**Sugarbeet response to variable soil texture and salinity**

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In California, perennial crops increasingly are planted on better, more uniform soils, but the most responsive locations to site specific management likely will be fields with more marginal soils and greater variation, where lower valued field crops like sugarbeets are produced. Soil texture, salinity, or other limitations can influence crop yields in these fields. In general, crop responses in poor quality soils are less understood than on better soils, and can be erratic in response to management inputs. Precision management techniques might be of use to farmers, but their successful adoption is dependent on poorly characterized crop response. An assessment of field-scale variation and the characterization of crop response associated with this variation are first steps in evaluating the potential for variable rate technologies and other aspects of precision agriculture. As an initial attempt at site characterization, the response of sugarbeets to salinity and residual nitrogen was studied at sites in the Imperial and San Joaquin Valleys.

## Methods

Two farm fields were identified in regions of California which have saline soils and were planted to sugarbeets. One was in the Imperial Valley (IV) near Brawley, the other was in Kings County (KC) near Stratford in the San Joaquin Valley. The soils at both sites were clay loams (**Table 1**). The IV site was underlain with a series of tile drain lines at approximately 2m (6 feet) in depth. This 34 ha (83 acre) field was furrow irrigated. The KC site was located along the western edge of the old Tulare Lake bed and was underlain with tile drains at 1.1 m (4 feet). This 60 ha (143 acre) site was sprinkler irrigated. It lies in a region with some of the most saline and sodic soils used for crop production in California. Details about planting, harvest, and crop management are summarized in **Table 1**.

At both sites, bulk soil electrical conductivity ($EC_a$) was mapped directly in the field prior to planting using techniques and equipment developed at the U.S. Salinity Lab by Rhoades and his colleagues (Rhoades, et al., 1997). Both surface variation and salinity distribution within most of the root zone can be estimated using their electromagnetic induction (EM) methods (Hendrickx et al., 1992). Using a stochastic modeling approach (Lesch et al, 1995a,b), the correlation between $EC_a$ and $EC_e$ (the electrical conductivity of a saturation paste extract) or other correlated soil properties can be based on the analysis of a limited number of soil samples at selected locations. At the IV site 16 soil samples were taken to a depth of 2 m (6 feet), and composited at each site into four equal depths (45 cm or 18 inches). At the KC site 20 soil samples were taken to a depth of 120 to 150 cm (4 or 5 feet) at 30 cm (1 foot) intervals. The sites for sub-sampling were chosen using a multiple linear regression algorithm developed by Lesch et al., (1995a). Soil samples were analyzed for $EC_e$, SAR, saturation percentage (SP)--a measure of soil clay content, $NO_3$-N, bulk density, and Se and B using standard procedures. Soil bulk electrical conductivity and correlated data were analyzed using ESAP-95 v2.01R software developed by Lesch (2000) for the U.S. Salinity Lab. Additional analyses were performed using SAS, Inc.

**Results**

*The detection of manageable variation* (Imperial Valley). At the high end of the $EC_e$ range in this field (2.0 to 9.1 dS $m^{-1}$), sugarbeet yield was adversely affected as predicted (Maas, 1990). $EC_e$ was correlated with field position, (salinity was greater at the tail end of the field). Lower SP in the lower half of the profile was also correlated with lower salinity levels throughout the profile, except in locations at the tail end of the field, which received larger amounts of salts due to irrigation management. Nitrate was correlated with $EC_e$ at depth, but differences in residual profile $NO_3$-N content were largely irrelevant by harvest, with the result that profile residual $NO_3$-N differences did not appear to adversely affect sugar content in roots.

Average yields were much larger at the IV site and the variation in yield was much less than at the KC site (**Table 3**). Even at the higher $EC_e$ levels, the combination of crop tolerance and management resulted in relatively uniform yields with a narrower range. Sixty percent of the field had yields at or above the field average (**Table 3**). Based on the yield map and correlations among subplot harvests, the lowest yielding portions of the field were the most salt-affected areas towards the tail end of the field. But higher sugar concentration in these areas reduced the importance of root yield differences.

*(Kings County)*. The range of variation in $EC_e$ at the KC site was much larger (from 3 to greater than 24 dS $m^{-1}$). Beets tolerated the high $EC_e$ levels found in portions of this field because the use of sprinkler irrigation throughout the season likely maintained tolerable levels of salinity in at least the first two to three feet of the profile. Nonetheless, the performance of sugarbeets under such highly saline conditions was unexpected and exceeds their reported salinity tolerance (Maas, 1990). Similarly, the effects of large amounts of soil $NO_3N$ were minimized.

The management of difficult or marginal soils and crop response under such conditions is poorly understood. The correlations between root and sugar yield and SP were unexpected, but in retrospect can be understood by hypothesizing a relationship between soil drainage and chronic anoxic conditions in the root zone. Beets grew best where soils had lower SP, and where infiltration of irrigation water was greater and soils were (presumably) less anoxic. Root systems were able to develop. But even in the best parts of the field, root uptake of $NO_3N$ apparently was restricted sufficiently to allow beets to accumulate reasonably high sugar concentrations. The lack of a strong correlation between SP and $EC_e$ at this site reduced the value of field scale salinity assessment as an aid to management.

## Conclusions

1. Bulk soil electrical conductivity values were accurately mapped using the techniques of Rhoades et al. (1997). The close correlation between $EC_a$ and $EC_e$ has been observed repeatedly making this technique accurate and precise. It is also fast and relatively inexpensive, making it potentially useful for some precision agriculture applications.
2. Despite accurate mapping of field scale EC, the usefulness of this characteristic for sugarbeet management appears limited because the effects of soil physical and chemical properties are not easily altered. Also, the adverse effects of salinity on root yield were compensated by increased sucrose content in saline areas.
3. There appears to be potential to use EC mapping to identify variation in correlated soil properties like $NO_3$-N, especially deeper in the profile.

## References

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**Table 1. Field management information**

| | Imperial Valley (IV) | Kings County (KC) |
|---|---|---|
| *area (ac)* | 83 | 143 |
| *soil types* | Imperial-Glenbar silty clay loam and Imperial clay loam | Wellbank clay, Houser clay, (Pitco clay) |
| *planting date* | Sept. 19, 1998 | Nov. 5, 1998 |
| *harvest date* | May 22-23, 1999 | Sept. 9-15, 1999 |
| *irrigation method* | furrow | sprinkler |
| *fertilization (lb N /ac)* | 200 | 100 |

**Table 2. Soil property correlation matrix**

| IV | ln (CECa) | ln (ECe) | SP | ln (NO3) |
|---|---|---|---|---|
| *ln (CECa)* | 1.000 | 0.979 | 0.903 | 0.507 |
| *ln (ECe)* | | 1.000 | 0.802 | 0.451 |
| *SP* | | | 1.000 | 0.553 |
| *ln (NO3)* | | | | 1.000 |

| KC | ln (CECa) | ln (ECe) | SP | ln (NO3) |
|---|---|---|---|---|
| *ln (CECa)* | 1.000 | 0.982 | 0.262 | 0.719 |
| *ln (ECe)* | | 1.000 | 0.091 | 0.780 |
| *SP* | | | 1.000 | -0.296 |
| *ln (NO3)* | | | | 1.000 |

$EC_a$: bulk average electrical conductivity estimated from field survey data; $EC_e$: electrical conductivity, estimated from soil samples; SP: saturation percentage; NO3: nitrate. Correlations derived from the ESAP software (Lesch et al., 1995).

**Table 3. Yields, sucrose percent, and ranges observed at each location**

| | Imperial Valley (IV) | Kings County (KC) |
|---|---|---|
| *subplot mean yield (t/ac)* | 37.2 | 26.2 |
| *subplot range (t/ac)* | 31.2 to 44.4 (13.2) | 7.0 to 41.4 (34.4) |
| *subplot mean sucrose percent* | 17.8 | 16.7 |
| *subplot sucrose range (%)* | 16.4 to 19.1 (2.7) | 15.0 to 18.7 (3.7) |
| *subplot sugar yield (lb/ac)* | 13240 | 8670 |
| *subplot sucrose range (lb/ac)* | 11930 to 15820 (3690) | 2580 to 12660 (10,080) |
| *yield monitor mean (t/ac)* | 36.6 | 25.8 |
| *yield monitor range (t/ac) and* | 0 to 26 (3.0 ac) | 1 to 12 (14.8 ac) |
| *acres harvested within that* | 26 to 32 (2.1 ac) | 12 to 22 (32.6 ac) |
| *range* | 32 to 38 (13.9 ac) | 22 to 30 (49.4 ac) |
| | 38 to 44 (37.2 ac) | 30 to 38 (39 ac) |
| | 44 to 60 (14.2 ac) | 38 to 50 (11.2 ac) |