Yield and Quality as Affected by Early and Late Fall and Spring Harvest of Sugarbeets*

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INTRODUCTION

Sugarbeets (*Beta vulgaris* L.) in the intermountain areas of the western United States are normally planted in early spring and harvested during October with the advent of cool temperatures. The beet roots during this harvesting period are near their maximum yield and sucrose concentration. Temperatures are cool and suitable for storing excess roots in piles for later processing. The factory processing of beet roots is presently limited to the period between harvest and mid-February after which stored roots in piles deteriorate rapidly in quality with increased temperatures (2, 10, 16, 17).

The closing of some sugar factories, and low prices currently received for other crops, has intensified demand by farm managers for increased acreage allotment for sugarbeets. Present low world sugar prices and the uncertainty of continued sugar legislation discourages the expansion of the cutting and processing facilities in factories. Methods and procedures are needed to increase the tonnage of beet roots that can be processed using existing equipment and facilities.

The objective of this study was to evaluate methods and procedures where factories can increase the amount of beet roots processed with existing equipment by methods such as early and late fall and spring harvest of

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sugarbeets.

MATERIALS AND METHODS

Two irrigated field experiments were conducted on Portneuf silt loam soil (Durixerollic Calciorthids, coarse-silty, mixed, mesic) near Twin Falls, Idaho, in the 1982-83 and 1983-84 seasons. The soil has a weakly cemented hardpan at the 50- to 60- cm depth that has little effect on water movement when saturated but may restrict root penetration. The areas used were deficient in nitrogen (N) and phosphorus (P) and required 56 kg P/ha (15) and 224 kg N/ha (7) for an expected maximum yield of 63 metric tons/ha of beet roots. The N and P fertilizers were applied as a broadcast application and incorporated with the upper 10 cm of soil as the seedbed was prepared.

Four replications involving four irrigation levels as main plots and three commercial hybrid cultivars as subplots were used in the 1982-83 season. Three of these replications received no further treatment; whereas one replication of each treatment was used as a covered plot during the winter months. During the 1983-84 season, four replications of a split-plot design with twelve winter cover treatments as main plots, and two commercial hybrids as subplots, were used. Each plot area was 8.9 by 12.2 m in 1982-83 and 8.9 by 11.0 m in the 1983-84 season.

Three hybrids (AH-10, WS-76, and GWD2) were planted in 16 row plots on 23 April 1982 and two hybrids (WS-76 and WS-88) in 16 row plots on 18 April 1983. All hybrids were planted in 56-cm rows that had previously been marked and treated with aldicarb at 2.24 kg of active ingredient per hectare to control insects. The sugarbeets were thinned to a 23-30-cm within row spacing in early June.

Four alternate row furrow irrigation levels M_1, M_2, M_3 and M_4 were used during the 1982 season and the M_1 irrigation treatment during the 1983 season. The irrigation treatments were as follows:

M_1 - Adequate irrigation based on previous experiments. Irrigation dates were based on estimated soil moisture depletion (12) and irrigation duration depended on the amount to be applied.

M_2 A light irrigation (50 mm) was applied on 1 September after the soil profile was filled with water on 1 August. Irrigations were the same as M_1 before 1 August.

M_3 No irrigation was applied after the soil profile was filled with water on 1 August. Irrigations were the same as M_1 before 1 August.

M_4 No irrigations after the soil profile was filled with water on 19 July. Irrigations were the same as M_1 before 19 July.

The soil water content in the 0- to 20- cm depth was determined gravimetrically from 9 November 1982 to 15 April 1983. One access tube located within the row in each hybrid and moisture treatment and a calibrated neutron probe were used to measure soil moisture in the 20- to 100-cm depth. In addition, one access tube located on each of the AH-10 hybrids and M_1 and M_4 irrigation treatments was used to measure the soil moisture to the 300 cm depth.

Following the October harvest, cover treatments were applied to specified plots in the 1982-83 and 1983-84 experiments. In the 1982-83 experiment, cover treatment consisted of applying the tops from two equal areas to sugarbeets on one replication of each treatment. All other sugarbeets for this year were left untreated as to cover. In the 1983-84 experiment, cover treatments were applied to areas 8 rows wide by 4.3 m long. The treatments imposed consisted of: (1) leaves on (the sugarbeet), and 2) leaves off; 3) leaves on, and 4) leaves off, both with soil cover; 5) leaves on, and 6) leaves off, both with top vegetative cover; 7) leaves on, and 8) leaves off, both with soil cover and top vegetative cover; 9) leaves on, and 10) leaves off, both with straw cover; and 11) leaves on, and 12) leaves off, both with soil and straw cover. Leaves were removed with a beater that had rubber flails. Soil cover consisted of covering the root crowns with soil using potato hillers and disks. Beet tops were applied at the rate of 160 metric tons/ha (tops from three equal areas). Straw was applied at the rate of 17.92 metric tons/ha.

Root samples were manually harvested from six uniform 3-m row sections from each plot on 28 October, 7 December, and 1 March in the 1982-83 study and from selected plots on 18 October and 21 March in the 1983-84 experiment. Root samples were cleaned, root and crown tissue were separated at the lowest leaf scar, weighed, and triplicate root samples (14 to 18 roots per sample) were taken for sucrose, purity, and other analyses. The sucrose concentration, purity, and other analyses were determined by The Amalgamated Sugar Company.

The specific procedures used for other studies can be found in earlier articles; i.e., 1977 (9), 1978 (8), and 1982 (5). These experiments were all conducted on Portneuf silt loam soil and were the average values for all preplant N fertilizer applications on the M_1 irrigation treatment.

RESULTS AND DISCUSSION

There are two apparent ways to increase the volume of beet roots that can be handled by processors using existing equipment and facilities in the intermountain areas of the western United States. The first would be to harvest and process the sugarbeet roots earlier than normal during September and early October. The early harvest would have the dual advantage of increasing the length of time that beet roots can be processed in the existing factories and generally having better weather conditions for harvest. The root and sucrose yields continue to increase in the late summer and early fall so earlier harvest has the disadvantage of reduced sucrose yields. The second would be to overwinter the beet roots in the field for harvest in the spring. The spring harvest has the potential advantage of capturing any increased root and sucrose yield benefits that take place from normal harvest until late fall when low temperatures stop all photosynthesis and growth processes.

It has been reported (1) that sucrose accumulation continues in the fall until the minimum air temperature reaches -4.4°C or 24°F. At this temperature, photosynthesis and transport mechanisms are damaged to the point that growth processes stop even though the leaves remain upright and green during the warmer periods of the day. When the minimum temperature reaches -8°C (17.6F) or below, the leaves are killed and do not recover during the warmer periods of the day. The time that the minimum temperature of -4.4°C is reached in the intermountain area of the West varies with season and location. In this area, it generally occurs in late October but may be as late as the middle of November. In the two years of this study, the minimum temperature of -4.4°C was reached on 19 October 1982, and on 9 November 1983 (Figure 1). Growth pro-

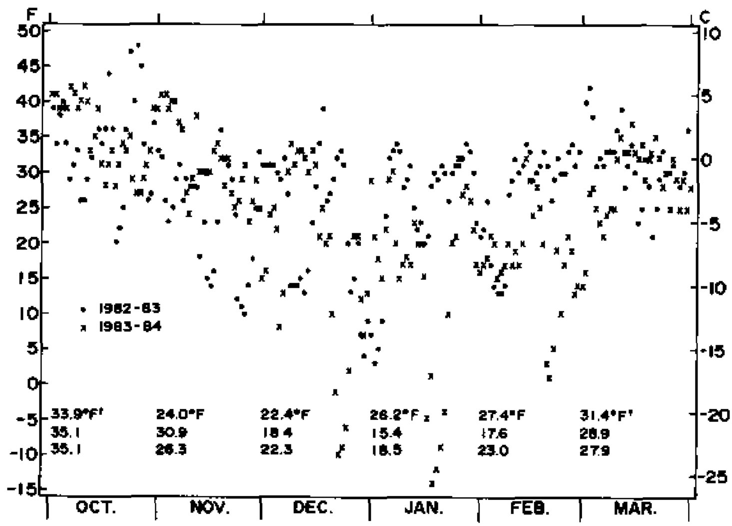

Figure 1. Daily minimum air temperatures at 1.52 meters during the 1982-83 and 1983-84 winter storage and harvesting period. †Average monthly air temperatures for 1982-83, 1983-84, and long term average, respectively.

cesses should continue to these dates or beyond depending upon the temperature and conditions at the leaf surface.

Root yields increased from the first sampling until harvest with growth rates greatest from mid-July until late August for the three years, as shown in Figure 2A (5, 8, 9). The root yield level and the rate of growth depended upon the climatic conditions for each year, available nutrients, and the yield potential of the sugarbeet hybrid grown. Growth rates during each of the years were reduced during September and October as day and night time temperatures decreased.

Sucrose concentration in the beet roots increased most rapidly during June and July (9, 14). From late July until harvest, the rate of increase in sucrose concentration was rather uniform for each of the three years provided that extra N was not taken up from residual or applied sources (Figure 2B). The sucrose concentration level depended upon the year and climatic conditions, N nutritional status of the plant, and the sugarbeet hybrid grown. During these studies, we found no indication of the commonly expected large increase in sucrose concentration during the latter part of the growing season when temperatures reduce the growth and respiration processes which is commonly called "sugaring up".

Total sucrose accumulation and extractable sucrose yields in the roots followed a consistent pattern for the three years with the greatest rates of increase in sucrose accumulation from late July until early September (Figure 2C, D). During each of the years, sucrose accumulation rates were reduced from early September until harvest with decreasing day and night temperatures. Total sucrose production is based on the product of root yield and sucrose concentration within the roots. Therefore, total sucrose accumulation and yields were affected by the same climatic, growth, and nutritional factors as root yield and sucrose concentration in total yield potential at any time during the season.

Sugarbeets in the cooler regions of the United States are normally harvested during the period from early October to mid-November when the temperatures are low enough for storing excess roots in piles for later proces-

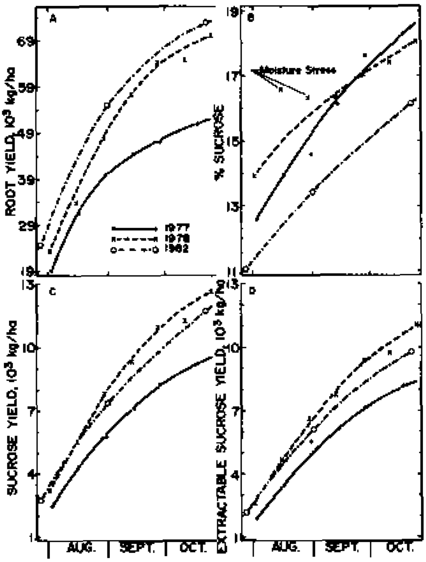

Figure 2. Root yield (A), sucrose percentage (B), sucrose yield (C), and extractable sucrose yield (D) as affected by year and time of harvest. Average values for all preplant N fertilizer and M_1 irrigation treatments.

sing. Farm managers, in most cases, select their own time of harvest so it may be coordinated with other farm operations. This generally provides a steady flow of sugarbeet roots to the factory for processing and piling even though potential yields are not generally reached by early October harvest.

The extent of the yield loss caused by early harvest will depend upon the time of actual harvest and the time that the roots would normally be harvested (11, 13). Figure 3 shows the values for the production factors obtained from early harvest as percentages of the values obtained from the harvest on 24 October for each of the three years. The values are plotted as percentages of the maximum assuming that near maximum production is reached by late October. Although the actual sucrose concentrations and yields varied widely for the three years, the percentage of the maximum values for the four production factors was remarkably uniform with only a few significant variations.

Similar production data are plotted in Figure 4 using average values for the three years; but, in this case, the

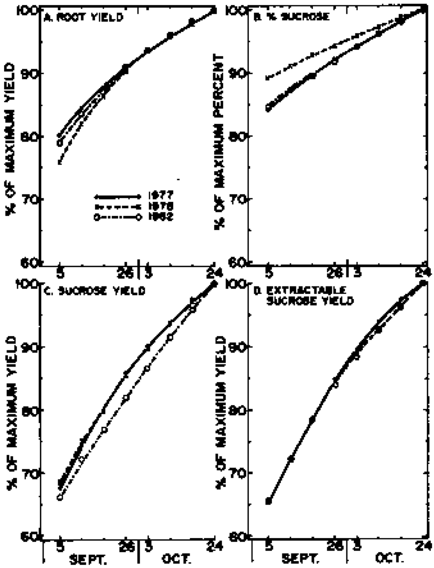

Figure 3. Percentage of the maximum yield and quality of root yield (A), sucrose percentage (B), sucrose yield (C), and extractable sucrose yield (D) as affected by year and time of harvest.

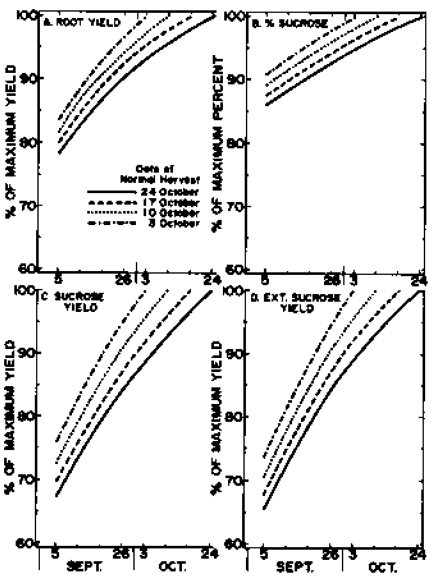

Figure 4. Percentage of the maximum yield and quality of root yield (A), sucrose percentage (B), sucrose yield (C), and extractable sucrose yield (D) as affected by time of harvest and the normal harvest period. Average values for 1977, 1978 and 1982.

percentages of the maximum are plotted for four different dates of harvest in October. These could be normal dates of harvest for different farm managers. In each instance, the values for the assumed normal dates of harvest are considered 100%, or maximum, and the values for prior dates of harvest are plotted as percentages of these maximums. The percentage of the maximum yields or sucrose concentrations vary from 65 to 100 percent with the extent of the decreases in the components depending upon the yield factor involved or the time of harvest in relation to the normal harvest period. The average reduction per week in percentage of the maximum extractable sucrose between early September and harvest was 6.6, 5.9, 5.4 and 4.9 for the 3, 10, 17 and 24 October normal harvest period, respectively. However, the greatest total reduction on all yields and yield factors occurred between the earliest harvest and latest normal harvest period.

There were no significant changes in the yield components or yields caused by a December harvest when compared with those beet roots harvested in late October (Table 1). The only consistent, but insignificant,

Table 1. Effect of delaying October harvest until December on sampling parameters of sugarbeets; mt = metric tons.

Treatment		Root - Crown#							
	Harvest	Root	Sucrose					Dry	
Hybrid	Date	Yield	Wet	Dry	Total	Extractable		Matter	
		mt/ha	%	%	mt/ha	%	mt/ha	%	mt/ha
AH-10†	Oct.	71.5	16.2	75.9	11.60	84.2	9.77	21.4	15.30
	Dec.	72.8	15.8	74.8	11.49	85.1	9.78	21.1	15.36
WS-76†	Oct.	74.2	16.7	76.0	12.38	84.7	10.48	22.0	16.31
	Dec.	75.8	16.3	75.3	12.39	85.5	10.59	21.7	16.46
GWD2†	Oct.	77.4	17.1	76.1	13.21	85.1	11.24	22.5	17.37
	Dec.	77.1	16.8	75.7	12.93	86.5	11.18	22.2	17.08
Avg	Oct.	74.4	16.7	76.0	12.40	84.7	10.50	22.0	16.33
	Dec.	75.2	16.3	75.3	12.27	85.7	10.52	21.7	16.30
LSD	(0.05)	6.6	0.9	NS	1.42	1.6	1.30	1.2	1.87

†Average of M_1, M_2, M_3 and M_4 irrigation levels.

#Three uncovered replications.

changes that did take place were slight decreases in the sucrose and dry matter concentrations and increased percent extractable sucrose. Sugarbeets that are subject to freezing temperatures and higher soil moisture levels generally have a higher water content which could account for the decrease in sucrose and dry matter concentrations. The critical air temperature of -4.4°C, where growth processes are stopped for sugarbeets (1), was reached on 19 October and during several periods in November (Figure 1). The low temperature at October harvest probably stopped all growth processes and yield benefits from later harvest. However, during certain years, this critical temperature is reached at a much later date and during those years some yield benefits would probably be achieved by the later harvest period.

The overwintering of the sugarbeet roots without cover for spring harvest caused a deterioration in both their physical and chemical quality during the two years of this study (Tables 2, 3). Starting in January and continuing for the remainder of the period of freezing and thawing temperatures, the crowns of a high percentage of the roots without cover developed a softness. The softness and later rot in the crowns moved through the center of the root and eventually throughout the entire root with increasing spring temperatures. The initial softness of the crown was probably the result of freezing with lower night temperatures and thawing with warmer daytime temperatures. This deterioration of the crown provided an entrance for the fungal pathogens that cause rot (4). Temperature fluctuation can be minimized by the addition of an insulating material over the crowns and soil.

The uncovered roots that were classified as hard, and could be harvested with a mechanical harvester, ranged from 46 to 74 percent and from 69 to 93 percent for the top vegetative covered roots during the 1982-83 season (Table 2). Moisture stress and dehydration of the sugarbeets increased the numbers of roots that were soft for both the covered and uncovered plot areas. The GWD2 hybrid had a higher number and percentage of roots that were classified as hard when compared with the other two hybrids used, regardless of cover. These moisture level and hybrid differences shown should be considered preliminary information because of the lack of replications of the covered plot and the variable results within treatments. The main deterioration in quality of roots was in the sucrose concentration and sugar composition of the hard roots (Table 2). The sucrose, as determined by the cold digestion and gas chromatography methods, was greatly reduced along with the thin juice purity when compared with those harvested in the fall. Invert sugar increased with essentially no change in the level of raffinose. Chemical changes resulting from moisture level and hybrid differences could not be determined because of the extent of the change for all beet roots and variable nature of the results. The low sucrose concentration and thin juice purity, along with increases in other impurities, would make these beet roots of no value for use in existing sugar processing plants (3).

The winter of 1983-84 was much more severe with many sub-zero (F) temperatures throughout the winter period and above average levels of snow (Figure 1). The insulating effect of the snow probably reduced the damage to the roots when present but compacted the top and straw insulating cover causing increased damage to the roots when the snow melted.

During the 1983-84 season, the sugarbeet roots deteriorated physically to a greater extent than during the previous season (Table 3). This increase in roots that were soft was undoubtedly due to the severity of the winter in comparison with the previous season. The sugarbeets that received no treatment, had their leaves removed, and received soil cover with and without leaves had 100 percent of their roots turn soft before spring harvest. The addition of insulating material such as top vegetative cover and straw increased the number of beet roots that were hard and could be mechanically harvested. Soil cover of the crown with and without leaves increased the percentage of hard beet roots when used with top or

Table 2. Effect of spring harvest on the quality of sugarbeet roots as affected by top vegetative cover, irrigation level, and commercial hybrid during the 1982-83 season.

Treatment		October		March						
		Sucrose		Roots		Sucrose†			Sugars†	
Irr. or Hybrid	Winter Cover	Cold Dig.	Extractable	Hard	Soft	Cold Dig.	Gas Chrom.	Syn. Thin Purity	Invert	Raffinose
		%								
M_1 #	None	16.4	84.9	73.6	26.4	3.2	2.2	34.0	6.6	0.13
	Tops	17.0	85.3	93.0	7.0	6.1	4.5	49.4	5.1	0.11
M_2 #	None	16.6	86.1	53.6	46.4	6.3	4.8	51.1	5.1	0.12
	Tops	17.8	86.2	78.8	21.2	7.8	6.1	59.9	4.6	0.12
M_3 #	None	16.3	85.1	48.8	51.2	4.3	3.2	37.8	6.2	0.14
	Tops	15.8	82.7	69.7	30.3	3.2	1.7	32.6	6.3	0.13
M_4 #	None	16.5	84.7	59.1	40.9	3.6	2.5	34.0	6.3	0.14
	Tops	15.8	80.7	70.6	29.4	4.6	3.3	38.8	5.3	0.13
AH-10 §	None	16.0	84.6	46.3	53.7	3.0	2.2	32.1	6.6	0.13
	Tops	16.0	82.6	75.2	24.8	4.3	3.4	40.0	5.6	0.12
WS-76 §	None	16.5	85.1	59.2	40.8	4.0	3.2	36.0	6.4	0.13
	Tops	16.7	83.6	77.6	22.4	6.8	5.0	51.4	4.9	0.11
GWD2 §	None	16.9	85.8	70.8	29.2	6.0	4.1	49.5	5.2	0.15
	Tops	17.1	84.9	81.4	18.6	5.2	3.3	44.1	5.4	0.12

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Table 2. continued.

Treatment		October		March						
		Sucrose		Roots		Sucrose†			Sugars†	
Irr. or Hybrid	Winter Cover	Cold Dig.	Extract-able	Hard	Soft	Cold Dig.	Gas Chrom.	Syn. Thin Purity	Invert	Raffinose
		%								
Avg.	None	16.5	85.2	58.8	41.2	4.3	3.2	39.2	6.1	0.13
	Tops	16.6	83.7	78.0	22.0	5.4	3.9	45.2	5.3	0.12

†Hard beet roots only. Synthetic thin juice purities are in units of g sucrose/100 g refractometric dissolved solids. All other results are given in g/100 g beet roots.

#Average of AH-10, WS-76 and GWD2 hybrids.

¶Average of M_1, M_2, M_3 and M_4 irrigation levels.

Table 3. Effect of spring harvest on the quality of sugarbeet roots as affected by type of cover during the 1983-84 season.

Treatment#		October		March						
		Sucrose		Roots		Sucrose†			Sugars†	
Leaves	Winter § Cover	Cold Dig.	Extract-able	Hard	Soft	Cold Dig.	Gas Chrom.	Syn. Thin Purity	Invert	Raffinose
		%								
On	Top	17.7	87.9	25.1	74.9	10.7	10.4	66.2	2.5	0.16
On	Top, Soil	17.6	87.2	29.2	70.8	10.9	10.2	69.1	2.3	0.19
Off	Top	17.6	87.3	8.5	91.5	10.9	9.7	63.0	2.2	0.17
Off	Top, Soil	17.6	87.3	26.7	73.3	12.1	11.1	76.1	1.8	0.20
On	Straw	17.6	87.3	63.9	36.2	12.9	12.4	81.9	1.3	0.20
On	Straw, Soil	17.6	87.3	74.4	25.6	13.3	12.5	83.6	1.3	0.18
Off	Straw	17.6	87.3	61.7	38.3	12.9	12.3	85.3	1.1	0.19
Off	Straw, Soil	17.6	87.3	73.9	26.1	13.0	12.2	86.0	1.1	0.20

†Hard beet roots only. Synthetic thin juice purities are in units of g sucrose/100 g refractometric dissolved solids. All other results are given in g/100 g beet roots.

#Treatments without top of straw cover were 100 percent soft roots, so further determinations were not made.

§Average of WS-76 and WS-88 sugarbeet hybrids.

straw cover. Straw cover was superior to top vegetative cover in maintaining the physical hardness of the roots. Although about 75 percent of the beet roots were hard at spring harvest when soil and straw were used as an insulating material, this was not considered high enough survival rate for use as a practical harvest method for sucrose production.

The sucrose concentration and sugar composition of the hard roots harvested in March of 1984 were far superior to those of the previous season (Table 3). This increase in chemical quality was probably caused by the low temperatures throughout the season and the roots remaining frozen until harvest when cover was provided. However, there was still a substantial reduction in the sucrose concentration and thin juice purity along with moderate increases in invert sugars, with essentially no change in the level of raffinose. The low sucrose concentration and thin juice purity, along with increases in other impurities, would make these beet roots of questionable value for use in existing sugar processing plants.

Deficit water management during the growing season for sugarbeets did not improve the storability (Table 2) or the surface soil water during the winter months and at spring harvest (Figure 5). The surface soil moisture was increased about equally by the movement of soil water towards the colder surface soil and rainfall staying near the surface on frozen soil. There was no visible difference in the surface soil between moisture levels (M_1 to M_4) at harvest. The roots were harvested in the spring by hand at a time when the soil had a high moisture level making it impossible, at this time, to harvest the roots by mechanical means. This would be another distinct disadvantage during most seasons to spring harvest of sugarbeet roots.

Seventy percent of the soil moisture deficit of over 11 cm of water, caused by no irrigation after 19 July, was refilled as a result of the dry soil absorbing more of the winter precipitation than the soils which were adequately

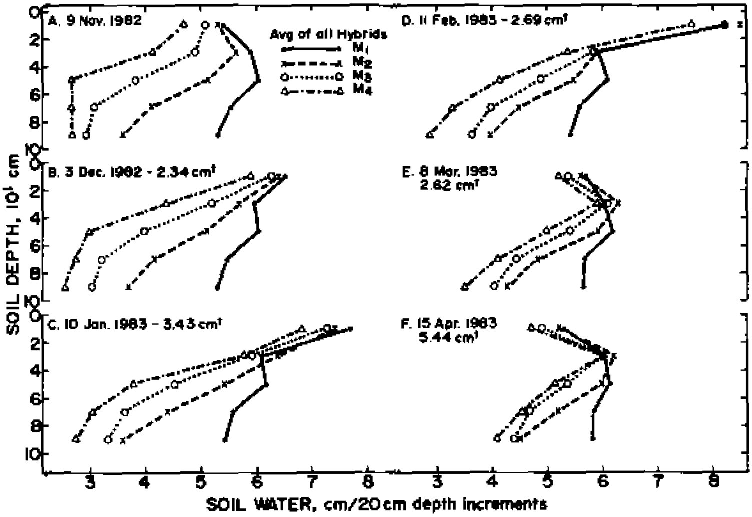

Figure 5. Effect of irrigation level during the sugarbeet growing season on the moisture content of the soil during the fall (A), winter (B, C, D), and spring (E, F) months during the 1983-84 season. † Rainfall between sampling periods.

irrigated (Table 4). Failure of the wetter soil to absorb as much water as the drier soil was probably due to both greater runoff and some deep percolation in the wetter soil. Consequently, it appears that the major portion of the water saved by withholding irrigation during August, September, and October was replaced during the winter months. This has the extra benefit of elimination of winter season deep percolation that results in nitrate loss.

In conclusion, the results of these experiments clearly show there is very little, if any, advantage to harvesting sugarbeet roots in the intermountain area of the western United States after the normal October period. Cold temperatures during the latter part of October and early November either reduce or stop photosynthesis and the accumulation of sucrose in the roots. Freezing temperatures during the latter part of October and November may change the proportions of sucrose and other sugars

Table 4. Effect of soil moisture level on the time and amount of water infiltration from precipitation during the winter months.

Irrig. Level	Date Sampled: 9 Nov. Water Decrease	3 Dec. Water† Gain	3 Dec. Water† Replaced	10 Jan. Water† Gain	10 Jan. Water† Replaced	11 Feb. Water† Gain	11 Feb. Water† Replaced	8 Mar. Water† Gain	8 Mar. Water† Replaced	15 Apr. Water† Gain	15 Apr. Water† Replaced
	cm	cm	%	cm	%	cm	%	cm	%	cm	%
To 100 cm depth											
M_1	0	1.1	--	2.8	--	3.1	---	1.0	--	0.9	--
M_2	4.5	1.4	31	3.5	78	4.6	102	3.3	74	3.4	75
M_3	8.4	1.9	23	5.0	59	6.8	80	5.6	66	5.7	67
M_4	11.3	1.6	15	5.3	47	6.4	56	6.9	61	7.6	67
To 300 cm depth											
M_1	0	1.6	--	3.2	--	3.3	--	2.1	--	3.1	--
M_4	12.7	1.5	12	4.8	38	5.2	41	5.9	47	9.1	72

†Soil water gain or replaced when compared with the level on 9 November.

in the roots as well as affect the storability of the roots. Sugarbeets held in the soil throughout the winter months deteriorate both physically and chemically. Although the physical quality of the roots can be improved with insulation from various plant materials that are readily available in the field, inversion of the sugars within the roots occurs to the extent that they have little value for processing using our existing equipment. However, these roots could have a use in the production of alcohol where the sugar composition is not important (6).

The early opening of the sugarbeet processing plants and early harvest of the roots for immediate processing seems to be the only viable option identified in this study for increasing the amount of roots processed using existing factory equipment. Although the roots harvested early have physical quality equal to those harvested later in the fall (11), there can be up to a 35 percent loss in the extractable sucrose potential depending upon the harvest time in relation to the normal harvest period. However, there are also losses of sucrose in the beet piles from beets harvested during periods of maximum yields due to respiration, freezing and thawing, and decomposition (2, 16, 17). Early harvest of the sugarbeet roots would increase the tonnage of roots that can be processed with existing facilities, increase the number of hectares allotted for sugarbeet production, and improve the economy of the sugar industry.

SUMMARY

Two sugarbeet (*Beta vulgaris* L.) experiments and data collected during three years in other studies were used to evaluate early and late fall, and spring harvest of beet roots. The results of these experiments clearly show there is very little, if any, advantage to harvesting sugarbeet roots in this climatic zone after the normal October period. Cold temperatures before or shortly after the late October period either reduce or stop photosynthesis and the accumulation of sucrose in the roots. Sugarbeets held in the field throughout the winter months, with

and without insulating materials, deteriorate both physically and chemically to the extent that they would have little value for processing using existing facilities. Sugarbeet roots harvested and processed earlier than the normal harvest period during October may lose up to 35 percent of their maximum sucrose potential depending upon the harvest period in relation to the normal harvest period. Early harvest and processing of beet roots would increase the tonnage of roots that can be processed with existing equipment, increase the number of hectares allotted for sugarbeet production, and improve the economy of the sugar industry.

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LITERATURE CITED

1. Akeson, W. R. 1981. Relationship of climate and sucrose content of sugarbeet roots. J. Am. Soc. Sugar Beet Technol. 21:27-40.

2. Akeson, W. R. and J. N. Widner. 1981. Differences among sugarbeet cultivars in sucrose loss during storage. J. Am. Soc. Sugar Beet Technol. 21:80-91.

3. Alexander, J. T. 1971. Factors affecting quality. p. 371-381. *In*: R. T. Johnson, J. T. Alexander, G. E. Rush and G. R. Hawkes (eds.). Advances in Sugarbeet Production: Principles and Practices. The Iowa State Univ. Press, Ames.

4. Bugbee, W. M. and D. F. Cole. 1976. Sugarbeet storage rot in the Red River Valley, 1974-75. J. Am. Soc. Sugar Beet Technol. 19:19-24.

5. Carter, J. N. 1984. Effect of fall and spring applied nitrogen fertilizer on growth and yield of sugarbeets. J. Am. Soc. Sugar Beet Technol. 22:252-267.

6. Carter, J. N., D. L. Doney and J. C. Theurer. 1982. Potential alcohol production from *Beta vulgaris* geno-

types as affected by nitrogen level and water stress. J. Am. Soc. Sugar Beet Technol. 21:324-344.

7. Carter, J. N., M. E. Jensen and S. M. Bosma. 1974. Determining nitrogen fertilizer needs for sugarbeets from residual soil nitrate and mineralizable nitrogen. Agron. J. 66:319-323.

8. Carter, J. N., M. E. Jensen and D. J. Traveller. 1980. Effect of mid- to late-season water stress on sugarbeet growth and yield. Agron. J. 72:806-815.

9. Carter, J. N. and D. J. Traveller. 1981. Effect of time and amount of nitrogen uptake on sugarbeet growth and yield. Agron. J. 73:665-671.

10. Cole, D. F. 1977. Effect of cultivar and mechanical damage on respiration and storability of sugarbeet roots. J. Am. Soc. Sugar Beet Technol. 19:240-245.

11. Hecker, R. J., M. G. Payne and E. E. Remmenga. 1967. Performance of sugar beet hybrids at different harvest dates. J. Am. Soc. Sugar Beet Technol. 14:455-464.

12. Jensen, M. E., D. C. M. Robb and C. E. Franzoy. 1970. Scheduling irrigations using climate-crop-soil data. J. Irrig. Drain. Div., Am. Soc. Civ. Eng. 96(IR1):25-38.

13. Oldemeyer, R. K., A. W. Erichsen and A. Suzuki. 1977. Effect of harvest date on performance of sugarbeet hybrids. J. Am. Soc. Sugar Beet Technol. 19:294-306.

14. Theurer, J. C. 1979. Growth patterns in sugarbeet production. J. Am. Soc. Sugar Beet Technol. 20:343-367.

15. Westermann, D. T., G. E. Leggett and J. N. Carter. 1977. Phosphorus fertilization of sugarbeets. J. Am. Soc. Sugar Beet Technol. 19:262-269.

16. Wyse, R. E. 1978. Effect of low and fluctuating temperatures on the storage life of sugarbeets. J. Am. Soc. Sugar Beet Technol. 20:33-42.

17. Wyse, R. E. and S. T. Dexter. 1971. Sources of recoverable sugar losses in several sugarbeet varieties during storage. J. Am. Soc. Sugar Beet Technol. 16:390-398.