P and K values are the sum of the top two feet of soil, with about 80% of the total P in the top foot. As expected, the Buttonwillow clay had the high values for all nutrients. For all fields in both years, except the Buttonwillow Clay, preplant N was applied @ 40 to 80 lb/ac. Because rain can often prevent access to the Buttonwillow clay field, grower practice is to apply all N preplant (Sept-Oct) at 185 lb/ac. P was applied sidedress at planting @ 40 to 80 lb/ac in all but one field and K was applied @ 100 lb/ac in the Milham sandy loam2 field.

In-season soil fertility and post-harvest nutrient depletion

The left half of Table 2 below shows N-P-K and TKN levels in lbs/acre for all fields as of mid-February when the four sampling sites in each field were selected and beets were 2 to 4 inches high. (*Since TKN measures ammonium and organic nitrogen it gives you an idea of the "potential slow release" N available in the soil.*) The numbers are given in lbs/acre for an easier comparison to equivalent fertilizer applications. This is a good time to sample fields with fall planted beets because the plants will begin their peak growth phase by the end of March and you still have time to adjust N rates and sidedress fertilizer. Results you get back from the lab are usually given in "ppm" (parts per million), on a dry soil basis. There's about 4 million lb/ac in every foot depth of soil. So the below numbers are simply the lab results for each foot of soil multiplied by 4 and added together for all the depths sampled.

Table 2. Post-plant fertility (mid February), post-plant applied N fertilizer and final nutrient removal for all fields. Nutrient removal determined by subtracting post-harvest soil nutrient content from the samples taken in February plus post-plant fertilization.

	Post-plant Soil Nutrient Content (lbs/ac)					**All Post-Plant N Fert**	**Post-harvest Nutrient Removal Plus Post-plant Fertilizer (lb/ac)**				
	NO3-N (0-3ft)	NO3-N (3-9ft)	TKN (0-1 ft)	P2O5 (0-1 ft)	K2O (0-1 ft)		NO3-N (0-3ft)	NO3-N (3-9ft)	TKN (0-1 ft)	P2O5 (0-1 ft)	K2O (0-1 ft)
February 2001											
Milham Sandy Loam	97	70	1470	265	989	187	264	4	340	(Not	231
[1]Panoche Clay Loam	105	57	1920	227	1159	90	168	21	560	avail-	142
Buttonwillow Clay	319	169	3720	422	1105	0	287	119	150	able)	183
February 2002			(0-2 ft)	(0-2 ft)	(0-2 ft)				(0-2 ft)	(0-2 ft)	(0-2 ft)
[2]Milham Sandy Loam1	160	90	2770	216	2183	140	271	39	360	14	636
[3]Milham Sandy Loam2	260	188	3350	280	1990	140	362	104	520	16	298
[2]Buttonwillow Clay	364	148	8330	577	2970	0	302	81	-10	5	780

[1]Saline/alkali, not as well drained as the other fields in this study.

[2]These fields were adjacent to fields tested during the previous year.

[3]Identical soil type to Field1, about 5 miles away.

The right half of Table 2 gives the average post-harvest (mid July) field removal of N-P-K and TKN in the soil at the end of the season plus the fertilizer that was applied sidedress and any waterrun after the February sampling. Notice that the combined loss of NO3-N and TKN in the top three feet ranges from 373 to 986 lb/ac N. While higher amounts of organic nitrogen (indicated by TKN) in the soil give you some increased confidence in having adequate N for the whole season it's also a number that varies greatly across any field, and, because of natural in and out cycling in this nutrient "pool", can't be used directly to account for how much N has been released during the season. In fact, in 2002 the Buttonwillow clay showed no loss of TKN at all (-10 lb/ac depletion).

The better measure is the **removal of nitrate nitrogen (NO3-N)** from February to after harvest plus added N fertilizer during this time. For the 0-3 foot depth, over all 24 monitoring locations (4 in each test field) this number varied from 107 to 421 lb/ac with hand-sampled root tonnage varying from 32.9 to 64.0 ton/ac. The correlation of root yield with this depletion was statistically significant but was still quite scattered around the predicted line. (R-squared = 0.238, meaning nitrate depletion in the top 3 feet only accounts for 24% of why you got that particular yield.)

More of the story is told by accounting for NO3-N (plus post-plant N fertilizer) down to 9 feet. This showed a depletion of 232 to 584 lbs/ac and explains 40% of the variation in root yield differences (R-squared = 0.398, see Fig. 1). Total sugar (almost a flat line in Figure 1), however, only increases at ¼ the rate of root yield because sugar % in the roots decreases as soil NO3-N increases. So excessive levels of soil N and/or added fertilizer will depress your sugar % at harvest.

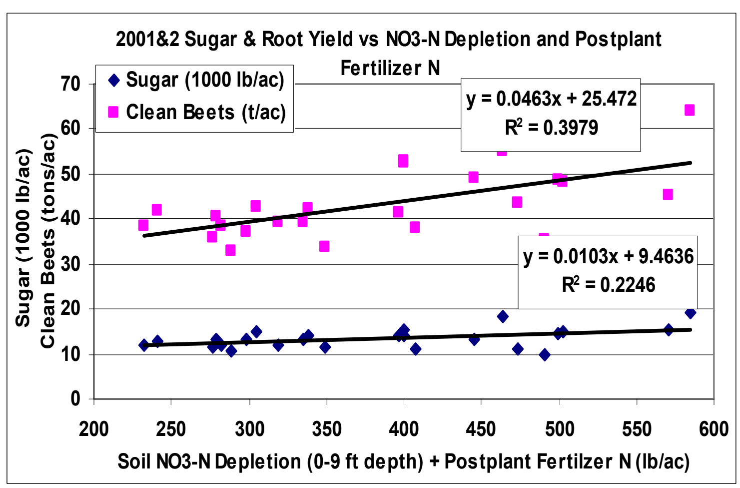


Fig. 1. Correlation of NO3-N depletion to 9 feet plus post-plant fertilizer N with root and sugar yield.

Table 1 says that a 32.9 ton/ac crop should require 280 lbs. N, and 64 ton/ac needs 544 lbs N. This isn't too far off the total N use found in these trials. However, the scatter of sample yields around 33 to 42 ton/ac (as shown in Figure 1) does not show a consistent 8.5 lb/ton N use and jumps around between 232 to 350 lb N use.

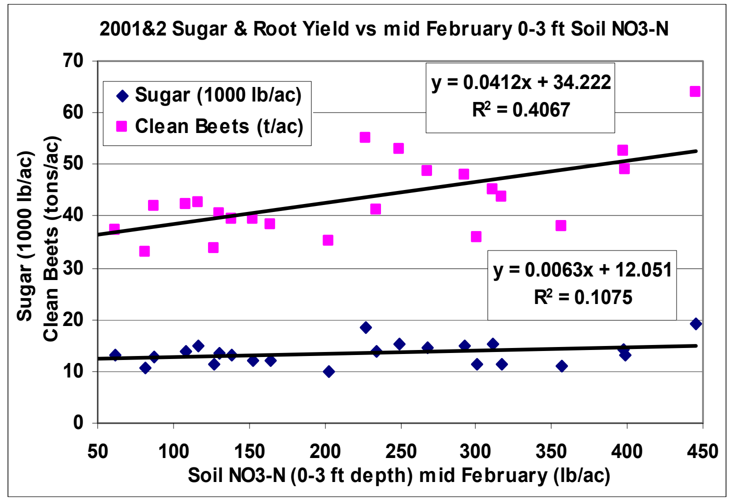


Fig. 2. Correlation of mid-February soil NO3-N in 0 to 3 foot depth of rootzone with root and sugar yield.

The level of stored soil NO3-N sampled in just the top 3 feet of soil in February (Figure 2) also showed a statistically significant relationship to root yield. Still a lot of scatter around this line, but it basically says **you need about 240 lb NO3-N/ac (a 20 ppm average reading on the lab report) to potentially make more than 40 ton/ac root yield.** The down side to this is that this is also the level at which sugar % was almost consistently less than 15% (Figure 3.)

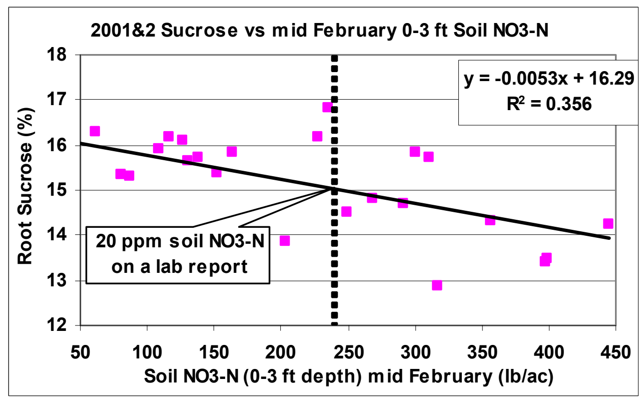


Fig. 3. Correlation of mid-February soil NO3-N in 0 to 3 foot depth of rootzone with % sucrose.

In 2002, almost as much K was found in the 1 to 2 foot depth as in the top foot of soil – ranging from 600 to 1900 lb K2O/ac-ft soil. The second foot was not tested in 2001. As expected, P was found mostly in the top foot @ 142 to 405 lb P2O5/ac (15 to 44 ppm). Table 2 shows that, except for the Milham2 field, a reasonable amount of K was depleted by the average 40 ton/ac crop. The depletion of P and K was not significantly correlated with yield. **In all sampling locations, K was greater than 200 ppm and P >= 15 pm. This appeared sufficient for all fields.** All fields, except for Milham 1, received starter phosphate to help seedling vigor in the cold months.

In-season petiole nitrate levels

The below figures show the seasonal changes in petiole nitrates for the 2002 season. The first plant petioles tested for NO3-N should be taken around the end of February/start of March. Numbers should be in the 4,000 to 10,000 ppm range at this time. The goal is to maintain petiole numbers above 1,000 ppm NO3-N until 4 to 6 weeks before harvest when nitrates should go below 1000 ppm to increase sugar %. The

Fig. 4. Petiole NO3-N for Milham Sandy Loam (Field 1)

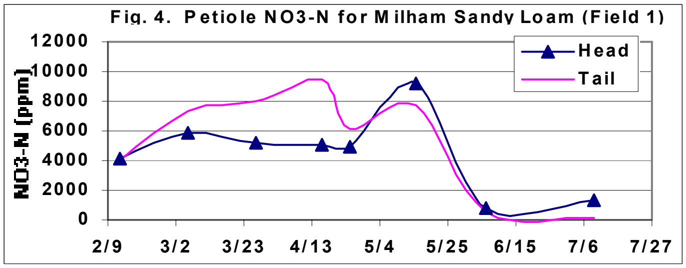


Fig. 5. Petiole NO3-N for Milham Sandy Loam (Field 2)

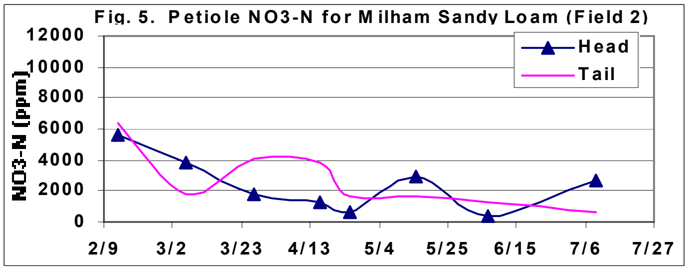
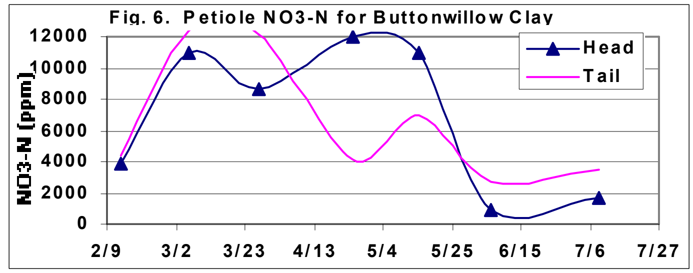


Fig. 6. Petiole NO3-N for Buttonwillow Clay



%. The Milham1 field (Figure 4) was sidedressed with 140 lb/ac N, the end of March and received no water run N. The Milham 2 field was sidedressed the end of February with 316 lb/ac 12-5-5. This was only 40 lb/ac N because soil tests indicated plenty of reserve nitrate already in the profile. However, petiole nitrates at the head end of the field dropped rapidly in March (Figure 5) and a 60 lb/ac N water run of UN32 was applied April 1. Nitrate levels continued to decline and an additional 30 lb/ac N was water run on April 20. This last water run proved unnecessary as the deeper roots tapped into stored moisture and soil nitrate in June. This contributed to excessive nitrates at harvest in the beets at the head end. Except for the head end samples on June 6, petiole nitrates on the Buttonwillow Clay were always 2000 ppm or higher – great for root growth due to the natural fertility of the soil, but difficult to manage for high sugar content.

<u>Soil Moisture and Irrigation Scheduling</u>

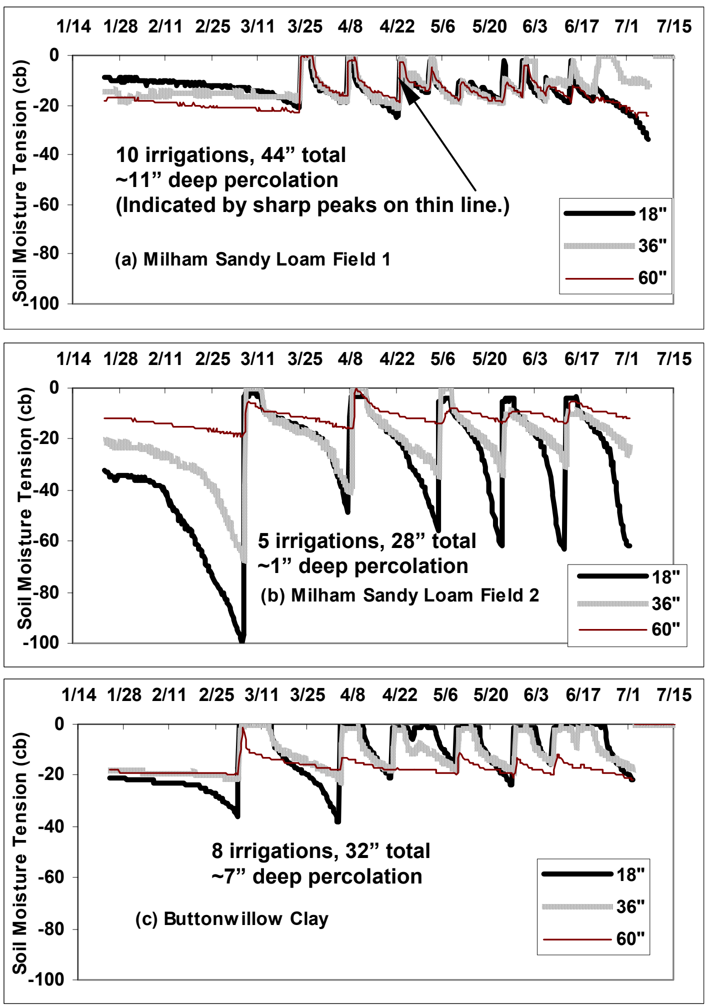


Fig. 7. Soil moisture “tension” changes during the 2002 season as measured by Watermark electrical resistance sensors and recorded every 8 hours with the AM400 data logger.

Table 3 in the next section shows applied water and estimated crop ET for both 2001 and 2002 seasons. Figures 7 (a), (b) and (c) chart the Watermark readings for 2002 that show the soil moisture changes for the different fields as measured 150 feet from the head end. Three sensors were installed at one location and set at 18, 36 and 60 inch depths. A second set of sensors were placed 800 feet from the end to check the water status nearer the tail end. Monitoring multiple depths is necessary to determine how quickly available water is depleted in the upper rootzone (0 to 3 foot depth) and if excess water is applied during irrigation to cause deep percolation past the 5 foot depth. This is essentially wasted water.

Soil moisture “tension” (technically called soil matric potential) is actually the amount of pressure that would need to be applied to the soil to push the water out of the capillaries. One “bar” of tension, -100 centibars (cb), is a perfect vacuum and the limit for a tensiometer with a vacuum gauge on top. Watermark sensors use electrical resistance and a calibration curve to estimate the capillary moisture “tension” in the soil: as the soil dries resistance increases. Watermark blocks can read down to -200 cb. When salinity is not a problem, sugarbeets can usually extract water down to –70 cb or more without going into stress. A reading of zero indicates a saturated soil. Figure 7(a), the **Milham sandy loam field 1**, shows the classic pattern of over irrigation – with 10 irrigations for the whole season. Without a data logger recording these readings 3 times/day it is very difficult to see the sharp peaks that indicate rapid drainage/deep percolation. The grower was advised to wait longer between irrigations, but chose to maintain his traditional schedule. Irrigation scheduling in the **Milham field 2** was almost perfect; with later irrigations about 3 weeks apart, no stress on the plants and no sharp peaks in the Watermark readings. In an effort

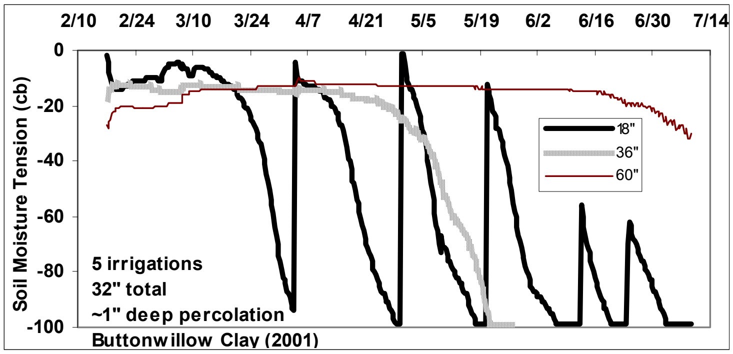


Fig. 8. Soil moisture "tension" changes during the 2001 season for beets in Buttonwillow Clay and irrigation intervals of approximately 3 weeks. This field is adjacent to the 2002 Buttonwillow Clay field.

to reduce available nitrate through leaching and denitrification, the grower farming the **Buttonwillow Clay** increased his irrigation frequency for 2002 and irrigated 3 more times than in 2001. Table 3 below shows that he was unsuccessful in this strategy; losing both tonnage and sugar percentage compared to 2001. The 2002 weather conditions undoubtedly had some affect, but Figure 7(c) shows periods of 3 to 4 days after irrigation where the beds stay saturated to 18 and 36", which was not the case for 2001 in the adjacent field with only 5 irrigations (Figure 8). Lack of aeration will shut down crop growth and is as much to be avoided as drought stress.

Yield, total sugar and water use

The numbers in Table 3 below compare the overall field characteristics at harvest with the averages from our 4 small, intensively monitored plots in each field. In general, small plot hand harvest yields overestimate the final field yield by about 10%. Small plot yields, sugar % and nutrient status are necessary to check for significant relationships like those of Figures 1 through 3. Crop water use (ET) ran about 30 inches for both seasons, except for the Panoche clay loam field in 2001 where the well had insufficient flow to meet full late season demand. Because of efficient irrigation scheduling, the Milham Field 2 actually extracted more stored water from the profile than was applied after stand establishment even though there was about 1 inch of deep percolation with the first irrigation. Harvest of this field was also moved up nearly 2 weeks due to the severity of bolting (~80%), which definitely impacted yield.

Table 3. Sugarbeet yield, quality, population and water management data for 2001 and 2002 seasons. Columns in **bold** type are from the entire field harvest or irrigation schedule. Columns in plain type are the mean values for the four intensively monitored plots in each field.

February 2001	Plot Root Yield (clean t/ac)	**Field Yield (clean t/ac)**	Approx. Bolting (%)	Plot Sucrose (%)	**Field Sucrose (%)**	Plot Sugar (lb/ac)	**Field Sugar (lb/ac)**	Plot Population (beets/ac)	**Population (beets/ac)**	**[4]Water Applied (inches)**	**[5]Crop ET (inches)**
Milham Sandy Loam	38.3	**35.4**	4	15.9	**16.1**	12,179	**11,399**	43,100	**33,200**	**37.9**	**30.9**
[1]Panoche Clay Loam	38.5	**33.5**	15	15.7	**16.3**	12,089	**10921**	40,900	**34,100**	**23.0**	**23.0**
Buttonwillow Clay	53.0	**47.0**	6	15.2	**15.1**	16,112	**14179**	42,000	**37,600**	**31.8**	**30.8**
February 2002											
[2]Milham Sandy Loam1	40.2	**39.4**	5	15.8	**14.7**	12,695	**11,584**	39,500	**32,900**	**43.5**	**32.5**
[3]Milham Sandy Loam2	45.2	**40.8**	80	14.0	**14.5**	12,647	**11,832**	44,600	**42,985**	**29.0**	**29.8**
[2]Buttonwillow Clay	43.9	**43.3**	12	14.3	**14.7**	12,543	**12,730**	43,800	**45,600**	**34.2**	**27.9**

[1]Saline/alkali, not as well drained as the other fields in this study.
[2]These fields were adjacent to fields tested during the previous year.
[3]Identical soil type to Field1, about 5 miles away.
[4]Applied water after emergence estimated by average furrow flow rates and set times minus runoff not recycled.
[5]Crop ET determined from weekly neutron probe soil moisture changes plus applied irrigation minus deep percolation.

SUMMARY – What did we learn?

- **STAND:** 35 to 40,000 plants to the acre provide top yield potential. Water up end Oct, 1st week Nov.
- **CROP ROTATION:** If you're following a cotton/wheat or cotton/cotton rotation then a standard N fertilizer program will probably work for you. If you're following garlic/onions, tomatoes, carrots or other highly fertilized veg crop, plan on soil sampling and cutting back on N fertilizer. Soil sampling is a good idea for either case to check the adequacy of P and K as well.

SUMMARY (continued)

- **FERTILITY:** Ensure plenty for early crop uptake. Where preplant soil tests show residual NO3-N greater than 250 lb/ac in the top 3 feet (20 ppm) use 25 to 40 lb/ac starter N only. Pay attention to early season phosphate. A little sidedress can help seedlings when it's cold, but usually not need later in the spring. K2O should be > 250 ppm, P2O5 > 25 ppm. Check soil again end of February. If NO3-N is still greater than 250 lb/ac, TKN in the top 2 feet > 3000 lb/ac (0.038%) and petioles NO3-N > 4,000 ppm then NO SIDEDRESS. Check petioles and, if NO3-N< 1000 ppm water run no more than 30 units N no later than April 10.
- **WATER:** Know system onflow and net applied inches. Monitor soil moisture status to schedule efficient irrigations. **Use a soil probe or Watermark blocks!** This will prevent premature cutout and leaching of nitrate that the crop needs during the big spring push. Most loam soils that don't "seal off" are good for a 2 to 3 week irrigation interval. Watermark Blocks with an AM400 logger provide inexpensive and accurate information for timing the onset of irrigation. 28 to 32" ET for Kern sugarbeets.
- **LUCK:** No Curly Top (the new high sugar varieties have NO resistance) and you own good dirt!!

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Upcoming Conferences and Workshops

Fertilizer Research and Education Program Conference
Topics: Fertilizer Use Efficiency and Nutrient Management
November 19, 2002
Edison Agtac – Tulare, CA
Call 916-653-5340 for Reservations

Mark Your Calendar!

Kern County Winter Irrigation Workshop
Topics: Well Head Protection, System Uniformity & Maintenance, Irrigation Scheduling Equipment & Grower Discussion Panel
December 5, 2002
Ag Pavillion – Bakersfield, CA
No Reservation Needed

Western Alfalfa & Forage Conference
Topics: Production, Irrigation, Pest Management, Varieties
December 11-13, 2002
Reno, NV
Call 530-752-0700 for Reservations