# POSSIBILITIES OF SWEET SORGHUM PRODUCTION ON A SALT AFFECTED SOIL

**Lajos Blaskó, Éva Babett Ábrahám, István Balogh**

*University of Debrecen CASE RIC Karcag Research Institute*
*H-5300 Karcag Kisújszállási út 166.*

***Abstract***
*Sweet sorghum production for manufacturing of alcohol production was investigated in a long term amelioration and fertilization experiment on a salt affected soil (meadow solonetz). By means of regression analyzes the effect of sodium content of the soil and increasing mineral fertilizer doses was studied. According to the multiple regression analysis only the effect of nitrogen was significant. On the solonetz type salt affected soil the effect of water soluble salt content of the soil was not significant, but there was a closer correlation between the ammonium-lactate sodium content and the yield of sweet sorghum. The maximum green mass and sugar production was 45-50 t ha$^{-1}$, in case of low Na content and high level of nitrogen fertilization.*

**Keywords**: salt affected soil, sweet sorghum, energy crop

## INTRODUCTION

According to the soil survey by Szabolcs, (1971) and Várallyay et al. (1979, 1980) the salt affected soils cover about 1 million hectares in Hungary. Salt affected soils (SAS) with structural B-horizon (meadow solonetz soils) represent the most widely spread group of SAS in Hungary. About 40-50 percent of these soils have been reclaimed and used as arable land until now. Bio-energy might offer an alternative land use of the territories covered by soils with different problems. The European Union aims at replacing 20% of the fossil energy in the transport sector by 2020 with renewable fuels (EC Green Paper, 2000). The territories with good soils are very limited and bio-energy production can reduce the territories for food production, that is why it is very important to investigate the production possibilities of energy crops on marginal soils. Sorghum seems to be a promising energy crop on SAS, because it can tolerate some salt content in the soil, and there were positive experiences with producing the different sorghum hybrids on heavy clay soils, and salt affected soils (Bocskai, 1968; Halász, 1968). In the Karcag Research Institute sorghum was introduced as an alcohol source by Kapocsi et al. (1984), Blaskó et al (2006).

## MATERIAL AND METHOD

To asses the response of sweet sorghum to salt affected soils and mineral fertilizer rate a part of the Karcagpuszta long term experimental field was used. The amelioration model site at Karcagpuszta was set up by L. Nyiri in 1977. The detailed introduction of the experiment carried out at the model site was published by Nyiri and Fehér (1977). The soil scientific and plant production results can be found in the publications of Nyiri and Fehér (1981), Nyiri (1988) and Blaskó (1996, 2004). The soil type of the experimental site is meadow solonetz with structural B-horizon, the texture of the parent material is clay and day loom. The characteristic groundwater depth varies between 1.5 and 2 meters.

The variability of salt and sodium content is consequence of natural heterogeneity of the soil. Four big plots of the experimental field were divided into 32 sub-plots for mineral fertilization trial in 1985. The water soluble salt content of the top layer of the soil varies between 0.07-0.14 percent. The AL-soluble Na-content changes in the range 100 and 1000 mg $kg^{-1}$. Some analytical data of the characteristic profile of the experimental site are indicated in *Table 1.* The chemical reclamations was made site specific. On the soils with neutral or slightly acidic top layer line was applied, wile on the soils with alkaline top layer gypsum was used.

*Table 1:*

Chemical data of the characteristic soil profile

| Pepth cm | Horizon | pH | | $y_1$ | $CaCO_3$ % | Humus content % | Water soluble salt % | $Na_2CO_3$ % | Exchangeable cations | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $H_2O$ | KCl | | | | | | Ca | Mg | K | Na |
| | | | | | | | | | meq100 g | | | |
| 0-5 | A0 | 5.90 | 5.09 | 14.25 | | 4.34 | 0.13 | | 15.0 | 4.6 | 0.5 | 4.2 |
| 5-15 | A1 | 6.30 | 5.22 | 8.75 | | 3.44 | 0.12 | | 17.0 | 7.7 | 0.8 | 4.2 |
| 15-40 | B-B1 | 7.27 | 6.15 | 2.50 | | 2.18 | 0.31 | | 15.2 | 9.1 | 0.7 | 11.2 |
| 40-70 | B2 | 8.30 | 7.12 | | 0.50 | 1.15 | 0.56 | 0.011 | 12.8 | 10.1 | 0.7 | 17.0 |
| 70-100 | B3 | 8.63 | 7.70 | | 14.10 | 0.48 | 0.47 | 0.085 | 11.4 | 7.7 | 0.4 | 14.0 |
| 100-140 | C | 8.90 | 7.85 | | 5.20 | 0.31 | 0.48 | 0.074 | 6.8 | 8.5 | 0.4 | 17.0 |

The sub plots are fertilized since 1985 with increasing NPK doses, which are indicated in *Table 2.*

*Table 2:*

Mineral fertilizer doses

| Treatment No. | N | $P_2O_5$ | $K_2O$ | Treatment No. | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|---|---|---|---|
| | kg $ha^{-1}$ $year^{-1}$ | | | | kg $ha^{-1}$ | | |
| 1 | 0 | 0 | 0 | 17 | 0 | 0 | 100 |
| 2 | 100 | 0 | 0 | 18 | 100 | 0 | 100 |
| 3 | 150 | 0 | 0 | 19 | 150 | 0 | 100 |
| 4 | 200 | 0 | 0 | 20 | 200 | 0 | 100 |
| 5 | 0 | 100 | 0 | 21 | 0 | 100 | 100 |
| 6 | 100 | 100 | 0 | 22 | 100 | 100 | 100 |
| 7 | 150 | 100 | 0 | 23 | 150 | 100 | 100 |
| 8 | 200 | 100 | 0 | 24 | 200 | 100 | 100 |
| 9 | 0 | 150 | 0 | 25 | 0 | 150 | 100 |
| 10 | 100 | 150 | 0 | 26 | 100 | 150 | 100 |
| 11 | 150 | 150 | 0 | 27 | 150 | 150 | 100 |
| 12 | 200 | 150 | 0 | 28 | 200 | 150 | 100 |
| 13 | 0 | 200 | 0 | 29 | 0 | 200 | 100 |
| 14 | 100 | 200 | 0 | 30 | 100 | 200 | 100 |
| 15 | 150 | 200 | 0 | 31 | 150 | 200 | 100 |
| 16 | 200 | 200 | 0 | 32 | 200 | 200 | 100 |

In 2008, the production possibility of sweet sorghum depending on the mineral fertilization rate and the sodium content of the soil was investigated. The meteorological conditions of the experimental site in the year of 2008 are indicated in *Table 3.*

*Table 3:*

Meterological data (Karcagpuszta, 2008)

| MONTHS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII |
| Precipitation (mm) | | | | | | | | | | | |
| 24.9 | 0 | 35.1 | 24 | 47.4 | 61.2 | 172.1 | 76.2 | 44.4 | 15.2 | 1.2 | 64.4 |
| Mean average temperature ($^oC$) | | | | | | | | | | | |
| 0.5 | 2.9 | 6.7 | 11.4 | 16.7 | 20.6 | 21 | 21.4 | 15.4 | 12 | 9.4 | 2.1 |

The investigated sorghum hybrid was the Sucrosorgo 506. The sowing date was 16 of May, the harvest time was 5th of November. For measuring the change of juice and sugar production in time sampling plots of 2 $m^2$ were formed. For the determination of the juice content, the sorghum was chopped with AL-KO dynamic H1600 and pressed with press machine STM Bologna AMP/E50/2. After the harvest soil samples from the 0-20 cm layer were taken, and the main chemical parameters of the soil were investigated according to the Hungarian standard (MSz-08-0206-2:1978).

**RESULTS AND DISCUSSION**

As a consequence of long term fertilization the increase of $NO_3$ + $NO_2$ and AL-$P_2O_5$ was significant (***Figure 1-2***). The potassium supply was good both in the fertilized and non-fertilized soil.

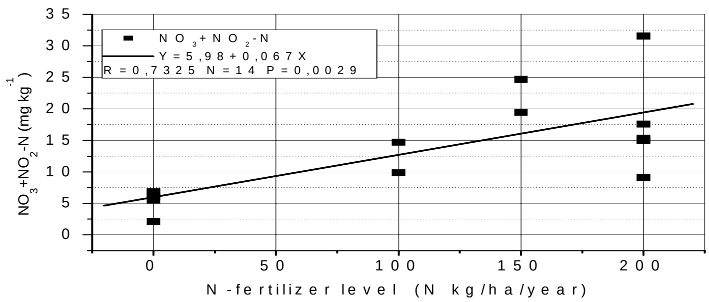


Fig. 1: $NO_3$+$NO_2$- content of soil depending on N-fertilizer level

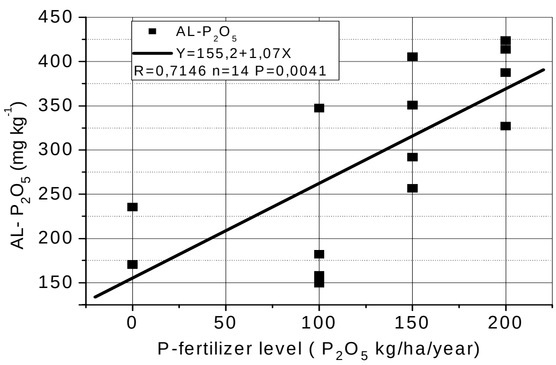


Fig. 2: AL-$P_2O_5$ content of soil depending on P-fertilizer level

Investigating the NPK-effect by multiple regression analysis, only the effect of nitrogen was statistically provable (*Table 4*).

*Table 4:*

Statistics of multiple regression N, P, K fertilizer level vs. yield of sorghum

| Independent: N, P, K-fertilizer level | | | | |
|---|---|---|---|---|
| Dependent: Sorghum yield green mass | | | | |
| Parameter | Value | Error | t-Value | Prob>\|t\| |
| Y-Intercept | 27.18723 | 2.5361 | 10.72009 | <0.0001 |
| **N** | **0.06401** | **0.01332** | **4.80584** | **<0.0001** |
| P | -0.01113 | 0.01332 | -0.83552 | 0.40674 |
| K | -0.00742 | 0.0197 | -0.37657 | 0.70782 |
| R-Square(COD) | Adj. R-Square | Root-MSE(SD) | | |
| 0,28517 | 0.24943 | 7.88037 | | |
| ANOVA Table: | | | | |
| Item | Degrees of Freedom | Sum of Squares | Mean Square | F Statistic |
| Model | 3 | 1486.42949 | 495.4765 | 7.97866 |
| Error | 60 | 3726.01166 | 62.10019 | |
| Total | 63 | 5212.44114 | | |
| Prob>F | | | | |
| 1,47E-04 | | | | |

The possible cause of the ineffectiveness of P and K might be that the soil contained enough available amounts of them even in the case of the low fertilizer rate.

The effect of nitrogen fertilizer rate on green mass yield, juice and sugar yield is demonstrated on *Figure 3-5*.

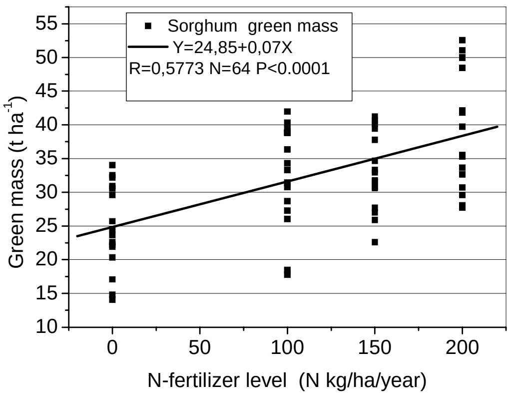


Fig. 3: Green mass yield of sorghum depending on N-fertilizer level

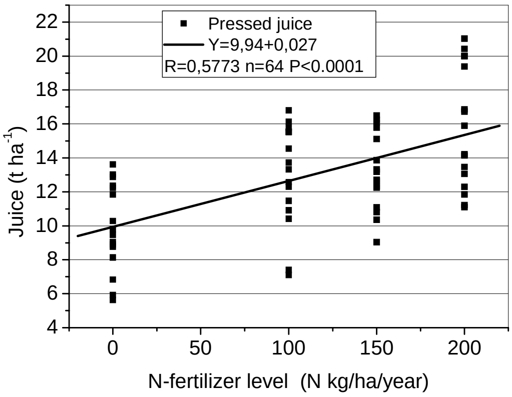


Fig. 4: Juice yield of sorghum depending on N-fertilizer level

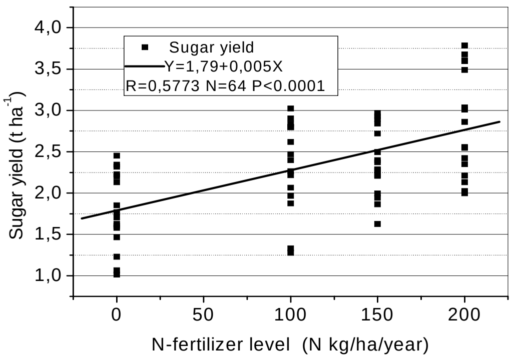


Fig. 5: Sugar yield of sorghum depending on N-fertilizer level

The juice and sugar production are the most important yield elements from the point of view of alcohol production. Both of them were strongly connected to the nitrogen fertilizer rate (*Figure 6*). The sugar content was determined mainly by the green mass yield, because the N and P fertilization level did not influence the sugar concentration in the juice *(Figure 7)*.

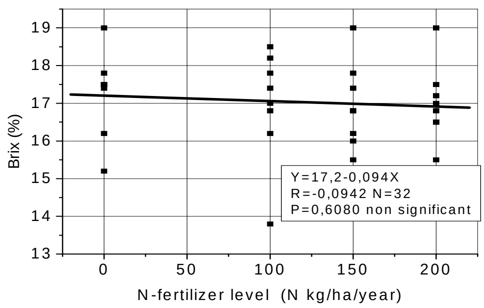


Fig. 6: Sugar content of sorghum juice vs. N-fertilizer level

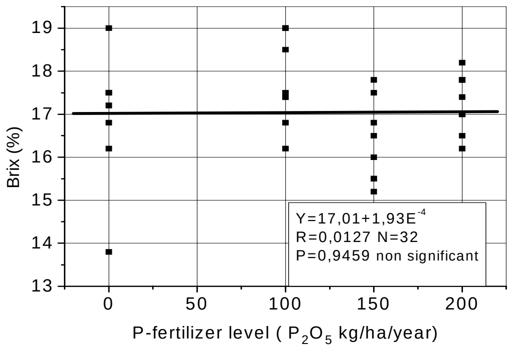


Fig. 7: Sugar content of sorghum juice vs. P-fertilizer level

Some instances of the best and worst yield results and the relevant mineral fertilizer treatments are summarized in *Table 5*.

*Table 5*

The mineral fertilizer doses and the relevant best and worst yields

| N | $P_2O_5$ | $K_2O$ | Green mass yield | Juice yield | Sugar yield |
|---|---|---|---|---|---|
| kg ha$^{-1}$ | | | t ha$^{-1}$ | t ha$^{-1}$ | t ha$^{-1}$ |
| 200 | 100 | 100 | 47 | 18.8 | 3.29 |
| 200 | 200 | 0 | 43 | 17.2 | 2.92 |
| 200 | 0 | 0 | 43 | 17.2 | 2.92 |
| 200 | 0 | 100 | 40 | 16.0 | 2.72 |
| 100 | 150 | 0 | 29 | 11,6 | 1.97 |
| 150 | 150 | 100 | 29 | 11.6 | 1.97 |
| 0 | 150 | 0 | 29 | 11.6 | 1.97 |
| 0 | 0 | 0 | 28 | 11.2 | 1.90 |
| 0 | 100 | 0 | 26 | 10.4 | 1.77 |
| 0 | 0 | 100 | 26 | 10.4 | 1.77 |
| 0 | 150 | 100 | 22 | 8.8 | 1.50 |
| 0 | 200 | 100 | 22 | 8.8 | 1.50 |
| 0 | 200 | 0 | 19 | 7.6 | 1.29 |

To determine the limits of tolerance of sorghum on the investigated salt affected soil with structural B-horizon, regression analysis between the soil properties and the yield of sorghum was calculated and found to be close. The relationship between the water soluble salt content of top layer and the yield of sorghum was not statistically provable (*Figure 7*).

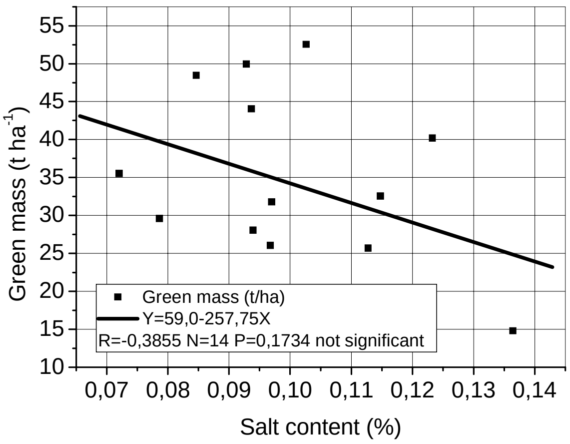


Fig. 7: Green mass yield of sorghum vs. salt content of soil

The relationship between the sodium content soluble in ammonium-lactate (AL-Na) and the yield was close (*Figure 8*).

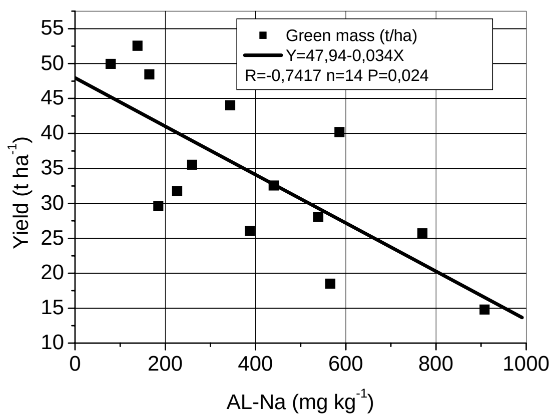


Fig. 8: Green mass yield of sorghum depending on AL-Na content of soil

The different sensitivity in the yield reaction to the water soluble salt content and AL-Na can be explained by the chemical properties of solonetz type salt affected soils. In these soils the bigger part of sodium can be found in exchangeable form. The water soluble salt content of the top layer is low, and in the low ranges the determination of salt content based on the electrical conductivity might be not accurate enough.

The linear regression between the AL-Na content of soil and the yield indicates that the yield is decreasing with the increasing AL-Na content. A yield above 30 t $ha^{-1}$ green mass can be expected if the AL-Na content of soil is less than 400 mg $kg^{-1}$.

When comparing the yield results of sorghum on salt affected soil to on a chernozem soil, it can be established that the highest yield on the salt affected soil is 25-30% lower than on the non-saline soil.

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