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VARIATIONS IN SUCROSE, TOTAL FREE AMINO ACIDS, AND NITRATES OF SUGARBEETS DURING THE GROWING SEASON UNDER HIGH NITROGEN NUTRITIONAL CONDITIONS[1]

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ABSTRACT

Seasonal variation in relative concentrations of total amino acids, nitrate N, and sucrose content under high N conditions was measured in control and N fertilized sugarbeet plants and found to be eratic. Relative concentrations of total amino acids in roots of control plants was high early and late in the season. In the N side dressed plants the total amino acid content in root was significantly higher than that of the control. The tops showed a similar pattern as that of roots for both control and fertilized plants. The nitrate N content of roots was significantly lower than that of tops. The sucrose content of the control plants showed a steady increase throughout the season and that of the fertilized plants a considerable lag soon after nitrogen application. Percent sucrose in fertilized plants was slightly lower than that of controls late in the season.

INTRODUCTION

There have been several reports on the depressing effect of high N application on the sucrose content of sugarbeets. The nitrate N is converted into amino acids in the plant. Therefore, a study of the seasonal variation of relative concentrations of total amino acids, nitrate N and sucrose content of beets was considered helpful in elucidating the relationship of amino acids with sucrose content during the growing season. This study was undertaken to follow the general pattern of change in variables described under high N levels.

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As early as 1912, Headden (7), and later Gardner and Robertson (6), Ulrich (12, 13) and Loomis and Ulrich (9) showed that excessive applications of N lowered the sucrose content of beets. Baver (2) stated that unassimilated nitrogenous compounds produced due to high N applications, consisted mainly of amino acids and related substances. Ulrich (14) found that the sucrose content of sugarbeet roots remained relatively low untill the occurrence of low fall temperatures, when a rapid rise in sugar content was noted. Bergen (3) studied seasonal patterns of sucrose accumulation and weight increase in two diploid varieties of sugarbeets in Taber, Alberta. He noted that the percent sucrose increased steadily (from 7.6 to 15.6%) from the first harvest (July 17) to the last harvest (Oct. 24) in both varieties. Percent sucrose measured on dry weight basis also rose from 64 to 73% during the same period.

Joy (8) studied carbon and N source of protein formed in young leaves of sugarbeets and noted that the main source of N being glutamine/glutamic acid. Snyder and Tolbert (11) used $C^{14}0_2$ in sunlight on sugarbeets grown in nutrient solutions and measured photosynthetic activity from September until early November. They found that roots and blades of the N deficient plants had a significantly greater percentage of C^{14} in sucrose and smaller percentage in malic, citric, and amino acids, whereas the blades of N fertilized plants contained a smaller percentage of C^{14} in sucrose and a greater percent in malic and amino acids.

MATERIALS AND METHODS

Hybrid blend variety of sugarbeet from the Great Western Sugar Company was sown on April 8, 1968 in an irrigated Nunn clay loam at Colorado State University Research Center near Fort Collins, Colorado and thinned to a uniform stand of 22 to 23 centimeters between plants by mid-June. At the time of sowing, soil analysis showed a nitrate N content of 43.5 kilograms per hectare. The N content of a soil immediately south of the experimental site indicating a high N content down to a depth of 150 cm was determined as :

Depth in cm	Available kg/ha	
	NH_4	NO_3
0 - 30	18.5	50.40
30 - 60	18.0	39.00
60 - 90	17.8	30.20
90 - 120	17.3	26.20
120 - 150	18.2	19.82

A side dressing application of 163 kg/ha N was made on July 13 to certain sections of the field in order to be able to have two groups of plants namely fertilized and non-fertilized. When plants reached the 2 true leaf stage (May 21) sampling by leaf stage began and continued until the last week of June when most plants had developed 18- 20 true leaves. From July 1 until harvest time (October 27) weekly random samples were taken from different parts of fertilized and non-fertilized field. 150 plants were used for analyses in each of 2 to 20 true leaf stage and 20 beets for each subsequent stage. Samples were frozen soon after harvest. Later, while frozen, tops (petioles and blades) were separated from roots, cut into small pieces, mixed well, and 2 samples of each (about 150 g)were taken for extraction of juice. Top and root samples were left to thaw at room temperature, and their juice was expressed at 290.5 kg of pressure per cm^2.

Nitrate N content of tops and roots was measured by the standard laboratory procedure as outlined by A.O.A.C. (1). Three groups of plants were used in this experiment :

Group 1. Control (crop season); including all control plants from 2 true leaf until harvest.

Group 2. Control (25 July harvest); including all control plants used for comparison with N fertilized plants.

Group 3. N fertilized plants; including all plants receiving N on July 25.

RESULTS AND DISCUSSION

Mean values of total amino acid, NO_3- N and sucrose contents of roots and tops of N fertilized and control plants are presented in Table 1. Statistical comparisons were made by the method described by Snedecor and Cochran (10). There was no significant difference between the two determinations made on control (crop season), on control (25 July harvest), or on N fertilized plants.

Table 1 shows that in roots of check plants amino acids were initially high, then surpassed the fertilized plants, and remained considerably high until harvest. In N treated plants amino acid content of roots showed a 3 to 6 - fold increased over the control in July, rising gradually until near harvest when it fell and remained below the level of check.

Table 1. Relative concentrations of total free amino acids, percent sucrose and nitrate nitrogen content of tops and roots of sugarbeets as affected by nitrogen application.

Date	Approximate leaf stage	Total amino acids per 100 ml juice				ppm NO_3- N				Percent sucrose	
		Roots		Tops		Roots		Tops		Roots	
		Check	+N	Check	+N	Check	+N	Check	+N	Check	+N
May 28	2-4	–	–	87	–	1935	–	4250	–	.40	–
June 4	5-8	99	–	54	–	2776	–	3483	–	1.45	–
June 11	9-12	201	–	80	–	4969	–	2797	–	3.90	–
June 18	13-16	194	–	64	–	5614	–	3536	–	3.94	–
June 25	17-20	156	–	37	–	2449	–	3071	–	6.25	–
July 1	21-25	128	–	48	–	2225	–	3540	–	8.75	–
July 8	26-30	78	–	40	–	1500	–	2890	–	9.30	–
July 15	–	53	–	58	–	275	–	2100	–	9.55	–
July 25	–	50	170	53	59	990	1420	3175	950	11.10	9.65
Aug. 1	–	47	178	59	72	1525	1640	10500	5600	11.25	9.80
Aug. 8	–	29	180	65	76	1720	2340	9680	5420	11.35	9.30
Aug. 15	–	97	235	84	88	2440	1380	8250	6900	10.15	9.15
Aug. 22	–	73	218	76	79	2230	1540	3450	3640	11.25	10.25
Aug. 29	–	95	209	63	71	1220	965	2440	3480	11.40	10.80
Sept. 5	–	180	190	53	128	2950	945	3150	5200	11.90	11.35
Sept. 12	–	268	401	105	165	3940	875	6650	3960	11.55	11.05
Sept. 20	–	270	292	112	125	1670	890	8360	4800	12.60	12.15
Sept. 27	–	211	350	160	98	1020	775	3110	3650	13.40	13.20
Oct. 3	–	305	108	158	123	1250	1970	5950	6500	13.35	13.20
Oct. 10	–	300	207	201	111	1380	1220	9000	2810	13.55	13.20
Oct. 17	–	306	286	215	66	1230	1320	5450	4300	14.15	12.90
Oct. 27	–	213	255	233	245	1015	860	5180	2500	13.90	13.60
Means :	Crop season	159	–	95	–	2105	–	5144	–	–	–
	July 25 harvest	174	234	117	107	1327	1295	6063	4265	12.22	11.40

For tops the control plants showed a relatively stable concentration of amino acids from May 28 until September 12, when it began to rise sharply and remained high until harvest. The N treated plants maintained a high initial level of amino acids from July 25 until September 20 when it began to fall below the level of control and remained so until harvest when it rose again.

As indicated in Table 1, the concentration of NO_3 - N roots of control plants was high early in the season and then increased sharply. Later it fluctuated with another sharp rise before harvest. The NO_3 - N content of N treated plants remained below the level of control from July 25 and maintained this general low level until harvest.

The percent sucrose in the roots of control plants showed a steady rise from 2 to 30 leaf stage. Application of N decreased the percent sucrose in treated plants and chemical analysis showed concentrations below the level of control throughout the season. There was a slight increase in percent sucrose as the season advanced.

Seasonal variations of amino acids, nitrate N and percent sucrose as affected by N applications are presented in Table 2. There was no significant difference between amino acid content of tops for control (crop season) and N fertilized plants. Similarly comparison of means for control (25 July harvest) and means for N fertilized plants showed no significant differences.

The nitrate N contents of roots showed a reverse trend compared with their amino acids. The means for nitrate N of roots of control plants (crop season) was significantly higher than those of N fertilized plants. There was no significant difference between 25 July - harvest and N - fertilized plants. The difference between means of ppm nitrate N in roots of the two controls (25 July harvest and crop season) was significant. When the mean for nitrate N in tops of control (crop season) was compared with the mean for tops of N fertilized plants there was no significant difference. The same was true when the means of tops for control (25 July harvest) and N - fertilized plants were compared. The mean percent sucrose for N - fertilized and control plants showed no significant difference but the sucrose level in N - treated plants remained below that of control plants.

Table 1 and 2 show that under conditions of high N nutrition even the relative total amino acid content of roots and tops of controls seem to follow a similar pattern to that of N - side dressed sugarbeets though at a lower level. Application of N raised the amino

Table 2. Means of relative total amino acids and nitrate nitrogen of tops and roots and percent sucrose of roots of sugarbeets under high nitrogen condition.

Characteristic under study		Means
Relative total amino acids		
1.	Roots, mg	
a.	Control (crop season)	159.0[a]*
b.	Control (25 July - harvest)	174.0[a]
c.	+N (25 July – harvest)	234.0[b]
2.	Tops, mg	
a.	Control (crop season)	95.0[a]
b.	Control (25 July - harvest)	117.0[a]
c.	+N (25 July - harvest)	107.0[a]
NO_3 - N		
3.	Roots, ppm	
a.	Control (crop season)	2105[a]
b.	Control (25 July - harvest)	1327[b]
c.	+N (25 July - harvest)	1295[b]
4.	Tops, ppm	
a.	Control (crop season)	5144[a]
b.	Control (25 July - harvest)	6063[a]
c.	+N (25 July - harvest)	4263[a]
Sucrose		
5.	Roots, %	
a.	Control (25 July - harvest)	12.22[a]
b.	+N (25 July - harvest)	11.40[a]

* Means in each group followed by the same letter are not significantly different at 5% probability level (Duncan's Test).

acid contents of roots considerably and significantly over the control of roots and tops for most part of the season. At harvest, controls and N - side dressed amino acids showed little difference. This may be due to penetration of roots to deeper zones in soil with greater nitrate concentration as the season advanced. The sucrose content of N - fertilized plants was far below the control soon after application of N in early August than later in the season. This may be due to high uptake of nitrates soon after application of ammonium nitrate and the depressing effect which it had on the sucrose content. The sucrose content of N - fertilized plants rose gradually until harvest when the difference between the control and N - fertilized plants became very small.

Due to available nitrates, the nitrate N content of roots in control plants, as is seen in Table 1, was high early in the season, declined to a minimum in mid-season and gradually rose later but never reached the early season peak. The nitrate N content of roots of the fertilized plants showed a sudden sharp rise above the control for the first 3 weeks after application of ammonium nitrate, but remained below the high level of control for the most part of the season with little fluctuation. The tops showed a high nitrate N content which fluctuated more than the roots did. It appeared that as season advanced roots penetrated deeper in soil where the nitrate concentration was higher and this was reflected by the gradual rise in their nitrate content as harvest approached.

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