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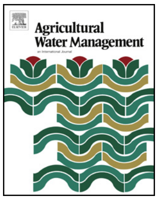

Yield production functions of irrigated sugarbeet in an arid climate

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ABSTRACT

Increased water demands and drought have resulted in the need to provide data to guide deficit water management decisions in irrigated sugarbeet (*Beta vulgaris* L.) production. The objective of this study was to quantify the yield response of sugarbeet to water input and actual crop evapotranspiration (ETa) on a soil type (silt loam) common to sugarbeet production in the Northwest U.S. These relationships are valuable to understanding sugarbeet response over a range of water availability and in developing tools to assess future production under water shortages. This paper consolidates data from three studies consisting of ten site-years from 2009 to 2016. The studies were at the USDA-Agricultural Research Service facility in Kimberly, ID on a Portneuf silt loam soil. Treatments consisted of varying levels of cumulative seasonal Kimberly-Penman ET model estimated crop evapotranspiration (ETc) rates ranging from rain-fed to 125% of ETc. Irrigation methods consisted of surface drip irrigation (3 site-years), linear/pivot overhead sprinkler (6 site-years), and solid-set sprinkler (1 site-year). Irrigation frequency was consistent for all studies with applications occurring 2–3 times per week depending on ETc demand. Estimated recoverable sucrose (ERS) yield and root yield were measured, and soil water contents were measured. Across all site-years, quantitative relationships between both actual crop ET (ETa) and water input, and sugarbeet yield and quality variables were developed. Significant (0.05 probability level) positive linear relationships were found between ETa and sugarbeet ERS and root yields ($r^2 = 0.78$). Estimated recoverable sucrose and root yields increased at rates of 19.4 kg ha^{-1} mm^{-1} ETa and 0.13 Mg ha^{-1} mm^{-1} ETa, respectively. When ETa depths of 719 and 729 mm were reached by the crop, root and ERS yields were maximized, respectively. When water input (irrigation + precipitation) depths of 598 and 605 mm were applied root and ERS yields were maximized, respectively. The quantitative relationships between both ETa and water input, and sugarbeet yields can be used to quantify sugarbeet production under deficit irrigation conditions (data derived from pivot/linear, drip, and solid set irrigation types), which may arise due to water shortage scenarios, or when drought occurs in non-irrigated areas.

1. Introduction

Increased water demand from agriculture and non-agricultural sectors, variable regional and seasonal precipitation, and increased irrigation costs have resulted in concerns about water supplies and availability for irrigation in arid Northwestern U.S. regions. As a result, science is being relied on to determine how to allocate limited water supplies. Water stress negatively affects plant physiology and metabolism (Zhu, 2002). The severity of water stress on plant function can range from mild to severe depending on the degree and extent of the stress (Jaleel and Llorente, 2009). Water deficits can limit growth and influence a host of physiological functions in plants to a greater extent than any other environmental factor (Cattivelli et al., 2008; Jaleel and Llorente, 2009). Thus, considerable research effort has been undertaken to improve crop production under deficit water conditions (Wang et al., 2003; Cattivelli et al., 2008).

Determining quantitative relationships between sugarbeet yields, and water input and water use variables is vital to develop tools to evaluate and guide sugarbeet deficit irrigation management decisions. In recent years numerous research studies have focused on developing these relationships in other crops such as corn (*Zea mays* L.), alfalfa (*Medicago sativa* L.), potatoes (*Solanum tuberosum* L.), dry bean (*Phaseolus vulgaris* L.), and spring wheat (*Triticum aestivum* L.) (Robins and Domingo, 1953; Benoit et al., 1965; Hanks et al., 1976; Barrett and Skogerboe, 1978; Gilley et al., 1980; Hill et al., 1982); Schneekloth et al., 1991; Stone, 2003; Klocke et al., 2004; Payero et al., 2006; Payero et al., 2008). Several studies have evaluated various effects of deficit irrigation in sugarbeets

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Table 1
Selected experimental and cultural information for irrigation types.

Study	Site-Years	ETc[†] Treatments % ETc	Other Treatment[§]	Previous Crops	Seeding Rate plant ha^{-1}	Fertilizer Recommendations	Plot Size m^2	Plot Harvest Area m^2
Solid Set	2009	R-F, 25, 50, 75, 100, 125	–	Barley	128,000	University of Idaho/Amalgamated Sugar Co.	29.7	10.2
Drip	2011, 2012, 2016	R-F[‡], 35, 65, 100	–	Barley	128,000	University of Idaho/Amalgamated Sugar Co.	29.7	10.2
Linear	2012, 2013, 2015	25, 50, 75, 100	ST, CT	Barley	128,000	University of Idaho/Amalgamated Sugar Co.	275.4	84.7

[†] ETc = ET estimated from the Kimberly-Penman ET model (Wright, 1982).
[‡] R-F = Rain-fed.%ETc for R-F treatments ranged from 5 to 12%.
[§] Other treatment included in analysis; ST = Strip Tillage, CT = Conventional Tillage.

Table 2
Average daily values of alfalfa reference evapotranspiration (ETr), minimum air temperature (T_{min}), maximum air temperature (T_{max}), average air temperature (T_{avg}), solar radiation (Rs), relative humidity (RH), and wind speed at 2-m height (μ_2) during site-year growing seasons in Kimberly, ID.

Year	Month	ETr	T_{min}	T_{max}	T_{avg}	Rs	RH	μ_2
		mm d^{-1}	°C	°C	°C	MJ m^{-2} d^{-1}	%	m s^{-1}
2009	April	4.2	1.3	14.0	7.6	20.8	61.1	3.2
	May	6.2	6.0	21.7	14.1	25.8	54.8	2.6
	June	6.1	10.2	23.3	16.5	23.9	68.0	2.3
	July	8.6	13.3	30.9	22.0	29.2	52.3	2.2
	August	6.6	11.2	28.6	19.9	23.7	55.0	2.0
	September	5.7	8.9	26.9	17.8	19.7	48.1	2.3
	October	2.5	1.2	13.2	6.9	12.8	70.1	2.7
	Average	**5.7**	**7.5**	**22.7**	**15.0**	**22.3**	**58.5**	**2.5**
2011	April	3.5	0.4	11.6	5.8	17.9	66.0	3.4
	May	5.0	4.4	17.0	10.5	21.5	65.5	3.0
	June	7.4	8.2	23.2	15.8	27.9	55.7	2.8
	July	8.5	12.7	30.1	21.5	29.3	48.7	2.0
	August	7.4	12.7	31.3	21.9	24.8	45.7	1.9
	September	5.7	8.5	27.2	17.8	20.3	47.3	2.1
	October	2.7	3.7	17.1	10.1	12.0	63.8	2.4
	Average	**5.8**	**7.2**	**22.5**	**14.8**	**22.0**	**56.1**	**2.5**
2012	April	5.1	3.0	18.3	10.6	21.7	50.3	3.2
	May	6.7	5.5	20.7	13.2	26.5	47.9	3.0
	June	8.7	8.8	25.9	17.9	29.8	42.0	2.7
	July	8.3	15.1	31.8	23.2	25.4	48.7	2.1
	August	7.7	12.7	31.6	22.1	22.6	44.5	2.2
	September	5.7	7.7	26.9	17.2	19.0	44.0	2.2
	October	3.3	2.1	17.5	9.7	13.1	51.8	2.4
	Average	**6.5**	**7.8**	**24.7**	**16.3**	**22.6**	**47.0**	**2.6**
2013	April	4.5	1.0	14.8	8.0	18.3	53.1	3.8
	May	6.3	5.7	21.5	13.8	22.1	48.6	3.1
	June	8.0	9.8	27.3	19.1	25.0	45.1	2.7
	July	8.6	14.2	33.2	23.9	23.3	43.1	2.2
	August	7.6	13.0	32.1	22.7	21.5	42.4	2.3
	September	4.8	9.9	23.8	16.5	14.7	60.2	2.7
	October	2.9	0.5	15.6	7.7	11.8	57.8	2.6
	Average	**6.1**	**7.7**	**24.0**	**15.9**	**19.5**	**50.1**	**2.8**
2015	April	4.9	1.1	16.5	8.9	19.6	47.5	3.6
	May	5.1	6.9	21.0	13.6	19.8	63.7	2.7
	June	8.1	12.3	29.6	21.4	25.5	46.6	2.3
	July	7.5	12.8	29.3	21.0	22.4	52.7	2.3
	August	6.7	12.1	29.9	20.9	19.8	50.4	2.2
	September	5.0	7.7	25.8	16.6	17.1	49.9	2.1
	October	3.1	5.8	20.7	12.8	11.3	63.1	2.3
	Average	**5.8**	**8.4**	**24.7**	**16.4**	**19.4**	**53.4**	**2.5**
2016	April	4.5	3.8	18.5	11.1	18.2	58.1	3.2
	May	5.5	5.9	20.6	13.2	21.7	59.9	2.8
	June	8.1	10.4	28.5	19.7	25.2	46.5	2.5
	July	8.5	11.6	30.7	21.5	26.0	43.1	2.3
	August	7.4	10.5	30.1	20.5	22.3	42.4	2.2
	September	4.4	7.8	22.3	15.0	15.3	58.0	2.5
	October	2.8	4.3	18.2	10.6	9.8	68.0	2.5
	Average	**5.9**	**7.8**	**24.1**	**16.0**	**19.8**	**53.7**	**2.6**