Osmolality of L19 Type Sugarbeet Germplasm

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ABSTRACT

Sucrose is the major soluble particle in mature sugarbeet root cells and differences in sucrose concentration should correlate with osmotic concentration. Extracts were prepared of frozen root tissue of 5-wk-old seedlings, and osmotic concentrations were determined with a vapor pressure osmometer. Tests were conducted under different levels of N fertility, drought, day length, and temperature, and for a wide range of commercial hybrids, experimental hybrids, and inbreds. Osmotic concentrations in sugarbeet seedlings were not affected by different levels of N fertility, drought, or temperature even though plant growth was affected significantly by these parameters. Correlations between seedling osmotic concentration and harvest sucrose concentration of sugarbeets grown in four separate field trials were significant in two experiments (r = 0.75 and 0.84) and non-significant in two others (r = 0.06 and 0.26). Significant correlations were due largely to the high sugar L19 inbred or to hybrids with L19 inbred as a parent. No cultivar X environmental interactions were detected in tests involving the L19 inbred. This inbred consistently gave significantly higher osmotic concentrations than the other cultivars, whereas no differences were found among non-L19 cultivars. Osmolality measurements may be used to identify L19 type germplasm but may not be useful to identify other high potential sucrose lines.

Additional Key Words: *Beta vulgaris* L., sucrose concentration, N fertility, drought, day length, temperature

Osmolality is an expression of the total number of solute particles dissolved in a given volume, without regard for particle size, density, configuration, or electrical charge. It is a measure of the concentration of soluble particles which, in mature sugarbeet root, is primarily sucrose. Differences in sucrose concentration should affect the osmolality of the beet root cells. Accordingly, sucrose concentrations may be determined indirectly by measuring the osmolality of the root cell juice.

As a general rule, the osmotic potential of plant cells remains relatively constant with cell growth and age (Lockhart, 1965). McCready et al. (1966) found that the calculated osmolality of sucrose and non-sucrose chemicals in pressed beet juice were remarkably constant. Since osmotic concentration is not a function of age, potential genetic differences in sucrose accumulation may be reflected by genetic differences in the osmolality of young plants.

Goodban and McCready (1968) studied the effects of nitrogen fertility and age on sucrose accumulation and osmotic concentration of sugarbeet root juice. Their first test involving two nitrogen levels showed no correlation between sucrose concentration and osmolality. Subsequent tests with high and low nitrogen levels and age differences of 8-, 12- and 17-wk postplanting gave significant correlations of $r = 0.75$ in a replicated field trial and $r = 0.58$ in a greenhouse trial. These results suggested the need for further studies.

K. Nielsen (1973, personal communication, unpublished) obtained a significant correlation between sucrose concentration and osmotic pressure in variety trials involving genotypes with genetically-different sucrose accumulation potential. In their studies of sucrose accumulation, Theurer and Doney (1989) reported a unique sucrose accumulation pattern for a high sucrose inbred, L19, *versus* most other sugarbeet inbreds.

In this paper we report the effects of environmental parameters and genotypes on the osmolality of young sugarbeet roots. Our ultimate objective is to identify, in the seedling stage, genotypes with high sucrose accumulation potential.

MATERIALS AND METHODS

Field Tests. Sucrose percentage measurements were made for brei of mature roots from 1976 and 1977 replicated field trials conducted at Logan, Utah (soil type: Millville silt loam). Each field trial had six replications in a randomized block design. Plots were two rows wide by 10.8 m long, with 55 cm between rows. Plants were thinned to a 23-cm spacing at the four-leaf stage. At harvest (early October), all beets from each plot were

machine-harvested and weighed. Duplicate samples of 10 beets were selected at random from each plot for sucrose analysis. Sucrose concentrations were determined on beet pulp by the cold digestion method (McGinnis, 1982).

Growth Chamber Tests. Osmotic concentrations for field-tested cultivars were determined on seedlings grown in growth chambers. All growth chamber experiments used 5 by 10.5 cm pots. Plots consisted of 30 plants of each variety in a completely randomized design. Each experiment was repeated twice. Plants were harvested at 5 wk post-emergence and the roots were weighed and frozen for subsequent osmolality measurements.

One of the most important variables affecting osmotic concentration is available water. Differences in available moisture could give differences in osmotic potential that are due to available moisture and not to genetic factors. Therefore, all soils were brought up to field capacity prior to harvest.

Genotypes L19 (a high sugar inbred), GWD2 (a moderate sugar hybrid) and USH10B (a low sugar hybrid) were tested under four environments (nitrogen fertility, drought, day length, and temperature). These three genotypes differed in potential harvestable sucrose concentrations by two percentage points each. These experiments were conducted in the growth chamber. The experimental design was a split-plot with 30 replicates (plants) per split plot. Nitrogen levels consisted of 1) half-strength Hoagland's solution, and 2) full-strength Hoagland's solution. Drought was simulated by adding polyethylene glycol (PEG 6000) to the nutrient solution. Drought treatments were 1) no PEG, 2) 1% PEG, and 3) 2% PEG. Day lengths were 1) continuous light, or 2) 9 hr light:15 hr dark. Temperature treatments consisted of 1) 24C continuously, or 2) 24C for 8 hr followed by 5C for 16 hr.

Osmolality Measurements. All osmotic concentrations of beet juice were measured with a vapor pressure osmometer. The vapor pressure method has an advantage over other methods because no change in the physical state of the tissue is necessary and artifacts that quite often occur when tissue is altered physically are eliminated. Frozen samples were allowed to thaw at room temperature for 10 min before testing. Juice was expressed from the thawed frozen root tissue and measured immediately for osmotic concentration. Osmotic concentrations are expressed as mmol/kg.

RESULTS

The stability of osmotic concentration in sugarbeet seedlings was evaluated at different levels of four environmental parameters (Table 1).

Table 1. Osmotic concentration and root weight of sugarbeet seedlings at different levels of drought, fertility, temperature and day length.

Treatment and level	Osmotic concentration	Root weight
	-----(mmol/kg) -----	(grams/plant)
Simulated drought (24 hr full light at 24C)		
No PEG	679	2.00
1% PEG	704	1.90
2% PEG	717	1.88
LSD ($P = 0.05$)	ns	ns
Fertility level (24 hr full light at 24C)		
Full-strength N	739	1.80
Half-strength N	708	1.65
LSD ($P = 0.05$)	ns	0.10
Temperature (24 hr full light)		
24C continuous	824	1.89
24C - 5C†	806	1.38
LSD ($P = 0.05$)	ns	0.18
Day length (24C continuous)		
24 hr full light	512	1.56
Alternate light and dark‡	428	1.43
LSD (P = 0.05)	28	0.12

† 8 hr at 24C followed by 16 hr at 5C.
‡ 9 hr full light followed by 15 hr dark.

PEG-simulated drought decreased root weight and increased the osmotic concentration. These effects, although in the expected direction, were small and not significant, except for root weight at 2% OEG.

Root weight was affected significantly by fertility, temperature and day length (Table 1). However, only day length significantly affected osmotic concentration. The plants

in the day length study were small and the cells may not have reached sufficient maturity to give reliable osmotic concentration data. Results tend to support the theory that plant cells remain relatively constant in osmotic concentration with growth.

Seedling osmotic concentration was compared with sucrose percentage at harvest for several cultivars from three separate replicated field trials. These field trials consisted of cultivars with sucrose concentration ranges of two (Tables 2 and 3) and three (Table 4) percentage points. In the test of 11 sugarbeet hybrids (Table 2), significant differences in sucrose concentration were present in the harvested beets. However, only small differences in osmotic concentration were observed in the seedlings, and there was no correlation between harvest sucrose percentage and seedling osmotic concentration (r = 0.06). In the other two tests (Tables 3 and 4), significant differences occurred

Table 2. Harvest sucrose concentration (mean of two 1977 replicated field trials) and seedling osmotic concentrationof 11 sugarbeet hybrids.[†]

Hybrid	Harvest sucrose	Seedling osmotic concentration
	(%)	(mmol/kg)
ACH 107	15.6 a[‡]	471 a
GWD2	15.5 a	465 ab
GWC3	15.1 ab	474 a
USH20	15.0 abc	455 ab
AH 10	14.8 bc	470 a
GWCx2	14.8 bc	443 ab
L53xg1	14.8 bc	484 a
GWCx1	14.6 bc	484 a
HH 22	14.5 bcd	434 b
AH 11	14.4 cd	482 a
USH 10B	13.9 d	464 ab

[†]Correlation between sucrose % and osmotic concentration, r = 0.06.
[‡]Means within a column followed by a common letter are not significantly different (P=0.05) according to Duncan's multiple range test.

Table 3. Harvest sucrose concentration (from 1976 replicated field trial) and seedling osmotic concentration of nine sugarbeet cultivars.[†]

Cultivar	Harvest sucrose	Seedling osmotic concentration
	(%)	(mmol/kg)
(L33xL5)xL19	16.5 a[‡]	432 a
(L29xL21)xL19	16.1 ab	413 a
A7113xL3	15.6 bc	374 b
Ultramono	15.2 cd	376 b
(L21xC1)xL37	14.8 d	389 b
(L1xL53)xE1xL29)	14.8 d	385 b
Marimono	14.8 d	369 b
(L33xL29)xL37	14.5 d	386 b
Monova	14.5 d	380 b

[†]Correlation between sucrose % and osmotic concentration, r = 0.76; without hybrids involving L19, r = - 0.47.
[‡]Means within a column followed by a common letter are not significantly different (P=0.05) according to Duncan's multiple range test.

in seedling osmotic concentrations, and positive correlations were found between sucrose concentration and osmotic concentration (r = 0.76, Table 3; r = 0.26, Table 4). However, the cultivars with the high sugar inbred L19 as a parent were the major contributors to the significant correlation (Table 3) and the significant differences in osmotic concentration (Tables 3 and 4). Removal of data points for the two hybrids that involved L19 reduced the correlations to r = - 0.47 (Table 3) and r = - 0.56 (Table 4).

Subsequently, a test was conducted involving six inbreds differing in potential sucrose concentration by over four percentage points (Table 5). Sucrose concentration differed significantly among most of the inbreds (Table 5). Significant differences in osmotic concentration also were observed among the inbreds. However, these differences again were due largely to the inbred L19. The significant correlation of r = 0.84 between sucrose percentage and osmotic concentration was due to the significant differences between the high sugar lines L19 and L53 and the lack of significance among other inbreds.

Three cultivars (L19, a high sugar inbred; GWD2, a medium sugar hybrid; and USH10B, a low sugar hybrid) were evaluated for cultivar X environmental interaction under the four environmental

Table 4. Harvest sucrose concentration (from 1977 replicated field trial) and seedling osmotic concentration of 10 experimental hybrids.[†]

Hybrid	Harvest sucrose	Seedling osmotic concentration
	(%)	(mmol/kg)
L53xL19	15.1 a	455 a
A5xL19	14.3 b	468 a
L29xE2	13.8 bc	436 bc
A5xL37	13.6 bcd	434 bc
L53xL37	13.5 cd	412 c
A5xE2	13.4 cd	439 bc
L53xE2	12.8 de	448 ab
L29xL10	12.6 e	447 ab
L53xL10	12.4 e	448 ab
A5xL10	12.3 e	437 bc

[†]Correlation between sucrose % and osmotic concentration, r = 0.26; without the two hybrids involving L19, r = - 0.56.
[‡]Means within a column followed by a common letter are not significantly different (P=0.05) according to Duncan's multiple range test.

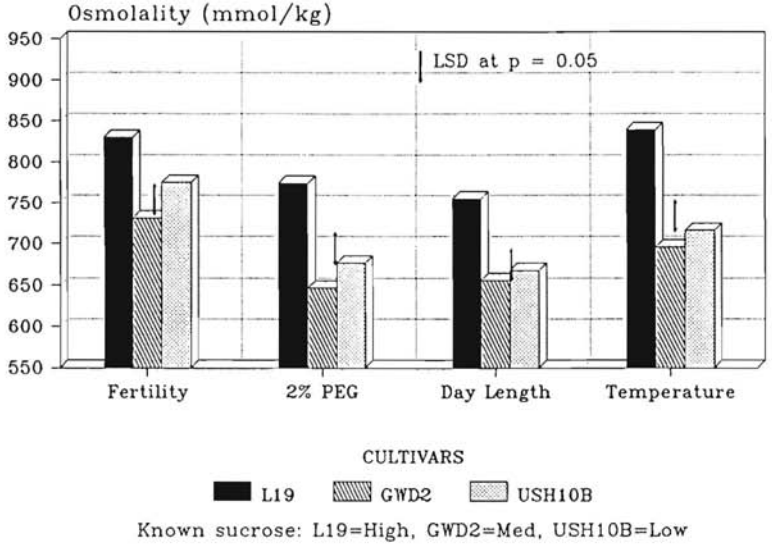
Table 5. Harvest sucrose concentration (from 1977 replicated trial) and seedling osmotic concentration of six inbreds.[†]

Inbred	Harvest sucrose	Seedling osmotic concentration
	(%)	(mmol/kg)
L19	15.3 a[‡]	472 a
L53	13.6 b	445 b
L10	12.8 c	413 c
L37	11.9 d	414 c
E2	11.3 de	434 bc
L29	10.9 e	406 c

[†]Correlation between sucrose % and osmotic concentration, r = 0.84.
[‡]Means within a column followed by a common letter are not significantly different (P=0.05) according to Duncan's multiple range test.

parameters (drought, fertility, temperature, and day length). No cultivar X environment interaction was observed. The three cultivars behaved similarly in each test. L19 had a significantly higher osmotic concentration than the other two cultivars in each experiment (Figure 1). USH10B, which has a potential sucrose concentration less than that of GWD2, did not differ in osmotic concentration from GWD2 in each test.

Figure 1.



Known sucrose: L19=High, GWD2=Med, USH10B=Low

DISCUSSION AND CONCLUSIONS

Osmotic concentration appears to be relatively stable over a wide range of environmental parameters and plant age. Even in seedlings, the osmotic concentration is stable. Any change (increase or decrease) of one of the solute particles in the cell (such as sucrose or N) may be compensated for by an equal change (decrease or increase) of the other solute particles.

This phenomenon may explain the negative effects of high nitrogen on sugar accumulation. Under high nitrogen fertilization, high concentrations of N are accumulated in the cell. In order to maintain a constant cell osmotic concentration, lower concentrations of sucrose are accumulated.

The potential osmolality of a genotype appears to be inherited. However, the osmolality of the majority of the germplasm tested (wide range of experimental and commercial hybrids) is not genetically different. Only the L19 type germplasm showed genetic differences in osmolality. L19 was

consistently higher in osmolality in every test and in every environment tested. This type of germplasm was shown to have a unique sucrose accumulation pattern compared with other high sugar lines (Theurer and Doney, 1989). L19 has a lower sucrose percentage in the early stages of growth, but accumulates sucrose more rapidly after 60 to 70 days than other high sugar lines. The L19 inbred also has a higher dry matter content than other high sugar lines (Theurer and Doney, 1989). Plants with high osmolality also should have high dry matter content.

The use of osmolality measurements in young plants may be effective in identifying L19 type germplasm but may be ineffective in identifying other high potential sucrose lines.

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