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# Cyanogenic glycosides in broomcorn (*Sorghum vulgare* var. *technicum* (Körn.)) according growth stages

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## Abstract

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The trials were carried out during the period 2017-2019 in the experimental field of the Institute of Forage Crops - Pleven with accessions of broomcorn (*Sorghum vulgare* var. *technicum* (Körn.) with different origins.

The aim of this study was to determine the optimal height of the plants and growth stage the development on the accessions of broomcorn for use as forage, depending on the the course of the changes in the quantitative content cyanogenic glycosides in them.

The content of cyanogenic glycosides in fresh above-ground biomass in five accessions of *Sorghum vulgare* var. *technicum* [Körn.] in four growth stages from culture development (BBCH 15, BBCH 18-19, BBCH 47 and BBCH 63-67) has determined according to the growth rate. Cyanoglycoside content of aboveground biomass in broomcorn (*Sorghum vulgare* var. *technicum*) depending on phenophase, variety and year of the study. The content of cyanogenic glycosides in fresh biomass by growth stage and development of broomcorn is high negative correlation according dynamics of growth – *r* ranges -0.911 to -0.884. The local population MI 16N has a relatively lowest concentration of cyanogenic glycosides in all growth stage of development and can be used in further breeding programs in this direction.

*Keywords:* broomcorn (*Sorghum vulgare* var. *technicum* Körn.); cyanogenic glycosides; plant height, cuting

## Introduction

Climate changes associated with rising air temperatures and frequent droughts in the summer season often compromise yields in forage crops. The growing need for food, the reduction of renewable energy resources and the changing climate are a prerequisite for the inclusion of alternative forage crops in crop rotation.

Species of the genus *Sorghum* have pronounced advantages in cultivation – drought resistance, salt tolerance, slopes, and the uses – in sealing crop rotations, as a cover and undergrowth crop and weed suppressing component in organic farming. They have and commercial application for forage, seeds, biofuels, brooms production, etc. (Moyer et al., 2003). These advantages allow the species of genus *Sorghum* to increase their interest in growing them. According to studies by a number of authors (Bibi et al., 2010; Ćupina et al., 2007; Rao et al., 2015; Mulatu & Kifle, 2016). Sorghum species have high productive potential and can provide fodder for animal husbandry due to their increased resistance to adverse abiotic environmental factors (high temperatures, prolonged drought, high soil pH, etc.) and adaptability to specific environmental conditions.

High environmental plasticity and multi-cuting in *Sorghum* species allow biomass to be formed during the summer depressions of perennial fodder grasses (Moyer et al., 2003). Depending on the agro-climatic conditions and the technology of cultivation, 2 to 4 cuts form growing season (Moyer, 1987; Zamfir et al., 2001; Kertikov, 2005). The yield of fresh biomass relatively reduced at each subsequent slope, but nevertheless it remains relatively high compared to other perennial fodder grasses under dry conditions (Chamble et al., 1995).

Characteristic feature for species of the genus *Sorghum*, to which *Sorghum vulgare* var. *technicum* is the accumulation in the aboveground biomass of the alkaloid chordein (about 0.07%) and cyan glycoside Durin (C14H17O7N) (Kunc et al., 1995; Erić et al., 2004; Sunaga et al., 2005). According to the same authors, the accumulation of high levels of hydrocyanic acid above 1000 PPM (dry matter) can cause rapid poisoning of animals with lethal outcome, since it binds to hemoglobin in the blood and does not allow the transfer of oxygen to the cells of the body. Studies on Pell (2005) have shown that cyanogenic glycosides content is highest in fresh biomass in young plants and in young leaves, which have the highest metabolism, whereas in older leaves and stems, and in the dry biomass is significantly lower. According to the same author, any abiotic stress leads to an increase in the hydrocyanic acid content.

The purpose of the study was to determine the optimal height and phenophase from the development of technical sorghum specimens (broom), depending on the quantitative content of cyanogenic glycosides.

## Material and Methods

The experimental work was conducted during the period 2017-2019 at the experimental field of the Institute of Forage Crops, Pleven (43° 37′ 70.80″N, 24°45′36.34″E) Bulgaria at 150 to 200 m altitude and weak southern slope of the experimental plots with soil type leached Chernozem without irrigation. Five accessions of *Sorghum vulgare* var. *technicum* [Körn.] are the subject of study (Table 1).

The accessions were included in two randomized block trials – for forage and for seeds in three replicates and a 5 $m^2$ plot size. The subject of this study is the experiment for seeds. The height of plants is determined by growth stages from development of culture, by measuring the height of the 25 plants in four replicates for all treatments of the experiment.

**Table 1. Accessions broomcorn (sorghum) (*Sorghum vulgare* var. *technicum* [Körn.])**

| № | Name and/or code | Origine |
|---|---|---|
| 1. | Szegedi 1023 | Cereal Research Non-Profit Company, Szeged, Hungary |
| 2. | S14 | local population from the region of Southeastern Bulgaria |
| 3. | GL15A | local population from the region of Central Northern Bulgaria |
| 4. | PL16 | |
| 5. | MI 16N | |

The cut of fresh biomass is carried out in the BBCH 47 determined by the unified system for the classification of phenological development phases for mono- and dicotyledonous plants (BBCH) (Meier, 2001). Fresh plant samples were taken from the trial for forage of each accession in growth stage BBCH 15, BBCH 17-18, BBCH 47 and BBCH 63-67. In laboratory conditions, an analysis was performed to determine the content of cyanogenic glycosides in the fresh biomass (Ermakov et al., 1987) by plant growth stages.

The ANOVA and correlation analysis of the results were performed with STATGRAPHICS Plus for Windows Version 2.1 at LSD 0.05%.The power of influence of the factors in the reliable factorial variant was determined by $\eta^2$, and the statistical processing by the Fisher φ-test (Plohinskii, 1967).

## Results and Discussion

Similar to the species of the genus *Sorghum* and the broomcorn (sorghum) (*Sorghum vulgare* var. *technicum* [Körn.]), in the early stages of development (BBCH 15), it accumulates more cyanoglycosides in its aboveground biomass - from 107.8 to 128.5 mg/100 g dry matter (Table 2). Later in the growing season (BBCH 14-15) and increasing plant height, the content of cyanogenic glycosides in broomcorn decreased and ranged from 51.2 to 67.1% on average for the tested accessions. In phenophase BBCH 47, the values of the indicator are in the minimum range 26.3 to 41.5 of mg/100 g. In older leaves and stems (BBCH 65-69), the content of cyanogenic glycosides is significantly reduced (19.7 to 37.3 mg/ 100 g).

Variation in the content of cygnogenic glycosides in aboveground biomass in broomcorn accessions is also associated with genetic differences. For the conditions of Central Northern Bulgaria during the study period, the lowest content of cygnogenic glycosides was local population MI16N and highest the PL16 average for the period. The other local varieties occupy an intermediate position, which may be explained by genetic differences, since the comparisons between them are made under the same agroecological conditions. Variation in the content of cyanogenic glycosides in above-ground biomass in many *Sorghum* species is also associated by genetic differences (Gleadow & Woodrow, 2002).

Practically cyanide poisoning is related to the amount of consumed fresh biomass and the physiological state and species of the animal, but HCN levels above 200 ppm in fresh biomass are dangerous. In dry biomass (feed) with more than 500 ppm, HCN should be considered as potentially toxic. The

**Table 2. Cyanogenic glycosides accumulation dynamics by grow stages of development of broomcorn**

| Grow stages | Accessions | Cyanogenic glycosides mg/100g dry biomass | % *St* | Cyanogenic glycosides mg/100g dry biomass | % *St* | Cyanogenic glycosides mg/100g dry biomass | % *St* | Cyanogenic glycosides mg/100g dry biomass | % *St* |
|---|---|---|---|---|---|---|---|---|---|
| | | 2017 | | 2018 | | 2019 | | 2017-2019 | |
| BBCH 12-13 | Szegedi1023(St) | 136.9 | 100.0 | 117.0 | 113.44 | 113.44 | 100 | 122.4 | 100.0 |
| | S14 | 135.1 | 98.7 | 82.8 | 108.04 | 108.04 | 95.2 | 108.6 | 88.7 |
| | GL15A | 126.4 | 92.4 | 102.0 | 113.44 | 113.44 | 100.0 | 113.9 | 93.1 |
| | PL16 | 118.8 | 86.8 | 118.1 | 148.56 | 148.56 | 131.0 | 128.5 | 104.9 |
| | MI 16N | 115.2 | 84.2 | 57.0 | 151.26 | 121.26 | 106.9 | 97.8 | 79.9 |
| Average | 126.5 | 92.4 | 95.4 | 81.5 | 120.9 | 111.9 | 116.3 | 93.3 | |
| BBCH 14-15 | Szegedi1023(St) | 103.1 | 100.0 | 41.6 | 46.08 | 46.08 | 100.0 | 63.6 | 100.0 |
| | S14 | 106.8 | 103.6 | 40.0 | 35.37 | 35.37 | 76.8 | 60.7 | 95.5 |
| | GL15A | 115.4 | 111.9 | 32.4 | 53.59 | 53.59 | 116.3 | 67.1 | 105.6 |
| | PL16 | 95.8 | 92.9 | 37.5 | 46.08 | 46.08 | 100.0 | 59.8 | 94.0 |
| | MI 16N | 82.3 | 79.8 | 14.4 | 56.81 | 56.81 | 123.3 | 51.2 | 80.5 |
| Average | 100.7 | 97.6 | 33.2 | 79.8 | 47.6 | 103.3 | 60.5 | 95.1 | |
| BBCH 47 | Szegedi1023(St) | 38.2 | 100.0 | 11.7 | 29.13 | 29.13 | 100.0 | 26.3 | 100.0 |
| | S14 | 54.8 | 143.3 | 9.6 | 22.51 | 22.51 | 77.3 | 29.0 | 110.0 |
| | GL15A | 39.5 | 103.5 | 7.8 | 31.78 | 31.78 | 109.1 | 26.4 | 100.1 |
| | PL16 | 57.2 | 149.7 | 11.3 | 45.02 | 45.02 | 154.5 | 37.8 | 143.6 |
| | MI 16N | 52.7 | 137.9 | 10.8 | 60.9 | 30.9 | 106.9 | 31.5 | 119.4 |
| Average | 48.5 | 126.9 | 10.6 | 87.5 | 31.9 | 130.0 | 32.2 | 114.6 | |
| BBCH 65-69 | Szegedi1023(St) | 32.4 | 100.0 | 7.1 | 12.12 | 42.12 | 100.0 | 27.2 | 100.0 |
| | S14 | 39.5 | 122.2 | 6.9 | 20.78 | 20.78 | 49.3 | 22.4 | 82.3 |
| | GL15A | 27.4 | 84.6 | 5.7 | 25.97 | 25.97 | 61.7 | 19.7 | 72.4 |
| | PL16 | 37.4 | 115.7 | 7.1 | 48.48 | 48.48 | 115.1 | 31.0 | 113.9 |
| | MI 16N | 36.4 | 112.4 | 6.1 | 69.26 | 69.26 | 164.4 | 37.3 | 136.9 |
| Average | 34.6 | 107.0 | 6.6 | 92.7 | 41.3 | 98.1 | 27.5 | 101.1 | |

content of cygnogenic glycosides in sorghum increases significantly under water stress (rain after hot and dry weather), freezing, attack by grazing animals and insects, and varies depending on the species and phenophase of plant development (Sun et al., 2018). This observation is in agreement with Wheeler (1994), who conclude that, in sorghum, the presence of dry stress of short duration may lead to a decrease in cyanide potential, whereas, in contrast, prolonged, chronic drought exposure may result in higher levels of cyanide potential.

Characteristic of the species of the genus *Sorghum*, to which the broomcorn belongs, is that in the in young plants accumulate cygnogenic glycosides and under certain stress agroclimatic conditions. In the initial stages of development, species of the genus *Sorghum* accumulate more cyanogenic glycosides, which can cause toxic effects in some farm animals due to hydrocyanic acid, which is released upon enzymatic hydrolysis of glycosides. The results of the comparative study on broomcorn accessions show differences in the content of cyanogenic glycosides in the initial stages of crop development and potential for the use of fresh biomass without the risk of animal intoxication after growth stage BBCH 14-15.

The dynamics of increase in plant height of broomcorn accessions within is depends on the biological characteristics of varieties and year of the study (Table 3). The local population MI16N is in with very highest plants (from 284.8 to 312.1 cm) in the end of growing season for the studied years.

According to the classification of Stoltenow and Hardy (1998) local population MI16N and PL16, conditionally can be determined with a low risk of toxicity of livestock with cyanogenic glycosides (from 14.4 to 95.8 mg/100 g of dry matter) and can used as forage in after BBCH 14-15 and plant height over 40 cm. Many authors reported that with the increase of plant height and the plant age the content of cyanogenic glycosides in *Sorghum* species ultimately decreases (Kim, 1987; Wheeler, 1994; Kumar & Devender, 2010).

Negative correlations in all studies years between plant height in different growth stage of development and con-

**Table 3. Dynamics of growth of the plants height of broomcorn accessions according to growth stage of development, cm**

| Grow stages | Accessions | Plants height, cm | % *St* | Plants height, cm | % *St* | Plants height, cm | % *St* | Plants height, cm | % *St* |
|---|---|---|---|---|---|---|---|---|---|
| | | 2017 | | 2018 | | 2019 | | 2017-2019 | |
| BBCH 12-13 | Szegedi1023(St) | 14.6a | 100.0 | 15.0a | 100.0 | 9.93a | 100.0 | 13.2a | 100.0 |
| | S14 | 15.4a | 105.5 | 15.0a | 100.0 | 10.2a | 102.7 | 13.5a | 102.7 |
| | GL15A | 15.3a | 104.8 | 16.4ab | 109.7 | 13.0b | 130.9 | 14.9b | 113.2 |
| | PL16 | 14.6a | 100.0 | 16.5ab | 110.2 | 13.3b | 133.9 | 14.8b | 112.4 |
| | MI 16N | 15.5a | 106.2 | 17.4b | 116.2 | 14.8c | 149.0 | 15.9c | 120.7 |
| Average | 15.1 | 103.3 | 16.0 | 107.2 | 12.2 | 123.3 | 14.5 | 109.8 | |
| BBCH 14-15 | Szegedi1023(St) | 37.4c | 100.0 | 47.8ab | 100.0 | 52.8a | 100.0 | 46.0a | 100.0 |
| | S14 | 33.7a | 90.1 | 49.3ab | 103.1 | 42.3a | 80.1 | 41.8a | 90.8 |
| | GL15A | 34.5ab | 92.2 | 46.7a | 97.8 | 52.0b | 98.5 | 44.4a | 96.5 |
| | PL16 | 36.4bc | 97.3 | 50.2b | 105.0 | 46.2b | 87.5 | 44.3ab | 96.2 |
| | MI 16N | 37.8c | 101.1 | 66.9c | 140.0 | 55.9b | 105.9 | 53.5b | 116.4 |
| Average | 36.0 | 96.1 | 52.2 | 109.2 | 49.8 | 94.4 | 46.0 | 100.0 | |
| BBCH 47 | Szegedi1023(St) | 83.8b | 100.0 | 117.8a | 100.0 | 106.2b | 100.0 | 102.6a | 100.0 |
| | S14 | 75.3a | 89.9 | 123.1a | 104.5 | 110.5c | 104.0 | 103.0a | 100.4 |
| | GL15A | 80.7b | 96.3 | 142.0b | 120.5 | 99.7a | 93.9 | 107.5a | 104.7 |
| | PL16 | 83.8b | 100.0 | 150.5c | 127.8 | 102.0a | 96.0 | 112.1a | 109.3 |
| | MI 16N | 156.9c | 187.2 | 208.8d | 177.2 | 197.8d | 186.3 | 187.8b | 183.1 |
| Average | 96.1 | 114.7 | 148.4 | 126.0 | 123.2 | 116.0 | 86.8 | 119.5 | |
| BBCH 65-69 | Szegedi1023(St) | 164.3a | 100.0 | 157.1a | 100.0 | 141.6b | 100.0 | 154.3a | 100.0 |
| | S14 | 155.9a | 94.9 | 164.1a | 104.5 | 147.3c | 104.0 | 155.8a | 100.9 |
| | GL15A | 207.0b | 126.0 | 189.4b | 120.6 | 132.9a | 93.9 | 176.4ab | 114.3 |
| | PL16 | 219.6c | 133.7 | 200.7c | 127.8 | 136.0a | 96.0 | 185.4ab | 120.2 |
| | MI 16N | 312.1d | 190.0 | 278.4d | 177.2 | 263.8d | 186.3 | 284.8b | 184.5 |
| Average | 211.8 | 128.9 | 197.9 | 126.0 | 164.3 | 116.0 | 199.1 | 124.0 | |

*Note:* a, b, c, d – statistically proven differences LSD at 5% ($P \leq 0.05$)

**Table 4. Correlations between plant height and content of cyanogenic glycosides in above-ground biomass in broomcorn accessions**

| Accessions | Years of the study | | |
|---|---|---|---|
| | 2017 | 2018 | 2019 |
| Szegedi1023(St) | -0.884 | -0.887 | -0.804 |
| S14 | -0.909 | -0.932 | -0.815 |
| GL15A | -0.856 | -0.845 | -0.924 |
| PL16 | -0.903 | -0.847 | -0.737 |
| MI 16N | -0.911 | -0.783 | -0.774 |

tent of cyanogenic glycosides in above-ground biomass in broomcorn accessions were established (*r* ranges -0.911 to -0.737) (Table 4).

## Conclusions

Cyanogenic glycosides content of aboveground biomass in broomcorn (*Sorghum vulgare* var. *technicum*) depending on phenophase, variety and year of the study. The results of the comparative study on broomcorn accessions show differences in the content of cyanogenic glycosides in the initial stages of crop development and potential for the use of fresh biomass for feed without the risk of animal intoxication after growth stage BBCH 14-15. Negative correlations between plant height in different growth stage of development and content of cyanogenic glycosides in above-ground biomass in broomcorn accessions were established (*r* ranges -0.911 to -0.737).

The local populations MI16N and PL16, conditionally can be determined with a low risk of toxicity of livestock with cyanogenic glycosides (from 14.4 to 95.8 mg/100 g of dry matter) and can used as forage in after BBCH 14-15 and plant height over 40 cm. The local population MI 16N has a relatively lowest concentration of cyanogenic glycosides in all growth stage of development and can be used in further breeding programs in this direction.

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