The Effects of Saline Soil, Irrigation, and Seed Treatments on Sugarbeet Stand Establishment

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ABSTRACT

Sugarbeet (*Beta vulgaris* L.) is among the most salt tolerant crops, but is reported to be less tolerant during germination and emergence. In trials in the western San Joaquin Valley and the Imperial Valley, The emergence of fall-planted sugarbeet seeds under a range of moderately saline conditions (2 to 10 dS m^{-1}) was studied. At electrical conductivity (EC_e) levels greater than 6.0 dS m^{-1} in a gypsum dominated soil in the San Joaquin Valley, rates of emergence and seedling dry weight were reduced, but not final stand counts. Priming seed before sowing reduced the effects of salinity on emergence rates and resulted in significantly larger seedlings in late fall. In the Imperial Valley, transient increases in soil salinity created by surface irrigation practices did not affect seedling emergence compared to sprinkler irrigation treatments with lower average EC_e. Imidicloprid increased seedling emergence and survival in the Imperial Valley but had no effect in the San Joaquin Valley.

Additional key words: *Beta vulgaris* L., imidicloprid, irrigation, salinity, seed priming, seed treatments, winter production

Sugarbeet is one of the most salt tolerant crops, but is reported to be less tolerant of salinity during germination, emergence, and in the seedling stage (Maas, 1986). Growers may have difficulty establishing adequate stands under saline conditions. A large portion of the western San Joaquin Valley (SJV) and parts of the Imperial Valley (IV) have some salinity limitations for crop production. In the western SJV, soils can be saline due to perched, shallow water tables, or to existing salts or both (Deveral and Gallantine, 1989). Furrow irrigation concentrates salts in the seed bed (Hanson, 1993). Electrical conductivity (EC_e) near the surface of flattened beds can increase up to seven times if water is applied in every furrow (Bernstein and Fireman, 1957). It changes with time, soil moisture content and plant growth (van Hoorn, 1991). In the IV, irrigation water deposits salts and irrigation practices can influence naturally occurring soil salinity (Rhoades et al., 1997). To counteract this problem, growers in the Imperial Valley may irrigate alternate furrows to move salt away from the seed line.

Sugarbeet is produced in both locations starting in autumn with harvest the following summer. Tolerant crops like sugarbeet can be produced successfully on moderately saline soils, or with saline irrigation water (Kaffka et al., 1999; Ayars et al., 1993) but problems with stand establishment may limit the use of these soil and water resources. If germination and emergence limit sugarbeet production where salinity occurs, it would be useful to have a better understanding of the emergence of sugarbeet seed under saline field conditions.

The objectives of this research were to evaluate rates of sugarbeet seed emergence when soils and irrigation water are moderately saline and to evaluate the use of selected seed protection and/or enhancement treatments to assess what influence they may have on enhancing or inhibiting emergence.

MATERIALS AND METHODS

Two field trials were conducted to assess the influence of soil and irrigation water salinity on sugarbeet emergence and seedling growth. One site was located in the IV, during September and October, 1997 at the UC Desert Research and Extension Center. The other was in the western SJV at the UC Westside Research and Extension Center, during October and November, 1997. Both trials were timed to coincide with farmers' normal planting times at these locations. Irrigation treatments were used to influence salinity in the seed zone. In the IV, plots were either furrow or sprinkler irrigated using water supplied by the Imperial Irrigation District (Table 1). Soil moisture during the emergence period was monitored using a time domain refractometer device (Theta meter HH1, manufactured by Delta T, Inc., Cambridge, England) and irrigation was applied as needed to maintain adequate levels of available water in the top three inches (7.5 cm) of the profile. Three furrow irrigations and five sprinkler irrigations were used over the thirty day period including emergence and development to the six

Table 1. EC_e in plots at the SJV site, 1997

Plot number	EC_W of irrigation water (dS m^{-1})	EC_e before irrigation (dS m^{-1})*	EC_e after irrigation (dS m^{-1})
9	0.4	1.5	2.3
10	6.7	7.9	9.8
12	0.4	2.1	1.8
14	0.4	5.3	5.0
15	6.7	7.1	10.1
16	6.7	4.4	8.1

to eight leaf stage. Two furrow irrigations were applied in the SJV. In the SJV, seeds were planted in plots with differing initial EC_e (Table 1). The plots were part of a larger group used for the study of crop response to soil and water salinity (Kaffka et al., 1999; Basil and Kaffka, 2002). Plots were selected from this larger group based on soil analyses from samples collected from the surface 30.5 cm (12 inches) of the plots in August prior to planting. To further increase pre-existing differences in salinity among the plots, some were irrigated with non-saline water from the Central Valley Project canal and others with moderately saline water from a nearby shallow well (Table 2). Seeds were planted approximately 2.1 cm (0.75 inches) deep. Soil samples were collected at a depth of 5 cm (0 to 2 inches) when emergence first began to estimate soil salinity conditions at the time of emergence. In the SJV, after emergence began, soils were sampled similarly to the IV to estimate salinity in the seed zone (Table 2). Values were determined on mixed, ground samples which integrate the salinity conditions of the entire soil area from the surface to 2.5 cm (1 inch) deep.

At both locations, six different seed treatments also were evaluated (Table 3). The same seed lot of SS-781R sugarbeet seed was used at both locations for all seed treatments. Film coated or encrusted seed coatings and insecticide and fungicide treatments were applied by Holly Hybrid Seeds (Sheridan, Wyoming). Pelleting, PAT treatments, and corresponding insecticide and fungicide were applied by Seed Systems, Inc, (Gilroy, California). Seeds were planted in rows with 100 seeds per row using a cone planter. Row length was 9.15 m (30 feet), and rows were 0.76 m (30 inches) apart. Two adjacent rows were planted with each seed treatment. Seed treatments were randomized within irrigation main plots at the IV location and within differing soil salinity plots at the SJV site. In the Imperial Valley, half the plots were also treated with

Table 2a. Water quality characteristics of irrigation water in the Imperial Valley.

Water Source	pH	ECw (dS m^{-1})	NO3-N (mg L^{-1})	B (mg kg^{-1})	Ca (meq L^{-1})	Mg (meq L-1)	Na (meq L^{-1})	SAR	ESP (%)	Cl (meq L^{-1})	SO4-S (meq L^{-1})	K sol (meq L^{-1})
Colorado River water	8.1	1.1	2.0	---	3.42	3.37	4.21	---	--	2.9	5.48	0.2

(Imperial Irrigation District data, 1997)

Table 2b. Mean water quality characteristics of the different types of irrigation water used at WSREC, 1997

Water Source	pH	ECw (dS m-1)	NO3-N (mg L-1)	B (mg kg-1)	Ca (meq L-1)	Mg (meq L-1)	Na (meq L-1)	SAR	ESP (%)	Cl (meq L-1)	SO4-S (meq L-1)	K sol (meq L-1)
CVP	---	0.4	< 0.5 (0.1)	Trace	1.1	1.0	1.7 (0.1)	2	2	0.04	0.3 (0.4)	0.18 (0.05)
Shallow	7.5	6.7 (0.3)	25.6 (1.6)	5.9 (0.3)	21.7 (0.4)	19.8 (0.6)	45.1 (1.7)	10	12	0.09 (0.02)	25.0 (0.84)	0.22 (0.01)

CVP: water taken form California's Central Valley Project, derived largley from the Sacramento River, a high quality source. Well water was taken from a nearby well, approximately 20 m deep. SAR: sodium absoprtion ratio. ESP: exchangeable sodium percentage. Standard deviations are reported in ().

Table 3. Seed treatments evaluated (SS781R)

Code	**Seed treatment**
C	Control (bare, processed seed)*
FC	Film coated
FC+I	Film coated + imidicloprid (45g a.i. per unit¶)
PAT	Primed (PAT treatment)
PAT+ T+I	Primed + imidicloprid + hymexazol (45g as formulated per unit)
PAT+ I	Primed + imidicloprid

* All seeds other than the control were treated with chloroneb and apron

metam sodium prior to planting to evaluate its effect on emergence. Metam sodium is a soil fumigant sometimes used by growers to control nematodes and soil insects.

Counting began at the first sign of emergence. All seeds emerging in the measured area were counted and labeled daily for the first seven consecutive days after emergence began, and every other day for the next 7 to 10 days, then less frequently until the 6 to 8 leaf stage was reached, 30 to 40 days after initial irrigation, depending on the location. Only newly emerged seedlings were counted each day. Any seedling dying after emergence was recorded, and the cause of mortality noted if possible. This method allows for an exact determination of the number of seedlings emerging, without underestimation due to post emergence losses (Durrant et al., 1988). At the SJV site, 20 seedlings from each plot were collected at the end of the trial by cutting them off at the soil level followed by drying. Dry weights were compared. Rates of emergence were estimated by determining the number of days to reach 50 % emergence using linear interpolation. All data were analyzed using SAS v 8.2 (2002). Both LSD and MSD (Tukey) tests were used to determine significance of seed treatments. The LSD test can result in a greater chance of a TYPE I error, determining a significant difference falsely. The MSD test has a reduced risk of a TYPE I error, but may obscure a real difference when one is present (TYPE II error) (Littel et al., 2002, page 60). The two tests provide complimentary information about significance.

RESULTS

In furrow irrigated plots in the IV, ECe averaged 10.1 dS m^{-1}, while in sprinkler-irrigated plots values were five times lower (2.0 dS m^{-1}). In the SJV location all plots were furrow irrigated and the ECe values in the most saline plots were approximately similar to those in the IV furrow irrigated plots (Table 1). At the IV site there was no significant effect from the use of metam sodium (p= 0.3410), so all results are reported for pooled treatments. There were no significant differences between the number of seedlings established 31 days after irrigation began (6 to 8 leaf stage) in furrow or sprinkler irrigated plots (Table 4). Most differences in emergence rates (days to 50 % emergence) between seed treatments were not significant. Encrusted or film coated seed (FC) emerged significantly slower than primed seed (PAT+I) based on the LSD test, but was not significantly different based on the Tukey (MSD) test. Use of imidicloprid (a systemic insecticide effective against aphids and flea beetles) resulted in significantly more seedlings established than in treatments without its use. The probability of a significant difference between the FC and PAT treatments and the FC+I and PAT+I treatments using a single degree of freedom contrast test was p<0.0001.

At the SJV site, sugarbeet establishment at 38 days after initial irrigation (approximately 6 to 8 true leaves), was not significantly affected by soil salinity (Fig. 1) or by irrigation treatment (using either saline or non-saline water, data not shown). Irrigation treatments were important only in so far as they affected salinity in the seed zone. Overall, days to 50% emergence (T_{50}) increased significantly

Table 4. Final establishment and days to 50% emergence in the Imperial Valley, 1997.

Seed Treatment	Plants with 4 to 6 true leaves (%)			Days to 50% emergence		
	furrow	sprinkler	ave.	furrow	sprinkler	ave.
C	45.3	44.5	44.9	5.53	5.75	5.54
FC	44.0	47.9	45.7	6.42	5.83	6.13
FC+I	53.0	51.6	52.5	6.50	6.33	6.42
PAT	44.0	54.3	49.6	5.83	5.58	5.78
PAT+T+I	68.5	63.5	66.0	5.58	5.92	5.75
PAT+I	77.0	74.0	75.5	5.58	4.92	5.25
LSD(0.05)			8.8			0.86
MSD(0.05)			13.6			1.29

at EC_e levels greater than approximately 6 dS m^{-1} (Fig. 2). Primed seed emerged slower when soils were saline, but at a greater rate than non-primed seed, approximately equaling the rate of non-primed seeds under non-saline conditions (Fig. 3). Plant dry weight was affected by EC_e levels greater than 6 dS m^{-1} as well (Fig. 4). There was an interaction between seed treatments and plant dry weight. Primed treatments were less affected by salinity than non-primed treatments. The primed seeds emerged faster (Fig. 3), and because day length and soil and air temperatures were declining in late October, faster emergence resulted in greater seedling dry weights under both sets of conditions (Fig. 4). Rates of decline in dry weight as salinity increased were similar for both

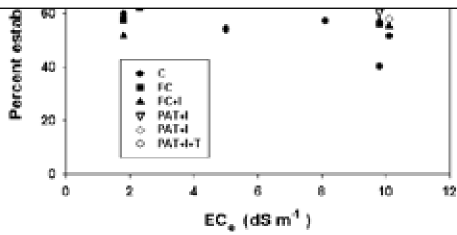

Fig. 1. Kaffka and Hembree

Fig. 1. Final establishment for different seed treatments in SJV trial. Open symbols are for primed treatments, closed symbols are not primed (see Table 3 for legend).

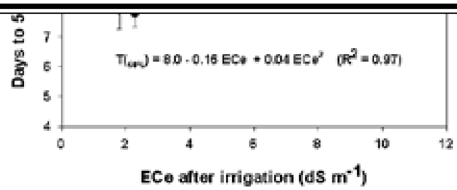

Fig. 2, Kaffka and Hembree

Fig. 2. Relation between average rate of emergence and ECe at WSREC. Error bars are standard errors.

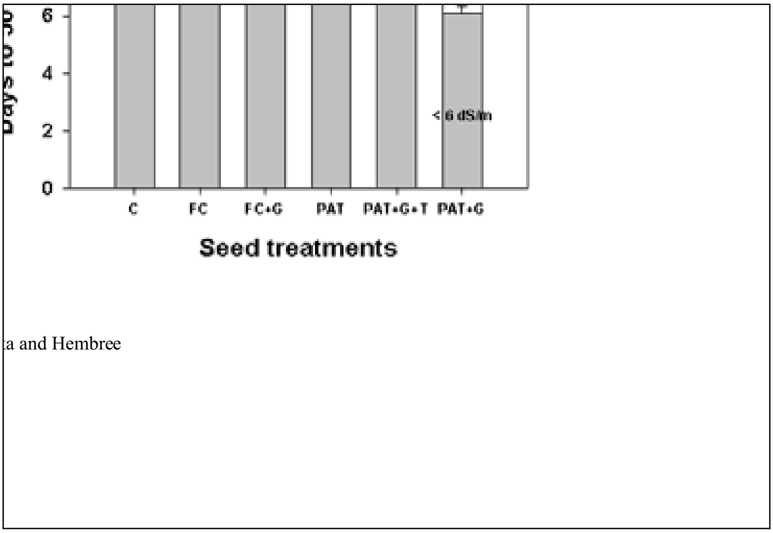

Fig. 3. Days to 50% emergence by seed treatment. Results are grouped by plots with $EC_W < 6.0$ (dark bars) and $EC_W \geq 6.0$ (clear bars). Error bars are standard errors.

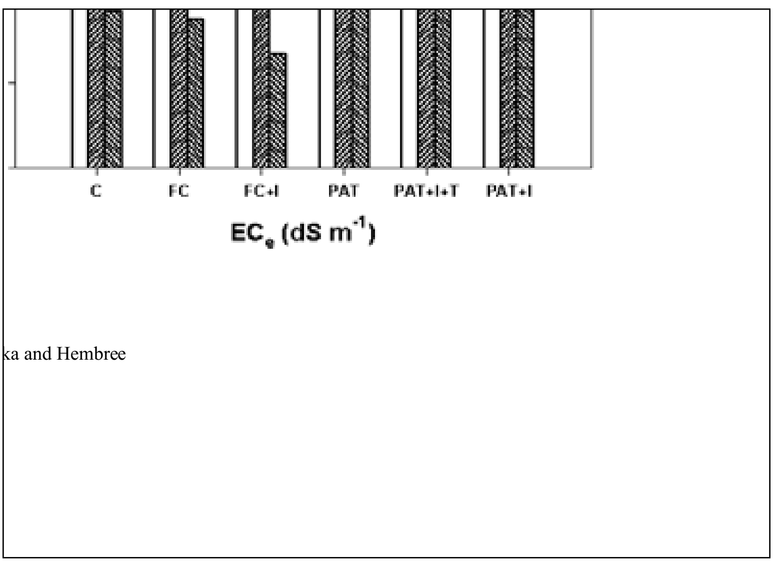

Fig. 4. Seedling dry weight as a function of seed treatment and soil EC_e at SJV site. Results are plotted for $EC_e < 6$ and $EC_e \geq 6.0$. Values from plots with $EC_e = 9.8$ and 10.1 are combined.

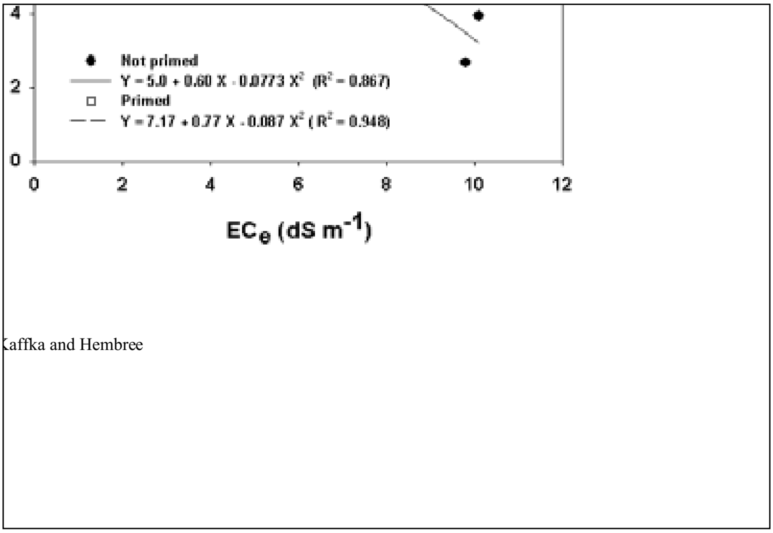

Fig. 5. Rates of dry weight decline as a function of increasing soil salinity. All primed seed treatment weights are averaged and compared to averages for non-primed seed treatments.

primed and non-primed seeds (Fig. 5).

DISCUSSION

Delayed seedling emergence can result from water stress and water stress results from increasing salinity (Ayers, 1952). Salinity levels of 6 to 12 dS m^{-1} were reported to delay and reduce emergence in sugarbeets (Maas, 1986). These observations were based for the most part on trials in which chloride type salts were mixed with soil or other media and these mixtures then used for emergence trials in pots or trays (Ayers, 1952). In our trials, salts were primarily of the sulphate type (gypsum dominated soils) rather than chloride type and seeds were planted in the field. Emergence was delayed at soil salinity greater than 6 dS m^{-1} but not significantly reduced at soil salinity levels up to approximately 10 dS m^{-1}. This was a greater tolerance to salinity than predicted. Sulphate type salts typically have less adverse effects on crops than chloride type salts (Ayers and Westcott, 1985). Seedling dry weight declined at the SJV site in response to increasing EC_e. In the fall, as day length and temperature declines, earlier emergence results in greater seedling weight.

Seed treatments which provide advantages under non-saline conditions, seem to provide similar advantages under saline ones as well. Primed seed in saline plots emerged at the same rate as non-primed seed in plots with low EC_e. Similar results were found with cotton (Shannon and Francois, 1977). Primed seed is advanced physiologically by exposure to water prior to planting (McDonald, 2000). This reduces the time needed after planting for re-imbibition of water and for the physiological events preceding germination.

There were no significant correlations between emergence and irrigation treatments at the IV site. Plots at that site had been treated uniformly prior to this experiment and initially were non-saline. The soil salinity differences observed were transient effects resulting from differences in irrigation method. When furrow irrigation is used on soils in arid regions, salts move with the water and concentrate near the center and surface of the bed (Bernstein and Fireman, 1957). Soil salinity continues to change with time since irrigation and soil moisture levels vary. Our sampling methods homogenized the surface 2 inches (5 cm) of soil, including salts deposited and crystalized on the soil surface by the movement of water. Mixing these samples overestimated the salinity of the seed zone. In non-saline or mildly saline soils furrow irrigation practices do not interfere measurably with emergence. In contrast, at the SJV site plots had been salinized for several years and soil samples reflected less transient soil conditions (Kaffka et al., 1999).

CONCLUSIONS

1. In the IV, transient differences in soil salinity in the surface two inches resulting from furrow irrigation did not affect final plant populations or rate of emergence in carefully irrigated plots. Metam sodium had no effect on emergence.

2. In soils at WSREC that had accumulated moderate amounts of predominantly magnesium and sodium sulphate salts, seedling dry weight and the rate of emergence declined at EC_e levels greater than 6 dS m-1. Final plant populations were not significantly affected by soil and water salinity.

3. The rate of emergence of primed seed in saline plots equaled that of unprimed seed in non-saline plots.

4. Seedling dry weight was reduced at EC_e greater than 6.0 dS m-1.

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