EXAMINATION OF RELATIVE CHLOROPHYLL CONTENT AND YIELD IN SMALL-PLOT EXPERIMENT OF SORGHUM (SORGHUM BICOLOR L.) IN 2019

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Abstract. *Sorghum is the fifth most popular grain in the world, with over 40 million hectares, according to 2017 FAO data. The amount of sorghum sown area in Hungary has been extremely fluctuating in the last decades. In 2018, this figure was close to 26,000 hectares. More than half of the sorghum crop in the world is present in the human diet, and therefore their importance is far from negligible. Sorghum is considered to be a drought-tolerant fodder plant and is therefore well suited for use in dry or seasonally drought-prone areas and in areas with poorer characteristics, even as an alternative to maize. In our research, we investigated the nutrient response of white grain sorghum at four nutrient supply levels in a small-plot randomized experiment in Szarvas, Hungary, at the Galambos experimental area of the Szent István University, Faculty of Agriculture and Economics. In our research, we explore the plant physiological, plant physiological and technological relationships that can serve as the basis for modern nutrient management and provide the scientific basis for the efficient development of sorghum production. The soil of the experiment is deep carbonated Chernozem meadow soil, its physical nature: clayey loam, with acidic and slightly acidic pH, its water management is characterized by poor conductivity and high water retention. The experiment investigates the effects of the 4 nutrient combinations. There were four nutrient treatments, four nitrogen levels (0 t/ha, 0,080 t/ha, 0,0120 t/ha, 0,0160 t/ha), four phosphorus (0 t/ha, 0,060 t/ha, 0,090 t/ha, 0,0120 t/ha) and four potassium levels (0 t/ha, 0,060 t/ha, 0,0120 t/ha, 0,0180 t/ha) was set. In addition to the yield results, we also measured the relative chlorophyll content several times during the growing season. For this purpose, a portable Minolta SPAD chlorophyll content meter was used to measure the chlorophyll content of the leaf, and the results were expressed as SPAD, a dimensionless number that can provide unambiguous data on the chlorophyll content of the leaf. In our experiment we investigated the nutrient response of sorghum in terms of changes in chlorophyll content and yield average. Among the nutrient combinations, the most significant positive effect was measured in the case of the 3rd treatment, while the effects of the highest nutrient levels were smaller. In the experiment yields varied between 4.9 t ha^{-1} and 7.11 t ha^{-1}.*

Keywords: *sorghum, nutrient supply relative chlorophyll content, yields*

INTRODUCTION

Sorghum is the fifth most popular grain in the world, with over 40 million hectares, according to 2017 FAO data. The amount of sorghum sown area in Hungary has been extremely fluctuating in the last decades. In 2018, this figure was close to 26,000 hectares. More than half of the sorghum crop in the world is present in the human diet, and therefore their importance is far from negligible. Sorghum is considered to be a drought-tolerant fodder plant and is therefore well suited for use in dry or seasonally drought-prone areas and in areas with poorer characteristics, even as an alternative to maize.

Sorghum is a monocotyledonous plant of the Poaceae family from Africa, characterized by outstanding drought and stress tolerance. It requires 30-50% less water to produce one unit of dry matter than corn, since it is characterized by reducing evaporation by selecting a wax coat in drought conditions. (www.euralis.hu). According to VINALL (1936), the origin of the sorghum is probable in the steppe and savannah areas of Africa and Ethiopia and Sudan. In Hungary, the breeding of sorghum was started in 1959 in Szarvas. The first variety was the Szarvasi Barna sorghum, whose certification was withdrawn in 1967 (KAPÁS 1969). The low annual rainfall in the semi-arid zone, which does not exceed 300-350 mm for the sorghum, has adapted well to this environment (ZHANG et al. 2010). Since sorghum is not demanding on the soil, it can be one of the plants in disadvantaged areas. (GYÖKÉR 1978, SIKLÓSINÉ 2001, GOSHADROU et al. 2011). Sorghum can be grown as a second crop, but seed and seed production can only be safely done in the main crop (ANTAL et al. 1966).

According to researchers, sorghum has the same nutrient requirements as maize and the same nutrient delivery time. (ROSS and DUNGAN 1957) In his book BOCZ (1992), he stated the following levels of fertilizer for sorghum grain:

- Specific Nutrient Requirements: N 29-36; P2O5 13-17; K2O 30-36 kg t-1
- 3.5-5 t ha-1 average yield on weaker soil: N 116-165; P2O5 53-75; K2O 116-165 kg ha-1 fertilizer application rate required

According to BUZÁS (1983), the following specific nutrient requirements should be considered: N, 29; P2O510; K2O 31 kg t-1 .

The sorghum takes up about 45% of the phosphorus and nitrogen by the end of flowering (Lásztity 1995), the most intensive incorporation of these nutrients can be observed during the period of eye formation and ripening. Other nutrient uptake dynamics are reported by Roy and Wright (1974) according to which nearly 60% of N and P are taken up by sorghum after flowering. Both corn and rice have higher uptake of nitrogen, potassium and phosphorus in longer sorghum hybrids (HAN et al. 2011)

BOKORI and KOVÁCS (1996) point out that high doses of N-fertilizer can increase the nitrate content of a plant to an extent that may be toxic.

MATERIAL AND METHODS

During the experiment, we examined the effects of the three main nutrients with four different doses of fertilizer. The drug levels were as follows:

Table:1

Levels of nutrient compounds kg ha^{-1} (Source: Author 's own editing)

Nutrient level	N	P	K
1	0	0	0
2	80	60	60
3	120	90	120
4	160	120	180

The size of the experimental plots is 5m x 8m. The 5 m plot width allows for 6 rows spaced at 76 cm row spacing. Seeding was performed using a field pneumatic seed drill throughout the experimental area, from which paths were ground after emergence to form plots. The seed spacing was determined at 5.3 cm, which means approximately 250,000 germs / ha. 2 of the 6 rows can be considered as a border, avoiding any overlap of fertilizer between plots. The samples needed for the tests, which were "destroyed", were taken from rows 2 and 5, while harvesting and other measurements were made in the two middle rows. Harvesting was done by mechanical power with the aid of a plow. According to previous section excavations and soil studies, the soil of the experimental area is deep-carbonated chernozem meadow soil, the physical quality of the soil is clayey loam, its acidity is acidic, the cultivated layer does not contain CaCO3, based on the humus content the soil has moderate N-supply, P-supply, K-supply, Zn- from Cu and Mn.

Table 2.

Characteristics of the soil in the experiment (Szarvas, 0-30 cm soil layer)

pH (KCl)	K_A	$CaCO_3$	Humus (%)	AL-P_2O_5 $mgkg^{-1}$	AL-K_2O $mgkg^{-1}$	Mg (KCl) $mgkg^{-1}$	EDTA-Zn $mgkg^{-1}$	EDTA-Cu $mgkg^{-1}$	EDTA-Mn $mgkg^{-1}$
4,95	44,6	0,0	2,89	216	260	687	3,26	7,35	428

The data in Table 3. present the weather data for the year 2019 for the growing year. For the entire growing year, precipitation fell close to the annual average, but the data show that we had been struggling for several months at the beginning of the year compared to the 30-year average. Then, at the time of sowing and the subsequent early stages of development, the plant had sufficient water. During the dry summer months, we replaced the missing water by irrigation. We watered it twice. In both cases, 25mm irrigation water was applied.

Table 3.

Data of weather between jan. of 2019. and sept. of 2019. Szarvas ,Source: Author 's own editing

Month (1)	**jan.**	**febr.**	**march.**	**apr.**	**may.**	**jun.**	**jul.**	**aug.**	**sept.**	**sum / average**
Temperature (°C)	-0,2	5,0	9,3	13,9	16,2	24,3	22,9	24,1	19,3	14,9
Rain (mm)	35	9	3	48	103	105	72	27	51	453
Mean of rainfall of 30 years (mm)	30,6	31,4	28,9	41,9	62,9	71,4	74,4	56,4	42,8	440,7
Difference (mm)	**4,4**	**-22,4**	**-25,9**	**6,1**	**40,1**	**33,6**	**-2,4**	**-29,4**	**8,2**	**12,3**

The hybrid sorghum we chose was Euralis-bred Albanus, whose general characteristics are summarized below by the breeder
- The white color of the fruit is sought after in the special target markets
- Above average adaptability
- Average height plant, strong stem, easy to harvest
-It doesn't tend to tip
- Above average Fusarium tolerance
- He doesn't tend to bounce

(www.euralis.hu)

For measuring the chlorophyll content of sorghum leaves, a portable Minolta SPAD photosynthetic pigment content meter was used.

RESULTS AND DISCUSSION

The yields at different nutrient levels after harvest are shown in Figure 1. It can be seen that yields increase only to a certain level with increasing nutrient supply. Then, at the highest saturation level, yield reduction can be realized.

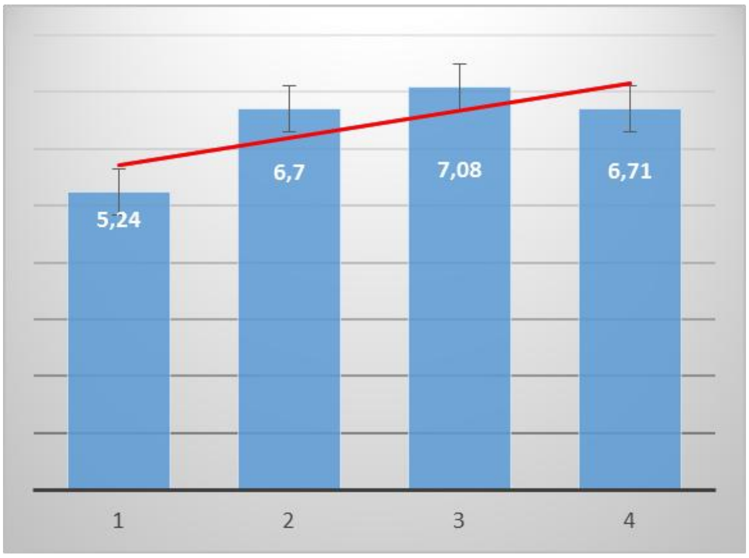

Fig. 1. Yield of the sorghum in 2019.(t ha^{-1})

By analyzing the variance analysis of the yield results measured at nutrient levels, we monitored whether the change occurring reaches the level of significant difference. The variance values are shown in Table 4.

Table 4

Table of variance analysis of yield 2019. Source: Author 's own editing

Dependent Variable: Yield

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7,885[a]	3	2,628	108,064	,000
Intercept	662,419	1	662,419	27234,353	,000
Nutrient levels	7,885	3	2,628	108,064	**,000**
Error	,292	12	,024		
Total	670,596	16			
Corrected Total	8,177	15			

a. R Squared = ,964 (Adjusted R Squared = ,955)

In order to confirm further correlations, we also performed Pearson correlation analysis of the factors. The analysis similarly confirmed the effect of nutrient levels, with significant differences in each case. The analysis shows a strong correlation.

Table 5

Correlation between sorghum yield and Nutrient levels in 2019. Source: Author 's own editing

		Nutrient levels	Yield
Nutrient levels	Pearson Correlation	1	**,779****
	Sig. (2-tailed)		,000
	N	16	16
Yield	Pearson Correlation	**,779****	1
	Sig. (2-tailed)	,000	
	N	16	16

**. Correlation is significant at the 0.01 level (2-tailed).

The relative chlorophyll content of sorghum leaves was measured four times in succession, in each case on the same pre-labeled leaf, so that differences in chlorophyll content due to its development would not alter the results of the measurements. Based on the results of the first measurement, the following SPAD values were obtained in the experiment.

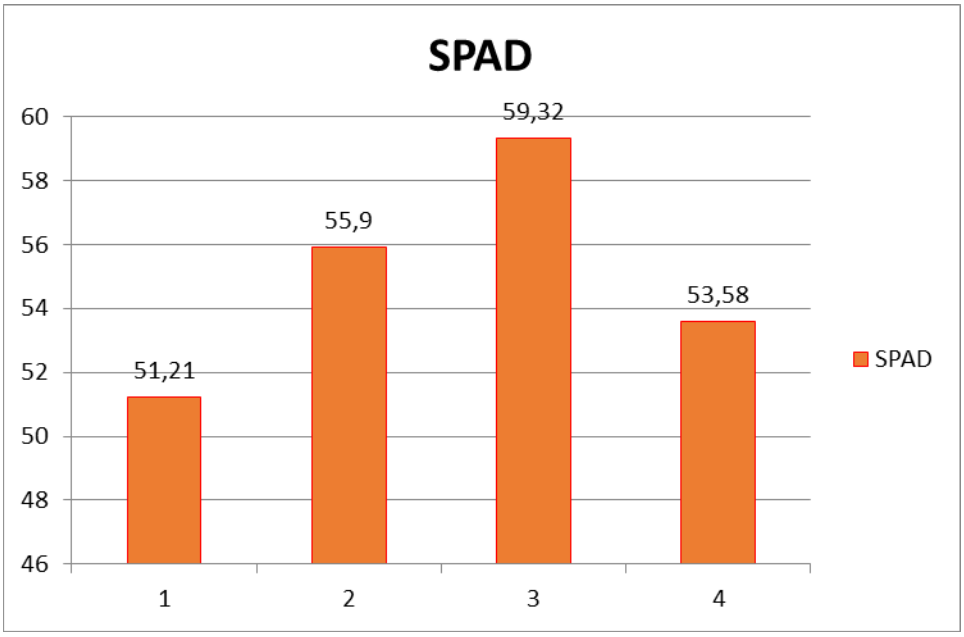

Fig. 2. SPAD value on different NPK nutrient levels in 2019. Source: Author 's own editing

As the SPAD values change, it is noticeable that as the nutrient levels change, the SPAD values for leaf chlorophyll content increase. However, here too, it is observed that values above a certain nutrient level, like crop yields, are declining and are close to those of the control, non-nutrient plots.

By analyzing the variance analysis of the SPAD values measured at nutrient levels, we monitored whether the change occurring reaches the level of significant difference. The variance values are shown in Table 3.

Table 6.

Table of variance analysis of SPAD 2019. Source: Author 's own editing

Dependent Variable: SPAD

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	143,412[a]	3	47,804	18,158	,000
Intercept	48395,600	1	48395,600	18382,497	,000
Nutrient levels	143,411	3	47,804	18,158	**,000**
Error	31,592	12	2,633		
Total	48570,604	16			
Corrected Total	175,004	15			

a. R Squared = ,819 (Adjusted R Squared = ,774)

CONCLUSIONS

The results of the experiment clearly show that adequate nutrient supply is an important cornerstone for the cultivation of sorghum. There was a significant difference between nutrient levels in terms of yield and SPAD values. However, both crop yields and the closely related leaf chlorophyll content data showed that under these climatic and soil conditions, the results were adversely affected by over-nutrition. In practice, the highest nutrient levels in both yield and SPAD could barely outperform those of the control plots. Among the nutrient combinations, the most significant positive effect was measured in the case of the 3rd treatment, while the effects of the highest nutrient levels were smaller. In the experiment yields varied between 4.9 t ha-1 and 7.11 t ha-1

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