

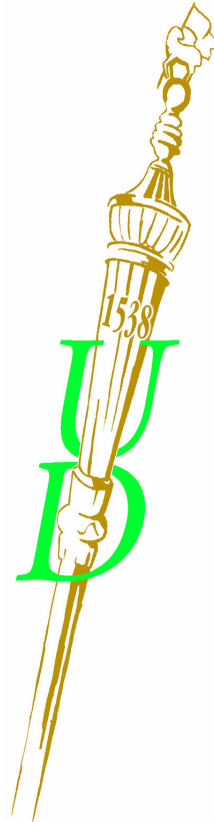
PhD thesis

**EFFECT OF NUTRIENT SUPPLY ON NUTRIENT UPTAKE, DRY MATTER
ACCUMULATION AND YIELD OF SWEET SORGHUM
(*SORGHUM BICOLOR L. /MOENCH*)**

TAMÁS NÉMETH

Supervisors:

Dr. Zoltán Izsáki, Dr. Péter Pepó



UNIVERSITY OF DEBRECEN

Hankóczy Jenő Doctoral School of Plant Production, Horticulture and Food Science

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1. Introduction

Sorghum is the 5th most important crop in the world after wheat, rice, maize and barley. It is basic food for more than 500 million people in 30 countries and it is grown on 42 million hectares in 98 countries. 59% of the total sorghum area is in Africa, 25% is in Asia, 11% is in North America and 4% in South America. Sorghum cultivation area in Europe is under 1%, which takes place in Southern Europe with less than 1 million hectares. 46% of the total produced quantity comes from Asia, 27% from Africa, 21% from North and Middle America and 6% from South America.

Sweet sorghum is a very important crop among sorghum sorts and besides its excellent internal content parameters the stem juice contains 15-17% saccharose, whereby we are able to produce a considerable amount of sugar with it.

Researchers dealing with this plant know about its excellent resistance, growth firmness and good internal content which capacitate sorghum to make good silage from it. Numerous experts have called attention to the sorghum cultivation area expansion in Hungary. According to HARMATI (1997) the climate is getting hot and dry which with the changed economical circumstances can lead to maize area decrease. A part of bulk feed demand on droughty areas and poor soils can be provided safely with sorghum so it may cause the sorghum area increase in the future.

There is another aspect of silage sorghum cultivation which has got into the public interest in the last decade. This is the sweet sorghum utilization as an energy crop. The investigation in this topic has started abroad and in Hungary by agricultural and technical experts, chemists and researchers have started their work to study several interesting parameters of sweet sorghum and decide about possible energy crop utilization of it.

The Faculty of Agricultural Water and Environmental Management of Tessedik Sámuel College participated in „The Development of an integrated technological system for environmental application of renewable energy” and in the „Biomass based complex, conjugated heat and electrical energy production technology” projects.

The Agricultural sciences Institute investigated the nutrient supply of sweet sorghum. I have participated in the investigation at our long term fertilization experiment to test sugar type silage sorghum variety Róna 4.

2. Objectives

A wide range of bibliography linked with sweet sorghum was worked up and realized though numerous famous researcher dealt and dealing nowadays as well with this promising plant, but there are just a few publications about its dry matter accumulation, dynamic of growth and nutrient uptake.

The aim of my PhD research activity was droved up by my supervisors and me in accordance with this realization for 2002-2004 experimental years, which is summarized in the followings:

- Study relationship between nutrient supply and green mass as well as examine the dynamic of growth with open field examination every two weeks during growing season.
- Study relationship between nutrient supply and dry matter yield as well as examine the dynamic of dry matter accumulation with open field examination every two weeks during growing season.
- Examination of the actual nutrient content of the plant from the collected samples as well as study the dynamic of its nutrient content change.
- Study nutrient uptake and its dynamic during growing season with knowledge of dry matter yield and nutrient content measured at sampling.
- Study relationship between investigated parameters of sorghum and certain crop years.
- Examine the effect of N-supply on sugar content and sugar yield.
- Determine dynamic of sugar content accumulation during the vegetation period.
- Define and specify nutrient demand of sweet sorghum.

3. Materials and methods

3.1. Treatments and experimental design

The experiment was started on the experimental station of Agricultural Sciences Institute of Faculty of Agricultural Water and Environmental Management of Tessedik Samuel College on chernozem meadow soil with four different N, P and K supply levels, in total combination of treatments i.e. 64 different nutrient treatments, in a split-split plot design with three replications. One of the four sign plants of the crop rotation was the sweet sorghum between 2001 and 2005 with fibre hemp as a previous plant. This thesis examines results from the period 2002-2004.

The following N-, P- and K supply levels were used in the experiment:

Treatments of factor „A”

K_0 = without fertilization

K_1 = 100 kg ha^{-1} K_2O yearly

K_2 = 600 kg ha^{-1} K_2O autumn 2001, and after 8 years

K_3 = 1200 kg ha^{-1} K_2O autumn 2001, and after 8 years

Treatments of factor „B”

P_0 = without fertilization

P_1 = 100 kg ha^{-1} P_2O_5 yearly

P_2 = 500 kg ha^{-1} P_2O_5 autumn 2001, and after 8 years

P_3 = 1000 kg ha^{-1} P_2O_5 autumn 2001, and after 8 years

The aim of use K_2 - K_3 and P_2 - P_3 supply levels was to create well segregated nutrient supply levels in the soil.

Treatments of factor „C”

N_0 = without fertilization

N_1 = 80 kg ha^{-1} N yearly

N_2 = 160 kg ha^{-1} N yearly

N_3 = 240 kg ha^{-1} N yearly

We have chosen from the 64 treatments the following 15 to accomplish experimental tasks:

$\mathbf{N}_0\mathbf{P}_0\mathbf{K}_0$	$\mathbf{N}_1\mathbf{P}_1\mathbf{K}_1$	$\mathbf{N}_0\mathbf{P}_3\mathbf{K}_3$
$\mathbf{N}_1\mathbf{P}_0\mathbf{K}_0$	$\mathbf{N}_0\mathbf{P}_2\mathbf{K}_2$	$\mathbf{N}_2\mathbf{P}_3\mathbf{K}_0$
$\mathbf{N}_2\mathbf{P}_0\mathbf{K}_0$	$\mathbf{N}_1\mathbf{P}_2\mathbf{K}_0$	$\mathbf{N}_2\mathbf{P}_0\mathbf{K}_3$
$\mathbf{N}_3\mathbf{P}_0\mathbf{K}_0$	$\mathbf{N}_1\mathbf{P}_0\mathbf{K}_2$	$\mathbf{N}_2\mathbf{P}_3\mathbf{K}_3$
$\mathbf{N}_1\mathbf{P}_1\mathbf{K}_0$	$\mathbf{N}_1\mathbf{P}_2\mathbf{K}_2$	$\mathbf{N}_3\mathbf{P}_3\mathbf{K}_3$

The total area of plots was 20 m², while the net area was 10.4 m². The 64 different N-P-K-fertilizer dose combinations were set up in three replications so the whole experiment was consisted of 192 plots on 0.4 ha.

The utilized variety

We have tested every year the sweet sorghum type silage sorghum variety Róna 4 which was given by Cereal Research Institute of Szeged.

3.2. Soil conditions

The soil of the Experimental Farm of the Agricultural Sciences Institute is deeply calcareous chernozem meadow soil with 85-108 cm humus layer, the $pH_{(KCl)}$ in the cultivated soil layer is 5.0-5.2 without $CaCO_3$, the humus content is 2.8-3.2 % and the clay content is 32%.

The average water depth in the soil is 300-350 cm. The nutrient content determination of the soil was made in the upper 60 cm layer in every 10 cm with Eikelkamp agrisearch equipment in every fall and N- content examination in every spring as well. Soil samples were examined in the DANAV laboratory in Békéscsaba city, Hungary. Nutrient content of the soil in the N-, P- and K-treatments are demonstrated in table 1.

Table 1. N-, P- and K-content of the soil in the NPK treatments (Szarvas, 2001-2004)

Time of sampling	NO ₃ -N kg ha ⁻¹ in the upper 60 cm soil layer			
	N ₀	N ₁	N ₂	N ₃
fall, 2001	41	43	54	84
spring, 2002	63	90	182	206
fall, 2002	27	31	48	55
spring, 2003	37	56	64	79
fall, 2003	44	63	69	88
spring, 2004	59	97	142	195
	AL-P ₂ O ₅ mg kg ⁻¹ in the upper 60 cm soil layer			
	P ₀	P ₁	P ₂	P ₃
fall, 2001	120	153	176	295
fall, 2002	128	183	195	339
fall, 2003	139	198	222	362
	AL-K ₂ O mg kg ⁻¹ in the upper 60 cm soil layer			
	K ₀	K ₁	K ₂	K ₃
fall, 2001	229	323	334	425
fall, 2002	215	347	394	465
fall, 2003	206	321	367	453

3.3. Sampling methods

The sowing was carried out on the 30th of April in every examination year with 25-26 seeds m⁻¹, 0.65 m row space and 4 cm sowing depth. This resulted 182600-186160 plant ha⁻¹ population which thinned out with 5-10% till harvesting (260-265 000 plant ha⁻¹), but it was compensated with tillering (5-6 shoots per plant). Due droughty spring in 2003 we had to

resow the experiment because the plant stand thinned out with more than 50%. The second sowing was carried out on the 12th of June. Sampling was started on the 30th day after the spring of the plant stand repeated every two week till harvesting at the wax ripening stage.

The sampling method based on recommendations of SVÁB, (1973); ELEK-KÁDÁR, (1980); KÁDÁR, (1980); KÁDÁR-ELEK, (1983); KÁDÁR, (1987). During our work on the field we have collected 15 plants from every selected treatment. By this way we had 45 studied plants from the three replications every sampling time.

We have studied in the sorghum stand the population density, number of shoots, height of plant and - after drying in green house - the dry weight. The absolute dry matter content of the plant tissue was determined by the way of 3 hours long drying on 105⁰C. The nutrient content of the aboveground part of the plant was determined for 10 nutrients (N, P, K, Na, Ca, Mg, Cu, Zn, Mn, Fe) in DANAV laboratory Békéscsaba.

Sugar content was investigated in the N-fertilized plots (N₀, N₁, N₂, N₃) during flowering, at the beginning- and at the end of the wax ripening stage. In the course of the examination we have chosen 15 sampled plants removed the leaves from the stems and chop them into 15 cm long pieces. Cooled samples were delivered immediately to University of Szeged to measure the quantity of stem juice and its sugar content.

Harvesting was started in 2002 on the 22nd of August, in 2003 on the 23rd of September and in 2004 on the 21st of August at the stage of wax ripening.

The mathematical and statistical evaluation of the results was carried out by Sváb's (1973) method of variance analysis.

3.4. Weather conditions

In 2002 the amount of precipitation was sufficient though its uneven distribution caused problems. The total amount of rainfall was 471 mm which was less than the many years average with 12%, but it was modified with irrigation to 510 mm.

The temperature of the vegetation period was higher than the average of many years with 3 degree in May, and 2 degree in June and July.

The 2003 experimental year was very hot and droughty. The amount of rainfall in the winter half year was similar to the average of the 1901-1975 years, but the summer half was extremely dry. The amount of precipitation of the summer half was just 96 mm in comparison with the 313 mm many years average. The total amount of rainfall of the winter and summer

half was 410 mm which was modified by the irrigation to 490 mm though it was less than many years average with 40 %.

In comparison with average of the 1901-1975 years the temperature in May and June was higher with 4 °C, in July with 1 °C and in August with 3 °C.

The winter half of 2004 experimental year was wet with 10 % more rainfall than the average of 1901-1975 years. The summer half was rainy enough as well and we observed a heavy aphid infection in April as a consequence of the humid circumstances. May was dry and the 38 mm rainfall was observed at the end of the month. The above mentioned conditions of the early development phase retarded development of the plant stand. The rainfall in June was like the many years' average but July and August was wetter. Considering the temperature 2004 was similar to 1901-1975 average.

4. Results

4.1. Effect of N-, P- and K-supply on the yield of silage sorghum

Green crop

The first 45 days after germination (May-June) is the moderated early development phase of sorghum which is followed by a more intensive period of growth, while more than 60% of the aboveground biomass is accumulated in 30 days.

Sweet sorghum reached the maximum of the green mass at different time during the three experimental years. The maximum of the green crop was observed in 2002 on the 85th day after germination (55.47 t ha⁻¹), in 2003 on the 75th day after germination (53.47 t ha⁻¹) and in 2004 on the 103 day (59.55 t ha⁻¹). Maximum of the average green crop was 56.16 t ha⁻¹.

Figure 3 demonstrates the effect of nutrient supply on green crop in the 15 sampled treatments as an average of the experimental years.

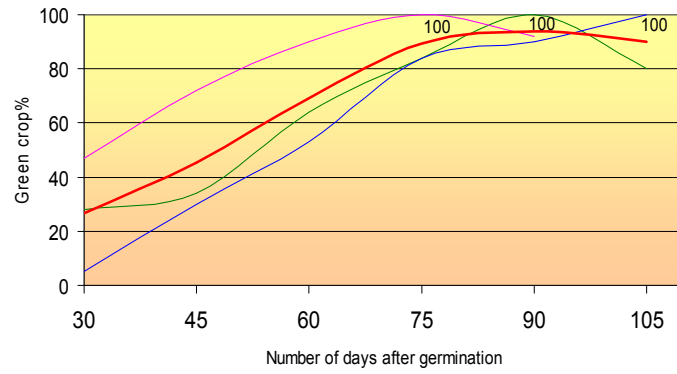
In 2002 and 2004 the 80 kg ha⁻¹ N-fertilizer dose increased the green mass significantly compared with control, however increased nutrient supply level of the soil did not result in a statistically proven better green crop. In 2003 the 160 kg ha⁻¹ N-fertilization led to significant yield increase in comparison with control plots.

The exaggerated N-supply when the N-supply level of the upper 60 cm soil layer was over 200 kg ha⁻¹ NO₃-N, caused biomass decrease.

The increasing P-supply compared to the 120-136 mg kg⁻¹ AL-P₂O₅ supply level of the control plots usually did not result in significant difference in the green crop, but during the droughty 2003 we observed a significant yield increase at the 222 mg kg⁻¹ AL-P₂O₅ supply level of the soil.

The K-fertilization at the 205-465 mg kg⁻¹ AL-K₂O supply level of the upper 60 cm soil layer did not changed the yield significantly.

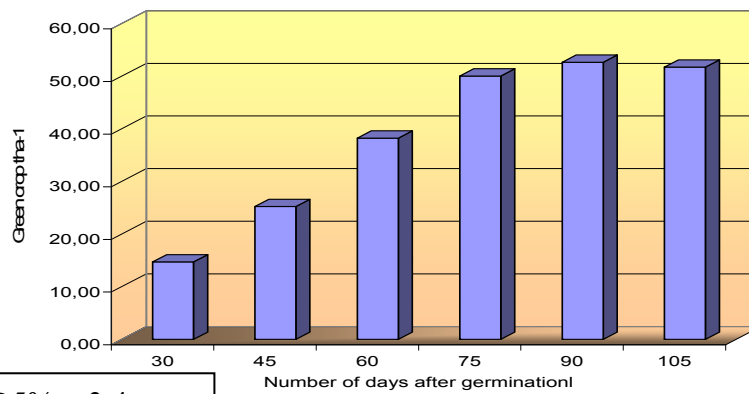
The exaggerated P- and K-supply - without N-fertilization - decreased the green crop compared to the maximum of the yield.



SD5% = 11,7

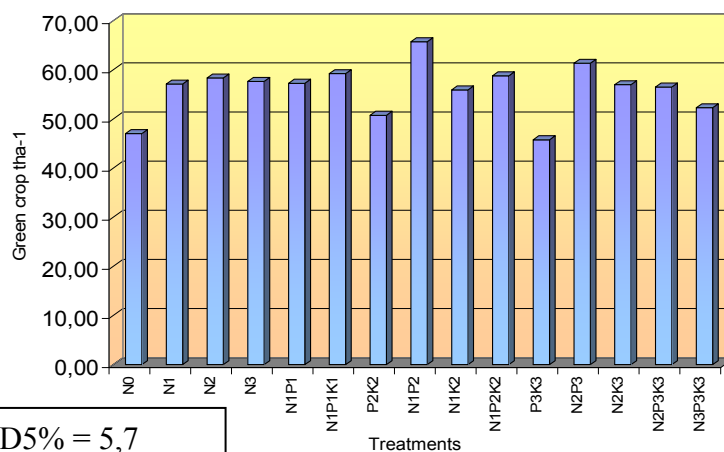
— 2002 — 2003 — 2004 — Average

Figure 1. The growth dynamic of sweet sorghum in average of treatments (Szarvas, 2002-2004)



SD5% = 3,4

Figure 2. Change of green crop during the growing season in average of treatments (Szarvas, 2002-2004)



SD5% = 5,7

Figure 3. The maximum of the green crop in the sampled 15 treatments (Szarvas, 2002-2004)

Dry matter yield

There were big differences between the green - and dry matter accumulation of sweet sorghum.

In 2002 more than 52% of the dry matter was developed during the last 35 days of the growing season.

In 2003 less than half part of dry matter was developed during the first 47 days and during the following 45 days culminated the yield.

In the last 40 days of the 2004 growing season was developed 68% of the dry matter yield. The main period of dry matter accumulation took place in the last third of the growing season, as during this time 60% of the whole dry matter yield of sweet sorghum was developed (figure 4).

The sweet sorghum reached the maximum of dry matter yield at the wax ripening stage in every experimental year. In 2002 the dry matter culminated on the 106th day of the growing season on 17.63 tha⁻¹, in 2003 on the 92nd day after germination on 17.93 tha⁻¹ and in 2004 on the 103rd day we measured 18.58 tha⁻¹. The dry matter yield in average of years and treatments was 18 tha⁻¹ (figure 5).

Effect of fertilization on dry matter yield can be followed by analysis of figure 6. At the maximum of the dry matter we measured 13.17-14.88 tha⁻¹ value in the control plots. 80 kgha⁻¹ N-fertilizer dose caused significant 3-5 tha⁻¹ yield increase in comparison with control every year.

Further improvement of N-supply did not influence the amount of the dry matter. Statistically proven effect of P-fertilization was observed just in 2003 between N₁ and N₁P₂ treatments.

We did not find out significant effect of P-fertilization on dry matter yield in the 120-140 mgkg⁻¹ AL-P₂O₅ supply level of the soil.

The K-fertilization on the AL-K₂O supply level of 205-465 mgkg⁻¹ did not caused statistically proven effect. The AL-K₂O content of 200 mgkg⁻¹ in the upper 60 cm soil layer means a good supply level for sweet sorghum.

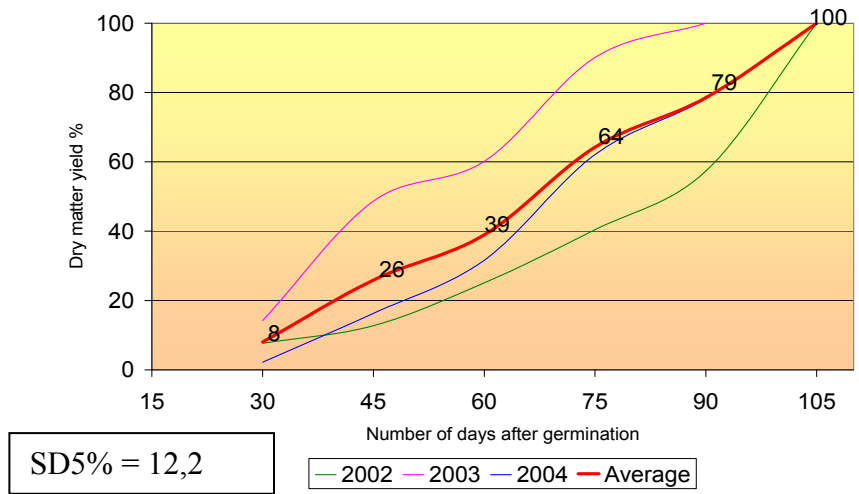


Figure 4. The dynamic of dry matter accumulation in average of treatments (Szarvas, 2002-2004)

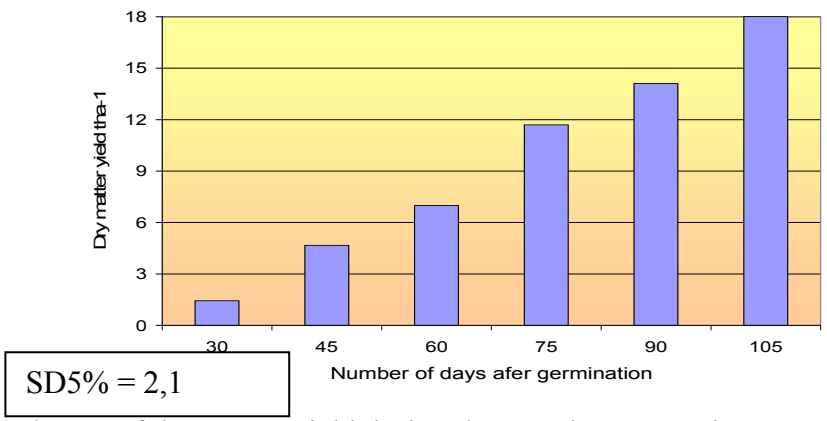


Figure 5. Change of dry matter yield during the growing season in average of treatments (Szarvas, 2002-2004)

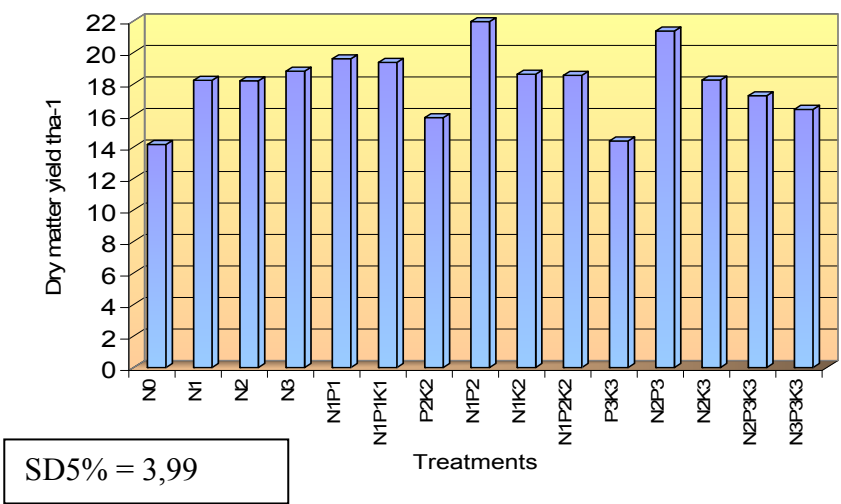


Figure 6. The maximum of the dry matter yield in the sampled 15 treatments (Szarvas, 2002-2004)

4.2. Sugar content, sugar yield

If the K-supply level of the soil is sufficient or good, the nitrogen fertilization influences the sugar yield through its strong effect on the green mass. According our experimental results the N - over fertilization disadvantageous on the sugar content and -yield.

The sugar content and sugar yield of sweet sorghum was studied in the N-treatments in 2002 and 2003 during the flowering, at the beginning- and at the end of the wax ripening stage.

Figure 7 demonstrates the change of sugar content and sugar yield of sweet sorghum during the growing season. According to the results of the experiment the sugar content was similar during the flowering (days 60-70) and at the beginning of the wax ripening stage (days 75-85) 8.6-9.3%, but at the end of the wax ripening (days 92-106) it was just 14,6% as an average of the two years and treatments.

The sugar yield during the flowering was 4.25 tha^{-1} , at the beginning of the wax ripening 4.91 tha^{-1} and at the end of this stage 6.3 tha^{-1} was observed.

Figure 8 demonstrates the negative effect of N-supply improvement on sugar content of the stem juice and its positive effect on the sugar yield till 160 kg ha^{-1} active agent doses. The sugar content loss (0.25-0.50 %) on N_1 - N_2 supply level was compensated with the additional green crop which was won with the improved N-supply. The N-over fertilization (N_3) caused decreased sugar content in the stem juice (12.6%).

In 2002 the highest sugar yield (6.57 tha^{-1}) was observed with an application of 80 kg ha^{-1} N-fertilizer dose. In 2003 the 160 kg ha^{-1} N-doses caused the best sugar yield (7.06 tha^{-1}). The over fertilization (240 kg ha^{-1} N) caused significant sugar yield decrease (5.80 tha^{-1}).

Figure 9 demonstrates correlation between N-supply level and sugar yield of sweet sorghum. The trend line characterizes negative effect of over fertilization on sugar yield on the level of 240 kg ha^{-1} N-dose.

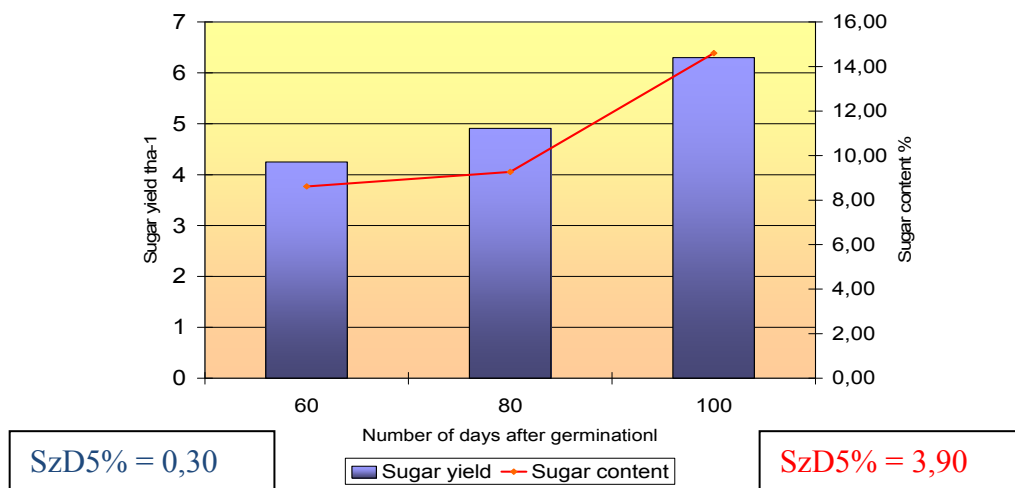


Figure 7. Change of sugar content and sugar yield during the growing season (Szarvas, 2002-2003)

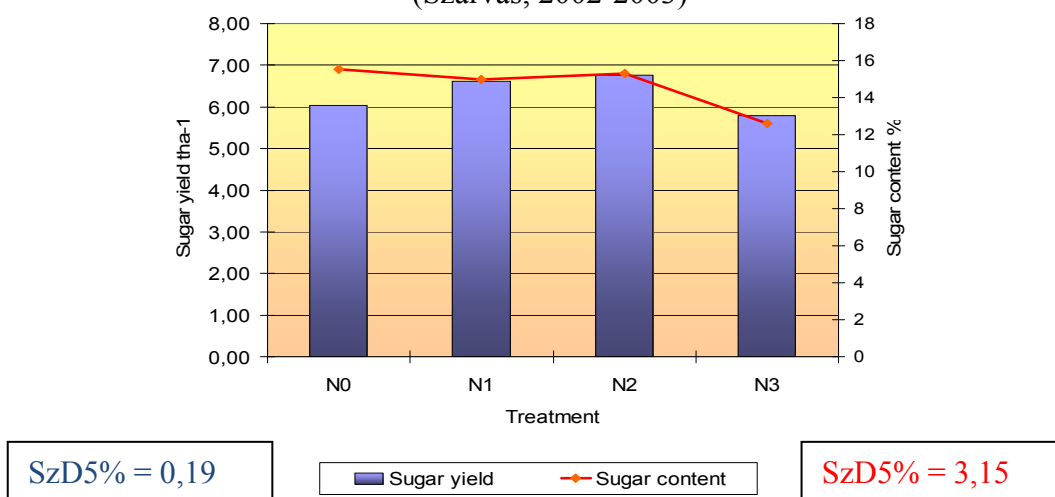


Figure 8. Effect of N-supply on sugar content and sugar yield of sweet sorghum (Szarvas, 2002-2003)

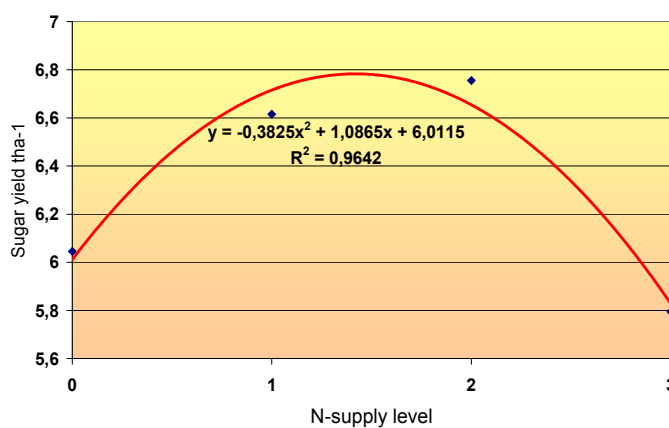


Figure 9. Relationship between N-supply level and sugar yield of sweet sorghum (Szarvas, 2002-2003-as)

4.3. Nutrient content, nutrient uptake

Experimental results show that the nutrient content of plant tissues increased significantly with the improvement of nutrient supply. The nutrient content – depending on type of the element – greatly decreased.

Figure 10 demonstrates the change of N-, P- and K-content of sweet sorghum during the vegetation period. In comparison with nutrient content measured in the early development phase (30 days) the N-content attenuation was 57%, the P-content attenuation was 46% and the K-content decrease was 68%.

Figure 11 demonstrates the dynamic of nutrient uptake of sweet sorghum. According to the experimental results the N-uptake is continuous until the end of the vegetation period and it culminates at the end of the wax ripening.

There are two intensive periods in the P-uptake of the sorghum, one is in the early development phase, and the other one is during the generative phase. P-uptake culminates in the wax ripening stage.

The most intensive period of the K-uptake is the shooting as the 60% of the whole amount of potassium was taken up during this time. The amount of infiltrated potassium decreased after flowering in certain treatments.

Figure 12 demonstrates the of NPK quantities which were taken up by sweet sorghum during the growing season. According the measurement results until the 30th day after germination sweet sorghum took up 43 kg ha^{-1} nitrogen, 7 kg ha^{-1} phosphorus and 69 kg ha^{-1} potassium. Until the end of the wax ripening stage the N-uptake culminated on 260 kg ha^{-1} , the P-uptake culminated on 57 kg ha^{-1} and the K-uptake was 270 kg ha^{-1} .

The greatest quantity of NPK was not infiltrated by sorghum in treatments set up with highest NPK fertilizer dose but in treatments characterized with highest yield.

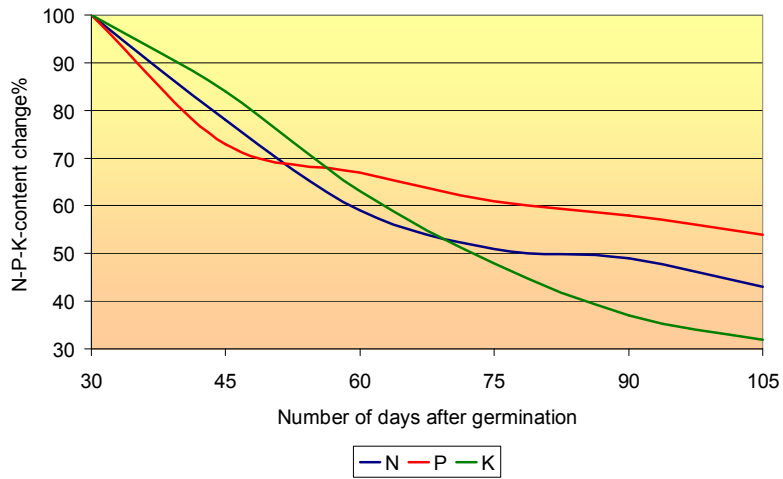


Figure 10. NPK-content decrease of plant tissues (Szarvas, 2002-2004)

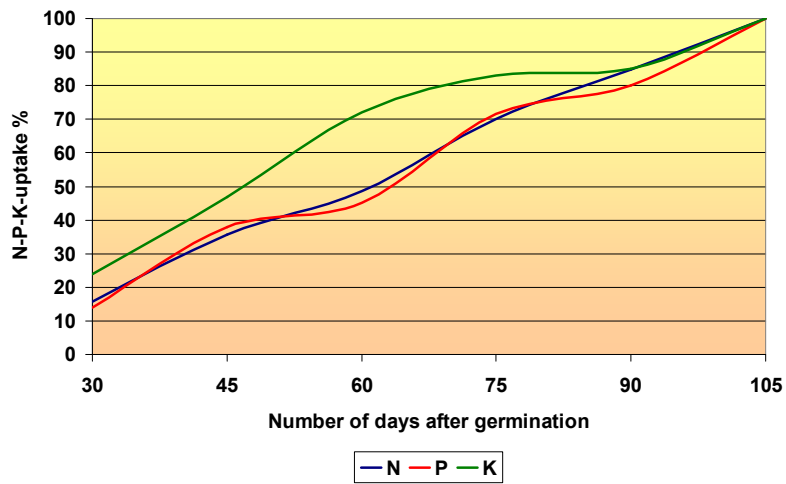


Figure 11. Dynamic of NPK-uptake of sweet sorghum during the growing season (Szarvas, 2002-2004)

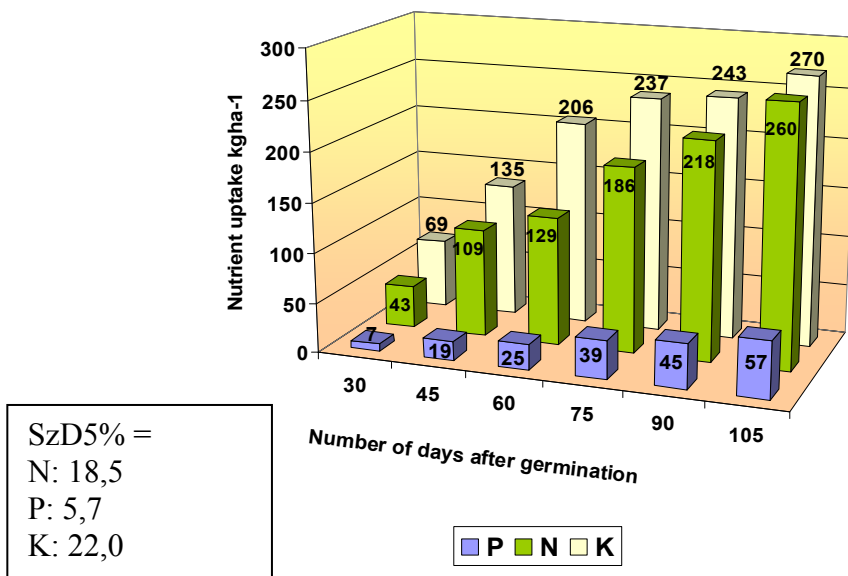


Figure 12. NPK-uptake of sweet sorghum during the growing season. (Szarvas, 2002-2004)

Table 2 demonstrates nutrient uptake per hectare as an average of years and the specific nutrient demand at the optimum supply level.

Table 2. Nutrient uptake of sweet sorghum
(Szarvas, 2002-2004)

Tápelem	Nutrient uptake for 56 tha⁻¹ green crop (kgha⁻¹)	Specific nutrient uptake (kg10t⁻¹green crop, g10t⁻¹ green crop)
N	253,00	44,00
P	57,00 (130 kg P ₂ O ₅)	10,00 (22,9 kg P ₂ O ₅)
K	258,00 (311 kg K ₂ O)	45,00 (54 kg K ₂ O)
Na	13,40	2,35
Ca	44,00	7,70
Mg	43,00	7,50
Cu	0,10	18,00*
Zn	0,38	66,00*
Mn	1,00	175,00*
Fe	1,74	305,00*

*grams

5. New scientific results

1. It is possible to reach 85-95% of the maximum green crop or dry matter yield with 80 kg ha^{-1} N-fertilizer dose on chernozem meadow soil, if the upper 60 cm soil layer contains $40\text{-}60 \text{ kg ha}^{-1}$ $\text{NO}_3\text{-N}$. Sugar content and sugar yield is favourable on this N-supply level as well. The N-overdose causes sugar content decrease and sugar yield loss.
2. On deeply calcareous acid clay soil if its P-content is $120\text{-}140 \text{ mg kg}^{-1}$ AL- P_2O_5 without fertilization, the yield was not influenced by P-fertilization in the range of $150\text{-}360 \text{ mg kg}^{-1}$ AL- P_2O_5 supply level of the soil.
The 120 mg kg^{-1} AL- P_2O_5 content in the upper 60 cm soil layer means a good supply level for sweet sorghum.
3. The K-fertilization on the AL- K_2O supply level of $205\text{-}465 \text{ mg kg}^{-1}$ did not cause a statistically proven effect. The AL- K_2O content of 200 mg kg^{-1} in the upper 60 cm soil layer means a good supply level for sweet sorghum.
4. The specific nutrient demand of sweet sorghum for 10 tons green crop: N = 46 kg; P = 10 kg; K = 48 kg; Na = 2,3 kg; Ca = 7,8 kg; Mg = 7,7 kg; Cu = 18 g; Zn = 68 g; Mn = 178 g; Fe = 310 g.
5. The first 45 days after germination (May-June) is the moderated early development phase of sorghum which is followed by a more intensive period of growth, while more than 60% of the aboveground biomass is accumulated in 30 days. Sweet sorghum reached the maximum of the green crop (56.16 t ha^{-1}) in the wax ripening stage between 75-100 days of the vegetation period.
6. It is possible to sow silage sorghum in the middle or at the end of June. Growth dynamic of the second crop sorghum is very intensive under irrigated circumstances and it is able to reach a similar yield as a main crop sorghum ($50\text{-}55 \text{ t ha}^{-1}$).

6. Practical results

1. 55-60 tha^{-1} green crop, 18-20 tha^{-1} dry matter yield and 6-7 tha^{-1} sugar yield is possible to reach with 260-265000 plants ha^{-1} sweet sorghum population on chernozem meadow soil. Possible to produce 85-90% of the maximum green -and dry matter yield on medium N- supply level of the soil with 80 kgha^{-1} N-fertilizer dose. Sugar content (15%) and sugar yield (6,5 tha^{-1}) is favourable on this N-supply level as well.
2. The 120 mgkg^{-1} AL- P_2O_5 content in the upper 60 cm soil layer means a good supply level for sweet sorghum and the P- fertilization is not justified.
3. The AL- K_2O content of 200 mgkg^{-1} in the upper 60 cm soil layer means a good supply level for sweet sorghum and the K- fertilization is not justified.
4. The specific nutrient demand of sweet sorghum for 10 tons green crop: N = 46 kg; P = 10 kg; K = 48 kg; Na = 2,3 kg; Ca = 7,8 kg; Mg = 7,7 kg; Cu = 18 g; Zn = 68 g; Mn = 178 g; Fe = 310 g.
5. Green crop of sweet sorghum culminated at the wax ripening stage between 75-100th day of the growing season.
6. Growth dynamic of the second crop sorghum is very intensive under irrigated circumstances and it is able to reach as similar yield as a main crop sorghum (50-55 tha^{-1}).

RELATED PUBLICATIONS TO THE SUBJECT OF THE DISSERTATION

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Hungarian scientific journals with impact factor in foreign language

1. **Németh T.** – Izsáki Z.:2005. Effect of N-supply on the dry matter accumulation and nutrient uptake of silage sorghum (*Sorghum bicolor* L./Moench). Cereal Research Communications Vol. 33. No. 1. 81-84.p. IF: 0,274
2. **Németh, T.** – Z. Izsáki: 2006. Relationship between nitrogen supply, dry matter accumulation and micro element content of silage sorghum (*Sorghum bicolor* L./Moench.). Cereal Research Communication, 34. 1. 593-596.p. IF: 1,037
3. Izsáki, Z. –**K Németh, T.:** 2007. Use of chlorophyll meter to determine the nitrogen status of winter barley (*Hordeum vulgare* L.). Cereal Research Communications, 35. 2. 521-522.p. IF: 1,190
4. **K Németh, T.** – Z. Izsáki: 2007. Effect of nutrient supply on the green mass, dry matter accumulation and nutrient uptake of silage sorghum (*Sorghum bicolor* L./Moench). Cereal Research Communications, 35. 2. 841-844.p. IF: 1,190
5. **K Németh,T.** – Izsáki, Z.: 2008. Effect of nitrogen supply on the green crop, sugar content and sugar yield of silage sorghum (*SORGHUM BICOLOR L./MOENCH/*) Cereal Research Communications, 36. 2051-2054.p. IF: 2,66
6. K Németh, G.- Izsáki, Z.- **K Németh, T.:** 2008. Influence of nutrient supply on tuber yieldof Jerusalem Artichoke (*Helianthus tuberosus* L.) Cereal Research Communications, 36. 1899-1902.p. IF: 2,66

Hungarian scientific journals without impact factor in Hungarian language

7. **Németh T.:** 2002. Tavaszi árpa fajták összehasonlító értékelése a Dél-Alföldi régióban. Tessedik Sámuel Főiskola – Tudományos közlemények. 2002. Tom.2. No 1. 47.p.
8. **Németh T.:** 2003. A tápanyagellátás hatása a silócirok (*Sorghum bicolor* L./ Moench) tápelem – tartalmára, szárazanyag-hozamára és tápelem-felvételére csernozjom réti talajon. TSF Tudományos Közlemények 2003. Tom.3. No. 1. 61-76.p.
9. Izsáki Z. – **Németh T.** – Otta E.: 2007. A Dél-Alföldi Régió biomassa eredetű megújítható energiaforrás potenciálja. Tessedik Sámuel Főiskola, Tudományos Közlemények, Tom. 7.1.1.. 55-61.

10. **K Németh T.** – Izsáki Z.: 2007. A nitrogénellátás hatása a cukorcirok (*Sorghum bicolor* L./Moench) cukorhozamára. *Acta Agronomica Óváriensis*, 49. 2. 321-324.

Hungarian scientific journals without impact factor in foreign language

11. **K Németh, T.** – Z. Izsáki: 2007. Development of silage sorghum (*Sorghum bicolor* (L./Moench)). Tessedik Sámuel Főiskola, Tudományos Közlemények, Tom. 7. 1.3. 655-660.
12. **K Németh, T.** – Z. Izsáki: 2007. Effect of nutrient supply on the yield of forage sorghum (*Sorghum bicolor* (L./Moench) fertilization. Tessedik Sámuel Főiskola, Tudományos Közlemények, Tom. 7. 1.3. 649-654.

Did not check by lecturer

Congress Proceedings edition in Hungarian language

13. **Németh T.:** 2002. Tavaszi árpa fajták összehasonlító értékelése Szarvas térségében. VIII. Ifjúsági Tudományos Fórum, Keszthely 2002.március 28.
14. **Németh T.:** 2002. Silócirok fajták kisparscellás összehasonlító értékelése Szarvas térségében. „JUTEKO 2002.” – Tessedik Sámuel Jubileumi Mezőgazdasági Viz – és Környezetgazdálkodási Tudományos Napok, TSF. Szarvas. 2002. augusztus 29-30. 193-195.p.
15. **Németh T.-Izsáki Z.** –Némethné Kádi G.: 2003. A tápelemellátottság hatása a silócirok szárazanyag-felhalmozására és növekedés-dinamikájára. III. Növénytermesztési Tudományos Nap, Szent István Egyetem – Gödöllő. 2003. május 15. 406-410.p.
16. Némethné Kádi G.-Izsáki Z. –**Németh T.:** 2003. A tápanyagellátás hatása a Tápiói korai csicsóka fajta növekedés-dinamikájára és szárazanyag-hozamára. III. Növénytermesztési Tudományos Nap, Szent István Egyetem – Gödöllő. 2003. május 15. 244-247.p.
17. **Németh T.-Izsáki Z.** –Némethné Kádi G.: 2003. A tápelemellátottság hatása a silócirok szárazanyag-felhalmozására és növekedés-dinamikájára. Magyar Tudomány Napja, TSF MVK Szarvas 2003. november 3.
18. Némethné Kádi G.-Izsáki Z. –**Németh T.:** 2003. A tápanyagellátás hatása a Tápiói korai csicsóka fajta növekedés-dinamikájára és szárazanyag-hozamára. Magyar Tudomány Napja, TSF MVK Szarvas 2003. november 3.

19. **Németh T.:** 2003. A tápelemellátottság hatása a silócirok szárazanyag-felhalmozására és növekedés-dinamikájára csernozjpm réti talajon. Magyar Tudomány Napja, TSF MVK Szarvas 2003. november 3.
20. **Németh T.- Izsáki Z. – Némethné Kádi G.:** 2004. A silócirok (*Sorghum bicolor* /L./ Moench) trágyázásának fejlesztése. IX. Nemzetközi Agrárökonómiai Tudományos Napok, Károly Róbert Főiskola, Gyöngyös. 2004. március 25-26. 332.p.
21. Némethné Kádi G. – Izsáki Z. – **Németh T.:** 2004. A csicsóka (*Helianthus tuberosus* L.) tápanyagellátásának fejlesztése. IX. Nemzetközi Agrárökonómiai Tudományos Napok, Károly Róbert Főiskola, Gyöngyös. 2004. március 25-26. 333.p.
22. **Németh T. – Izsáki Z.:** 2006. A nitrogén ellátás hatása a silócirok energetikailag hasznosítható komponenseire. X. Nemzetközi Agrárökonómiai Napok, 2006. március 30-31. Gyöngyös. Tudományos Napok előadásai és poszterei, 1-4.
23. Némethné Kádi G.-**Németh T.** 2006. :A trágyázás hatása a csicsóka (*Helianthus tuberosus* L.) gumó – és cukorhozamára. XII. Ifjúsági Tudományos Fórum, Keszthely, 75-76
24. Némethné Kádi G.-**Németh T.** 2006. : Összefüggés a csicsóka (*Helianthus tuberosus* L.) tápanyagellátása, valamint gumó és cukorhozama között. V. Alföldi Tudományos Tájékoztató Napok, Mezőtúr, 2006. október 26-27. 126.

Congress Proceedings edition in English language

25. **K Nemeth, T. :** 2005. Effect of nutrient supply on the dry matter yield of silage sorghum. XI. Ifjúsági Tudományos Fórum, Veszprémi Egyetem Georgikon Mezőgazdaságtudományi Kar, Keszthely 2005. március 24.
26. **K Németh, T. – Németh, G.:** 2006. Effect of nutrient supply on the dry matter accumulation and micro nutrient uptake of silage sorghum. XII. Ifjúsági Tudományos Fórum, Keszthely
27. **K Németh, T.:** 2007. Development of sweet sorghum (*Sorghum bicolor* L./MOENCH/) fertilization. XIII. Ifjúsági Tudományos Fórum, NYME Georgikon Mezőgazdaságtudományi Kar, Keszthely. 2007. március 22. CD kiadván
28. **K Németh T.:** 2007. Effect of nitrogen supply on the green mass of forage sorghum (*Sorghum bicolor* L./MOENCH/). XIII. Ifjúsági Tudományos Fórum, NYME Georgikon Mezőgazdaságtudományi Kar, Keszthely. 2007. március 22. CD kiadvány

Congress Abstract edition in foreign language

29. **K Németh T.**- Némethné Kádi G.: 2004. The development of silo sorghum manure. IV. Alföldi Tudományos Tájgazdálkodási Napok, TSF Mezőgazdasági Főiskolai Kar, Mezőtúr. 2004. október 21-22. 135.p.
30. Izsáki, Z. – **K Németh,T.**: 2006. Effect of N- P- K fertilisation on the dry matter accumulation and micro nutrient uptake of silage sorghum. 14th World Fertilizer Congress, 22-27 January, 2006. Chiang Mai, Thailand. Abstracts, 144.
31. **K Németh,T.**- K Németh G.: 2006.: Relationships among the nutrient supply, dry matter accumulation and the micro nutrient uptake of silage sorghum. 5th International Scientific Days of Land Management in the Great Hungarian Plain, 26-27 October, 2006. Mezőtúr, Hungary 127.

Part of scientific book

32. Izsáki Z.- Iványiné Gergely I. – **Németh T.** – Otta E.: 2007. Biomassza. In: Patay I. (Szerk.): Mindentudás a megújuló energiaforrásokról a Dél-Alföldi Régióban. Békés Megyei Kereskedelmi és Iparkamara. 29-54.

Publications of general knowledge

33. **Németh T.**: 2002. Zab – csupaszon is. Magyar Mezőgazdaság 57. évf. 9. szám.14.p.
34. **Németh T.**: 2002. A silócirok, mint alternatív tömegtakarmány-termő növény. Gyakorlati agrofórum füzetek 6. szám, 54-55.p.
35. Izsáki Z. – **Németh T.** – Otta E.: 2007. Biomassza-források a Dél-Alföldön. Magyar Mezőgazdaság, 62. 45. 12-13.
36. **Németh T.** - Izsáki Z. — Némethné Kádi G.: 2005. Energianövények szénhidrát akkumulációjának vizsgálata. Kutatási altéma. In: Integrált technológiai rendszer kifejlesztése a megújuló energiaforrások környezetbarát hasznosítására. NKFP -3/012, zárójelentés. TSF MVKK, Szarvas, 1-38.