African Journal of Biotechnology Vol. 10(67), pp. 15179-15183, 31 October, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.2324
ISSN 1684–5315 © 2011 Academic Journals

*Full Length Research Paper*

# Non-sugar matter as an indicator of technological value in different sugar beet genotypes

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Accepted 15 September, 2011

**This work represents a research of non-sugar matter (the content of α- amino nitrogen, potassium and sodium) in the root, and their effect on the recoverable sucrose quantity of three genotypes (Esprit, Belinda and Chiara) of sugar beet from vegetation areas of different sizes. They were grown by standard agrotechnical measures for sugar beet in the densities of 80.000, 100.000 and 120.000 plants per hectare. In 2005, the highest sugar utilization coefficient (12.94%) was achieved in the variant where plant density was 120.000 per hectare (0.083 $m^2$) and the genotype was Esprit (N-type), which was 5.48% more than that in the variant with the lowest utilization coefficient (12.23%), where density was 100.000 per hectare (0.1 $m^2$) and the genotype was Chiara (E-type). In 2006, the highest sugar utilization coefficient of 14.03% was achieved in the variant where plant density was 120.000 per hectare (0.083%) and the genotype Belinda (Z-type), which was 6.84% more than that in the variant with the lowest utilization coefficient (13.07%), with the density of 100.000 per hectare (0.1$m^2$) and genotype Esprit (N-type). In 2007, the highest sugar utilization coefficient of 14.27% was recorded in the variant with the plant density of 80.000 per hectare (0.125 $m^2$) and the genotype Belinda (Z-type), which was higher by 8.26% as compared to the variant with the lowest utilization coefficient (13.09%), where density was 100.000 per hectare (0.1$m^2$) and the genotype was Chiara (E-type).**

**Key words**: Sucrose content, recoverable sucrose, alpha amino nitrogen, potassium, sodium, genotype, sugar beet.

## INTRODUCTION

Sugar beet technological value is determined by sucrose and non-sugar matter content in the storage root. Non-sugar components (α-amino-nitrogen or harmful nitrogen, potassium, sodium, magnesium, calcium) in the root reduces sugar crystallization from molasses during sugar beet processing (Sinobad and Brdar, 1996; Bashir et al., 2000; Sklenar et al., 2000; Radivojević and Kabić, 2000; Leilah et al., 2005; Pytlarz-Kozicka, 2005; Jaćimović et al., 2006; Mahmood et al., 2007; Filipović, 2009). The percentage of crystallized sugar from molasses is calculated with Reinefeld’s formula. The obtained value is the percentage of total sugar content utilization from the storage root. The percentage of crystal sugar content is affected by a multitude of factors. Significant differences between total and crystal sugar content are caused by the size of plant’s vegetative site as well as by sugar beet genotypes (Filipović, 2009).

The selection of the best suited genotype should involve the testing of large number of genotypes differing in sugar synthesis intensity and sugar accumulation in the storage root. Genotypes of a shorter vegetative period have faster initial growth and earlier sugar synthesis hence they achieve earlier technological maturity, that is, the period of sugar optimal utilization from the root starts earlier. These genotypes are referred to as sugary genotypes or Z-type genotypes, and they are suitable for early harvest dates. E-type genotypes, on the other hand, have the longest sugar accumulation period and they

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**Table 1.** Analysis of variance for indicators of technological value of sugar beet root (2005).

| Source of variation | df | Mean squares | | | | |
|---|---|---|---|---|---|---|
| | | Sucrose content | Potassium content | Sodium content | α-Amino nitrogen content | Recoverable sugar content |
| Blocks | 3 | $0.30^{NS}$ | $0.07^{NS}$ | 0.20* | $0.13^{NS}$ | $0.30^{NS}$ |
| Plant density | 2 | 0.61* | $0.09^{NS}$ | 0.69** | $0.03^{NS}$ | 0.61* |
| Genotype | 2 | $0.11^{NS}$ | $0.06^{NS}$ | $0.03^{NS}$ | $0.03^{NS}$ | $0.11^{NS}$ |
| Plant density x Genotype | 4 | $0.14^{NS}$ | $0.02^{NS}$ | $0.06^{NS}$ | $0.07^{NS}$ | $0.14^{NS}$ |
| Error | 24 | 0.13 | 0.09 | 0.05 | 0.05 | 0.13 |

NS = Non-significant; * = significant at 0.05 probability level; ** = significant at 0.01 probability level.

are suitable for late harvest dates (Ramadan, 1999). Total sugar content in the root and percentage of sugar utilization is considerably affected by nitrogen rates and arrangement of fertilizer application and plant nutrition (Halvorson and Hartman, 1975).

This paper presents, firstly, the studies of non-sugar matter content in the root of three sugar beet genotypes (Belinda Z–type, Esprit N–type and Chiara E–type) grown at different crop densities and, secondly, the effect of non-sugar matter on percentage of crystal sugar sucrose.

## MATERIALS AND METHODS

Three-year trials were conducted during 2005 to 2007 period on the experimental field of the Institute of *"Tamiš"* Pančevo (N 44° 56`, E 20° 43`) as a randomized complete block design with four replications. The size of vegetative site for individual plants was 0.125 $m^2$ (80.000 plants per hectare), 0.1 $m^2$ (100.000 plants per hectare) and 0.083 $m^2$ (120.000 plants per hectare). It was formed by crop hand thinning during a sprouting stage. The studies comprised genotypes Belinda (KWS – 2004. Z–type), Esprit (Strube Dieckmann – 2004. N–type) and Chiara (KWS – 2004. E–type). Sugar beet was hand harvested and analysis was conducted on the sugar beet roots from middle rows of the elementary site. About 150 g of pulp from each plot was prepared by Venema apparatus and kept in a freezer until analysis. Frozen sugar beet pulp samples were analyzed in sugar technology laboratory in Sugar Factory ˝Jedinstvo˝ from Kovačica of Serbia for purity parameters with Betalyser. Betalyser is a computer-controlled system for automated routine analysis of sugar beet on sugar content and impurities including $Na^+$, $K^+$ and α-amino-N. Sugar content ($S^0$) was measured by polarimetry, $Na^+$ and $K^+$ by flame-emission photometry and α-amino-N by double beam filter photometry using the blue number method (Sheikh-Aleslami, 1997).

The values of potassium, sodium and harmful nitrogen were expressed in mmol/100 g of sugar beet, while content of total sugar sucrose and crystal sugar content are given in percentages (%). Based on the results obtained, computations were done for crystal sugar percentage on Reinefeld formula (1974):

$$SU = S^0 - [0.343 \times (K + Na) + 0.094 \times \alpha\text{-amino-N} + 0.29]\%$$

Where, SU is sugar utilization and $S^0$ is sugar content.

The obtained data were analyzed by mathematical-statistic methods (Snedecor and Kochran, 1971). The statistical analysis was performed according to the design established in each field using the SYSTAT 7.0 statistical package (SYSTAT, 1997). Analysis of variance was applied to estimate significance derived by F-test and LSD-test for 5 and 1% significance.

## RESULTS AND DISCUSSION

In the first study year, the impact of crop density on sodium content ($p<0.01$) was highly statistically significant. In the same year, the recorded statistical significance of the effect of crop density on sucrose content and sugar utilization coefficient was at the significance level of 0.05 (Tables 1 and 2).

The highest content of total sugar was found in genotype Esprit grown on the vegetative site of 0.083 $m^2$ (13.25%) and the lowest was found in genotype Chiara, with vegetative site of 0.1 $m^2$ (12.54%). In genotype Esprit, the content of harmful nitrogen was highest in the crop of the lowest density (2.69 mmol/100 g of sugar beet) and lowest when the size of vegetative site was 0.1 $m^2$ (2.40 mmol/100 g of sugar beet). Many researchers have also suggested that choice of genotypes increased the yield and quality of sugar beet (Lauer, 1997; Wyszynski et al., 1998; Sohrabi and Heidari, 2008). Genotype Chiara had the highest potassium and sodium content in the root. On the vegetative site of 0.125 $m^2$, the content of potassium was 3.38 mmol/100 g of sugar beet and in genotype Belinda (0.1 $m^2$) it amounted to 3.03 mmol/100 g of sugar beet. According to Kessel and Schladen (1984), the values of potassium content lower than 4 mmol/100 g of sugar beet are low, while those that are higher than 5 mmol/100 g of sugar beet are high. The highest difference in sodium content per genotype was found between genotype Chiara (1.80 mmol/100 g of sugar beet) and genotype Esprit (1.14 mmol/100 g of sugar beet) with identical size of the vegetative site (0.1 $m^2$). The amounts of non-sugar matter which varied per genotype and crop density influenced the percentage of crystal sugar sucrose too. The lowest content of crystal sugar was in genotype Chiara on the vegetative site of 0.1. $m^2$ (12.23%) and it was highest in genotype Esprit on the vegetative site of 0.083 $m^2$ (12.94%). These results conform to the reports by Radivojević and Kabić (2000).

Interaction of genotypes and plant density produced significant effects on difference in sodium content potassium ($P<0.05$). Variations per genotype were not

**Table 2.** Effect of sugar beet genotypes and plant density treatments combination on sucrose content and technological value of sugar beet root (2005).

| Genotype (A) and plant density (B) | Sucrose content (%) | Potassium content (mmol/100 g of root) | Sodium content (mmol/100 g of root) | α-Amino nitrogen content (mmol/100 g of root) | Recoverable sugar content (%) |
|---|---|---|---|---|---|
| **Genotype (A)** | | | | | |
| Esprit | $12.95^{a\dagger}$ | $3.28^{a}$ | $1.47^{a}$ | $2.61^{a}$ | $12.64^{a}$ |
| Chiara | $12.95^{a}$ | $3.22^{a}$ | $1.43^{a}$ | $2.58^{a}$ | $12.64^{a}$ |
| Belinda | $12.78^{a}$ | $3.13^{a}$ | $1.37^{a}$ | $2.52^{a}$ | $12.48^{a}$ |
| **Plant density (B)** | | | | | |
| 80000 | $13.13^{a}$ | $3.30^{a}$ | $1.66^{a}$ | $2.62^{a}$ | $12.82^{a}$ |
| 100000 | $12.88^{ab}$ | $3.16^{a}$ | $1.44^{b}$ | $2.54^{a}$ | $12.57^{ab}$ |
| 120000 | $12.68^{b}$ | $3.16^{a}$ | $1.18^{c}$ | $2.53^{a}$ | $12.37^{b}$ |

$^{\dagger}$Means not sharing a common letter in a column differ significantly at 0.05 probability.

**Table 3.** Analysis of variance for indicators of technological value of sugar beet root (2006).

| Source of variation | df | Mean squares | | | | |
|---|---|---|---|---|---|---|
| | | Sucrose content | Potassium content | Sodium content | α-Amino nitrogen content | Recoverable sugar content |
| Blocks | 3 | $0.69^{NS}$ | $0.09^{NS}$ | $0.08^{NS}$ | $0.23^{NS}$ | $0.69^{NS}$ |
| Plant density | 2 | $0.67^{NS}$ | $0.05^{NS}$ | $0.09^{NS}$ | $0.30^{NS}$ | $0.67^{NS}$ |
| Genotype | 2 | $0.13^{NS}$ | $0.01^{NS}$ | $0.02^{NS}$ | $0.04^{NS}$ | $0.13^{NS}$ |
| Plant density x Genotype | 4 | $0.29^{NS}$ | $0.14^{NS}$ | 0.51* | $0.11^{NS}$ | $0.29^{NS}$ |
| Error | 24 | 0.29 | 0.10 | 0.13 | 0.35 | 0.29 |

NS = Non-significant;* = significant at 0.05 probability level; ** = significant at 0.01 probability level.

significant. In the second study year, individual variations in total sugar and non-sugar matter content as well as sugar utilization from juice were not significant (Tables 3 and 4).

The highest total sugar content (14.34%) was found in genotype Belinda at crop density of 120.000 plants per hectare, and the lowest was in genotype Esprit (13.38%) at the density of 100.000 plants per hectare. In average, the lowest values of potassium, sodium and harmful α-amino nitrogen content were found in the variant genotype Esprit × 100.000 plants per hectare. This automatically resulted to the lowest sugar utilization in this variant, while the highest sugar utilization was found in genotype Belinda at crop density of 120.000 plants per hectare.

In the third study year, the effect of crop density showed extremely high statistical significance for sugar content, sodium content and utilization coefficient ($p<0.01$). However, the coefficient of sugar utilization was at the same level; over 97.6%. According to the results reported by Sinobad and Brdar (1996), non-sugar components significantly reduced total sucrose content in the root but did not significantly reduce the coefficient of sugar utilization. Sklenar et al. (2000), on the other hand, pointed out that non-sugar matter content significantly influences the coefficient of sugar utilization. Technological value of sugar beet roots, at total average, was highest in the third study year (Tables 5 and 6).

The size of vegetative site influenced total sugar content in the root. As crop density was increased, total sugar content was decreased; 14.09 to 13.89%. This difference was significant. The coefficient of nitrogen utilization in the soil depends on the number of plants per unit area. In more dense crops, the competition is great, which causes reduced crop nitrogen supply and lesser production of sugar (Winter, 1990). Variations in total sugar content per genotype were not significant. Non-sugar matter content was significantly influenced by crop densities. As vegetative site was increased, sodium content was also increased; 1.25 to 1.42 mmol/100 g of sugar beet, the obtained difference was very significant. Sugar utilization from juice was higher in the roots that were developed on a larger vegetative site, and variations from crops of highest density to crops of lowest density were very significant. Increased content of non-sugar matter did not significantly influence sugar

**Table 4.** Effect of sugar beet genotypes and plant density treatments combination on sucrose content and technological value of sugar beet root (2006).

| Genotype (A) and Plant density (B) | Sucrose content (%) | Potassium content (mmol/100 g of root) | Sodium content (mmol/100 g of root) | α-amino nitrogen content (mmol/100 g of root) | Recoverable sugar content (%) |
|---|---|---|---|---|---|
| **Genotype (A)** | | | | | |
| Esprit | 13.77$^{a†}$ | 2.58$^{a}$ | 1.64$^{a}$ | 2.92$^{a}$ | 13.46$^{a}$ |
| Chiara | 13.76$^{a}$ | 2.54$^{a}$ | 1.59$^{a}$ | 2.88$^{a}$ | 13.45$^{a}$ |
| Belinda | 13.59$^{a}$ | 2.52$^{a}$ | 1.57$^{a}$ | 2.81$^{a}$ | 13.28$^{a}$ |
| | | | | | |
| **Plant density (B)** | | | | | |
| 80000 | 13.93$^{a}$ | 2.61$^{a}$ | 1.69$^{a}$ | 3.05$^{a}$ | 13.62$^{a}$ |
| 100000 | 13.73$^{a}$ | 2.54$^{a}$ | 1.59$^{a}$ | 2.84$^{a}$ | 13.42$^{a}$ |
| 120000 | 13.46$^{a}$ | 2.49$^{a}$ | 1.52$^{a}$ | 2.74$^{a}$ | 13.15$^{a}$ |

†Means not sharing a common letter in a column differ significantly at 0.05 probability.

**Table 5.** Analysis of variance for indicators of technological value of sugar beet root (2007).

| Source of variation | df | Mean squares | | | | |
|---|---|---|---|---|---|---|
| | | Sucrose content | Potassium content | Sodium content | α-Amino nitrogen content | Recoverable sugar content |
| Blocks | 3 | 0.23$^{NS}$ | 0.06$^{NS}$ | 0.04$^{NS}$ | 0.52$^{NS}$ | 0.23$^{NS}$ |
| Plant density | 2 | 2.39** | 0.33$^{NS}$ | 1.28** | 0.56$^{NS}$ | 2.39** |
| Genotype | 2 | 0.13$^{NS}$ | 0.07$^{NS}$ | 0.02$^{NS}$ | 0.16$^{NS}$ | 0.12$^{NS}$ |
| Plant density x Genotype | 4 | 0.12$^{NS}$ | 0.04$^{NS}$ | 0.06$^{NS}$ | 0.47$^{NS}$ | 0.11$^{NS}$ |
| Error | 24 | 0.24 | 0.22 | 0.03 | 0.28 | 0.25 |

NS = Non-significant; * = significant at 0.05 probability level; ** = significant at 0.01 probability level.

**Table 6.** Effect of sugar beet genotypes and plant density treatments combination on sucrose content and technological value of sugar beet root (2007).

| Genotype (A) and Plant density (B) | Sucrose content (%) | Potassium content (mmol/100 g of root) | Sodium content (mmol/100 g of root) | α-Amino nitrogen content (mmol/100 g of root) | Recoverable sugar content (%) |
|---|---|---|---|---|---|
| **Genotype (A)** | | | | | |
| Esprit | 14.09$^{a†}$ | 3.26$^{a}$ | 1.46$^{a}$ | 2.32$^{a}$ | 13.78$^{a}$ |
| Chiara | 14.00$^{a}$ | 3.19$^{a}$ | 1.42$^{a}$ | 2.23$^{a}$ | 13.70$^{a}$ |
| Belinda | 13.88$^{a}$ | 3.11$^{a}$ | 1.37$^{a}$ | 2.10$^{a}$ | 13.58$^{a}$ |
| | | | | | |
| **Plant density (B)** | | | | | |
| 80000 | 14.30$^{a}$ | 3.28$^{a}$ | 1.64$^{a}$ | 2.43$^{a}$ | 14.00$^{a}$ |
| 100000 | 14.19$^{a}$ | 3.28$^{a}$ | 1.56$^{a}$ | 2.24$^{a}$ | 13.89$^{a}$ |
| 120000 | 13.48$^{b}$ | 2.99$^{a}$ | 1.04$^{b}$ | 2.00$^{a}$ | 13.17$^{b}$ |

†Means not sharing a common letter in a column differ significantly at 0.05 probability.

crystallization, so in the third study year, its coefficient of utilization was very high; over 97.7%. Variations in the amount of total sugar and non-sugar matter per genotype were not significant and depended individually on the size of vegetative site and environmental conditions throughout vegetative period in sugar beet. These results are in agreement with the findings of Rother (2000), Rosso and Candolo (2001) and Hoffman et al. (2009).

## Conclusions

Three sugar beet genotypes were studied for the effects of "non-sugar" matter on sugar utilization of different technological value at different crop densities. Genotype Esprit (N – type) gave on average, the highest sucrose and recoverable sugar content. Plant density significantly influenced the quality parameters (sugar content, K, Na and alpha-amino-nitrogen). The highest recoverable sugar content was achieved at plant densities of 100.000 plants per hectare. Higher densities led to decrease in quality parameters. According to the study, genotype Belinda (Z – type) is more related to medium and low plant density.

## ACKNOWLEDGEMENTS

This paper represents a part of the research results of the Project of Integral and Interdisciplinary Research (No. 046006) "Sustainable Agriculture and Rural Development in the Function of the Accomplishment of Strategic Objectives of the Republic of Serbia in the Danube Region", funded by the Ministry of Education and Science of the Republic of Serbia.

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