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ASSESSMENT OF GRAIN SORGHUM (*SORGHUM BICOLOR (L.) MOENCH*) HYBRID COMBINATIONS

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Abstract. *Grain sorghum is a very prospective plant in Europe and the potential role of this crop can be enhanced by sorghum breeding which can improve the yield and the nutritional values as well. In this study eleven sorghum hybrids were evaluated. During this experiment some morphological parameters, starch- and protein contents were assessed. Starch contents were carried out by using polarimetric method while Kjeldahl method of nitrogen content was used to determine the protein content. Based on the measured data, heterosis values were calculated and ANOVA was applied in order to determine the potential differences appeared among the hybrids. From the viewpoint of the investigated aspects significant differences were found. Parameters of the investigated morphological parameters differed in a large scale, while in the case of the starch content Hybrid 6 obtained the highest values with a remarkable 26.19% heterosis value. Protein contents ranged from 10.59% to 14.25%. The highest value for protein content was obtained by Hybrid 2 with 12.59% value of heterosis*.

Keywords: grain sorghum, threshing %, starch content, protein content, plant breeding

1. Introduction

Sorghum is produced for a diversity of uses, but this crop is mostly grown for forage in Europe. It is a very prospective crop in Hungary due to its great tolerance against drought and unfavorable soil conditions, which are actual problems in the Hungarian agriculture [1, 2]. Thus growing and breeding of sorghum can be an adequate method to decrease risks caused by drought. In the field of sorghum breeding the most widespread conventional breeding method is hybridization.

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Heterosis in sorghum can be manifested in improved performance of several characteristics. In a case study the manifestation of heterosis among 19 sorghum hybrids was reported appearing in the yields and plant height [3]. In another case 84% increase of grain yield had been reported as compared to the parents in the United States of America [4] while in Kenya the mean hybrid superiority over mid-parent values was 54% for grain yield and 35% for above-ground biomass [5]. Other research works also studied the manifestation of heterosis on grain sorghum and reported an increased yield of the hybrid compared to the parent lines as well [6, 7] moreover, in some cases the percentage of the increase was 238% [8].

Primer proteins are essential in the field of human nutrition and animal husbandry, therefore a respectful attention focused on the investigation of this parameter [9]. Some studies mention negative heterosis values for protein content in the case of grain sorghum [10, 11] therefore more attention should focused on this parameter. Remarkable starch- and protein content enhancement can be obtained by crossing inbred lines resulting significant differences among the hybrid combinations from the viewpoint of these parameters [11]. Based on a Hungarian research work notable outbreeding enhancements were reported in the case of sorghum hybrid combinations from the point of view of starch- and protein content [12]. The starch contents of the single cross hybrids varied between 48.37% and 62.63% while the protein content ranged between 9.43–17.7%.

In this study eleven hybrid combinations were evaluated by the viewpoints of some morphological parameters, starch- and protein content in order to reflect the impacts of the hybridization.

2. Materials and methods

The field experiment was fixed on the H2 plant growing site of the Research Institute of Karcag. The soil type of the area was meadow chernozem with the main characteristics determined by the Hungarian standards (MSZ 20135:1999) shown in Table 1.

Table 1) The main parameters of the topsoil of the experimental area

pH (KCl)	Total salt content (m/m%)	Humus (m/m%)	P_2O_5 (mg/kg)	K_2O (mg/kg)	NO_2^-, NO_3^- (mg/kg)
4.8	0.04	3.06	101	399	21.3
Na (mg/kg)	Mg (mg/kg)	SO_4 (mg/kg)	Mn (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
21	458	10.1	483	8.2	1.2

The field experiment was carried out between 27th of April and 10th of September in 2015. Annual precipitation was 414 mm and annual average temperature was 12.1^{O}C respectively. The applied row space was 76.2 cm, the distance of the plants was 5 cm and the depth of sowing was 5 cm as well. The preemergent and postmergent weed control was done by using metolachor and terbutylazine and dicamba+bentazone herbicides and herbicide combinations. The site was free of weeds, and fitotoxic symptoms weren't appeared.

Before harvesting ten panicles were collected from each hybrid and parent line so as to guarantee the reliability of the statistical analysis. The collected panicles were dried for a few days and then the weight of each panicle was measured. After that the panicles were threshed by a laboratory grain thresher. After threshing, the weight of the grains threshed from each panicle was measured in the case of all panicles. The moisture content of the grains varied between 12% and 14%. By the measured data the threshing percentage was calculated using the equation below:

$$T=(P-g)/P*100 \quad (1)$$

Where:
T =Threshing percentage
P = The average weight of the panicle
g = The average weight of the grain in a panicle

The determination of starch content was done by polarimeter which is used to measure the angle of rotation caused by passing polarized light through an optically active substance. During the measurements 2.5 g of milled samples were destructured by 50 ml HCl (1,124 m/m %). After heating and blending the tincture, 10 ml of phosphorous-wolfram acid was added to aggregate protein of the sample. After blending, the tincture was filtered and measurements were done by a polarimeter. The starch content was calculated by the equation below:

$$S = (104[\alpha]) / ([\alpha]D20 * l * m) \quad (2)$$

Where:
S = starch content (m/m%)
[α] = the angle of rotation red during the measurement
[α]D20 = the specific ability of rotation of the evaluated substance
l = the length of the polarimeter tube (dm)
m = the measured amount of the substance (g)

The determination of the protein content was done by the Kjeldahl method: 0.5 g of milled sample was digested with sulphuric acid and the released nitrogen was determined by titration. The amount of protein was calculated from the nitrogen concentration of the sample by multiplying with a conversion factor (6.25).

On the bases of the measured and calculated data, the percentage heterosis was calculated by using the equation below:

$$H = \frac{\left[F1 - \frac{(P1 + P2)}{2}\right]}{\left[\frac{P1 + P2}{2}\right]} * 100 \quad (3)$$

Where:

H = The percentage of heterosis
F1 = The mean of the measured/calculated data of the hybrid
P1 = The mean of the measured/calculated data of the better parent line
P2 = The mean of the measured/calculated data of the vulnerable parent line

Based on the calculated heterosis values, the hybrid combinations were investigated whether they can provide better results than their parent lines by the evaluated viewpoints. So as to determine the potential differences among the hybrids ANOVA was applied. The calculations were performed by using MS Office Excel and R Softwares.

3. Results and discussion

Based on the results the average weight of panicle ranged from 25.10 g to 64.50 g. Hybrid 8 had the highest value of this parameter while Hybrid 2 had the lowest. From the viewpoint of this morphological parameter the observed standard deviations ranged in a large scale from 5.93 g to 19.68 g.

Table 2) Morphological parameters of the investigated hybrids

	Weight of panicle			Weight of grains			Threshing%		
Hybrid	Mean (g)	SD (g)	Heterosis (%)	Mean (g)	SD (g)	Heterosis (%)	Mean (%)	SD (%)	Heterosis (%)
Hybrid 1	35.60	5.93	25.80	24.39	6.44	15.07	32.13	9.27	33.56
Hybrid 2	25.10	19.68	0.88	19.17	13.20	-4.56	29.88	9.75	20.68
Hybrid 3	48.90	13.87	88.08	40.40	11.25	38.36	17.29	2.26	-29.52
Hybrid 4	55.00	12.81	144.99	43.90	10.08	41.84	20.14	2.03	-20.94
Hybrid 5	48.20	10.13	73.38	39.20	7.11	44.57	18.13	4.11	-45.05
Hybrid 6	48.70	9.15	85.17	41.35	8.08	46.68	15.22	1.70	-46.96
Hybrid 7	53.73	16.87	66.93	44.70	13.60	49.67	16.44	2.43	-42.99
Hybrid 8	64.50	15.80	61.25	53.60	12.80	56.20	16.74	2.56	-51.22
Hybrid 9	34.80	11.81	-4.66	20.18	9.31	16.80	40.62	10.46	42.07
Hybrid 10	35.20	12.78	44.56	26.24	11.03	27.16	26.24	8.27	-23.29
Hybrid 11	45.00	7.64	71.76	36.90	6.87	42.11	18.20	2.38	-43.11

The heterosis value for this parameter was negative only in the case of Hybrid 9, hence ten of the investigated hybrid combinations reached a higher panicle weight than the mean of parent lines' performance. In the case of Hybrid 3, Hybrid 5, Hybrid 6, Hybrid 7, Hybrid 8, Hybrid 10 and Hybrid 11 remarkable heterosis values were calculated while for Hybrid 4 a prominently high outbreeding enhancement was determined with 144.99% heterosis value (*Table 2*).

The average weight of grains of the hybrids ranged from 19.17 g to 53.60 g. From this viewpoint only the Hybrid 2 provided negative heterosis value. Positive hybrid vigour was found in all the other cases. Hybrids providing high positive heterosis values for the weight of panicle reached high heterosis values of the weight of grains as well.

Regarding the threshing percent of the hybrids, the average values ranged from 15.22% to 40.62%. Hybrid 9 gave the highest threshing percent value while Hybrid 6 had the lowest. Thus in the case of Hybrid 9, there was more stem parts in the panicle than other cases while in the case of Hybrid 6 the average ratio of grains in the panicle was higher than in the case of any other investigated hybrids. The standard deviation of the threshing percent for all the hybrids evaluated was recorded as 9.7 g, which means that the deviations were ranged on a large scale. In the case of eight hybrids, the heterosis value of the threshing percent was negative while Hybrid 1, Hybrid 2 and Hybrid 9 produced positive heterosis results for this parameter.

Table 3) Alignment of hybrids by the evaluated morphological parameters

Weight of panicle $LSD_{5\%}$=11.31		Weight of grains $LSD_{5\%}$=9.08		Threshing % $LSD_{5\%}$=5.22	
Group	Hybrid	Group	Hybrid	Group	Hybrid
a	Hybrid 8	a	Hybrid 8	a	Hybrid 9
ab	Hybrid 4	ab	Hybrid 7	b	Hybrid 1
ab	Hybrid 7	b	Hybrid 4	bc	Hybrid 2
b	Hybrid 3	b	Hybrid 6	c	Hybrid 10
b	Hybrid 6	b	Hybrid 3	d	Hybrid 4
b	Hybrid 5	b	Hybrid 5	d	Hybrid 11
bc	Hybrid 11	b	Hybrid 11	d	Hybrid 5
cd	Hybrid 1	c	Hybrid 10	d	Hybrid 3
cd	Hybrid 10	c	Hybrid 1	d	Hybrid 8
cd	Hybrid 9	c	Hybrid 9	d	Hybrid 7
d	Hybrid 2	c	Hybrid 2	d	Hybrid 6

Threshing percent reflects on the ratio of stem parts in the panicle, therefore in the case of eight hybrids with negative heterosis value an enhanced performance were observed by the investigated viewpoint. In the case of positive heterosis values of this parameter, the ratio of stem parts in the panicle was higher than the mean of the parent lines performance, this means that the ratio of grains in the panicle was lower.

According to the results significant differences were found among the hybrids by the viewpoints above. Hybrids with the same letters are in the same group and differ significantly by the evaluated aspect while hybrids with two letters are not significantly different from one another (*Table 3*.).

The highest value of starch content was obtained by Hybrid 6 (72.30%) while the lowest value was calculated for Hybrid 9 with the value of 57.32%. The hybrids' heterosis values for starch was negative in the case of Hybrid 2 and Hybrid 9 while in other cases the value of hybrid vigour was positive. In the case of Hybrid 6 and Hybrid 8 a remarkable outbreeding enhancement was determined from the viewpoint of starch content (*Table 4*).

Table 4) Starch- and protein contents of the investigated hybrid combinations

	Starch content			Protein content		
Hybrid	Mean (%)	SD (%)	Heterosis (%)	Mean (%)	SD (%)	Heterosis (%)
Hybrid 1	67.78	2.47	8.61	11.03	0.33	-5,99
Hybrid 2	58.29	8.87	-7.42	14.25	1.58	12.59
Hybrid 3	59.85	1.48	2.16	11.34	1.88	-6.80
Hybrid 4	67.92	3.60	9.57	11.19	0.51	-9.02
Hybrid 5	63.50	2.77	2.96	10.72	2.64	-24.28
Hybrid 6	72.30	1.10	26.19	10.59	0.66	-22.51
Hybrid 7	66.27	2.10	6.26	10.97	0.99	-14.49
Hybrid 8	66.95	1.68	13.38	12.59	0.52	-9.13
Hybrid 9	57.32	3.84	-6.55	12.81	2.44	-6.92
Hybrid 10	63.16	8.77	2.25	12.88	1.15	-7.31
Hybrid 11	61.99	2.36	4.56	10.72	0.73	-20.14

The highest value of protein content was obtained by Hybrid 2 (14.25%) while the lowest value was calculated for Hybrid 6 with the value of 10.59%. The results of the hybrids' heterosis values for protein content showed that ten hybrids provided negative values and only Hybrid 2 gave positive value for the heterosis. Hybrid 5 gave the lowest value of heterosis for protein content with the value of -24.28%. According to these results it could be deducted that in the case of the Hybrid 2, the protein content was higher than the average value of its parent lines, whereas in the other cases the mean of the parent lines' protein content were higher than the protein content of the hybrid combination.

Table 5) Alignment of hybrids by their starch- and protein contents

Starch content (%) $LSD_{5\%}$=4.06		Protein content (%) $LSD_{5\%}$=1.33	
Group	Hybrid	Group	Hybrid
a	Hybrid 6	a	Hybrid 2
b	Hybrid 4	b	Hybrid 10
b	Hybrid 1	b	Hybrid 9
bc	Hybrid 8	bc	Hybrid 8
bc	Hybrid 7	cd	Hybrid 3
cd	Hybrid 5	d	Hybrid 4
cd	Hybrid 10	d	Hybrid 1
de	Hybrid 11	d	Hybrid 7
def	Hybrid 3	d	Hybrid 11
ef	Hybrid 2	d	Hybrid 5
f	Hybrid 9	d	Hybrid 6

According to the results significant differences were found among the hybrids by the viewpoints of starch- and protein contents. Hybrids with the same letters can be sorted into the same group by the evaluated aspect while hybrids with two or more letters are not significantly different (*Table 5*.).

Conclusions

According to the results significant differences were found among the investigated hybrids from the point of view of the investigated aspects. Considering the aspects of the weight of panicle and weight of grains Hybrid 8 proved to be the most prospective hybrid combination. If the goal of the breeding process is to enhance yields this hybrid combination can be the best among the investigated hybrids. For industrial purposes (e.g. bioethanol production) Hybrid 6 can be the best, hence it achieved 26.19% heterosis value for this parameter. For these kinds of purposes Hybrid 1 and Hybrid 4 are also adequate combinations. Regarding the protein contents Hybrid 2 proved to be the most valuable hybrid. In this case 14.25±1.58% protein content was determined, which makes this combination adequate for foddering. Considering all of the evaluated aspects it can be set up that Hybrid 6 can be a good solution if the aim is to produce grain sorghum with high starch content. In the case of Hybrid 2 the protein content was high, but 19.17±13.20 g grain weight and 29.88±9.75% threshing percent was determined hence this hybrid can be described as a less prospective combination regarding the yields.

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