Early Harvest of Sugarbeet: Yield and Quality Response to Irrigation, Cultivar and Nitrogen

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ABSTRACT

A recent significant change in the sugar beet *(Beta vulgaris* L.) industry has been the adoption of an early harvest option in the grower-processor contract which allows harvest and delivery of sugar beets 30 days earlier than normal. This lengthens the harvesting period from 30 to 60 days or more. Management adjustments may be necessary for early harvested fields. The objectives of this study were: 1) to describe sugar beet yield and quality response to harvest date, and 2) to determine optimum management strategies for early versus normal harvest, with emphasis on irrigation, cultivar selection, and N rate. From 1986 to 1988, a total of three cultivars were established in experiments conducted at Powell, WY. Irrigation was either normally applied or discontinued four to six weeks prior to harvest. Ammonium nitrate was applied at rates ranging from 0 to 336 kg N ha^{-1}. Harvests were at 4 to 15 d intervals beginning 4 September and ending 19 October. Discontinuing irrigation increased sucrose content from 174 to 183 g kg^{-1}, but did not significantly affect root yield or recoverable sucrose. Significant irrigation treatment X harvest date interactions were observed for some sugar beet yield and quality traits during early harvest, but when all treatments were irrigated immediately prior to the last harvest date, no differences were observed between irrigation treatments for any trait. Depending upon location and year, cultivar differences were observed for yield and quality traits. Root yield increased with later harvest date 0.363 Mg ha^{-1} d^{-1}, sucrose content increased 8.94 g kg^{-1} d^{-1}, and brei impurities and sucrose loss to molasses decreased thereby improving quality. Under the management conditions of this study, few interactions with harvest date were observed. Management adjustments involving irrigation, cultivar, and nitrogen may not be necessary for early versus late harvested fields.

Additional Key Words: *Beta vulgaris* L., harvest management, sugar beet production, extended factory campaign, harvest premium.

A recent change in the sugar beet *(Beta vulgaris* L.) industry has been the adoption of an early harvest option in the grower-processor contract. To offset anticipated lower sugar beet yield and quality, growers usually receive a premium for beets harvested early. In many factory areas, harvest may begin four to six weeks earlier than normal, resulting in a loss of 20 to 35% in the recoverable sucrose potential (Carter et al., 1985; Hills et al., 1954; Nelson, 1969; Draycott et al., 1973).

Carter et al. (1985) concluded that earlier harvest would be preferable over late fall or early spring harvest in Idaho. Extended factory campaigns utilize processing equipment over a longer period attempting to get more use from the large capital investment incurred by growers and the sugar company. Growers with large acreage can decrease risk during harvest by lengthening the harvest season or owning less equipment. Date of sugar beet harvest may have considerable effect on irrigation strategy, cultivar selection, and nitrogen (N) rate.

In Idaho, discontinuing irrigation after filling the soil profile with water on 1 August resulted in little sucrose yield reduction (Carter et al., 1980a; 1980b). Discontinuing irrigation five to seven weeks prior to harvest resulted in lower root yields and higher sucrose content than irrigation until three weeks prior to harvest (Howell et al., 1987; Davidoff and Hanks, 1989). These responses to soil water deficits result from dehydration of the beet roots and do not increase sucrose yield (Carter, 1982; Miller and Hang, 1980). However, Winter (1990) demonstrated the potential for serious impurity problems with reduced irrigation, because of increased sucrose loss to molasses.

Recently some sugar beet cultivars have been promoted as high sugar content cultivars especially adapted for early harvest. N fertilizer rate affects the rate of sugar beet growth (Storer et al.,1973; Carter and Traveler, 1981). However, Halvorson and Hartman (1980) concluded that sucrose yield response was similar for all cultivars at the same N rate, and thus, growers need not vary N fertilizer rate for each sugar beet cultivar grown. Large cultivar differences in crown tissue production (Halvorson et al., 1978) and development rate may cause quality differences among cultivars, and thus, require different harvesting strategies.

The nitrogen rate most efficient for optimum sugar beet yield and quality is usually location specific and ranges from 56 to 179 kg ha^{-1}, but rates up to 364 kg ha^{-1} are applied in some locations (Carter and Traveller, 1981; Hills and Ulrich, 1976; Carter et al., 1976; Smith and Martin, 1977; James et al., 1978; Halvorson and Hartman, 1975; Anderson and Peterson, 1988; Adams et al., 1983; Winter, 1990). Total sucrose accumulation patterns in the roots are rather consistent for any particular N level, with the greatest rates of increase between late July and early September (Carter and Traveller, 1981). Date of harvest can have a considerable effect on optimum nitrogen rate (Hills and Ulrich, 1971).

Relatively little information is available on the interaction between harvest date and management practices such as irrigation, cultivar selection, and N rate. The objectives of this study were: 1) to describe sugar beet yield and quality response to harvest date, and 2) to determine optimum management strategies for early versus normal harvest, with emphasis on irrigation, cultivar selection, and N rate.

MATERIALS AND METHODS

Experiments were conducted on a Garland clay loam (fine, mixed, mesic Typic Haplargid) and on an Asherton-Bessler fine sandy loam (coarse loamy, mixed, mesic Ustollic Calciorthid) at Powell, WY during 1986. In 1987 and 1988, experiments were conducted at Powell, WY on the Garland soil. Soil characteristics and plot management of sugar beet experiments are shown in Table 1.

Soil test results indicated adequate levels of potassium, while phosphorus was applied at sufficient levels for root yields of 67.2 Mg ha^{-1} (Table 1). The study area was prepared for planting by moldboard plowing, roller harrowing, leveling, and corrugating. The sugar beet cultivars 'American Crystal Hybrid 164' (ACH 164), 'Holly Hybrid 30' (HH 30), and 'Hilleshog Mono-Hy R2' (MH R2) were planted at 126,000 seeds ha^{-1} with 56 cm between rows and thinned to 63,000 plants ha^{-1} by 20 June. ACH 164 had improved sucrose content characteristics and was recommended for early harvest, while HH 30 and MH R2 were standard cultivars for the factory district. In every year, aldicarb (2 methyl-2-[methylthio]propionaldehyde-*O*-[methylcarbamoyl]oxime) was applied at the rate of 11.2 kg ai ha^{-1}. Various combinations of the herbicides cycloate (S-ethyl cyclohexylethylcarbamothioate), desmedipham (ethyl[3-[[(phenylamino)carbonyl]oxy]phenyl] carbamate), diethatyl *(N*-(chloroacetyl)-*N*-(2,6-diethylphenyl)glycine), ethofumesate (±)-2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranyl methanesulfonate), and/or phenmedipham (3-[(methoxycarbonyl)amino]phenyl(3-methylphenyl) carbamate) were applied at recommended rates. In addition, plots were hand weeded to control escape weeds.

On each harvest date, one center 3.05 m row section of sugar beets within each plot was hand topped and lifted. The sampled row section

Table 1. Soil characteristics and plot management of sugar beet experiments grown from 1986 to 1988 at Powell, WY.

	Asherton-Bessler fsl	Garland cl		
	1986	1986	1987	1988
Previous crop	*Phaseolus vulgaris* L.	*P. vulgaris* L.	*Hordeum vulgare* L.	*P. vulgaris* L.
Upper soil depth (mm)	0-300	0-300	0-230	0-300
Organic matter (g kg^{-1})	15	25	11	12
pH (Saturated paste)	7.6	7.6	8.0	7.9
P (mg kg^{-1})	24	20	10	6
K (mg kg^{-1})	101	226	175	142
NO_3-N (mg kg^{-1})	6	20	1	9
Lower soil depth (mm)	300-600	300-600	230-1000	300-1000
NO_3-N (mg kg^{-1})	10	2	1	3
Planting date (day of the year)	100	115	119	111
Sugar beet cultivars	ACH 164 MH R2	ACH 164 HH 30	ACH 164 HH 30 MH R2	ACH 164 HH 30 MH R2
Furrow irrigation treatments (day of the year)†				
Irrigate 1	—	218, 230	216	223
Irrigate 2	—	218, 237	216, 230	—
Irrigate 3	—	218, 244	—	—
Control	—	218, 237, 251, 265	216, 230, 244, 260	223, 242, 266
Applied N rates (kg ha^{-1})	112, 136, 179	112, 179	112, 140, 168 224, 336	0, 72, 128, 184, 240, 296
Harvest dates (day of the year)	247, 253, 258, 262, 267, 274	248, 258, 268, 279	251, 259, 265, 272, 279, 292	259, 264, 271, 277, 292

† All irrigation treatments on the Garland clay loam were furrow irrigated on (day of the year):
1986: 121, 178, 190, 204
1987: 121, 183, 201, 209, 280
1988: 121, 142, 181, 191, 201, 211, 278

was bagged and measured for tare, root fresh mass, sucrose content and purity parameters by The Western Sugar Company in Billings, MT. Brei samples were frozen and later analyzed for sodium (Na) and potassium (K) by flame photometry (William, 1984), and amino-N by ninhydrin procedures (Quinn, 1974; Lawrence and Grant, 1963). Sucrose loss to molasses was calculated using a modified Carruthers and Oldfield (1960) procedure.

On the Asherton-Bessler soil, the experimental design was a randomized complete block in a split-plot arrangement with three replications. Main-plots were cultivars, and split-plots were a three by six factorial of N rates and harvest dates (Table 1). On the Garland soil, the experimental design was a randomized complete block arranged in a split-split plot design with plots harvested and measured over time. Three replications were established in 1986 and four replications in 1987 and 1988. Main plots were irrigation treatments. Irrigation was discontinued three to seven weeks prior to the beginning of early harvest. In 1987 and 1988, all irrigation treatments were irrigated on dates 280 and 278, respectively (Table 1). Split-plots were cultivars established in plots measuring 6.7 by 68.6 m. Split-split-plots were N rates in plots measuring 3.4 by 22.9 m. Various N rates were applied by broadcasting ammonium nitrate (34-0-0) and pre-plant incorporating with a roller harrow.

Data were analyzed by SAS (1985) analysis of variance or general linear models procedures. For the 1986 and 1987 Garland soil experiments, two separate analyses were performed. In 1986, irrigation effects were measured only on harvest date 258. In 1987, irrigation effects were measured on harvest dates 265, 272, 279, and 298. Irrigation main effects and interactions between irrigation and cultivar, N rate, or harvest were analyzed by year. For 1986 and 1987, a separate analysis using only the control irrigation was performed to address cultivar, N rate and harvest date main effects and interactions. Treatment mean comparisons were made using least significant difference when F values were significant ($P \leq 0.05$).

RESULTS AND DISCUSSION

Three-way and four-way interactions were not significant in any experiment. Two-way interactions were significant, however, they were not consistent between experiments (Tables 2 to 7). Irrigation treatment, cultivar, N rate and harvest date main effects were usually significant and consistent trends among years were observed. Normal harvest typically begins on 1 October (day of the year = 274). Averaged across environment, root yield increased 0.363 Mg ha^{-1} day^{-1} during the

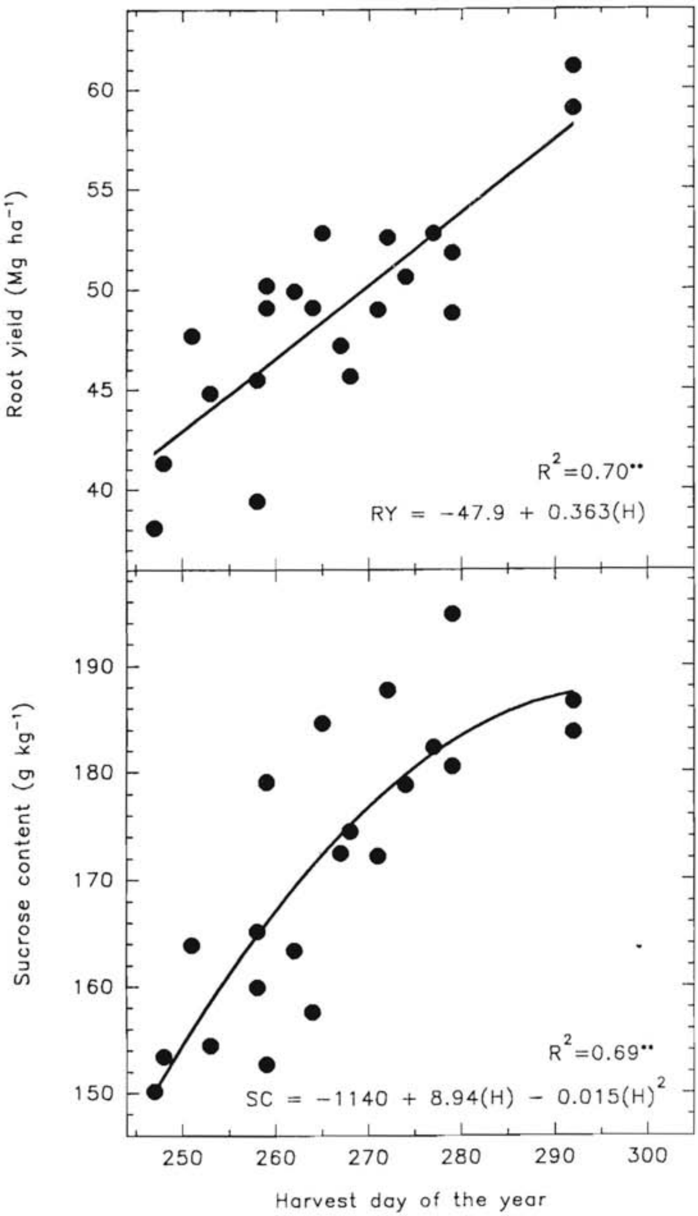

Figure 1. Root yield and sucrose content versus harvest date of the control irrigation treatment on sugarbeet grown at Powell, Wyoming during 1986 to 1988. Data are combined across cultivar and nitrogen treatments.**Significant at the 0.01 probability level.

months of September and October (Figure 1). During this same period, sucrose content increased at the rate of 8.94 g kg^{-1} day^{-1} with the rate of change decreasing during later harvest. Irrigation treatment had no effect on sugar beet root yield during 1986 (Table 2). Sucrose content of sugar beet was lower for the control irrigation treatment than for treatments 1 and 2, which discontinued irrigation for 28 and 21 days prior to harvest, respectively. No difference in sucrose content was observed between the control irrigation treatment and treatment 3 where irrigation was discontinued for 28 days and then plots were irrigated 14 days prior to harvest. Likewise, irrigation had no effect on root yield during 1987 (Table 5). Brei-Na, brei-K, brei-amino N, and sucrose loss to molasses were not affected by irrigation treatment. Sucrose content increased from 188 to 192 g kg^{-1} when irrigation was discontinued prior to harvest. Irrigation treatment had no effect on root yield, brei-Na, and recoverable sucrose during 1988 (Table 7). Sucrose content increased from 170 to 176 g kg^{-1} when irrigation was discontinued prior to harvest. The discontinued irrigation treatment decreased brei-K, brei-amino N, and sucrose loss to molasses by 6 to 9 percent.

Table 2. Effect of irrigation on sugar beet yield and sucrose content on a Garland clay loam during 1986. Plots were harvested on date 258. Values are combined across cultivar and N rate.

Irrigation treatment	Root yield	Sucrose[†] content
	Mg ha^{-1}	g kg^{-1}
Irrigate 1	46.2	179
Irrigate 2	43.5	181
Irrigate 3	43.7	164
Control	45.5	165
ANOVA		
Irrigation (I)	NS	**
I X Cultivar	NS	NS
I X N	NS	NS

*,** Significant at the 0.05 and 0.01 probability levels; NS = Nonsignificant
[†] Grams of sucrose per kilogram of fresh roots.

Table 3. Effect of cultivar, N, and harvest date on sugar beet yield and sucrose content on a Garland clay loam during 1986. Cultivar, N, and harvest date values only include observations from the control irrigation treatment.

Main effect	Root yield	Sucrose† content
	$Mg\ ha^{-1}$	$g\ kg^{-1}$
Cultivar		
ACH 164	40.2	168
HH 30	50.4	168
N rate ($kg\ ha^{-1}$)		
112	43.7	167
179	46.6	169
Harvest (day of the year)		
248	41.3	153
258	45.5	165
268	45.7	175
279	48.8	181
ANOVA		
Cultivar (C)	*	NS
N	NS	NS
N_{linear}	—	—
$N_{quadratic}$	—	—
C X N	NS	NS
Harvest (H)	**	**
H_{linear}	**	**
$H_{quadratic}$	NS	**
$H_{residual}$	NS	**
C X H	NS	**
N X H	NS	NS

*,**1 Significant at the 0.05 and 0.01 probability levels; NS = Nonsignificant

† Grams of sucrose per kilogram of fresh roots.

Table 4. Effect of cultivar, N, and harvest date on sugar beet yield and sucrose content on an Asherton-Bessler fine sandy loam during 1986.

Main effect	Root yield	Sucrose[†] content
	$Mg\ ha^{-1}$	$g\ kg^{-1}$
Cultivar		
ACH 164	42.8	167
MH R2	46.9	159
N rate ($kg\ ha^{-1}$)		
112	44.9	165
136	46.1	162
179	43.8	162
Harvest (day of the year)		
247	38.1	150
253	44.8	154
258	39.4	160
262	49.9	163
267	47.2	172
274	50.6	179
ANOVA		
Cultivar (C)	NS	*
N	NS	*
N_{linear}	NS	*
$N_{quadratic}$	NS	NS
C X N	NS	NS
Harvest (H)	**	**
H_{linear}	**	**
$H_{quadratic}$	NS	*
$H_{residual}$	**	**
C X H	NS	*
N X H	NS	NS

*,** Significant at the 0.05 and 0.01 probability levels; NS = Nonsignificant

† Grams of sucrose per kilogram of fresh roots.

Significant irrigation treatment X cultivar interactions were observed for root yield and recoverable sucrose during 1988 (Table 7). HH 30 and MH R2 produced root yields of 56 and 57 Mg ha^{-1}, respectively, under the control irrigation treatment, which decreased to 55 and 51 Mg ha^{-1}, respectively, when irrigation was discontinued (data not shown). Meanwhile, ACH 164 produced root yields of 43 Mg ha^{-1} under control irrigation treatments, which increased to 45 Mg ha^{-1} when irrigation was discontinued. ACH 164 and HH 30 produced recoverable sucrose yields of 7.3 and 9.1 Mg ha^{-1}, respectively, under the control irrigation treatment, which increased to 7.9 and 9.3 Mg ha^{-1}, respectively, when irrigation was discontinued. In contrast, MH R2 produced recoverable sucrose yields of 9.6 Mg ha^{-1} under the control irrigation treatment, which decreased to 8.9 Mg ha^{-1} when irrigation was discontinued. These interactions were not expected, and are not readily explained. Few consistent interactions were observed between cultivar and other management factors.

Irrigation treatment X N rate interaction was significant for recoverable sucrose during 1987 (Table 5). Under the control irrigation treatment, increasing N rate from 112 to 336 kg N ha^{-1} increased recoverable sucrose from 7.6 to 10.2 Mg ha^{-1} (data not shown).

Table 5. Effect of irrigation on sugar beet yield and quality on a Garland clay loam during 1987. Values include all observations from harvest dates 265 to 292 and are combined across cultivar, N rate, and harvest date.

Irrigation treatment	Root yield	Sucrose† content	Brei impurities Na	K	Amino-N	Sucrose loss† to molasses	Recoverable sucrose
	Mg ha^{-1}	g kg^{-1}	—— mg kg^{-1} ——			g kg^{-1}	Mg ha^{-1}
Irrigate 1	51.2	192	137	922	108	5.19	8.93
Irrigate 2	55.4	192	108	864	96	4.71	9.60
Control	54.1	188	115	961	99	5.11	8.95
ANOVA							
Irrigation (I)	NS	*	NS	NS	NS	NS	NS
I X Cultivar	NS	NS	NS	NS	NS	NS	NS
I X N	NS	NS	NS	NS	NS	NS	*
I X Harvest	NS	*	—	—	—	—	—

*,** Significant at the 0.05 and 0.01 probability levels; NS = Nonsignificant

† Grams of sucrose per kilogram of fresh roots

Table 6. Effect of cultivar, N rate, and harvest date on sugar beet yield and quality on a Garland clay loam during 1987. Values are observations from the control irrigation treatments.

Main effect	Root yield	Sucrose[†] content	Brei impurities Na	K	Amino-N	Sucrose loss[†] to molasses	Recoverable sucrose
	$Mg\ ha^{-1}$	$g\ kg^{-1}$	—— $mg\ kg^{-1}$ ——			$g\ kg^{-1}$	$Mg\ ha^{-1}$
Cultivar							
ACH 164	49.9	187	127	891	94	4.86	8.47
HH 30	55.6	180	123	1001	103	5.33	9.30
MH R2	51.6	181	96	990	100	5.13	9.08
N rate ($kg\ ha^{-1}$)							
112	47.5	186	85	884	70	4.34	7.63
140	48.1	183	97	1010	96	5.16	7.77
168	52.5	185	123	988	96	5.20	9.45
224	55.9	181	114	951	97	5.05	9.72
336	57.9	179	159	970	133	5.79	10.17
Harvest (day of the year)							
251	47.7	164	—	—	—	—	—
259	50.2	179	—	—	—	—	—
265	52.8	185	—	—	—	—	—
272	52.6	188	—	—	—	—	—
279	51.8	195	115	961	99	5.11	8.95
292	59.0	187	—	—	—	—	—
ANOVA							
Cultivar (C)	**	*	NS	NS	NS	NS	NS
N	**	*	NS	NS	NS	NS	**
N_{linear}	**	**	*	NS	*	NS	**
$N_{quadratic}$	*	NS	NS	NS	NS	NS	NS
$N_{residual}$	NS	NS	NS	NS	NS	NS	NS
C X N	NS	NS	NS	NS	NS	NS	NS
Harvest (H)	**	**	—	—	—	—	—
H_{linear}	**	**	—	—	—	—	—
$H_{quadratic}$	NS	**	—	—	—	—	—
$H_{residual}$	**	**	—	—	—	—	—
C X H	NS	NS	—	—	—	—	—
N X H	NS	NS	—	—	—	—	—

*,** Significant at the 0.05 and 0.01 probability levels; NS = Nonsignificant

[†] Grams of sucrose per kilogram of fresh roots

Table 7. Effect of irrigation, cultivar, N rate, and harvest date on sugar beet yield and quality on a Garland clay loam during 1988.

Main effect	Root yield	Sucrose† content	Brei impurities Na	K	Amino-N	Sucrose loss† to molasses	Recoverable sucrose
	Mg ha^{-1}	g kg^{-1}	—— mg kg^{-1} ——			g kg^{-1}	Mg ha^{-1}
Irrigation treatment							
Irrigate 1	50.3	176	315	1190	117	7.08	8.71
Control	52.2	170	339	1270	128	7.60	8.71
Cultivar							
ACH 164	44.2	177	368	1130	101	6.92	7.64
HH 30	55.6	169	360	1330	135	8.00	9.22
MH R2	54.0	173	256	1230	132	7.12	9.25
(kg ha^{-1})							
0	47.4	174	255	1170	91	6.40	8.39
72	50.0	174	271	1180	104	6.64	8.54
128	52.2	174	308	1220	120	7.18	8.89
184	53.5	173	388	1300	132	7.98	8.92
240	53.0	172	355	1250	139	7.76	8.98
296	51.4	171	392	1270	153	8.17	8.57
Harvest (day of the year)							
259	47.9	158	—	—	—	—	—
264	49.8	163	423	1440	133	8.65	7.64
271	47.4	176	367	1450	120	8.26	7.95
277	50.0	183	247	910	116	5.78	8.86
292	61.0	184	255	1080	122	6.48	10.79
ANOVA							
Irrigation (I)	NS	*	NS	*	*	**	NS
Cultivar (C)	**	**	**	**	**	**	**
I X C	*	NS	NS	NS	NS	NS	*
N	**	**	**	*	**	**	NS
N_{linear}	**	**	**	**	**	**	NS
$N_{quadratic}$	NS	*	NS	NS	**	*	NS
$N_{residual}$	NS	NS	NS	NS	NS	NS	NS
I X N	NS	NS	NS	NS	NS	NS	NS
C X N	NS	NS	NS	NS	NS	NS	NS
Harvest (H)	**	**	**	**	**	**	**
H_{linear}	**	**	**	**	NS	**	**
$H_{quadratic}$	**	**	**	**	**	**	*
$H_{residual}$	*	**	**	**	NS	**	NS
I X H	*	**	NS	NS	NS	NS	**
C X H	NS	NS	NS	NS	NS	NS	NS
N X H	NS	NS	NS	NS	NS	NS	NS

*,** Significant at the 0.05 and 0.01 probability levels; NS = Nonsignificant

† Grams of sucrose per kilogram of fresh roots

When irrigation was withheld, recoverable sucrose increased from 8.6 to 10.1 Mg ha^{-1} as N rate increased from 112 to 224 kg N ha^{-1}, but then decreased to 9.4 Mg ha^{-1} with 336 kg N ha^{-1}.

Irrigation treatment X harvest date interaction was significant for root yield and recoverable sucrose during 1988 (Table 7), and for sucrose content during 1987 and 1988 (Tables 5 and 7). As the harvest season progressed, root yield and recoverable sucrose was slightly lower for the discontinued than the control irrigation (data not shown). During this time sucrose content increased more for the discontinued irrigation treatments than the control irrigation. After all the plots were irrigated on date 278 and then harvested on date 292, no difference was observed between irrigation treatments for root yield, sucrose content, and recoverable sucrose.

Usually ACH 164 had greater sucrose content, and lower brei impurities and sucrose loss to molasses than HH 30 and MH R2 (Tables 3, 4, 6 and 7). However, ACH 164 root yield was always lower than HH 30 and MH R2, and thus, resulted in lower recoverable sucrose (Tables 6 and 7).

Cultivar X harvest date interactions were significant for sucrose content during 1986 (Tables 3 and 4). On the Garland clay loam, ACH 164 and HH 30 had similar sucrose contents throughout harvest, except on harvest date 279 when HH 30 had greater sucrose content (data not shown). On the Asherton-Bessler fine sandy loam, ACH 164 had greater sucrose content than MH R2 on all harvest dates, except on harvest date 253 when it was equivalent to MH R2.

Relatively little response to N rate was observed in all experiments. Increasing N rate from 112 to 179 kg ha^{-1} had no effect on root yield during 1986 on either the Garland clay loam or the Asherton-Bessler fine sandy loam (Tables 3 and 4). Sucrose content decreased slightly with increasing N rate on the Asherton-Bessler fine sandy loam (Table 4). Increasing N rate from 112 to 336 kg ha^{-1} increased root yield, brei-Na, brei-amino N, and recoverable sucrose, but decreased sucrose content during 1987 (Table 6). Root yield increased from 47.4 Mg ha^{-1} at 0 kg N ha^{-1} to a maximum of 53.5 Mg ha^{-1} at 184 kg N ha^{-1} and then decreased to 51.4 Mg ha^{-1} at 296 kg N ha^{-1} during 1988 (Table 7). Increasing N rate from 0 to 184 kg N ha^{-1} increased brei-K to its highest level. Increasing N rate from 0 to 296 kg N ha^{-1} linearly increased brei-Na, while both linear and quadratic increases were observed for brei-amino N and sucrose loss to molasses. Sucrose content decreased in a linear fashion with increasing N.

In every experiment, root yield and sucrose content increased in a linear or sometimes quadratic fashion with later harvest date (Tables 3, 4, 6 and 7). Depending upon year, root yield increases of 15 to 25 percent, with an average of 20 percent, were observed during harvest (derived from Tables 3, 4, 6, and 7). Sucrose content increases of 12 to 16 percent, with an average of 14 percent, were observed as harvest date was delayed. In 1988, brei impurities and sucrose loss to molasses tended to decrease, while recoverable sucrose increased with later harvest date (Table 7). A slight increase in brei impurities was observed on the last harvest date due to good October growing conditions and complete irrigation of all treatments in the study on date 278.

Root yield and sucrose content are currently the most important parameters used in calculating grower payments for most factory districts of the western U.S. Root yield and sucrose content were affected by irrigation treatment, cultivar selection, N rate, and harvest date. Few consistent interactions among treatments were observed for these measurements.

Management that optimized beet quality by increasing sucrose content, and decreasing brei impurities and sucrose loss to molasses, would usually result in lower root yield. For example, discontinuing irrigation consistently increased sucrose content, decreased brei impurities and sucrose loss to molasses, but also decreased root yield (Tables 6 and 7). Discontinuing irrigation had no effect on recoverable sucrose for any harvest. Consistent with observations in Idaho, there was little if any effect on recoverable sucrose when irrigation was discontinued 1 August after the soil profile was filled with water (Carter, 1982; Carter et al., 1980).

Lower rates of N consistently produced greater sucrose content and lower brei impurities and sucrose loss to molasses than high rates of N, but root yield was also usually lower (Tables 6 and 7). One cultivar consistently had greater sucrose content, and lower brei impurities and sucrose loss to molasses, but it also had lower root yield and recoverable sucrose. This study was established on fields with low initial soil N availability, and a cultivar X N rate interaction was expected (James et al., 1978). However, no cultivar X N rate interaction was observed for yield and quality measurements in any experiment. This observation supports the conclusions of Halvorson and Hartman (1980) that sugar beet producers need not vary N rates for each sugar beet cultivar grown. However, it is in contrast to the observations of James et al. (1978), who found significant cultivar X N rate interactions.

Later harvest date was the only management factor from which both root yield and quality consistently improved resulting in greater recoverable sucrose. Later harvest date resulted in greater root yield and sucrose content than earlier harvest. Brei impurities and sucrose loss to molasses were lower during later harvest. Recoverable sucrose increased 29 percent over a 32 d harvest period. Burcky and Winner (1986) observed recoverable sucrose increases of 9 to 39 percent over a harvest period of 43 days.

Only harvest date X irrigation treatment interactions were consistently significant. These were usually due to differences on harvest dates where water was withheld. When the soil profile was refilled with water no differences for any yield or quality parameters were observed on the subsequent harvest.

Few consistent cultivar X harvest date or N rate X harvest date interactions were observed, indicating that cultivar and N rate decisions for early harvest fields should be similar to late harvest fields. This observation is contrary to the recommendation of Hills and Ulrich (1971) that N rate should be decreased 11 kg ha^{-1} $week^{-1}$ prior to the start of normal harvest. The management of these fields was typical of the grower management currently used for sugar beet production in northwest Wyoming and southern Montana. No attempt was made to monitor the amount of irrigation water applied to these study areas. Significant amounts of nitrogen may be lost from this furrow irrigated production system earlier in the growing season. Tendencies were observed which may suggest that decreasing N rate may increase sugar beet quality for early harvest dates and thus translate into economic advantages, although no significant agronomic interaction for any measurement was observed in these experiments. Thus, adjustment in the management factors evaluated in this study was not necessary between early and late harvested fields. Changes in irrigation management may warrant changes in nitrogen and harvest date management.

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