Effect of Nitrogen and Irrigation Levels, Location and Year on Sucrose Concentration of Sugarbeets in Southern Idaho *

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INTRODUCTION

Sucrose concentration of sugarbeets (*Beta vulgaris* L.) grown in the U.S. varies over a wide range of 10 to 20 percent. Within a climatic zone such as southern Idaho, sucrose concentration varies over a narrower but still wide range of 14 to 20 percent. This variation in sucrose concentration is due to many factors that include variety (19, 24, 26), nitrogen (N) level (18, 23), growth patterns of the crop (3, 16, 25, 29), climatic conditions (1, 22, 28), and other factors that are not fully understood. Refined sucrose production is based on the product of root yield and extractable sucrose concentration. Therefore, it is of prime importance to have practices and conditions that provide adequate root growth while maintaining sufficiently high sucrose percentages and purity for profitable sucrose extraction and yield.

Sugarbeet quality, mainly due to sucrose concentration, has been steadily decreasing in southern Idaho as well as other sugarbeet growing areas of the U.S. since the early 1950's (2). This decrease in beet root quality has accompanied an increase and in some cases, excessive use of N fertilizer for the growth of this crop (14, 15). However, within seasons between adjacent fields where the total available soil and fertilizer N were similar, large differences have been measured in sucrose concentration and root quality. These differences in the quality factors may be due to differences in time and amount of N uptake, irrigation levels, cultural practices or other unknown reasons. A better understanding of the reason for this decrease in suc-

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rose concentration and quality is needed so that a reversal of this trend can be achieved with increased production efficiency that will economically benefit the consumer, producer, and manufacturer.

The objective of this study was, by the use of data collected at several locations in southern Idaho since 1966, to identify and evaluate the effect of factors and conditions that significantly affect sucrose concentration and root quality such as N application, N uptake, irrigation level, location, year, and growth patterns during the growing season.

MATERIALS AND METHODS

Experiments on sugarbeets have been conducted since 1966 by scientists located at Kimberly, with experimental plots at several locations in southern Idaho. The procedures used in these experiments have been published in numerous articles since the initiation of these studies. The specific procedures used for each of these experiments can be found in the article for the year: 1966 (6), 1967 (6), 1968 (7, 8), 1969 (7), 1971 (15), 1972 (14), 1976 (12), 1977 (11), 1978 (9), 1979 (13), and 1980 (5). These experiments were conducted on Portneuf silt loam soil (Durixerollic Calciorthids; coarse-silty, mixed, mesic) with the exception of some of the plot areas in the 1971 and 1972 studies.

Most of the agronomic practices such as variety, planting date, and irrigation level were rather uniform between years. However. variation in these practices that caused significant changes in the sugarbeet growth and yield components are given in the tables, figures, or the discussion of this information.

In most cases, the sugarbeets (Amalgamated AH10) were planted in early to mid-April in either 56 or 61 cm rows and were thinned to a 23 to 30 cm spacing in early June. Preplant and mid-June N applications were applied as a broadcast and sidedress application, respectively, as ammonium nitrate. Later applications of N were broadcast as urea and moved into the soil with sprinkler irrigation.

Alternate furrow (every other furrow and alternating

furrows at each irrigation) or sprinkler irrigation were used. Previous experiments (10) have indicated that the irrigation method (furrow or sprinkler) had little effect on root and sucrose yields. Experimental areas were adequately irrigated (20) except where deficit irrigation was intentionally imposed.

The sugarbeets were harvested during the season and in October by taking 3-m row lengths or by mechanically harvesting larger areas of each plot at final harvest in October. All beet roots were adequately crowned before duplicate or triplicate root samples (16 to 18 roots per sample) were taken for purity and sucrose analyses. The sucrose concentration in the beet roots was determined by the Amalgamated Sugar Company (9).

The beet top, root, and crown samples were dried at 65°C and their dry weights determined. The dried samples were ground to pass through a 40-mesh sieve and total N was determined by the macro- or semimicro- Kjeldahl procedure (4), both modified to include nitrate. Nitrogen uptake was estimated by assuming that the N concentration was the same in both the fibrous and storage roots and the weight of the unharvested fibrous roots was equal to 25% of the total harvested storage root weight (21).

RESULTS AND DISCUSSION

Total N uptake by the sugarbeet crop at harvest was linearly related to the total available N (N_T) that was varied by preplant and seasonal N fertilizer addition at one location in 1977 (Figure 1), and in 1976. This relationship also applied when N_T was varied by past N fertilizer management (14, 15). Increasing the N available to the sugarbeet plant from residual sources or by N addition at any stage of plant growth increased the plant part N content and the amount of N uptake. Mid-June and mid-July applications generally increased the efficiency and amount of N uptake by the plant as compared with similar amounts applied preplant. This was probably a result of minimizing the time between N application and N uptake by sugarbeets which allowed less opportunity for N to be leached out of the root zone, denitrified, or incorporated into the soil microorganisms and their by-products. Mid-August N addition at

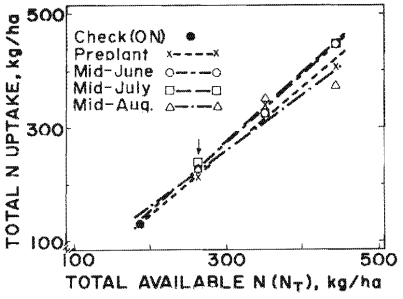

Figure 1. Effect of total available N (N_T) on total N uptake (r= 0.99, 0.98, 0.99, 0.96 for preplant, mid-June, mid-July, mid-August N applications, respectively). Arrow indicates maximum sucrose yield for preplant N.

higher N rates decreased the N fertilizer efficiency (E_f) and N uptake below those of other treatments which was probably due to the short time period between N application and cessation of active plant growth.

The wet root (Figure 2A) and dry root (Figure 2B) sucrose concentrations and root percent dry matter (Figure 2C) at harvest were linearly decreased with increased total N uptake by the plants that was varied by preplant and seasonal N additions. Applying N during the growing season and subsequent late season N uptake reduced sucrose percentage more than did the N preplant application. This was particularly noticeable from the mid-August N application. The assumption can be made that the decrease in sucrose concentration in the wet roots with N addition and N uptake by the plant was caused primarily by a decrease in the dry matter concentration of the roots and by a lesser but still important decrease in the sucrose concentration in the dry matter. Therefore, this relationship between N uptake level and dry matter concentration was associated with a strong positive relationship between percent dry matter and sucrose concentration in the beet roots (Figure 2D).

Sucrose concentration of the dry roots (Figure 3A, B) and wet roots (Figure 3C, D) during the season was dependent upon the N fertility level and time the N was taken up by the sugarbeet. Increasing the N uptake by N fertilizer addition either preplant or during the season, generally decreased both the suc-

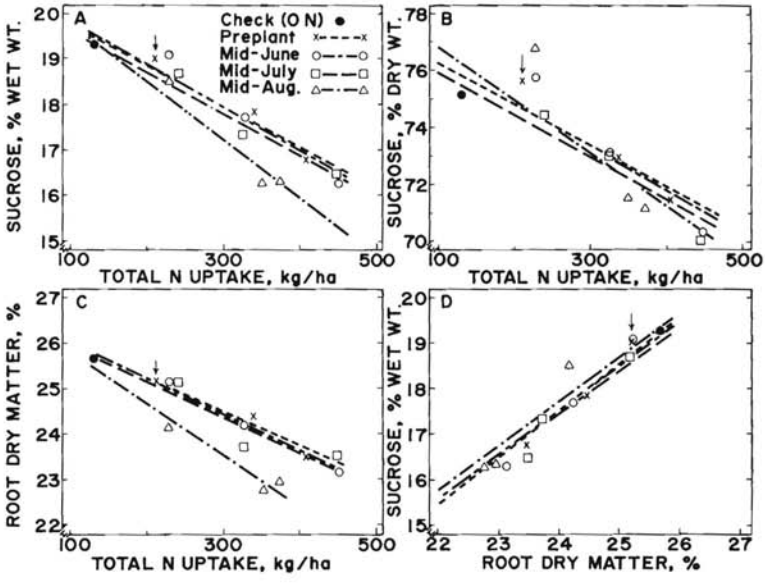

Figure 2. Effect of: A) Total N uptake on sucrose percentage in the wet root (r=0.94, 0.91, 0.95, 0.92)† , B) Total N uptake on sucrose percentate in the dry root (r=0.77, 0.66, 0.64, 0.64)†, C) Total N uptake on percent root dry matter (r=0.87, 0.85, 0.88, 0.88)† , and D) Percent root dry matter on sucrose percentage in the wet root (r=0.92, 0.88, 0.84, 0.90)†. † r value for preplant, mid-June, mid-July, and mid-August N applications, respectively. Arrows indicate maximum sucrose yield for preplant N.

rose concentration in the wet and dry roots from the time of application until harvest. When 112 kg N/ha was applied preplant, which was the rate for maximum sucrose yield, the sucrose concentration of the wet and dry roots was at least equal to that of the check by the end of the season. However, sucrose concentration generally was decreased by each increase in the N application rate and by each delay in its application time.

Sucrose concentration of the wet and dry roots increased most rapidly during June and July for the check and for all preplant N treatments. From late July until harvest, the rate of increase in sucrose concentration of the wet roots was rather uniform when no N was applied during this period. The rate of increase in sucrose concentration of the beets fertilized at mid-

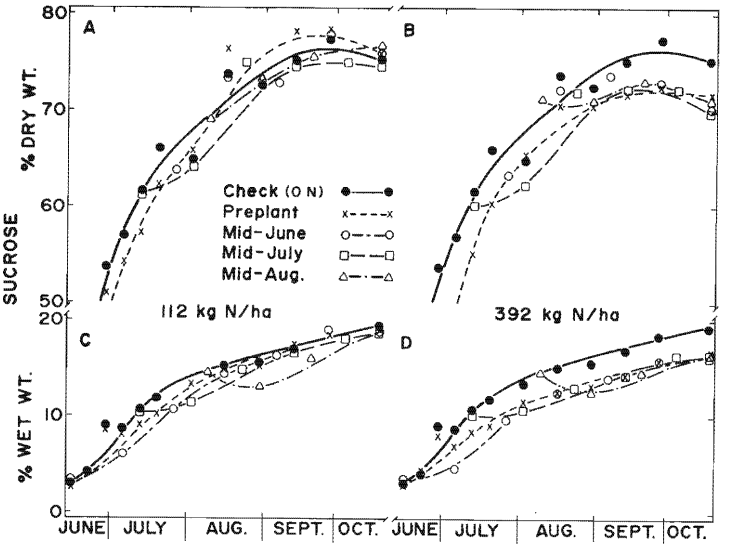

Figure 3. Sucrose percentage of the dry root (A, B) and wet root (C, D) as affected by time of sampling, N fertilizer level, and time of N application in 1977.

season was greater during the latter part of the growing season than those fertilized earlier. This would indicate that an extended season through good weather conditions for plant growth during September and October in the intermountain area or delaying harvest as long as weather conditions permit should improve both sucrose yield and concentrations regardless of the N nutritional status of the crop.

The decrease in the sucrose concentration with N addition preplant or during the season was due to a decrease in the percent sucrose of the dry matter and to a decrease in dry matter concentration in the wet roots at all plant growth stages at one location in 1976, 1977, and 1978 (Table 1). A change in sucrose concentration between locations during the same season or between seasons was also due to a change in these two components in the beet root at harvest. Although sucrose concentration of the dry matter influenced the sucrose concentration in the wet roots, the major changes due to location-to-location, year-to-year variation or N uptake by the plant occurred because of a change in the dry matter concentration in the beet roots. High sucrose concentration in the wet roots occurred when both

Table 1. Effect of N fertilizer level and time of sampling on dry matter and sucrose concentrations in sugarbeet roots in 1976, 1977, and 1978.

Year	N Level	Component	Date Sampled (± 1 day) 5 July	19 July	2 Aug.	16 Aug.	30 Aug.	13 Sept.	27 Sept.	18 Oct.
			%							
1976	Max. Suc. Yd.†	Dry Matter	16.9	17.0	16.7	17.8	18.6	19.8	22.2	22.4
		Sucrose, Dry‡	59.3	66.1	71.1	73.5	75.0	75.4	71.8	76.6
		Sucrose, Wet§	10.0	11.2	11.9	13.1	13.9	14.9	15.9	17.1
	High N	Dry Matter	15.3	14.1	15.5	16.8	17.8	17.7	19.3	20.8
		Sucrose, Dry	54.1	64.8	66.8	71.3	72.4	73.3	72.8	74.8
		Sucrose, Wet	8.3	9.1	10.3	12.0	12.9	13.0	14.1	15.6
1977	Max. Suc. Yd.	Dry Matter	14.7	16.6	20.2	19.5	20.8	22.4	23.5	25.2
		Sucrose, Dry	54.1	62.2	65.9	76.3	72.8	78.1	78.3	75.6
		Sucrose, Wet	7.9	10.3	13.3	14.8	15.1	17.5	18.4	19.0
	High N	Dry Matter	14.0	15.1	17.8	17.8	18.7	20.1	21.9	23.5
		Sucrose, Dry	49.1	60.3	65.3	70.6	70.4	71.7	72.4	71.5
		Sucrose, Wet	6.9	9.1	11.6	12.5	13.2	14.4	15.9	16.8
1978	Max. Suc. Yd.	Dry Matter	14.2	17.5	20.4	22.7	22.5	21.9	22.6	24.3
		Sucrose, Dry	54.2	64.6	70.7	74.6	74.7	77.0	77.3	77.6
		Sucrose, Wet	7.7	11.3	14.5	16.9	16.8	16.9	17.5	18.8
	High N	Dry Matter	13.3	16.1	18.9	21.8	21.6	20.8	21.6	23.0
		Sucrose, Dry	53.9	61.8	71.0	74.1	73.3	75.8	77.0	75.2
		sucrose, Wet	7.2	10.0	13.4	16.2	15.9	15.8	16.6	17.3

†Maximum sucrose yield. ‡sucrose, %dry wt. § sucrose, % wet wt.

dry matter concentration and percent sucrose of the dry matter were high and low levels of sucrose were obtained when both of these components were low. This may be due to year-to-year variation or to treatment within any particular year. Excessive or late additions of N fertilizer and uptake by the plants may make large decreases in sucrose concentration of the wet root because there is generally a major reduction in both these components in the roots. Therefore, any treatment or agronomic practice that will maintain a high dry matter concentration and sucrose level of the dry matter will assure a high quality beet root for processing.

Sucrose concentration of the wet roots was dramatically influenced by moisture stress of the plant during the growing season and at harvest (Figure 4C, D). When irrigation water was adequate, sucrose concentration increased most rapidly during June and July and progressed at a rather constant decreased rate from late July until harvest. If an irrigation was delayed or stopped, sucrose concentration of the wet roots started to increase significantly above the control about 2 weeks after the last irrigation when the surface soil became dry and the sugarbeet leaves showed signs of water stress. The rate of increase in sucrose concentration was generally higher during this initial period of plant stress. Following this initial large increase in sucrose concentration due to water stress, the rate of increase was similiar to that of the control. The increase in sucrose concentration above that in the control was not evident when sucrose concentration was calculated on a dry weight basis (Figure 4A, B). This indicated that the increase in sucrose concentration as determined on a wet weight basis was largely due to dehydration of the roots. This was further shown in 1978 on all treatments by the decrease in sucrose concentration after the water application by irrigation or rainfall to stressed plants. This demonstrated that irrigation level can influence the dry matter and sucrose concentration in beet roots at harvest. However, root quality may be improved by increased sucrose concentration, but sucrose yield will not be benefitted by this practice.

Total N uptake by the sugarbeets at harvest was linearly

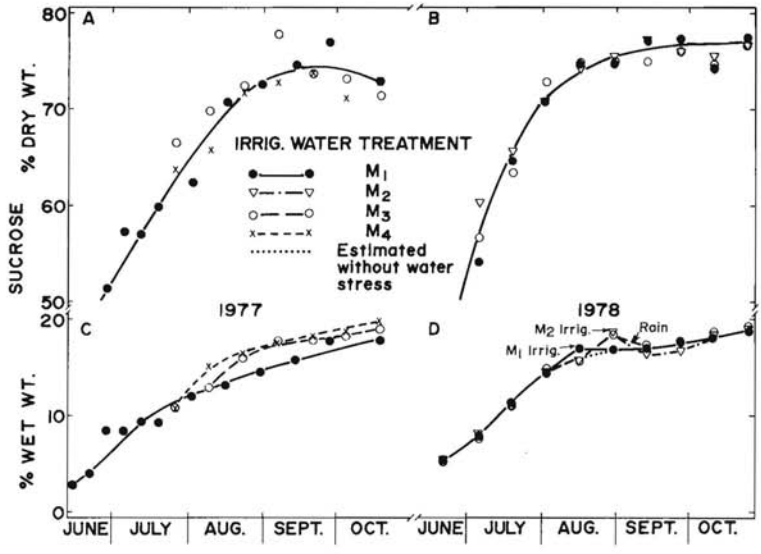

Figure 4. Sucrose percentage of dry root (A, B) and wet root (C, D) as affected by time of sampling and irrigation water treatment in 1977 and 1978 (M_1=farm level irrigation, M_2=1 August water cutoff and light irrigation 1 September, M_3=1 August water cutoff, M4=15 July water cutoff.)

related to N_T at each of eight sites in 1972 with the amount and rate of N uptake varying with site and treatment (Figure 5A). The amount or rate of total N uptake with N fertilizer (N_f) addition at each site had little relationship with the starting N_T values. Sucrose concentration of the roots was also linearly related to N_T at each of the eight sites with the rate of decrease with increased N_T varying with the site (Figure 5B). If the slopes of the regression lines for increased N uptake and decreased sucrose concentration with increased N_T are used in a regression analysis, the rate of decrease in sucrose (S) concentration depended upon the rate of increase in total plant N uptake (N_{up}) with fertilizer addition [$\hat{y}(\Delta S/\Delta N_T) = 0.00055 - 0.0141\ (\Delta N_{up}/\Delta N_f)$, $r = 0.89$ or $\hat{y}(\Delta S/\Delta N_T) = 0.00083 - 0.0094\ (\Delta N_{up}/\Delta N_f$ at 65% N fertilizer efficiency (E_f), $r = 0.89$]. There was very little relationship between the N_T values and the N uptake at the various sites and the starting (check) sucrose concentration values in 1972 [$\hat{y}(\%S) = 17.39 - 0.0018\ N_{up}$ r =

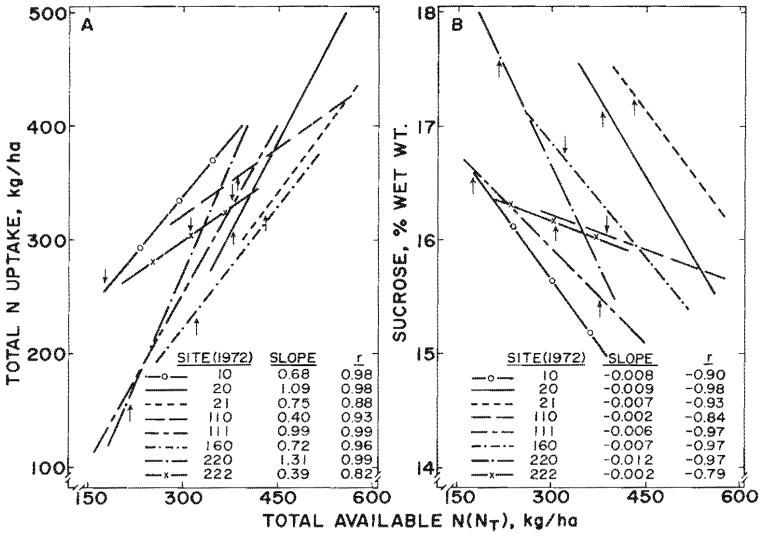

Figure 5. Effect of total available N (N_T) on total N uptake (A) and sucrose percentage (B) at different locations in southern Idaho in 1972. Regression line is N_T range for each site. Arrows indicate maximum sucrose yield N_T level for each site.

0.22]. However, a better relationship was obtained between these components at the different sites in 1971 [$\hat{y}$(%S) = 19.66–0.0105 N_{up}, r = 0.73]. This would indicate that between sites and location, there was a factor or factors other than total N uptake that was influencing the components that determine sucrose concentration in beet roots.

When the various parameters that influence sucrose concentration in beet roots were compared at maximum sucrose yield, an excellent correlation generally existed between these components if the data were obtained at one location during any one year (Table 2). If these same parameters were compared using data from different locations during the same year or at the same location during different years, correlations were smaller. However, the better correlations using data at all locations and years existed between the total N uptake and percent dry matter or sucrose concentration of the wet roots and between dry matter and sucrose concentration of the wet roots.

Table 2. Relation of total N uptake and percent dry matter (DM), location, and year to sucrose (Suc.) concentration in sugarbeet roots (average values for all replications used).

Treatment	Maximum Sucrose Yield			
	Regression Equation	r	Regression Equation	r
	Total N uptake (N_{up}) on root DM, %		DM, % on Suc., % wet wt.	
1†	$\hat{Y} = 26.73 - 0.0076\ N_{up}$	0.98	$\hat{Y} = -11.47 + 1.203\ DM$	0.99
2‡	$\hat{Y} = 25.49 - 0.0132\ N_{up}$	0.64	$\hat{Y} = 2.45 + 0.663\ DM$	0.84
3§	$\hat{Y} = 24.43 - 0.0107\ N_{up}$	0.71	$\hat{Y} = 2.72 + 0.655\ DM$	0.87
4¶	$\hat{Y} = 27.45 - 0.0186\ N_{up}$	0.64	$\hat{Y} = 3.09 + 0.641\ DM$	0.95
	Total N uptake (N_{up}) on Suc., % wet wt.		DM, % on Suc., % dry wt.	
1	$\hat{Y} = 20.71 - 0.0091\ N_{up}$	0.98	$\hat{Y} = 26.31 + 1.924\ DM$	0.95
2	$\hat{Y} = 20.06 - 0.0113\ N_{up}$	0.69	$\hat{Y} = 87.99 - 0.475\ DM$	0.23
3	$\hat{Y} = 18.84 - 0.0074\ N_{up}$	0.65	$\hat{Y} = 91.56 - 0.624\ DM$	0.33
4	$\hat{Y} = 20.96 - 0.0131\ N_{up}$	0.68	$\hat{Y} = 92.36 - 0.644\ DM$	0.57
	Total N uptake (N_{up}) on Suc., % dry wt.		Suc., % wet wt(S) on Suc., % dry wt.	
1	$\hat{Y} = 77.78 - 0.0146\ N_{up}$	0.93	$\hat{Y} = 43.85 + 1.643\ S$	0.98
2	$\hat{Y} = 79.04 - 0.0051\ N_{up}$	0.12	$\hat{Y} = 63.04 + 0.862\ S$	0.33
3	$\hat{Y} = 76.96 + 0.0046\ N_{up}$	0.16	$\hat{Y} = 70.44 + 0.479\ S$	0.19
4	$\hat{Y} = 75.96 + 0.0066\ N_{up}$	0.23	$\hat{Y} = 86.73 - 0.494\ S$	0.29

†Same year and location. ‡Same year and different locations (1971). §Same year and different locations (1972). ¶Different years and same location.

This relationship between N uptake, percent dry matter and sucrose concentration would indicate that the amount of N uptake necessary to achieve maximum sucrose yield and its effect on dry matter concentration was a major contributing factor to the variation in sucrose concentration in the wet roots at the various locations and between different years. However, other factors were contributing to these differences in sucrose concentration.

One of the closest correlations at the different locations and different years was the effect of percent dry matter on sucrose concentration. The effect of these factors was compared in Figure 6. The slopes of the regression lines were essentially the same in all but one treatment (check, 1972) when percent dry matter was compared to sucrose concentration during different years and locations (Figures 6B, C, D). The slopes of these regression lines were the same as those obtained at one location and year by plant water stress and dehydration of the roots (Figure 6A). The slope of the regression line changed because of N fertilizer (N_f); therefore, N_f seemed to be the major contributing factor to the decrease in sucrose concentration due to the decrease in percent dry matter (Figure 6A). This was probably caused by major decreases in both percent dry matter and percent sucrose of the dry matter with N addition. Whereas, between locations and years at maximum sucrose yield, the difference in sucrose concentration can be attributed more to the change in percent dry matter than to the change in percent sucrose of the dry matter. However, because the slopes of the regression lines were uniform and the slopes of these lines were less than those for N differences alone, a factor or factors other than N level are probably major contributing factors to the differences in dry matter and sucrose concentration at the different locations and years. Some of these factors could be irrigation level, time of N uptake due to either application or soil location of the available N, growth patterns of the crop, climatic conditions during the season, or insect damage to the roots early in the season. All of these conditions could either increase or decrease the dry matter in the roots or delay the N uptake by the plants to a period in plant

growth where it could have increasing effect on sucrose concentration.

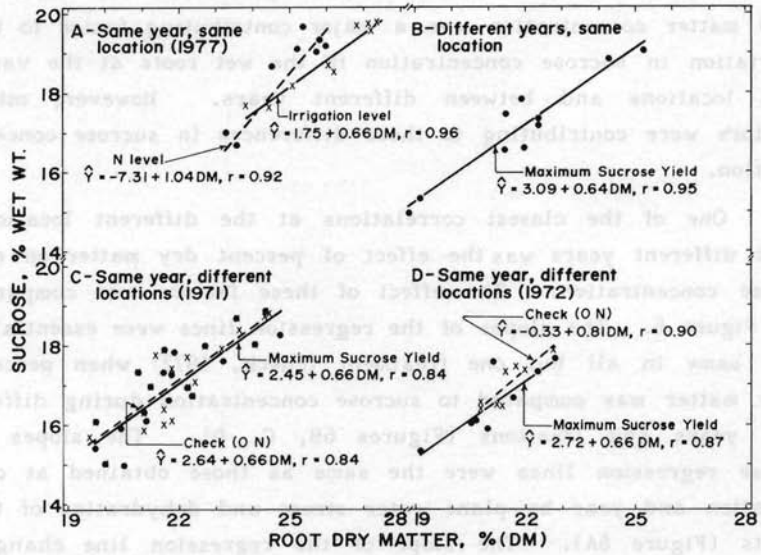

Figure 6. Effect of percent dry matter on sucrose percentage in the wet root in: A) Same year and same location with varying N and moisture levels in 1977, B) Different years and same location (1966-1979), C) Same year and different locations (Check and maximum sucrose yield in 1971), D) Same year and different locations (Check and maximum sucrose yield in 1972).

Beta varieties, varying widely in their root yield potential and sucrose concentration, were grown at one location at two N levels in 1980 (5) and showed an important relationship between dry matter and sucrose concentration (Table 3). There was an inverse linear relationship between root yield and dry matter or sucrose concentration in sugarbeet roots grown at farm level irrigation (M_1) and at mid- to late-season moisture stress (M3) within each N level. The sucrose concentration in the roots was primarily dependent upon the dry matter concentration within the roots with a lesser but sill important sucrose concentration within the dry matter. Increased N level, as previously shown, reduced the sucrose concentration in the wet roots by reducing the percent dry matter and the sucrose concentration of the dry matter. Therefore, sucrose yield was primarily dependent upon the dry matter yield at the different irrigation

Table 3. Effect of root yield on percent root dry matter and percent sucrose, percent root dry matter on percent sucrose, and dry matter yield of roots on sucrose yield as affected by N fertilizer level, mid- to late-season moisture stress, and Beta genotype.†

N Fertilizer	M_1‡ Regression equation	r	M_3‡ Regression equation	r
kg/ha	Root Yield (Yd) on Root Dry Matter, %§			
196	$\hat{Y} = 41.1 - 0.210$ Yd	0.92	$\hat{Y} = 39.1 - 0.197$ Yd	0.91
392	$\hat{Y} = 36.3 - 0.154$ Yd	0.95	$\hat{Y} = 36.2 - 0.163$ Yd	0.93
	Root Yield (Yd) on Sucrose, % wet wt.¶			
196	$\hat{Y} = 31.2 - 0.163$ Yd	0.91	$\hat{Y} = 29.7 - 0.155$ Yd	0.89
392	$\hat{Y} = 27.9 - 0.126$ Yd	0.94	$\hat{Y} = 26.8 - 0.127$ Yd	0.93
	Root Dry Matter, % (DM) on sucrose, % wet wt.#			
196	$\hat{Y} = -0.98 + 0.787$ DM	0.99	$\hat{Y} = -1.03 + 0.783$ DM	0.98
392	$\hat{Y} = -1.70 + 0.812$ DM	0.98	$\hat{Y} = -0.99 + 0.758$ DM	0.97
	Root Dry Matter Yield (YDM) on sucrose Yield††			
196	$\hat{Y} = -2.10 + 0.848$ YDM	0.95	$\hat{Y} = -0.37 + 0.753$ YDM	0.86
392	$\hat{Y} = 1.39 + 0.654$ YDM	0.82	$\hat{Y} = 1.06 + 0.650$ YDM	0.77

†Two commercial, two experimental, two fodder beet, and two fodder beet-sugarbeet combination varieties included in data. Whole root (root + crown) harvested for yield determination.

‡M_1 = Farm level irrigation, M_3 = 1 August water cutoff.

§S_b (Common standard error of the slopes) = 0.011, ¶S_b = 0.009, #S_b = 0.022, ††S_b = 0.063.

water and N levels. This emphasizes the point that the variety of sugarbeets grown within any climatic zone and N level can have an influence on the sucrose concentration and yields obtained.

Within any climatic zone, season, and variety, the major contributing factors that affect sucrose concentration is the amount of N uptake by the plant, the plant growth period of the N uptake, and the water status of the plant. Petiole NO_3-N is an excellent indicator of the N status of the crop at any time during the growing season (27). The level and the rate of change in petiole NO_3-N reflects the net uptake and N assimilation rates. Therefore, the accumulative effect of both time and N uptake rate is taken into consideration when petiole NO_3-N is used to determine the effect of N on sucrose concentration and growth patterns of sugarbeets. The N status late in the season can be predicted from soil and petiole samples (17) or

petiole samples (6) taken earlier in the season. Sucrose concentration at harvest at one location during the same year (1968) was shown to be inversely related to the amount of N fertilizer that was applied preplant ($r = 0.99$), to the NO_3-N concentration on 21 August ($r = 0.96$), and to the average ($r = 0.99$) or integrated average ($r = 0.99$) petiole NO_3-N from 8 July to 21 August (8). In the work described, petiole NO_3-N was used to determine the N status throughout the season at maximum sucrose yield for sugarbeets grown with adequate water at different locations during the same year (Figure 7B) and at the same location (Kimberly) during different years (Figure 7A). High sucrose concentration, in every case, depended upon an early N_o (peak NO_3-N concentration) and upon a decline to a low NO_3-N level during the latter part of the growing season. The peak concentration, N_o, was attributed to high available soil and fertilizer N and a low rate of N use by the plant which usually occurred during the early growth stages. If this peak concentration is delayed due to known or unknown problems in plant growth, low sucrose concentration in the roots may occur. The level of NO_3-N in the petioles at N_o seems to have little effect on the sucrose concentration provided that the rate of decline in petiole NO_3-N is high enough so that low levels are obtained during the latter part of the growing season. The critical low range for NO_3-N has been established at 1000 ppm (27) and experience in this area indicated that petiole NO_3-N should be near 1000 ppm by 20 August to maximize yields, sucrose concentration, and purity. A better method of determining the N status for high sucrose concentration may be the use of the average or integrated average petiole NO_3-N during August when the maximum sucrose is being partitioned to the roots for storage (11). The integrated average is preferred because it can be predicted at mid-season using the given equation (Figure 7). Generally, the petiole NO_3-N concentration during August was associated with the level of sucrose concentration at harvest at any one location. However, there was variation caused by site location.

Maximum sucrose yield was obtained at rather high petiole NO_3-N levels late in the season at some locations where added

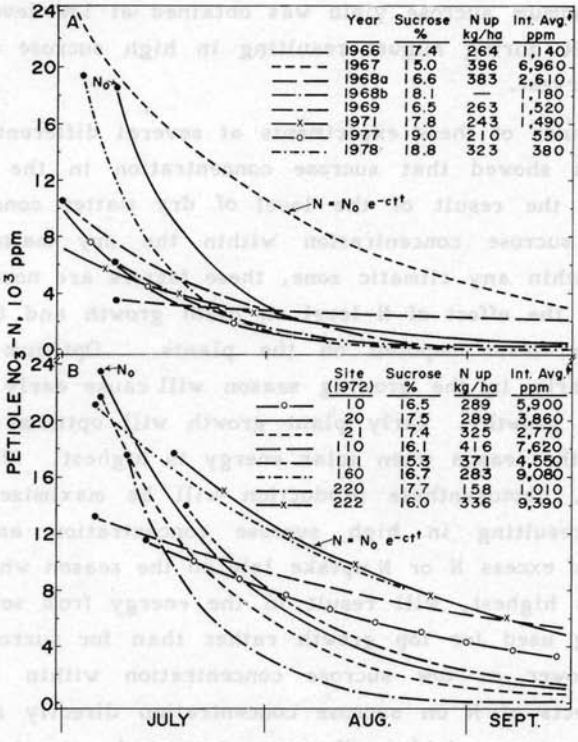

Figure 7. Effect of year (A) and location (B) on the NO_3-N concentration in sugarbeet petioles and its effect on sucrose concentration in the wet roots. † N is the NO_3-N concentration at time t, N_o is the concentration at the first sampling date after the peak occurs, t is any time after the first sampling date, and C is a constant for any given treatment or beet field (6)

‡ $\bar{N} = -\frac{N_o}{C}\frac{(e^{-Ct_2} - e^{-Ct_1})}{t_2 - t_1}$ where $\bar{N}$ is the integrated average

(8) petiole NO_3-N, t_1 = 8/1, t_2 = 9/1.

N was necessary to achieve yield benefits. This was probably caused by high levels of N being available from residual sources in the lower soil profiles caused by past management practices that resulted in N accumulation. This resulted in low sucrose concentration on all treatments including the zero-N treatment. Yield benefits were achieved by fertilizer application to a N deficit surface soil by its effect on early plant growth. In every case, where the field was prepared for sugarbeets by growing a grain crop without fertilizer (1968b, 1971, 1977,

1978), maximum sucrose yield was obtained at low levels of petiole NO_3-N during August resulting in high sucrose concentration at harvest.

The results of these experiments at several different locations and years showed that sucrose concentration in the sugarbeet roots was the result of the level of dry matter concentrations and the sucrose concentration within the dry matter of the roots. Within any climatic zone, these factors are normally controlled by the effect of N level on plant growth and the irrigation water level imposed on the plants. Optimum N levels applied early in the growing season will cause early N uptake and plant growth. Early plant growth will optimize leaf area early in the season when solar energy is highest. Under these conditions, photosynthate production will be maximized for the location resulting in high sucrose concentration and yields. Addition of excess N or N uptake late in the season when sucrose storage is highest, will result in the energy from solar radiation being used for top growth rather than for sucrose storage causing lower or low sucrose concentration within the roots. These effects of N on sucrose concentration directly affects the root and sucrose yields. However, increased sucrose concentration within the roots by moisture stress placed on the roots by limiting irrigations, is basically caused by dehydration of the roots and has little, if any, effect on sucrose production at harvest.

In the production of high quality roots, it is extremely important that fields be selected for the growth of this crop that have low levels of residual N at all soil depths that are within the root zone of sugarbeets. Fields where past management has applied too much N for the crop grown or has leached the N to lower depths within the profile, should be avoided in sugarbeet production. Soil testing at all depths within the root zone of sugarbeets would be advantageous and would locate fields favorable for quality beet root production. However, soil testing by universities commercial consultants, and fertilizer companies do not normally sample or recommend sampling below 60 cm. Past cropping and N fertilizer management provides an alternate

way to determine the fields that are favorable or unfavorable for sugarbeet production if the actual soil N levels are not available.

Fields where a grain crop such as wheat, barley, or corn was grown without N fertilizer or under optimum N fertilization for the crop, have been shown to use up most of the surface and deep N and if the subsequent sugarbeet crop is fertilized according to a reliable soil test, high quality sugarbeet roots should be produced. Whereas, fields where legumes or shallow rooted crops such as potatoes were grown with N fertilizer addition, could contain high levels of N in the lower soil profile and may be detrimental to the production of high quality sugarbeet roots.

The sucrose concentration in the beet roots has been shown to be highly dependent upon the total N uptake and the time the N is taken up by the plant. Within any field, excellent relationships exist between N uptake and sucrose concentration in the roots. However, between fields and years, total N uptake gives only an indication of sugarbeet quality because of the effect of residual N and its location within the profile. Petiole NO_3-N reflects the net effect of N uptake and assimilation rates, and the time that the N is taken up by the sugarbeet. Therefore, an accurately determined petiole NO_3-N for the entire season by methods proposed should give a predictable indication of the quality of the beet root at harvest from samples taken early in the season. However, additional research is needed so that climatic factors between locations and years, and the actual N uptake can be considered for more accurate predictability of actual sucrose concentration in the sugarbeet roots at harvest.

SUMMARY

Data collected at several locations in southern Idaho since 1966 on sugarbeets (*Beta vulgaris* L.) were used to identify and evaluate the effects of factors and conditions that significantly affect sucrose concentration and root quality such as N application, N uptake, irrigation levels, location, year, and growth patterns during the growing season. Optimum N application

applied preplant or during the early plant growth stages, maintains sucrose concentration to a near maximum level for the season. Excessive and late N fertilizer application and plant N uptake from fertilizer or residual N sources caused an increasing proportion of the photosynthate to be used for top growth at the expense of sucrose accumulation in the roots. Increased sucrose concentration caused by irrigation water deficit results from dehydration of the beet roots and does not increase sucrose yield. Fields used for sugarbeet growth should be carefully selected so that the surface and subsoil contain low levels of residual N and N should be applied to these fields in amounts needed for maximum sucrose yield as determined by soil tests. Petiole NO_3-N reflects the net effect of N uptake and assimilation rates, and the time that the N is taken up by the sugarbeet plant indicating that it can be used to predict sucrose concentration within the roots at harvest.

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