DEVELOPMENT OF SWEET SORGHUM CULTIVATION TECHNIQUES FOR ALTERNATIVE ENERGY PURPOSES

Thesis of doctoral dissertation

Kovács Gergő Péter

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Name of the PhD School:

PhD School of Plant Sciences

Major PhD Program area:

Plant and horticulture sciences

Director:

Prof. Dr. Lajos Helyes

Director of the Institute of Horticulture

Szent István University

Faculty of Agricultural and Environmental Sciences

Institute of Horticulture

Superviser:

Dr. Csaba Gyuricza

Associate professor, dean
Szent István University

Faculty of Agricultural and Environmental Sciences

Institute of Crop Production

....	....
Director of School	Superviser

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1 Introduction

Today the vast majority of humanity's energy needs, nearly 75%, derive from the use of oil, coal and gas. These resources are of course finite so it is more and more urgent to explore those energy resources which can cover the humanity's energy needs in the long run (Ghatak 2011). Under the Convention on Climate Change adopted in 2007 Hungary undertook to increase the share of renewable energies in the total energy use from the current 6% to 13% by 2020. Hungary is weak in fossil fuels, however the half of its land is down to arable corps and the agro-ecological characteristics are favorable for biomass production. As a result, in the future the production of biomass as an alternate energy resource can be the main perspective in our country. Energy crops might have legitimacy mainly on those fields where the conditions of feed or food uses do not or only partially given (LUKÁCS 2009), however, they are suitable for the production of an alternative woody or herbaceous energy corps (GYURICZA 2008, GUO et al. 2010). Taking into account the energy and production aspects, the significance of biomass plants with high sugar, starch and cellulose-content increased in the last decade. That is why Hungarian research institutions and universities are paying more and more attention to the sorghum, energy plant which can be the base of the production of bioethanol and biogas (*Sorghum bicolor* L. Moench). In order to meet the commitments Hungary had taken towards the European Union on climate and energy objectives (to reach 14,65% share of the renewable energy) our energy production, mainly heat energy should be based on the biomass-based decentralized sub-regional power plants. The engine of the renewable energies' extension can be the industrial mass production, technological innovation and the growing consumer awareness. With the help of these new technologies which receive lot of scepticisms nowadays, can become more simple and cheaper. The biggest challenge for Hungary and for many domestic scientific workshops dealing with alternative energy resources is to remain at the forefront of research and development globally and in Europe.

During the research in order to prepare this thesis we intended to find out how the current agronomic procedures affect the sweet sorghum cultivation under unfavourable field and weather conditions. The research objectives were the following:

- Determination of the effect of nutrient supply on the yield of sweet sorghum;
- The effect ofdifferent tillage operations on the production of sorghum biomass under unfavorable field and weather conditions;
- Exploration of links between sweet sorghum nutritional parameters and the year effect;
- The examination of the effect of the nutrient supply and tillage operation on the sugar content;
- Exploration of coherency between the soil physical parameters and yield of green;
- Analysis of sugar content distribution in the sorghum's stem

2 Methodology

2.1 Agro-ecological features of the examined area

Soil conditions

The exemined area is located at the Gödöllő's Hills that forms a bridge between Cserhát and the sand ridges of Danube -Tisza rivers. The area is at an average altitude of 247 metres above sea level. The area is situated at latitude 47o46'N and longitude 19o21'E.

According to the Hungarian genetic soil classification the soil of the examined area is mainly rust brown earth formed on sand (Luvic Calcic Phaeozem). The rust brown earth subtype formed on tertiary sand and marl substrate belongs to Ramann brown forest soil's type. The soil texture is sandy loam, which is sensitive to compaction. The upper 20 cm layer of the soil contains 53% of sand, 26% of loam and 20% of clay. The topsoil (0-35 cm) contains 26% of clay and its permeability is good while the permeability of the subsoil is poor. Due to the degradation processes this is soil of medium depth with poor humus content (STEFANOVITS 1999, MÁTÉ 2005). The area is at risk from erosion and sensitive to compaction.

The main soil-forming factors are the evolution of humus and soil depletion. The thickness of the 'A' level which contains humus is about 40cm; its colour is brown with crumbly structure and with pH slightly acidic, neutral or slightly alkaline. The water management of the Ramann brown soil is in general positive with good water permeability and moderate water-holding capacity. It mostly contains sufficient water for crops. The water- management characteristics of the rust brown earth formed on sand is not as good as the conditions of brown soil. Its productivity is lower because of the lower humus content and nutrient availability.

Climate conditions

The Gödöllő Hills belong to the drier regions of the country. The average annual precipitation varies from 500 to 600 mm. The average annual temperature is above 10 degrees C, the warmest month is July when the average temperature is closed to 22 degrees C. In contrast, the average temperature of the coldest month, January is under -1 degrees C. The area is rich in sunlight; the hours of sunshine exceed 2100 hours per year. The prevailing wind direction is north-west and the average wind speed is up to 2.9 m / s. However, climate change can be felt in this part of the country, too. The summer maximum temperature increased by almost 3 degrees C in the last 30 years and according to the forecast the average summer temperature can rise by up to 5 degrees C in the future.

Metrological data of the examined years

In 2009, the annual average temperature was 11.5 degrees. 265,4 mm rain fell in the vegetation which was under the long-term average. The annual rainfall was 556.6 mm. The April (2.0 mm) was very dry and less than the average rain fell between July and September.

In 2010, the annual average temperature was 10.2 degrees. 646.6 mm rain fell in the vegetation which was above the average of many years. The annual rainfall was 858.0 mm. Especially in May (183.4 mm), in June (172.0 mm) and in September (92.8 mm) were lot of rain.

In 2011, the annual average temperature was 11.1 degrees. Only 172.0 mm rain fell in the vegetation. The annual rainfall was only 235.4 mm; February (7.2 mm), April (4.6 mm), August (4.6 mm) September (1.0 mm) and November (0.0 mm) were extremely dry.

2.2 Experiment's set up and management

In the technological development experiment we used lane arrangement with three replications by using 4 different tillage systems (plow, cultivator, disc harrow, direct sowing) and applying 7 different levels of nutrient supply.

Nutrient treatments:
- N0K0 (control)
- N1K1 (50kg/ha N , 40kg K2O)
- N1K0 (50kg/ha N)
- N2K2 (100kg/ha N , 80kg K2O)
- N2K0 (100kg/ha N)
- N0K1 (40kg/ha K2O)
- N0K2 (80kg/ha K2O)

Tillage operations :
1. Plowing (22 - 25cm)
2. Cultivation (15- 25cm)
3. Disc harrow (16 - 20cm)
4. Direct sowing

The size of the parcel: 500 m2
The width of the roads among the replications: 2 m
Total space: 1,5 ha

Time of sowing:
- April 2009. 20th week
- April 2010 26th week
- April 2011 18th week

Sucrosorgo 506 long-term cultured sorghum hybrid was tested in the experiment. The hybrid characteristics are the following:

- Type of Owner Northrup -King Seed Company / Syngenta USA
- Year of qualification: 1991.
- Late maturing, usually harvested from mid- September.
- High -yielding and drought -tolerant sweet sorghum hybrid type.
- Height: 260-280 cm; succulence with thick-stemmed, good stem- strength, high sugar content (15-20 %).
- Green yield: 75-85 t/ha
- Sowing norm: 250-300 thousand seed /ha
- Recommended number of germs: 25-30 germs/m

Applied agro-technologies in the experiment

We used winter wheat as preceding crops in all three years. Prior to the minimum tillage on the stubble field we stirred the organic residues into the shoal soil. We used mechanical cultivation in the weedy stubble field. In 2009 and 2011 during the vegetation period we applied mechanical weed control by inter-row cultivator two times; the same procedure was applied once in 2010. Chemical control of pests and pathogens was not necessary. The seedbed preparation was done by combinator. There were no cultivation of catch crops, green manure crops and plants improving soil structure. The soil surface was not covered with organic residues of the stubble field in order to protect the soil and reduce the loss of water.

2.3 Experiments' methods and instruments

In order to determine the physical parameters of the soil soil resistance and soil moisture resistance measurements were made. Testing included the yields of sorghum biomass and the refactrometer dry matter method (Brix).

Soil resistance measurement

Operating principle of the penetrometer from Szarvas: after grasping the handle push the machine towards the required soil layer. The required soil depth can be observed on the measurement placed on the probe; the result of the measurement can be read at the front of the instrument. The probe cane optimally goes into the soil by a speed of 2 cm/sec. By performing the measurements it should be ensured that the probe penetrating into the soil perpendicular otherwise the results would be not real and the instrument would put in risk of breakdown. The measurements were taken up to 50 cm deep, in the distance of 10 cm and in 5 levels of depth 3-4 times in the vegetation period. The results of the soil resistance measurement are introduced in the Results' chapter. In order to determine the physical parameters of the soil we made soil resistance measurements every time by the Szarvas penetrometer of the MOBITECH Bt. The machine is capable to measure the consistence of soil up to 50cm depth on the spot. (DARÓCZI and LELKES 1999).

Soil moisture measurement

The measurements were carried out by a Aquaterr T -300 soil moisture meter. This method developed in the United States based on the percentage of high frequency measurements. This method does not take into account other characteristics such as PH, salinity, temperature etc. so it is optimal solution for mobile, pointwise soil moisture measurement. The method is simple: sensor must be inserted into the soil and you can see the moisture content in percentage on the LCD screen. The sensor is located at the tip of the probe and it is only 10 cm long which allows to determine the moisture content of the soil levels and provide an overview on the pervious and retention of soil capacity. T-300 measuring device is equipped with a temperature sensor (not like the M-300 device). It makes possible not only to determine the moisture content but also to measure the temperature. The digital display shows the date in °C. The electronics of the meter is located in a shielded, robust covering made of aluminum for continuous outdoor use.

Determination of refactrometer dry content (Brix)

Measuring principle:

The refractrometer is used for the examination of the dry content in clear liquids (pressed liquids, solutions). With the use of the refractometer it is possible to determine the sugar content directly. There is more than 90 % correlation between the dry content of the sorghum's juice and its sugar content.

Appurtenances:

- Digital refractometer – type-PR-201
- Distilled water
- Wipe
- Secateurs
- permanent marker
- sample storage bag
- Digital Scale

Sampling procedure:

The first step is the calibration of the refractometer which was done every day when measurement was taken. The sampling was done according to the SVÁB methodological descriptions. For each treatment we examined five plants from the middle rows. The selected plants were felled by secateurs. Stems and leaves were set apart. Stems were cut for the needed size by secateurs. We got the necessary amount of liquor for the measuring by pressing. The liquor was put to the prism of the digital refractometer and the results were recorded in the report. The prism of the machine was cleaned from the measured liquor by distilled water.

Determination of green yield

In order to determine the biomass yield of the sweet sorghum biomass we harvested it from an area of 10 linear meters of each parcel. After harvesting we weighted the samples in a factory scale of Kem De type which scale interval is 100 gram.

Statistical evaluation

I have done the statistical evaluation with the use of *IBM SPSS 12* program. I used single variance and regression analysis during the statistical evaluation (BARÁTHNÉ et al. 1996 KETSKEMÉTY et al. 2011). Before I made the variance analysis I had done the examination of the received data. In order to make comparisons among the treatments post-hoc analyses had been done. Post-hoc analysis indicates the significant differences between the averages of the sample pairs. To prove the differences between the averages of treatments I applied the least significant difference method (LSD) at 5% probability level. Statistical analyses extended to soil resistance, soil moisture content and the green yield and sugar content of sweet sorghum.

3. Results

3.1 Soil physical parameters on the green yield of sorghum

Soil resistance measurements were made at a depth of three. The tests were carried out before the time of sowing and harvesting. It can be observed that there is an increase in the values by the time of the harvest in each year. By those measurements which were taken before the sowing none of the tillage treatments reached the 3.0-3.5 MPa penetrometer resistance value which is harmful to the developments of the soil and the plants according to the studies (HAKANSSON 1994; BIRKÁS 2001).

There are significant differences among the soil resistance values of the different tillage treatments. The justified differences can be observed in the measurements carried out before sowing and harvesting in all three years. Post-hoc analysis of the results was done by LSD (Least Significance Difference) method at 0.05 significance level. Correlating to the direct sowing, in 2009 and in 2011 there were significant differences among the measurements carried out before sowing in the plowing, cultivating and disc treatments. On the contrary, in 2010 there was no difference between the results of the direct sowing or disc sowing. There was no big difference in the disc and cultivating treatments thanks to the fact that the operating depth is almost the same.

Significant differences can be discovered between the soil resistance values of the operating depth. In 2009 and in 2011 there were not statistical differences prior to the sowing in the depth of 0-10 and 10-20 cm but on the other hand there were differences in 2010 in all the three examined depths. In 2009 there was significant difference between the 0-10 and 20-30 cm depths prior to the harvesting. In 2011 there were statistically proved differences in all the three depths. In 2010 there was a statistically proved difference between the depth of 20-30 cm and the depths of 0-10 and 10-20 cm but there was no difference between the depth of 0-10 and 10-20 cm.

It is appropriate to carry out the measurements on soil resistance and soil moisture at the same time. According to the academic literature (RÁTONYI 1999) and our experiences in case of higher soil moisture there is a decrease in the soil resistance. In 2009 and 2010 the moisture content was close to 20% before sowing in all depths. In 2011 the moisture content of the soil did not reach 20% in any of the depths.

There are statistically proved differences among the examined years. The cultivation had an effect not only on the soil resistance but on the soil moisture too. In 2009 there was a significant difference in the moisture content of ploughing treatment prior to the sowing compared to the treatments' values carried out by cultivator, disc and direct sowing. Prior to sowing there was no significant difference between the values of cultivating and disc treatment in any of the examined years. This tendency can be observed in the results of the testing prior to the harvest. The pre-harvesting values of the direct sowing treatments showed a significant difference in the moisture content in the years of 2009, 2010 and 2011 compared to the values of the ploughing, cultivating and disc treatments.

Using regression – analysis we looked for correlation between the green yield's soil resistance and green yields soil moisture. Statistical analysis and presentation of the results based on control (N0K0) nutrient treatment in the average of 0-30 cm soil layer. The result is 0,726 R^2 between the green yield and the soil resistance and 0,757 R^2 between the green yield and the soil moisture. It can be said that there is a positive correlation between the variables in both regressions but the correlation is not strong enough. In Figure 1, between 1.5 to 2.5 MPa - favorable soil - soil resistance value coupled with the highest green yield's values. According to Figure 2 it can be stated that the higher soil moisture content significantly affects the yield of biomass per hectare.

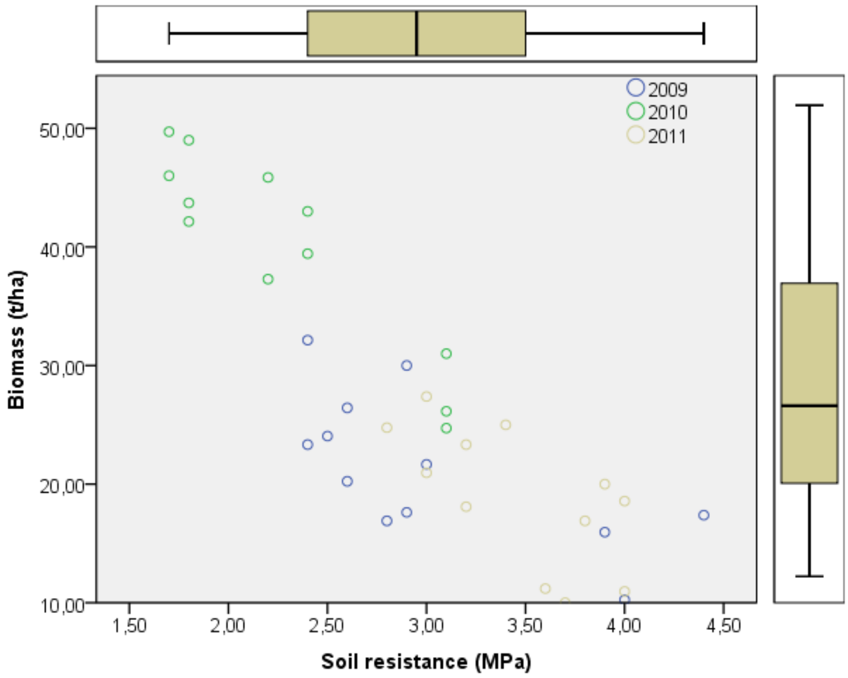


Figure 1 Correlation between green yield and soil resistance

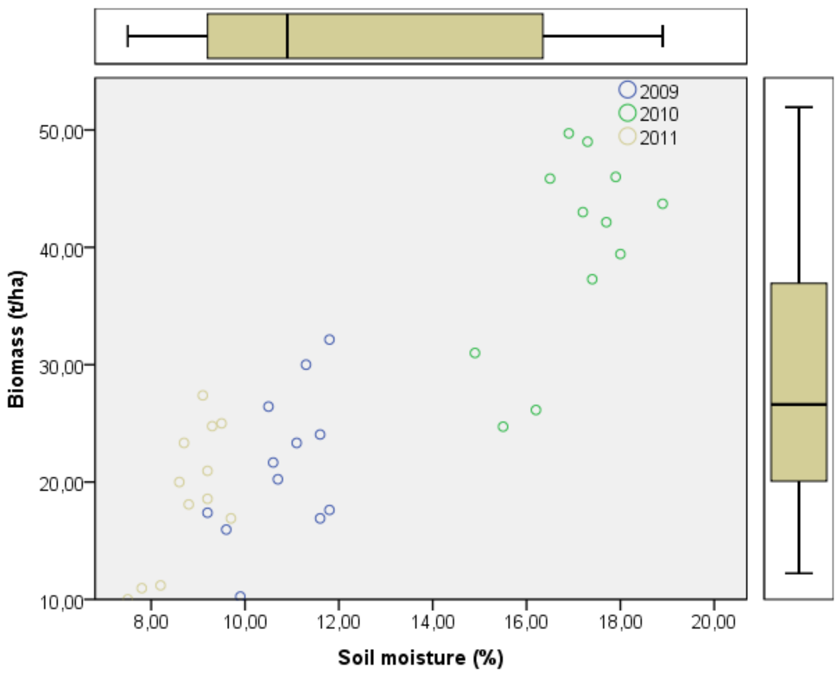


Figure 2. Correlation between green yield and soil moisture

3.2 The effect of tillage on the sorghum's green yield

The harvest took place in the phase of full maturation in all three years. In 2009 harvesting took place on 5 October. Considering the tillage operations, this year we got the biggest amount of green yield from the spot treated by rotating operation. This method brought an average of 41,4 t/ha green yield. Due to the different tillage operations amount of green yield differs as follows: cultivator tilling: 28,1 t/ha, rotary tilling: 26,4 t/ha, direct sowing: 15,0 t/ha (see Figure 3.). With other words, soil status evolved by direct sowing was unfavourable for the sorghum plant development. The difference between the tillage treatments can be significantly justified. The yield of direct sowing differs from the yields of cultivating and disking treatments. There were no significant differences between the yields of the disking and cultivating treatments.

Ploughing operation seemed to be the most effective in 2010 in comparison with the direct sowing operation. By the time of harvesting (11 October) the average amount of the green yield differs as follows: ploughing treatments: 55.4 t / ha, cultivator treatment: 48,7 t/ha, rotary treatment: 48,6 t/ha, direct sowing: 32,8 t/ha. The significant differences among the tillage treatments can be observed this test year as well. Similarly to the year of 2009, there were no significant differences between the yields of disking and cultivating treatments. The yields of parcels cultivated by direct sowing and ploughing differ significantly from the yields of those parcels which were treated by disk and cultivator.

In 2011 the harvest took place on 21 September. Unlike in previous year, the operation which resulted in the biggest amount of green yield in average was not the rotating operation but the cultivating one. The average amount of the green yield differs as follows: ploughing treatments: 34,5 t / ha, cultivator tilling: 37,2 t/ha, rotary tilling: 28,1 t/ha, direct sowing: 14,5 t/ha. Significant differences among the tillage treatments can be observed in 2011 as well. As it happened is 2010, the yields of parcels cultivated by direct sowing and ploughing differ significantly from the yields of those parcels which were treated by disk and cultivator. Furthermore, the difference between the yields of disk and cultivator treatments can be proved.

The results imply to the fact that the tillage adapted to the soil affects biomass yield per hectare. As a result of deeper tillage the soil's water holding and storage capacity increased so with those methods which helped more the water usage capacity of the sorghum bigger amount of yield was achieved.

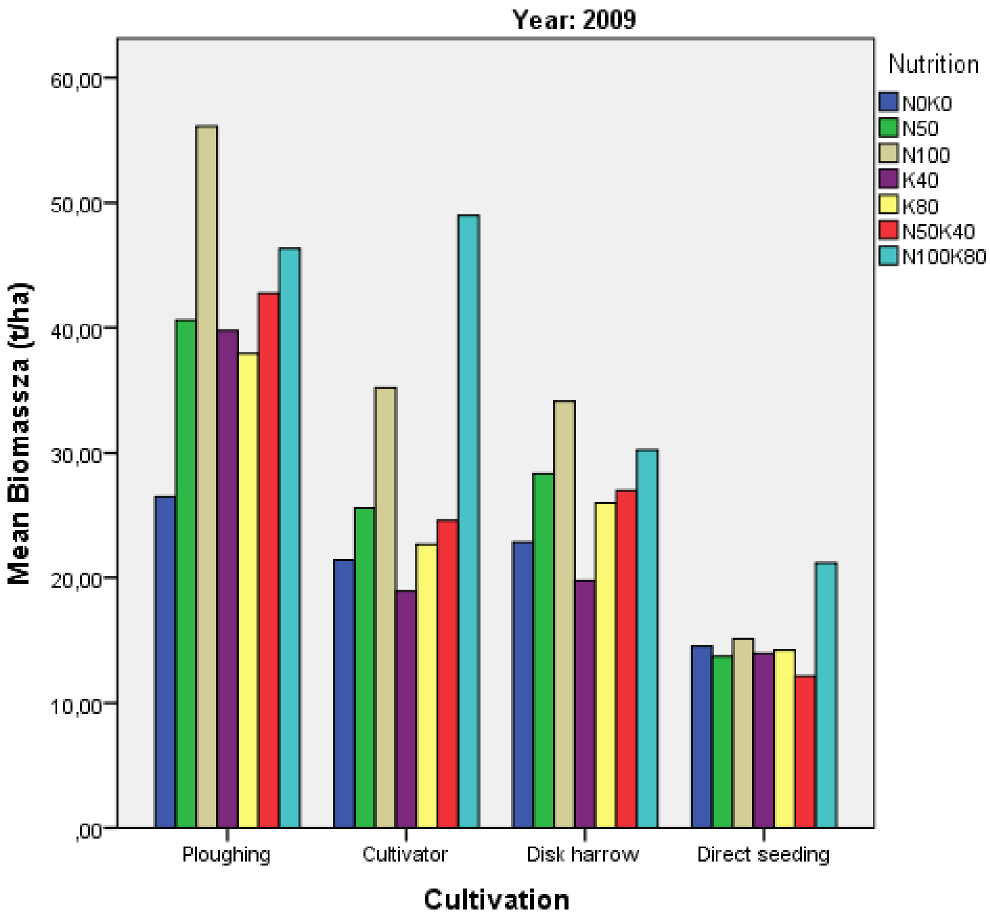


Figure 3 The effect of tillage on the sorghum's green yield (Gödöllő 2009)

3.3 The effect of nutrient supply on sorghum's green yields

In 2009 the maximum biomass yield was 56,1 t/ha, while the minimum was 12,1 t/ha. Significant difference can be observed among the control treatment (N0K0) and the N100 and N100K80 treatments. The use of 100 kg/ha N active substance resulted in 13,8 t/ha yield surplus by the N100 treatment and 15,4 t/ha yield surplus by the N100K80 treatment. Correlate to the control, it is proved by statistical means that the 50 kg/ha active substance did not increase the green yield. The same observations can be done concerning the potassium treatments.

The effect of the given vintage year can be observed well in the testing year of 2010. There was almost 300 mm more rainfall in the tested area in that year than in the previous drought year. Correlate to the control (N0K0), yield increase was proven statistically in the following treatments: N50, N100, N50K40 and N100K80. The average yield increase is 11,3 t/ha in the treatments. Similarly to the year of 2009 there was no significant yield increase in the K40 and K80 treatments.

The effect of certain nutrient treatments on the sorghum's yield is statistically proven in the year of 2011. It can be observed that on average the yield maximum is coupling with the nitrogen supply of 100 kg/ha. Compared to the control treatment, yield increase's effect of nitrogen fertilisation is demonstrable in all cases. As the impact of the fertilisation there was a yield increase of 22 t/ha in the N100K80 treatment compared to the control (N0K0). There was no yield increase's effect of the potassium fertilisation in that testing year.

Effect of Nitrogen (N) and Potassium (K) supply on sorghum's green yield

Figure 4 shows the correlation between the N supply and the yield. By examining the correlation between the N-supply and the biomass it can be stated that as the effect of the nitrogen there was a significant yield increase in 2009, 2010 and in 2011 compared to the control treatment. In 2009 with the use of 50kg/ha nitrogen (N50) the yield increase reached the 5,7 t/ha. With the use of 100 kg/ha nitrogen (N) the yield increase was 13,8 t/ha which is more than the double of the results reached in the N50 treatments. In 2010 the yield increase was 10,3 t/ha in the N50 treatment and 13,2 t/ha in the N100 treatment. As the impact of the fertilizer we could count with the yield increases of 11,1 t/ha (N50) and 18,3 t/ha (N100) in 2011. Regression analysis is advised to use in order to prove the correlations.

After carrying out the analysis in 2009, the $R^2 = 0.758$, $R^2 = 0{,}776$ in 2010, and in 2011 $R^2 = 0942$. In all three years, a positive correlation was established.

The potassium had no significant effect on the sorghum's green yield in the test so the regression analysis of the treatment was not done.

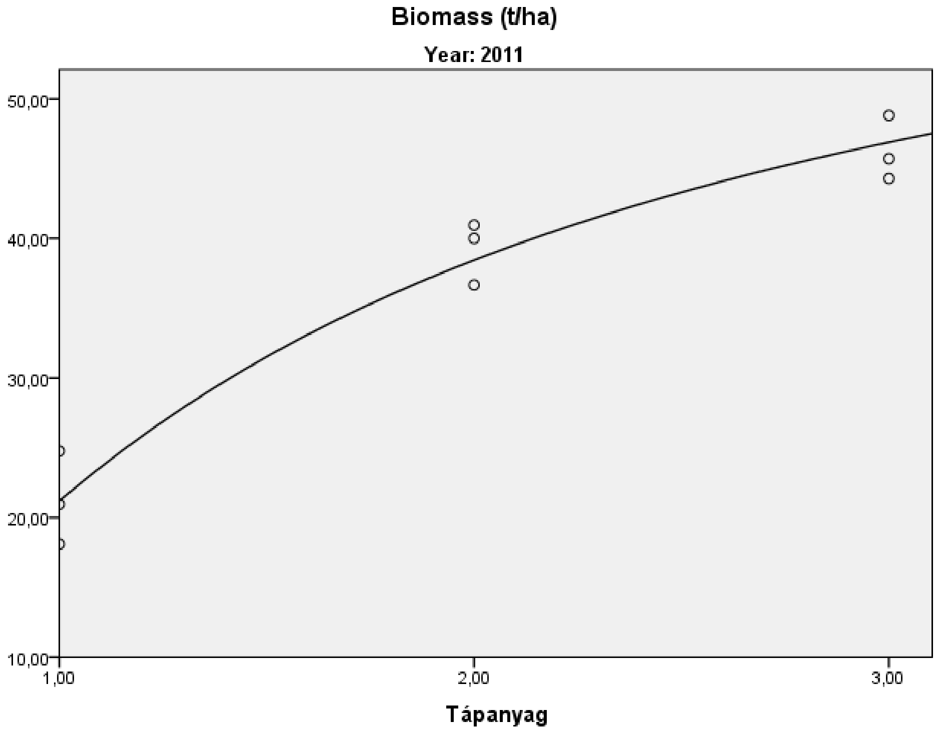


Figure 4: Effect of nitrogen (N) supply on sorghum's green yield (Gödöllő 2011)

3.4 The effect of tillage on the refractometeric dry matter yield (Brix)

In order to determine the sugar content of sweet sorghum's stem Brix-degrees were used. The Brix degree or sugar degree is the traditional unit for measuring the sugar content of liquors. Refractometric dry substance testing of sorghum was carried out at the time of harvest as described in the chapter Methodology. The effects of tillage operations on the refractometeric dry matter yield are statistically proven in the years of 2009, 2010 and 2011 (figure 5). There is a significant difference between the direct sowing treatment and the treatments of disking and ploughing in 2009. In 2010 there is a difference between the fields which were cultivated and which were not. The results were almost the same in 2011. There is significant difference between the direct sowing treatment and the treatments of disking and cultivating.

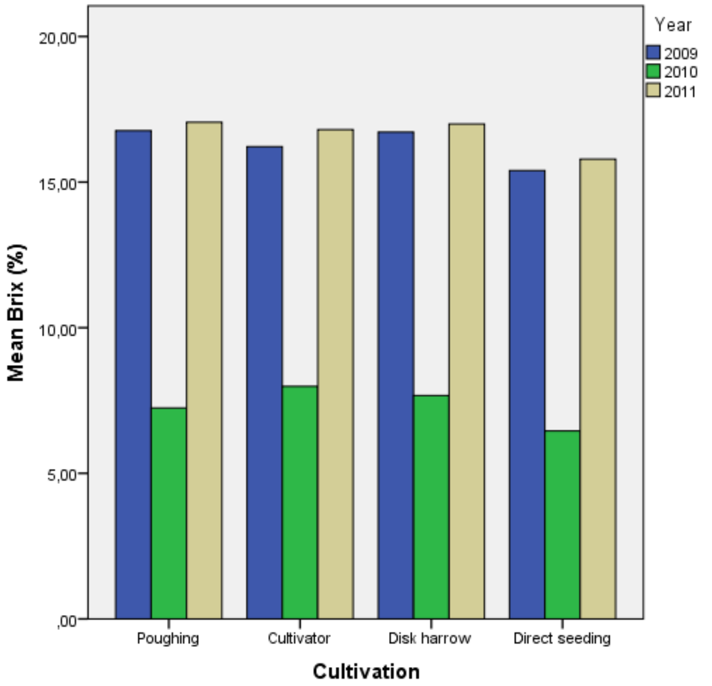


Figure 5: The effect of tillage on the refractometeric dry matter yield (Gödöllő 2009-2011)

3.5. The effect of nutrient supply on the refractometeric dry matter yield (Brix)

A number of domestic and international documents were published in which the correlations of the nutrient supply and the stem's juice were studied (ALMODARES et al. 2008). According to these studies as an effect of potassium fertilisation the sugar content of the stem is increasing. Potassium has a positive influence on the plant carbohydrate metabolism. In addition, potassium has a favorable effect on the plant water balance and stress - tolerant capability as well.

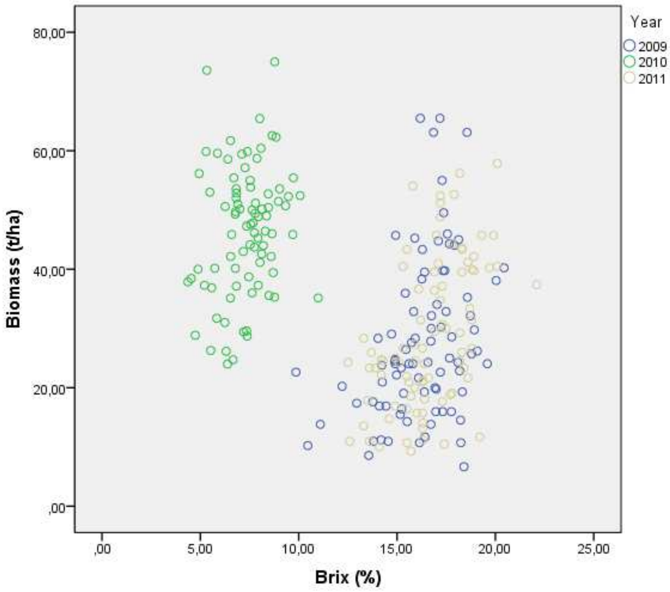
Before the evaluation of the results it is important to note that the potassium and phosphorus supply of the tested area is very good.

In 2009 nitrogen and potassium fertilisation had a significant effect on the dry matter. On average, the maximum values can be observed in the N100 treatment (17.7 %). Minimum values occurred in the control (N0K0) and K40 treatments. Compared to the control treatment (N0K0) there is statistically proven differences in the following treatments: N50, N100, K80, N50K40 and N100K80. The 40kg/ ha dose of potassium (K40) was indifferent to the dry matter. It is a contradictory outcome that in the treatment (K80) in which only potassium fertilizer was used dry matter yield grew by 2.2%.

The effect of the drought in 2011 resulted in similar outcomes as were measured in 2009. Compared to the control treatment (N0K0) there is statistically proven differences in the following treatments: N50, N100, K80, N50K40 and N100K80. The 40kg/ha dose of potassium (K40) did not result in sugar yield surplus.

3.6 Relation between the distribution of green yield and Brix (sugar content)

Figure 6 shows the value pairs of green yield and Brix in annual presentation. The impacts of the year effects can be followed in the figures. The data of the rainy year of 2010 form a separate cluster with low sugar content and high green yield. In that extremely wet year the summer months were colder as the normal so the amount of heat of the vegetation period remained lower which did not help the development of the sugar in the sorghum' stem. Years of the 2009 and 2011 show more similarities. There were droughts and high heat amounts in both years which resulted in lower green yield and increased sugar content. Differences between the year effects were statistically justified. In conclusion, the year effect significantly affects the qualitative and quantitative parameters of sweet sorghum.



Fugure 6: Relation's test between the green yield and the sugar content (year effect, Gödöllő 2009-2011)

3.7 Distribution of sugar content in the sorghum's stem

There are only few academic literatures on the distribution of the sugar content in the juice of sorghum's stem. There are no reliable evidence if the tilling operations, nutrient supply or other agro-technical procedures have any effect on the localization of sugar content.

Figure 7 and 8 show the dynamic of sugar content's distribution in the stem. The internodes with smaller numbers are close to the soil's surface; going up on the stem vertically to internode number 10 which is close to the flower. The inflexion point on the curves fall between no 3-6 internodes which means that the maximum values of sugar content in the stem can be found here.

Based on these results it can be stated that the tilling operations had no effect on the distribution of sugar content. Similar curves can be observed in the case of plowing, direct sowing, cultivator and disc treatment.

Nutrition management had not a significant effect on the sugar content's distribution in the internodes. However, it can be stated that in the most cases higher sugar content can be seen on the graphic compared to the control treatments (N0K0). In the case of the control treatment the inflexion point falls between the internodes no 2 and no 4.

The year effect can be observed in the graphics evaluating the years of 2009, 2010 and 2011. The sugar content shows similarities in the two years of drought. On the contrary, the outcomes of the year of 2010 cannot be evaluated. There are no tendencies among the differences of internodes (figure 8).

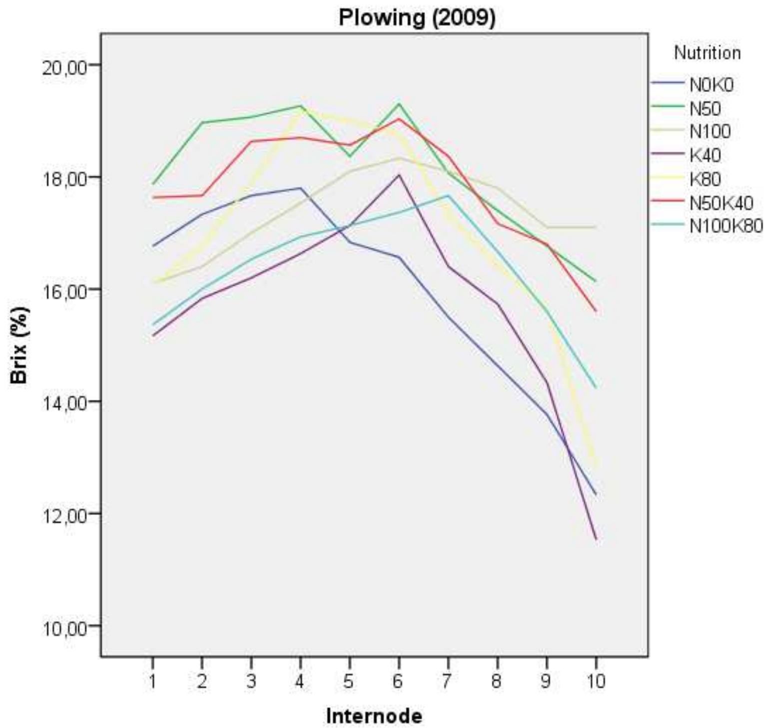


Figure 7: Sugar content variation in the stem in case of plowing (Gödöllő 2009)

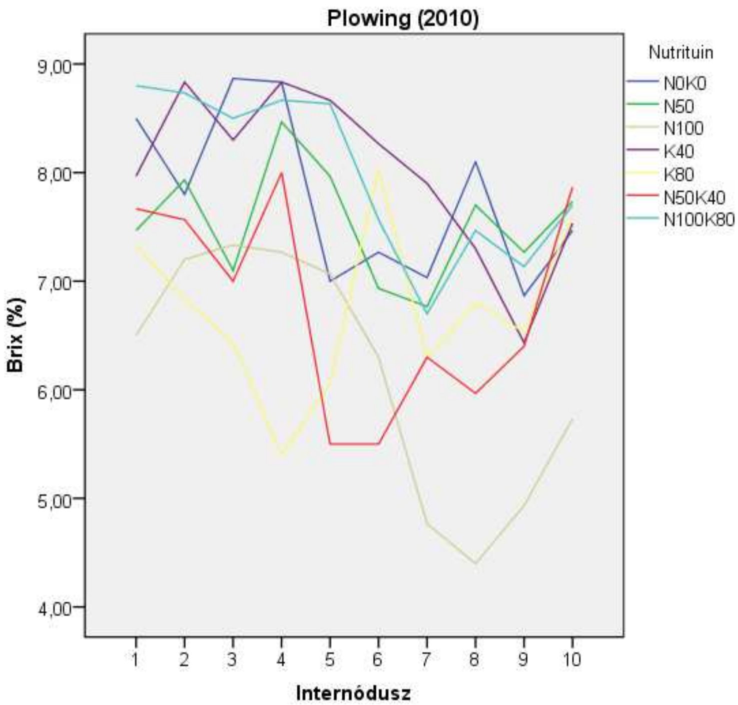


Figure 8: Sugar content variation in the stem in case of plowing (Gödöllő 2010)

New scientific evidences

1. I have proved/ demonstrated that in a given specific region (Szárítópuszta) in a soil disposed to deposition the growing of sorghum is less determined by the minimum tillage method (rotating and without rotating) then the depth of the tillage. In case of at least 25 cm deep tillage the sufficient high amount of biomass can be achieved. Because of its lower moisture absorption and storage capacity, which is one of the characteristics of the disturbed soil, based on economical and professional reasoning, direct sowing does not fits in the sorghum culture's profile.

2. I have found that there is a correlation between the soil resistance and the yield of biomass. At a bigger resistance value (($\geq$3,0 MPa) there were significantly less green yields in all three years of experiment.

3. During the research the need of limited soil investigation has been shown. We proved that in the soil rich in potassium the use of potassium fertilizer does not influence significantly the sugar content of the sorghum's stem. We have not seen significant differences in the green yields and sugar content of the plants derived from the control parcels (N0K0) and from those where 40 kg/ha (N0K1) potassium fertiliser had been used. We achieved significant differences with the use of combined nutrient's treatments (N1K1 and N2K2).

4. I found that there is no influence of the applied tillage method and nutrient management on the distribution of the refractometric dry matter. This factor can be influenced by the year effect and the amount of rainfall.

5. In years of drought the average refractometric dry matter content of the stem is higher (Brix 12-20%) than in the year when the weather is colder and there are a lot of rainfall.

Conclusions and recommendations

Conclusions:

Tests which served the basis of the thesis were carried out in the Institue of Horticulture of Szent Istvan University in Szaritopuszta, Godollo on a low quality rust brown earth formed soil between 2009-2011. Findings, conclusions and recommendations derive from the experimentations I had carried out.

In the tillage operations we have measured 67% higher soil resistance between the time of sowing and harvesting in 2009. In 2010, an extremely wet year, we have measured 63% higher soil resistance between the time of sowing and harvesting. In 2011, which year was similar to 2009, we have measured 71% higher soil resistance. Averaging the results of the three years we can see that there was an increase of 67% in the soil consistency by the time of harvesting.

According to our experiments and the academic literatures the undisturbed soil is more compact (1,5-4,2 MPa) in the case of direct sowing then in cultured fields. According to the data, measured prior to harvesting, penetrometer resistance increased by an average of 0.8 Mpa in all the three depths.

At the time of sowing the soil moisture was equitable among the tillage operations in all the three years despite the fact that there were droughts in 2009 and 2011. At the time of harvesting the values (7,5-16,1%) of the soil moisture were the lowest in the operation of direct sowing in all three years .

Using regression – analysis we looked for correlation between the green yield soil resistance and green yields soil moisture. The result was 0,726 R2 between the green yield and the soil resistance and 0,757 R2 between the green yield and the soil moisture. It can be said that there is a positive correlation between the variables in both regressions but the correlation is not strong enough. Between 1.5 and 2.5 MPa – in a given soil - soil resistance value coupled with the highest green yield values.

In 2009 we received 28,7 t ha-1 green yield on the average of the tillage operations. The average amount of green yields was 32,7 t ha-1 in 2010 and 28,9 t ha-1 in 2011. The highest amount of green yields was measured in the case of ploughing (42,2 t ha-1) and cultivator operations (56,0 t ha-1). Soil condition formed by direct sowing is unfavourable for the sorghum plant development.

The 100 kg ha-1 N active substance resulted in 13,8 t ha-1 yield surplus in the N2K0 treatment, while the same amount of N active substance brought 15,4 t ha-1 yield surplus in the N2K2 treatment. Compared to the control treatment in 2009 we harvested the following amount of yield surplus: N1K0 treatment: 5,8 t ha-1, N0K1 treatment 1,8 t ha-1, N0K2 treatment 3,9 t ha-1 and N1K1 treatment 5,3 t ha-1 . The 100 kg ha- 1 nitrogen fertilizer increased the green yield of sorghum in all three years.

Despite the high potassium content (156 to 206 mg kg-1) of the pilot area potassium treatments had statistically proven effects on the weight of the biomass sorghum. Examining the relations between the N supply and the biomass we realized that the green yields increased as the impact of the 50 kg ha-1 és a 100 kg ha-1 nitrogen doses and the positive correlation (R2=0,735) is proved in all the three years. In 2009 and 2010 we did not see any correlation between the increased potassium fertilizer treatments and the biomass.

I have examined the the effect of tillage and nutrient treatments on the refractometeric dry matter content of the sorghum. In 2009 there was statistically verifiable difference only in the cultivator treatment (SzD5 % = 1.1). In 2010 there were no significant differences in any of the tillage operations. In 2011 statistically verifiable differences were observed in plowing (SzD5%=0,9) and cultivator (SzD5%=0,9) treatments. Overall, it can be stated that the tillage operations had no significant effect on the the refractometeric dry matter content of the sorghum.

We received statistically verifiable difference in the N2K2 treatment in 2009 (SzD5%=0,6). The lowest dry matter values were measured in N0K0 and N0K1 treatments. Significant differences were observed in the N0K0 and N2K2 treatments. However, compared to the control (N0K0) 0.5% reduction in the dry matter content occurred in the N2K2 treatment. In 2010 the treatments of 100 kg ha-1 and 80 kg ha-1 N reduced the dry matter content which can be proved. Positive significant difference was observed in the N1K1 treatment. Compared to the control treatment there was a 3.1% dry matter's growth in the N1K1 treatment.

In the case of cultivator treatment we obeserved a positive correlation ($R2=0,706$) between nitrogen treatment and dry matter content in 2009. In 2010 there was no correlation in the tillage operations. In 2011, the cultivator treatment showed positive correlation again ($R2 = 0.626$), that is statistically justified. There was no correlation between potassium and Brix-values in the applied tillage operations. We could not prove the effect of the combined nutrient treatments on the dry matter.

I have examined the distribution of the sugar content in the sorghum's stem. The highest dry matter's values were measured between no. 3-6 internodes. The measurements of KRISHNAVENI et al. (1984) confirm the results we obtained which means that the maximum refractometric dry matter content is in the middle part of the stem (4-6 internodes).

Recommendations

Due to the high percentage of potassium of the highly heterogeneous brown forest soil in the Gödöllő-hills and Institute of Crop Production (Szárítópuszta) the use of more than 40 kg ha-1 K is not reasonable for silos sorghum culture.

The biomass production of the Sucrosorgo 506 forage sorghum hybrid used for the experiment setup was 25-30 % less in the tested area as it was determined by the owner (75-85 t ha-1). Despite the variant weather conditions (drought in 2009 and 2011; extreme amount of rainfall in 2010), the hybrid's biomass yield considered to be balanced. Its excellent drought tolerance ability has been demonstrated. Although, I have not examined its digestibility and those parameters important for animal husbandry but because of the hybrid's balance its cultivation would be reasonable in the Animal Husbandry Institute of Szent István University.

In order to achieve successful silos sorghum production it is reasonable to increase the 100 kg ha-1 N dose which was used in the experiment as the experimented soil's (Szárítópuszta) nitrogen – supply capacity is very poor.

Due to non-rational use of the soil of the Institute of Crop Production it is highly sensitive to compaction and erosion. Contrary to the practice which had been used up to now the rotary cultivation carried out in more phases should be replaced by the not rotary tillage operations. Having known the soil conditions of the Institute the use of cultivator operation would be reasonable. This statement applies not only to sorghums but to the all plants' cultures. According to my experiences the depth of the tillage shall be at least 25-30 cm. In case of base soil tillage and any other tillage operations it is important to seal the soil surface.

Refractrometric dry matter test should be used in order to determine the exact harvest time. Stem sample for measurement should be taken from the middle part of the stem (3-7 internodes).

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