PROTEIN CONTENT ENHANCEMENT IN GRAIN SORGHUM (*Sorghum bicolor (L.) Moench*) BY CONVENTIONAL PLANTBREEDING METHODS

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Abstract

Proteins perform a vast array of functions within organisms, consequently the adequate production of the primer protein resources is one of the major goals of the plant production. Breeding of suitable sorghum hybrids can improve the protein content and accordingly the nutritional value of grain sorghum. This study was conducted to determinate the heterosis of F1 hybrids with respect to the protein content. Within this workmanship eleven hybrids and their parent lines were evaluated. The applied method to measure the protein contents was the Kjeldahl method of nitrogen content determination respectively. The protein content of the parent lines averaged 12.40% while this result averaged 11.74% in the cae of the hybrids. The mean of the heterosis of this characterictic was -10.36% which implies that most of the hybrids had lower protein content than that of the average of the parent lines. This investigation reveals that heterosis breeding indeed improves the nutritional values of the F1 hybrids, moreover in some cases the new hybrid combinations provided prosperous results compared with nationally registered hybrids.

Key words: Plant breeding, *Sorghum bicolor*, hybrid combinations, heterosis, protein,

INTRODUCTION

Sorghum [*Sorghum bicolor (L.) Moench*] is one of the most valuable cereal staple crops in the sub-tropical and semi-arid regions of Africa and Asia (Kresovich et al., 2005). It is one of the cheapest sources of energy and micronutrients, thus a great number of the population in Africa and Asia are dependent on it for their dietary requirements (Parthasarathy et al., 2006). About 90% of sorghum produced by U.S.A. and India is primarily used for animal feed, whilst Nigeria is the leading country of the world in terms of grain sorghum production for food purposes (Gourichon, 2013).

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 unfavourable soil conditions, which are actual problems in the hungarian agriculture (Gálya et al., 2015a; Gálya et al., 2015b). It is suitable crop for the utilisation of salt affected soils (Blaskó, 2010) and these characteristics of sorghum make the foundation of sorghum breeding.

The concept of outbreeding enhancement or heterosis results from hybridization and it can be manifested as an increased performance of several viewpoints. Conner and Karper (1927) were the first to record the occurrence of heterosis in sorghum whilst Mather and Jinks (1971) defined heterosis as the amount by which the mean of any F1 family exceeds its better parent genetically. Since the discovery of Conner and Karper, several research work have shown frequent occurrence of positive heterosis of grain yield by the increase in the number of seeds per panicle and higher grain weight. Early flowering and superior early vigour just as the number of grains per panicle and fodder yields are also commonly observed aspects in the case of sorghum hybrids (Quinby, 1974). Bartel (1949) reported on the manifestation of heterosis among 19 sorghum hybrids. Results showed that sixteen hybrids had grain yields in excess as compared to their mid-parent values and all of the hybrids were taller than the mean heights of their parents. Kirby and Atkins (1968) investigated the heterotic response of some vegetative and mature plant characters in grain sorghum in which 24 hybrid were evaluated. Results showed that average heterosis was observed for mature plant height, stalk diameter and grain yield. Grain yield for the hybrids ranged from 106 to 147% of the means of their parents within individual hybrids with art average of 122%.

Quinby (1967) reported an increase of 84% in grain yield increase as compared to the parents in the evaluation of hybrid vigour in grain sorghum in United State of America. Kambal et al. (1976) studied the manifestation of heterosis in grain sorghum and reported an increased yield of the hybrid as compared to the parent lines. The percentage of the increase ranged from 35 to 238%. Haussmann (1998) by an evaluation of sorghum hybrid performance and its relationship to morphological and physiological traits under variable drought stress in Kenya reported that mean hybrid superiority over mid-parent values was 54% for grain yield and 35% for above-ground biomass. Mahmoud (2007) found that some hybrids showed earlier maturity than the parents and in the result of most crosses were a higher grain weight appeared. Also, all the hybrids were taller, higher in number of grains per panicle and higher in grain yield per plant than best parents. Makanda et al. (2010) determined the combining ability of 18 sorghum lines, the level of heterosis and cultivar superiority of experimental hybrids in tropical lowland and mid-altitude environments in which eight cytoplasmic male-sterile lines were crossed with 10 male-fertile lines. Cultivar superiority was obtained using the cultivar superiority index (Pi). Hybrids produced showed up to 285% standard heterosis. Overall hybrid average yield was significantly higher than that of parents and standard check varieties, which was linked to the immense levels of mean heterosis and standard heterosis, respectively

Proteins are essential in the field of human nutrition and animal husbandry, therefore a respectfull attention focused on the investigation of this parameter (Bökfi et al., 2016). The protein content is an important aspect of sorghum's nutritive value (Waggle et al., 1965), which is a fequently evaluated factor in the case of grain sorghum (Miller et al., 1964.; Deosthale et al., 1970.; Duodu et al., 2002) In the current work eleven hybrid combinations were evaluated by the viewpoint of protein content in order to reflect the impacts of the hybridization.

MATERIAL AND METHOD

In this research eleven parent lines comprising of two male sterile lines (A-lines) and nine fertility restorer lines (R-lines) were used. The A-lines includes A1 and A2 while the R-lines include R1 to R9. Crossings between these lines resulted in the generation of eleven hybrids which were evaluated. These crossings were done in 2014 in three plot repetitions, while the investigations were done in 2015.

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)	PIA*	Salinity (m/m%)	Humus (m/m%)	P_2O_5 (mg/kg)	K_2O mg/kg	NO_2^-, NO_3^- (mg/kg)	Na (mg/kg)	Mg (mg/kg)	SO_4 (mg/kg)	Mn (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
4.8	49	0.04	3.06	101	399	21.3	21	458	10.1	483	8.2	1.2

**Plasticity Index according to Arany*

Source: Research Institute of Karcag, 2016

The field experiment was carried out between 27th of April and 10th of September in 2015. Annual precipitation was 414.0 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 determination of the protein content was done by the Kjeldahl method: 0.5g milled sample was digested with a strong sulphuric acid, so that the investigated material releases nitrogen which 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 calculated threshing percent values and the measured values of the starch and protein contents, the percentage heterosis was calculated by using the equation below (Pepó et al., 2011):

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

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. The calculations were performed by using MS Office Excel Software.

RESULTS AND DISCUSSION

The hybrids' average protein content was within the range of 10.59% – 14.25%. The highest value (14.25%) was obtained by A2XR2 while the lowest value was calculated in the case of A1XR3 with the value 10.59%. The results of the hybrids' heterosis of protein content showed that ten hybrids gave negative values and only the combination A2XR2 gave positive value for the heterosis. The combination of A1XR2 gave the lowest value for heterosis of protein content with the value -24.28% while the highest value (12.59%) was obtained in A2XR2. According to these results it could be deduced that in the case of the hybrid A2XR2, the protein content was higher than the average value of the parent lines of the combination, whereas in the other cases the average protein content of the parent lines were higher compared with the hybrids.

Table 4.

The main calculated data of the hybrid's protein content

Sample	Average protein content	Standard deviation	Variance	Heterosis of protein content (%)
A1XR2	10.72	2.64	6.95	-24.28
A1XR3	10.59	0.66	0.44	-22.51
A1XR5	10.97	0.99	0.98	-14.49
A1XR6	12.59	0.52	0.27	-9.13
A1XR7	12.81	2.44	5.93	-6.92
A1XR8	12.88	1.15	1.32	-7.31
A1XR9	10.72	0.73	0.54	-20.14
A2XR1	11.03	0.33	0.11	-5.99
A2XR2	14.25	1.58	2.51	12.59
A2XR3	11.34	1.88	3.52	-6.80
A2XR4	11.19	0.51	0.26	-9.02

The overall standard deviation for the average protein content of the hybrids evaluated was recorded as 1.20 while variance was recorded as 1.44.

The overall protein content of the hybrids averaged 11.74% while the mean heterosis of protein content was -10.36%. This result correlates with the nexuses published by Kambal and Webster (1966) and Thokoza (2005) who evaluated the heterotic potential of sorghum from South African region.

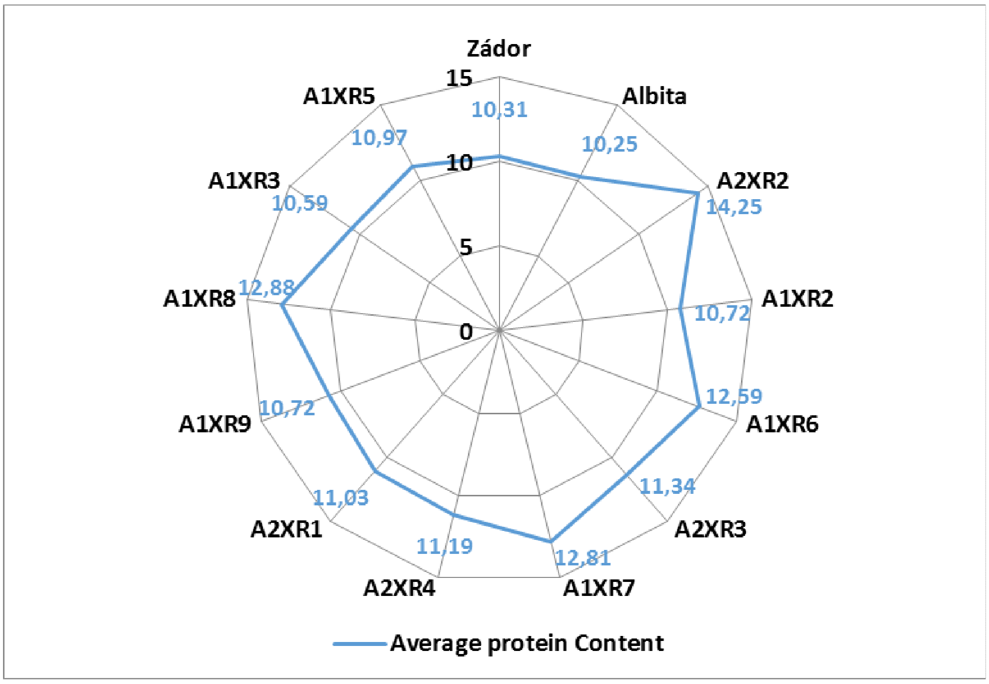

Figure 1. Protein contents of the investigated hybrid combinations and nationally registered hybrids (%)

The results of the average protein content of the hybrids showed that A2XR2 gave the highest protein content of 14.25% while A1XR3 gave the lowest protein content with the value of 10.59%. A2XR2, which gave an average protein content of 14.25%, was reportedly higher than A1XR2 which recorded 10.72%. This could probably be attributed to the specific combining ability of the parent line A2. The registered hybrids Zádor and Albita gave the values of 10.31% and 10.25% as average protein content respectively. The results showed the all eleven hybrids evaluated in this study provided a higher protein content than the registered hybrids which can be found in the EU Plant Variety Catalogue.

CONCLUSIONS

In the case of the new hybrid combinations the highest value (14.25%) for protein content was obtained by A2XR2. The results of the hybrids' heterosis showed negative values of theprotein contents. The average protein content of the hybrids was 11.74% while the mean of the heterosis values in the case of protein content was -10.36%. Positive value was for the heterosis (12.59 %) was obtained only in the case of hybrid combination A2XR2.

In the case of the average protein contents all of the hybrids evaluated in this study had higher protein content than the nationally registered hybrids. Similarly, the combination with A2 in the case of A2XR2 and A2XR3, as against A1XR2 and A1XR3 showed that A2 also offers great opportunity for improvement of protein content. In general, results showed that outbreeding enhancement can further improve the functionality of grain sorghum in terms of higher nutritional value.

REFERENCES

1. Bányai I.: 1967. Results of morphological and fenological tests in sorghum assortment. Agrobotanika. National Agrobotanical Institute. Tápiószele. (In Hungarian)
2. Bartel A. T.: 1949. Hybrid vigor in sorghums. Agronomy Journal 41:147-152.
3. Blaskó L: 2010. Possibilities of sweet sorghum production on the soils of Karcag micro-region. International Seminar on Crop Science for Food security, Bio-energy and Sustainability In: Behl RK, Bona L, Pauk J, Merbach W, Veha A (ed.) Crop Science for Food security, Bio-energy and Sustainability: Proceedings of the 3rd IFSDAA International Seminar on Crop Science for Food security, Bio-energy and Sustainability. Szeged, Hungary,
4. Bökfi K., Nagy A., Riczu P., Gyug N., Petis M., Blaskó L., Tamás J.: 2016. Evaluation of the blood product characteristics of meat meal and hemoglobin with non-invasive methods in the VIS-NIR wavelength. Acta Agraria Debreceniensis, 69. 49-56. (In Hungarian)
5. Conner A. B., Karper R. E.: 1927. Hybrid vigor in sorghum. Texas Experiment Stations Bulletin, 359. Texas A&M University, Texas, USA
6. Deosthale Y. G., Mohan V. S., Visweswara Rao K.: 1970. Varietal Differences in Protein, Lysine and Leucine Content of Grain Sorghum. Journal of Agricultural and Food Chemistry. Vol.: 18 644-655.
7. Duodu K. G., Nunes A., Delgadillo I., Parker M. L., Mills M. N. C., Belton P. S., Taylor J. R. N.: 2002. Effect of grain structure and cooking on sorghum and maize in vitro protein digestibility. Jurnal of Cereal Science. Vol.: 35. 161-174.
8. Gálya B., Nagy A., Blaskó L., Dályai B., Tamás J.: 2015. Comperission of Pálfai's drought index and the Normalised Precipitation Index in the North Great Plain region. Agrártudományi közlemények, 63 59-64. (in Hungarian)
9. Gálya B., Blaskó L., Riczu P., Tamás J.: 2015b. Risk assessment of drought impacted areas in Great Plain of Hungary. In: Agriculture, Ecology & Water Abstracts, Eighth Annual International Symposium on Agriculture, Third Annual International Conference on Ecology, Ecosystems and Climate Change & Third Annual International Forum on Water 13-16 July 2015, Athens, Greece / ed. Gregory T. Papanikos, Athens Institute for Education and Research, Athens, 58,
10. Gourichon H.: 2013. Analysis of incentives and disincentives for sorghum in Nigeria. Technical notes series, MAFAP, FAO, Rome.
11. Haussmann B. I. G., Obilana A. B., Blum A., Ayiecho P. O., Schipprack W., Geiger H. H.: 1998. Hybrid performance of sorghum and its relationship to morphological and physiological traits under variable drought stress in Kenya. Plant Breeding, 117:223–229.
12. Kambal A. E., Webster O. J.: 1966. Manifestations of Hybrid Vigor in Grain Sorghum and the Relations among the Components of Yield, Weight per Bushel, and Height. Crop Science.6: 6:513-515.

13. Kirby J. S., Atkins R. E.: 1968.Heterotic Response for Vegetative and Mature Plant Characters in Grain Sorghum, Sorghum bicolor (L.) Moench.Crop Sci.8:335-339.
14. Kresovich S., Barbazuk B., Bedell J. A., Borrell A., Buell C., Burke R., Clifton J., Cox S., Hash S. C. T.: 2005. Toward sequencing the sorghum genome. A U.S. National Science Foundation-sponsored workshop report. Plant Physiology 138:1898–1902.
15. Mahmoud K. M.: 2007. Performance, heterosis, combining ability and phenotypic correlations in grain sorghum (*Sorghum bicolor (L) Moench*), Egyptian Journal of Applied Sciences, 22:389-406.
16. Makanda I., Tongoona P., Derera J., Sibiya J., Fato P.: 2010.Combining ability and cultivar superiority of sorghum germplasm for grain yield across tropical low- and mid-altitude environments. Field Crops Research 116, 75–85
17. Mather K., Jinks J. L.: 1971. Biometrical Genetics. London. Chapman and Hall. 382 pp.
18. Miller G. D., Deyoe T. L., Walter T. L., Smith F. W.: 1964. Variations in protein levels in Kansas sorghum grain. Agronomy Journal. Vol.: 56. 302
19. Parthasarathy R. P., Birthal B. S., Reddy B. V. S., Rai K. N., Ramesh S.: 2006. Diagnostics of sorghum and pearl millet grains-based nutrition in India. International Sorghum and Millets Newsletter. 47, 93–96.
20. Pepó P., Erdei É., Kovácsné Oskolás H., Tóth Sz., Szabó E.: 2011. Examination of the nutrional values of inbred sorghum lines and their single cross sorghum hybrids. Növénytermelés, 60. 83-95. (In Hungarian)
21. Quinby J. R.: 1967. Manifestations of hybrid vigor in sorghum. Crop Sci. 3:288–291.
22. Quinby J. R.: 1974. Sorghum improvement and the genetics of growth. Texas A&M University Press, College Station, TX.
23. Thokoza M. L.: 2005. Evaluation of the heterotic potential of sorghum [*Sorghum bicolor (L.) Moench*] adapted to the southern Africa region. Master's thesis, Texas A&M University. Texas A&M University.
24. Waggle D., Parish D. B., Deyoe C. W.: 1966. Nutritive Value of Protein in High and Low Protein Content Sorghum Grain as Measured by Rat Performance and Amino Acid Assays. Journal of Nutrition. Vol.: 88. 370-374.