Preliminary results for the 2013/2014 HM Clause drip irrigation management under water deficit field trial

With the cooperation of HM Clause Seed Company, a field experiment was established to investigate and identify traits or collections of traits in tomatoes convey an advantage in crop performance under low water availability. The field trial consisted a number of production hybrids and 8 novel genotypes (introgression lines or ILs) that differ from a background cultivated tomato (e.g.the cultivars M82, E6203, or Hunt 100) by the incorporation of small segments of the chromosomes of a wild species (*Solanum pennellii*) through an extensive breeding program. The tomatoes were grown under a control or full irrigation treatment, or one of two deficit irrigations. The deficit irrigations consisted of a full season 20% of full irrigation treatment (conducted in 2013), and a terminal deficit of 20% of full irrigation (conducted in 2014). These deficit irrigation treatments represent the most commonly used approaches to irrigation management under drought in California processing tomatoes. The control treatment is representative of another common response of tomato growers in California under limited water availability – decrease planted acreage bur supply the full water needs of the crop.

As expected, experimental results showed that decreasing irrigation by 80% in 2013 resulted in lower yields, smaller fruit size, and greater amounts of variation in the yield measurements, compared to typical irrigation. The reduction in applied irrigation only produced a roughly 40-50% reduction in yield resulting in an increase in water use efficiency of roughly 2-3 times as well as increasing desirable fruit quality characteristics including sugar content under deficit irrigation. Some of the ILs (e.g., IL2-1, IL5-4, and the Sucrose IL) had lower rates of rotten fruit, sunburned fruit, and lower levels of blossom end rot than the background cultivars under both the control and deficit irrigation treatments. ILs with greater shoot biomass and canopy cover also tended to have greater sugar content than the background cultivars. Harvest index varied substantially among the ILs, and while a larger ratio of shoots to fruit enhanced sugar accumulation in the fruit, it was negatively associated with fruit size and harvest index. Preliminary results also suggested that a smaller canopy and lower shoot biomass (e.g., IL2-1) was associated with more stable photosynthetic rates throughout the growing season compared with larger genotypes.

Extreme spatial variation in soil properties within the 2013 field hampered efforts to analyze the production hybrid portion of the experiment and increased the variation among the introgression line genotypes as well. Additional analytical approaches were instituted to minimize the effects of the field variation on the experimental results. Development of analytical approaches will be a very useful outcome of this project, for general use in field trials that are testing genotypes and new production cultivars as many experimental fields are spatially heterogeneous.

Harvest-related measures for the 2013 field experiment included yield, sugar content, soil moisture, canopy cover, and shoot and fruit biomass as well as negative crop parameters including sunburn, rotten fruit, and fruit with blossom end rot (see Table 1). Differences were observed in many of these measurements between the introgression line genotypes and the background parental genotype. For example the prevalence of blossom end rot had a lower mean occurrence in the IL genotypes 2-1, 5-4, and 9-1 relative to the background M82 cultivar. However, the IL LA3965 had a higher prevalence than the background E6203 cultivar. Despite this higher rate of blossom end rot, LA3965 had greater yield than E6203 under both irrigation treatments.

Based on early results for the 2014 trial (full irrigation vs terminal deficit), IL9-1 and IL5-4 had much better yield under the terminal deficit treatment than was observed under the full season deficit. Thus, this study is showing traits pertinent to different irrigation strategies that are options for growers. Both IL5-4 and IL9-1 had greater yield than M82 under the control, but a similar amount under the deficit treatment, showing a ‘safe’ set of traits that permits spring planning for resilience in irrigation strategies. These two genotypes have much improved brix and lower rates of end rot than the background M82 genotype. The very low incidence of end rot under deficit irrigation was observed once again in the IL9-1 genotype and with the exception of M82, the other genotypes showed improvement in the incidence of end rot relative to 2013. Stomatal conductance rates were greater in all genotypes than was observed in 2013 under both treatments. Sap flow rates were much greater for the larger (IL5-4 and IL9-1) than the smaller (M82 and IL2-1) genotypes.

Analyses of the 2013 and 2014 seasons completed so far have shown that M82 has performed consistently across all treatments and years, and has the most stable yield of all the genotypes tested. This confirms why it has been a popular line for many years in regions prone to drought, as it is known for its earliness and determinate plant growth habit. Of the introgression line genotypes, IL9-1 is particularly interesting because it has a large canopy with high light interception and is able to maintain high photosynthetic and stomatal conductance rates even under water stress. Data from the 2014 experiment suggest that high sap flow rates from the roots contribute to the maintenance and photosynthetic activity of its extensive canopy. IL 9-1 also consistently had the lowest rates of blossom end rot and rotten fruit in addition to one of the highest brix (sugar) levels. This was true even under the stress of terminal drought. The low incidences of rotten fruit and blossom end rot are traits of great interest to plant breeders.

Altering irrigation management to a terminal season deficit produced very different results as compared to the full season deficit. The greater amount of water applied during the early part of the season, particularly during plant development and fruit set increased yields substantially for M82, IL5-4, and IL9-1. Shoot biomass and canopy cover were larger in the 2014 trial as well, regardless of irrigation treatment, suggesting that the terminal drought strategy may be an effective way to ‘hedge bets’ early in the season, to deal with the uncertainty of availability of late season water. This uncertainty has increased in California due to the combined effects of unknown precipitation during the winter and the depletion of reservoir and groundwater reserves during the summer.

Irrigation	100%		Drought (20%)		100%		Drought (20%)		100%				Drought (20%)			
Genotype	**E6203**	LA	**E6203**	LA	**Hunt100**	Sucr	**Hunt100**	Sucr	**M-82**	IL2-1	IL5-4	IL9-1	**M-82**	IL2-1	IL5-4	IL9-1
FRUIT QUALITY																
NTSS	6.18	5.57	6.96	6.66	6.53	7.48	7.20	***8.54***	5.60	5.06	6.28	6.50	5.89	6.12	***7.17***	6.85
S.E.	0.21	0.35	0.40	0.58	0.09	0.40	0.34	0.23	0.29	0.29	0.33	0.28	0.49	0.36	0.21	0.25
pH	4.55	4.47	4.60	4.57	4.59	4.52	4.65	***4.57***	4.38	***4.45***	4.37	4.42	4.42	4.43	4.38	4.41
S.E.	0.02	0.01	0.07	0.03	0.01	0.02	0.02	0.04	0.02	0.02	0.01	0.04	0.03	0.01	0.02	0.05
color (l)	24.90	25.35	25.19	***25.96***	24.33	24.70	24.54	***25.77***	24.80	25.03	***25.65***	24.86	24.74	***25.62***	***25.58***	25.17
S.E.	0.18	0.17	0.16	0.39	0.08	0.18	0.26	0.29	0.18	0.35	0.24	0.05	0.08	0.11	0.16	0.18
BIOMASS																
Shoot wt (kg dry)	0.22	0.18	0.14	0.11	0.28	0.26	0.19	0.19	0.17	0.15	***0.45***	***0.28***	0.11	0.10	***0.30***	***0.22***
S.E.	0.01	0.02	0.01	0.01	0.04	0.02	0.03	0.02	0.01	0.02	0.03	0.04	0.03	0.01	0.00	0.03
Yield (T/ha)	63.75	67.25	32.53	34.48	79.80	74.48	40.87	37.18	66.97	48.80	53.69	56.55	44.10	28.60	31.55	35.70
S.E.	8.01	6.78	4.70	5.28	13.41	5.34	10.88	4.54	6.56	4.50	6.95	10.14	6.21	3.25	1.67	3.63
End Rot (%)	6.13	2.72	10.80	12.30	3.21	2.50	9.38	3.97	3.91	1.37	2.09	1.49	5.66	***1.28***	4.18	***0.73***
S.E.	2.15	0.82	1.30	3.01	0.75	0.22	3.32	0.47	0.94	1.19	1.42	0.69	1.95	0.70	0.82	0.51
Sunburn (%)	1.69	2.28	2.73	2.77	1.46	4.26	4.05	3.20	1.88	1.45	1.40	1.20	1.43	1.22	1.42	0.82
S.E.	0.72	1.06	0.86	1.17	0.32	1.09	1.56	0.99	0.79	0.87	0.78	0.46	0.48	0.47	0.57	0.61
Rotten (%)	5.66	3.07	6.65	5.02	4.51	2.76	5.01	1.88	2.36	2.84	1.49	2.47	2.10	1.43	2.12	0.37
S.E.	1.91	1.21	1.71	2.07	0.90	0.41	1.39	0.24	0.78	0.92	0.87	0.94	1.03	0.57	0.39	0.21
Fresh Fruit wt (g)	69.38	63.75	48.39	50.68	44.50	***33.06***	39.08	30.96	42.63	44.45	48.40	***31.29***	41.56	34.13	32.75	***27.19***
S.E.	2.58	6.46	4.00	1.42	3.14	2.08	2.99	3.12	3.39	3.38	1.96	2.69	5.15	4.02	3.46	3.04
WUE (ton/cm)	2.72	2.87	7.46	7.91	2.87	2.68	7.71	7.01	2.86	***1.99***	***2.03***	***2.04***	10.11	***6.56***	***5.95***	***6.43***
S.E.	0.34	0.29	1.08	1.21	0.48	0.19	2.05	0.86	0.28	0.18	0.26	0.37	1.43	0.74	0.31	0.65

Table 1: Shown are the means and standard errors of the means for the 2013 season. Shaded columns represent the full irrigation treatment and white columns are the deficit treatment. Bolded and italicized indicate statistically different means with the irrigation treatment and the genotype group (E6203, Hunt100, or M82 groups).