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DISTRIBUTION OF NUTRIENTS IN DIFFERENT ORGANS OF PLANTS OF *MISCANTHUS* ANDERSS. GENOTYPES

Objective *— to investigate the accumulation of biochemical compounds in the different organs of cultivars and varieties of Miscanthus Anderss. in conditions of M.M. Gryshko National Botanical Garden of the NAS of Ukraine.*

Material and methods. *Investigated plants were cultivars and varieties of species of the genus of Miscanthus collected in an experimental collection of Cultural Flora Department of M.M. Gryshko National Botanical Garden of the NAS of Ukraine: M. ×giganteus, cv. Huliver (MGH), M. ×giganteus, f. ESBMG-3 (MGE-3), M. sacchariflorus, cv. Snihopad (MSS), M. sacchariflorus, f. ESMBS-3 (MSE-3), M. sinensis, cv. Veleten (MSV), M. sinensis, f. ESBMK-1 (MSE-1).*

The content of dry matter was determined according to A.I. Yermakov et al. (1972), the total content of sugars and ascorbic acid concentration — according to V.P. Krishchenko (1983), the content of carotene — according to B.P. Pleshkov (1985), the content of ash — according to Z.M. Hrycaenko et al. (2003), the content of calcium and phosphorus — according to H.M. Pochinok (1976). Energetic value of dry plant raw material determined on calorimeter.

Results. *In the period of full seed ripening the plant raw material of Miscanthus genotypes accumulated dry matter from 38.99 % (MSE-1, leaves) to 88.08 % (MSE-3, leaves), total content of sugars — from 2.72 % (MSE-3, panicles) to 10.03 % (MGH, stems), ascorbic acid — from 4.40 mg% (MSE-3, panicles) to 40.03 mg% (MGE-3, leaves), carotene — from 0.09 mg% (MSE-3, stems) to 0.26 mg% (MGH, leaves), ash — from 1.38 % (MSS, stems) to 8.65 % (MSV, leaves), calcium — from 0.19 % (MSS, stems) to 0.91 % (MGH, leaves), phosphorus — from 0.032 % (MGE-3, stems) to 0.412 % (MSE-3, panicles), protein — from 4.82 % (MSE-3, stems) to 12.28 % (MSE-1, leaves). Energetic value of dry raw was from 3811.87 cal/g (MSS, leaves) to 4193.17 cal/ g (MSV, panicles).*

Conclusions. *Obtained data demonstrated that in conditions of M.M. Gryshko National Botanical Garden of the NAS of Ukraine cultivars and varieties of Miscanthus ×giganteus, M. sacchariflorus, M. sinensis are the valuable source of nutrients and biofuel in the period of full seed ripening. Distribution of biochemical compounds in different organs resulted that accumulation of it depends on genotype. It was found that content of sugars was maximal and content of ash with macroelements, protein, carotene was minimal in the stems of investigated plants.*

Key words: *Miscanthus*, plant raw material, biochemical properties, calorific value.

The cultivation of energy crops to produce alternative transportation fuels is a promising option under increasing demands for fuels, decreasing available lands and competition of food and fuel production [8]. Among common cultures that use for biofuel production today can be highlight *Miscanthus* Anderss. genotypes. Miscanthus has a variety of names, such as Asian elephant grass and Chinese silvergrass. The commonly accepted historical origin of miscanthus is Asia. First miscanthus cultivation in Europe took place during the 1930s (imported from Japan). From the 1980s these plants have started to use for the biofuel production [1]. Plants of *Poaceae* and specifically *Miscanthus* species described in recent reports as raw for biofuel production [2; 4; 10; 21].

Results of Pidlisnyuk et al. (2018) reported that *M. ×giganteus* plants characterized by the ability to grow at the contaminated soils with further production of energy biomass [9].

In addition, plants of *Miscanthus* species are the high productive cultures and effective heavy metal accumulator [13]. Plants of *Miscanthus sinensis*, *M. sacchariflorus* and *Panicum virgatum* known as ornamental grasses in different compositions [16].

Objective — to investigate the accumulation of biochemical compounds in the different organs of cultivars and varieties of *Miscanthus* in conditions of M.M. Gryshko National Botanical Garden of the NAS of Ukraine.

Material and methods

Plant material was collected from the experimental collection of Department of Cultural Flora in M.M. Gryshko National Botanical Garden of the NAS of Ukraine at the stage of full seed ripening: *M. ×giganteus*, cv. Huliver (MGH), *M. ×giganteus*, f. ESBMG-3 (MGE-3), *M. sacchariflorus*, cv. Snihopad (MSS), *M. sacchariflorus*, f. ESMBS-3 (MSE-3), *M. sinensis*, cv. Veleten (MSV), *M. sinensis*, f. ESBMK-1 (MSE-1). Different organs such as leaves, stems, and panicles were used for analyses.

All biochemical analyses were conducted using above-ground part of plants at the period of full ripening of seeds. The determination of absolutely dry matter was done by drying to constant weight at 100—105 °C according to A.I. Yermakov et al. [22]. The total content of sugars was investigated by Bertrand method in water extracts. The concentration of ascorbic acid (AA) of the acid extracts was determined by a 2.6-dichlorophenolindophenol method based on the reduction properties of AA. Both analyses carried out according to V.P. Krishchenko [5]. The concentration of total carotene determined according to B.P. Pleshkov. The procedure carried out in petrol extracts by spectrophotometric method using 2800 UV/VIS Spectrophotometer, Unico. Mixtures were left in a shaker for 2 hours and their absorbance was measured at the wavelength of 440 nm [11]. The level of total ash was determined using the method of combustion in muffle-oven (SNOL 7.2-1100, Termolab) at 300—800 °C until the samples turned into white ash to constant weight according to Z.M. Hrycajenko et al. [3]. The concentration of calcium was determined by the titration method of acid extracts with Trilon B. Phosphorus content in plants was identified in acid extracts using molybdenum solution. These analyses were done according to H.N. Pochinok [12]. The procedure of detection of energetic value was measured on calorimeter IKA-200. I this case, dry plant raw material was burned in an oxygen bomb. Measurement of every sample was 15 minutes approximately and expressed in cal/g. The content of protein was determined by nitrogen definition (by chloramine method) according to H.N. Pochinok [12].

Experimental data were evaluated by using Excel 2010. Mean values of three replicates and standard deviation are given in Tables 1, 2 and Figures 1—4.

Results and discussions

Plants from *Poaceae* Barnhart. family well adapted to low input conditions as well as to biotic and abiotic stress factors [17]. Last time carry out investigations of miscanthus concerning biochemical composition due to ecological properties of these plants. Biochemical composition of these plants is carbon, nitrogen, sulfur, oxygen, and hydrogen which are relatively close to that of other energetic crops [1]. We investigated before the biochemical composition of some *Poaceae* plants including miscanthus and found that the most content of dry matter and the total content of sugars were detected in the stage of full seed ripening [14; 19]. Our results showed that above-ground part of *Miscanthus* genotypes accumulated dry matter of 26.16— 5.80%, total content of sugars — 1.27—5.13 %, ascorbic acid — 11.42—43.61 mg%, carotene — 0.197—1.113 mg%, ash — 2.06—6.11 mg%, calcium — 0.203—1.070 %, phosphorus — 0.023—0.121 % [18]. Moreover, in report identified that these plants accumulate compounds with antioxidant activity [20].

The content of dry matter among investigated plants was in the range from 38.99—88.08 % (Tabl. 1). Considering obtained data in detail it should be noted that in leaves we found content of dry matter 38.99 % (MSE-1) to 88.08 % (MSE-3), in stems — in range from 44.59 % (MSS) to 52.48 % (MSV), in panicles — from 46.23 % (MGH) to 87.43 % (MSE-3). The content of sugars was 2.72—10.03 %. This parameter on leaves was from 3.10 % (MSS) to 9.20 % (MGE-3), in stems — from 5.77 % (MSS) to 10.03 % (MGH), in panicles — from 2.72 % (MSE-3) to 6.77 % (MSE-1).

One of the most important features in the growth and generation of *Poaceae* is the accumulation of total sugars in plant raw material. Kumar et al. (2010) reported that the sugar content of sorghum genotypes was higher at post-physiological maturity [6].

Most of lignocellulosic biomass is rich in inorganic components such as Ca, Mg, P, K, Na etc.

Table 1. **The content of dry matter and the total content of sugars in different organs of *Miscanthus* Anderss. genotypes in the stage of full ripening of seeds**

Name of species, cultivar or variety	Part of plant	Dry matter, %	Total content of sugars, %
M. ×*giganteus*, cv. Huliver	Leaves	48.26 ± 0.23	6.53 ± 0.11
	Stems	44.73 ± 0.07	10.03 ± 0.14
	Panicle	46.23 ± 0.24	5.85 ± 0.11
M. sinensis, cv. Veleten	Leaves	39.27 ± 0.21	7.12 ± 0.09
	Stems	52.48 ± 0.22	6.53 ± 0.28
	Panicle	52.16 ± 0.25	6.24 ± 0.18
M. sacchariflorus, cv. Snihopad	Leaves	83.57 ± 0.85	3.10 ± 0.11
	Stems	44.59 ± 0.22	5.77 ± 0.05
	Panicle	85.30 ± 2.45	3.81 ± 0.26
M. sacchariflorus, f. ESMBS-3	Leaves	88.08 ± 0.78	3.55 ± 0.14
	Stems	48.38 ± 0.12	5.86 ± 0.11
	Panicle	87.43 ± 0.62	2.72 ± 0.12
M. sinensis, f. ESBMK-1	Leaves	38.99 ± 1.45	7.76 ± 0.58
	Stems	45.82 ± 0.44	9.23 ± 0.09
	Panicle	52.72 ± 2.25	6.77 ± 0.65
M. ×*giganteus*, f. ESBMG-3	Leaves	44.73 ± 2.31	9.20 ± 0.58
	Stems	48.03 ± 3.22	9.34 ± 0.78
	Panicle	53.55 ± 0.23	4.11 ± 0.09

Table 2. **The content of ash, calcium, and phosphorus in different organs of *Miscanthus* Anderss. genotypes in the stage of full ripening of seeds**

Name of species, cultivar or variety	Part of plant	Ash, %	Calcium, %	Phosphorus, %
M. ×*giganteus*, cv. Huliver	Leaves	6.32 ± 0.11	0.91 ± 0.05	0.085 ± 0.001
	Stems	1.48 ± 0.08	0.27 ± 0.02	0.055 ± 0.002
	Panicle	2.54 ± 0.13	0.33 ± 0.02	0.098 ± 0.002
M. sinensis, cv. Veleten	Leaves	8.65 ± 0.67	0.54 ± 0.09	0.112 ± 0.005
	Stems	1.50 ± 0.04	0.39 ± 0.02	0.053 ± 0.001
	Panicle	2.24 ± 0.17	0.55 ± 0.07	0.154 ± 0.002
M. sacchariflorus, cv. Snihopad	Leaves	7.25 ± 0.23	0.64 ± 0.02	0.096 ± 0.003
	Stems	1.38 ± 0.06	0.19 ± 0.02	0.034 ± 0.003
	Panicle	2.55 ± 0.12	0.50 ± 0.02	0.132 ± 0.005
M. sacchariflorus, f. ESMBS-3	Leaves	8.02 ± 0.15	0.79 ± 0.03	0.264 ± 0.001
	Stems	2.04 ± 0.13	0.33 ± 0.01	0.111 ± 0.007
	Panicle	2.74 ± 0.21	0.62 ± 0.01	0.412 ± 0.012
M. sinensis, f. ESBMK-1	Leaves	7.51 ± 0.23	0.63 ± 0.01	0.071 ± 0.006
	Stems	2.84 ± 0.05	0.27 ± 0.02	0.066 ± 0.001
	Panicle	5.18 ± 0.34	0.58 ± 0.04	0.108 ± 0.002
M. ×*giganteus*, f. ESBMG-3	Leaves	5.86 ± 0.32	0.81 ± 0.05	0.109 ± 0.001
	Stems	1.60 ± 0.08	0.35 ± 0.02	0.032 ± 0.001
	Panicle	3.66 ± 0.18	0.60 ± 0.04	0.070 ± 0.002

[15]. Miscanthus ash reportedly includes 30—40 % SiO_2, 20—25 % K_2O, and approximately 5 % of P_2O_5 and MgO [1]. Determination of ash content showed that this parameter was for all samples 1.38—8.65 % (Tabl. 2). In the leaves it was identified from 5.86 % (MGE-3) to 8.65 % (MSV), in

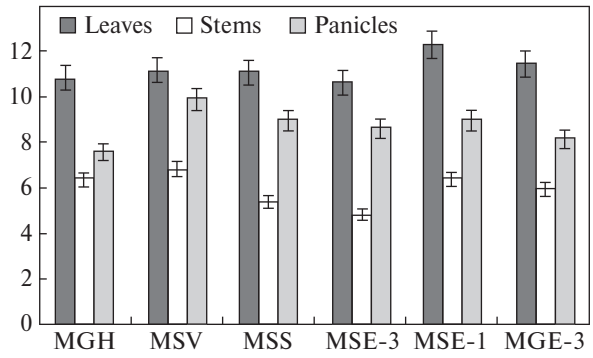

Fig. 1. The content of protein in different organs of plant raw material of *Miscanthus* Anderss. genotypes, %

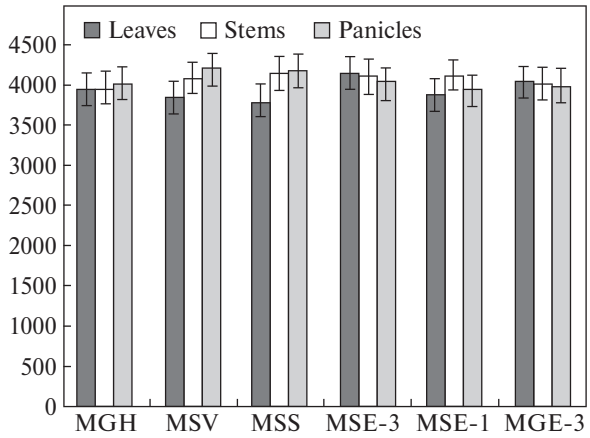

Fig. 2. The calorific value of different organs of plant raw material of *Miscanthus* Anderss. genotypes, cal/g

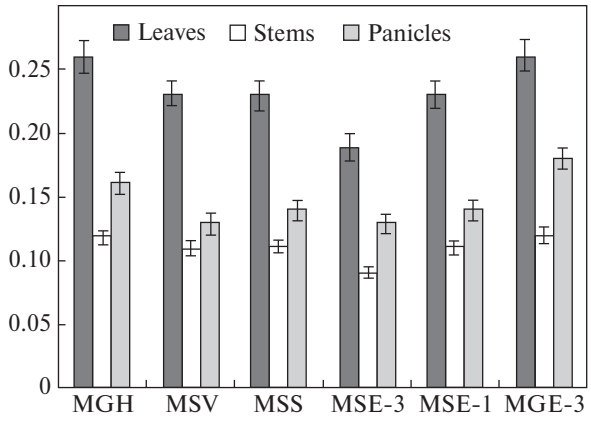

Fig. 3. The content of carotene in different organs of plant raw material of *Miscanthus* Anderss. genotypes, mg%

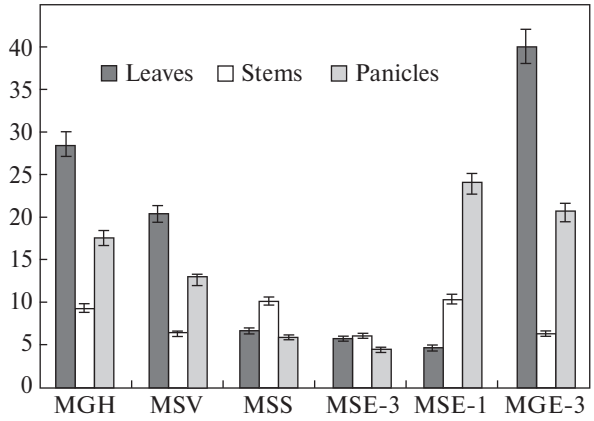

Fig. 4. The content of ascorbic acid in different organs of plant raw material of *Miscanthus* Anderss. genotypes, mg%

stems — from 1.38 % (MSS) to 2.84 % (MSE-1), in panicles — from 2.24 % (MSV) to 5.18 % (MSE-1). Accumulation of calcium in plant raw material of investigated plants was 0.19—0.91 %. In the leaves calcium determined in range from 0.54 % (MSV) to 0.91 % (MGH), in stems — from 0.19 % (MSS) to 0.39 % (MSV), in panicles — from 0.33 % (MGH) to 0.62 % (MSE-3). Content of phosphorus in ash of different organs of investigated plants was 0.032—0.412 %. Leaves accumulated this macroelement in range from 0.071 % (MSE-1) to 0.264 % (MSE-3), stems — in range from 0.032 % (MGE-3) to 0.111 % (MSE-3), panicles —from 0.070 % (MGE-3) to 0.412 % (MSE-3).

According to Lanzerstorfer (2019), miscanthus ash after combustion contains K, P, Ca and heavy metals. It is possible to use ash of miscanthus as soil conditioner [7].

The protein content was minimal in the stems and maximal — in leaves in plant raw material of all investigated plants (Fig. 1). Generally, the content of protein in different organs was 4.82—12.28 %. In the leaves identified content of protein from 10.61 % (MGH) to 12.28 % (MSE-1), in the stems — from 4.82 % (MSE-3) to 6.82 % (MSV), in panicles — from 7.57 % (MGH) to 9.88 % (MSV).

According to Altawell (2014), nitrogen in dried crushed sample form was around 3 % of the total mass [1]. In our experiments, we determined nitrogen in the range of 0.77—1.96 % comparing all organs.

The energetic value of different organs raw was measured in calories per g. As shown in Figure 2, the content of calories was variable depending on the investigated organ. So, we determined that on the whole content of calories per gram was from 3811.87 to 4193.17.

The high content of carotene was determined in leaves, the lowest — in the stems. The content of carotene generally was from 0.09 to 0.26 mg% (Fig. 3). In the leaf's carotene was determined from 0.19 mg% (MSE-3) to 0.26 mg% (MGH, MGE-3), in stems — from 0.09 mg% (MSE-3) to 0.12 mg% (MGH, MGE-3), in panicles — from 0.13 mg% (MSV, MSE-3) to 0.18 mg% (MGE-3).

The content of ascorbic acid was 4.40—40.03 mg% (Fig. 4). Concentration of ascorbic acid in leaves was from 4.59 mg% (MSE-1) to 40.03 mg% (MGE-3), in stems — from 6.03 mg% (MSE-3) to 10.33 mg% (MSE-1), in panicles — from 4.40 mg% (MSE-3) to 23.99 mg% (MSE-1).

Conclusions

Based on obtained data, it can be concluded that in conditions of M.M. Gryshko National Botanical Garden of the NAS of Ukraine plants of *Miscanthus* Anderss. accumulated nutrients in different organs the stage of full seed ripening. Investigation showed that distribution of biochemical compounds depended on the investigated organ. The highest concentrations of vitamins, protein, and calcium, the content of dry matter found in the leaves. The concentration of sugars was maximal in the stems. Accumulation of phosphorus and calorific value of plant raw material was highest in the panicles. Minimal accumulation of vitamins detected in stems and panicles, ash with macroelements — in the stems, sugars — in the panicles. The calorific value of investigated plant raw material showed the minimal result in the leaves.

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РОЗПОДІЛ ПОЖИВНИХ РЕЧОВИН У РІЗНИХ ОРГАНАХ РОСЛИН ГЕНОТИПІВ *MISCANTHUS* ANDERSS.

Мета — дослідити накопичення біохімічних речовин у різних органах сортів та форм *Miscanthus* Anderss. в умовах Національного ботанічного саду імені М.М. Гришка НАН України.

Матеріал та методи. Досліджені рослини — сорти та форми видів роду *Miscanthus*, зібрані на експериментальних ділянках відділу культурної флори Національного ботанічного саду імені М.М. Гришка НАН України: *M. ×гігантський,* с. Гулівер (MGH), *M. × гігантський,* ф. ЕСБМГ-3 (MGE-3), *M. цукроквітковий,* с. Снігопад (MSS), *M. цукроквітковий,* ф. ЕСБМС-3 (MSE-3), *M. китайський,* с. Велетень (MSV), *M. китайський,* ф. ЕСБМК-1 (MSE-1). Вміст сухої речовини визначали за А.І. Єрмаковим та ін. (1972), загальний вміст цукрів та аскорбінову кислоту — за В.П. Крищенком (1983), вміст каротину — за Б.П. Плєшковим (1985), золи — за З.М. Грицаєнком (2003), кальцію та фосфору — за Х.М. Починком (1976). Енергетичну цінність сухої сировини визначали за допомогою калориметра.

Результати. В період повної стиглості насіння в рослинній сировині генотипів *Miscanthus* накопичувалося сухої речовини від 38,99 % (MSE-1, листки) до 88,08 % (MSE-3, листки), загальний вміст цукрів становив від 2,72 % (MSE-3, суцвіття) до 10,03 % (MGH, стебла), аскорбінової кислоти — від 4,40 мг% (MSE-3, суцвіття) до 40,03 мг% (MGE-3, листки), каротину — від 0,09 мг% (MSE-3, стебла) до 0,26 мг% (MGH, листки), золи — від 1,38 % (MSS, стебла) до 8,65 % (MSV, листки), кальцію — від 0,19 % (MSS, стебла) до 0,91 % (MGH, листки), фосфору — від 0,032 % (MGE-3, стебла) до 0,412 % (MSE-3, суцвіття), протеїну — від 4,82 % (MSE-3, стебла) до 12,28 % (MSE-1, листки). Енергетична цінність сухої сировини становила від 3811,87 кал/г (MSS, листки) до 4193,17 кал/г (MSV, суцвіття).

Висновки. В умовах Національного ботанічного саду імені М.М. Гришка НАН України сорти та форми *Miscanthus ×giganteus*, *M. sacchariflorus* та *M. sinensis* — цінне джерело поживних речовин та біопалива в період повної стиглості насіння. Вивчення розподілу біохімічних речовин в різних органах показало, що накопичення їх залежить від генотипу. Вміст цукрів був максимальним, а золи з макроелементами, протеїну та каротину — мінімальним у стеблах досліджуваних рослин.

Ключові слова: *Miscanthus*, рослинна сировина, біохімічні особливості, енергетична цінність.

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РАСПРЕДЕЛЕНИЕ ПИТАТЕЛЬНИХ ВЕЩЕСТВ В РАЗНЫХ ОРГАНАХ РАСТЕНИЙ ГЕНОТИПОВ *MISCANTHUS* ANDERSS.

Цель — исследовать накопление биохимических веществ в разных органах сортов и форм *Miscanthus* Anderss. в условиях Национального ботанического сада имени Н.Н. Гришко НАН Украины.

Материал и методы. Исследованные растения — сорта и формы видов рода *Miscanthus*, собранные на экспериментальных участках отдела культурной флоры Национального ботанического сада имени Н.Н. Гришко НАН Украины: *M.* × *гигантский,* с. Гуливер (MGH), *M.* × *гигантский,* ф. ЕСБМГ-3 (MGE-3), *M. сахароцветковый,* с. Снегопад (MSS), *M. сахароцветковый,* ф. ЕСБМС-3 (MSE-3), *M. китайский,* с. Велетень (MSV), *M. китайский,* ф. ЕСБМК-1 (MSE-1). Содержание сухого вещества определяли по А.И. Ермакову и др. (1972), общее содержание сахаров и аскорбиновой кислоты — по В.П. Крищенко (1983), содержание каротина — по Б.П. Плешкову (1985), золы — по З.М. Грицаенко (2003), кальция и фосфора — по Х.Н. Починку (1976). Энергетическую ценность сухого вещества определяли с помощью калориметра.

Результаты. В период полного созревания семян в растительном сырье генотипов *Miscanthus* накапливалось сухого вещества от 38,99 % (MSE-1, листья) до 88,08 % (MSE-3, листья), общее содержание сахаров составляло от 2,72 % (MSE-3, соцветия) до 10,03 % (MGH, стебли), аскорбиновой кислоты — от 4,40 мг% (MSE-3, соцветия) до 40,03 мг% (MGE-3, листья), каротина — от 0,09 мг% (MSE-3, стебли) до 0,26 мг% (MGH, листья), золы — от 1,38 % (MSS, стебли) до 8,65 % (MSV, листья), кальция — от 0,19 % (MSS, стебли) до 0,91 % (MGH, листья), фосфора — от 0,032 % (MGE-3, стебли) до 0,412 % (MSE-3, соцветия), протеина — от 4,82 % (MSE-3, стебли) до 12,28 % (MSE-1, листья). Энергетическая ценность сухого сырья составляла от 3811,87 кал/г (MSS, листья) до 4193,17 кал/г (MSV, соцветия).

Выводы. В условиях Национального ботанического сада имени Н.Н. Гришко НАН Украины сорта и формы *Miscanthus*×*giganteus*, *M. sacchariflorus* и *M. sinensis* — ценный источник питательных веществ и биотопливо в период полного созревания семян. Изучение распределения биохимических веществ в разных органах показало, что накопление их зависит от генотипа. Содержание сахаров было максимальным, а золы с макроэлементами, протеина и каротина — минимальным в стеблях исследованных растений.

Ключевые слова: *Miscanthus*, растительное сырье, биохимические особенности, энергетическая ценность.