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EVALUATION OF COCKSFOOT (*DACTYLIS GLOMERATA* L.) COLLECTION OF DIFFERENT GEOGRAPHICAL ORIGIN IN THE LENINGRAD REGION

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Abstract
The aim of the work was to study accessions of *Dactylis glomerata* L. of different origin for breeding in the Leningrad region. The work was carried out at the Leningrad Agricultural Research Institute. The study involved 15 accessions. The nursery was founded in 2016 and included two replications for green yield and two – for seed production. Cutting and sampling for biochemical studies were conducted in May-June 2018, seeds were collected in July. The amount of ascorbic acid, carotenoids and chlorophylls and crude protein were determined. Statistical analysis included the calculation of the parameters of variation, ANOVA and correlation analysis. Three groups were identified by the degree of ripeness: a small group of early maturing – 31 days, a group of late maturing (single accession from Karelia) – 51 days, a large group of middle maturing – 34-37 days. For the late maturing accession the mechanism of regulation of the beginning of heading is due to the sensitivity to photoperiod. The adaptive potential of widely zoned varieties is wider than for localized. Their productivity is higher. The content of pigments in the green mass is closely correlated. The system of pigments in the complex of characters is separate, but is positively associated with the seed productivity and negatively – with the content of ascorbic acid. The seed productivity of the accessions is related to the total pigment content and power of the generative shoots (length and mass).
Key words: cocksfoot, agronomic evaluation, pigment system.

Introduction

Cocksfoot (*Dactylis glomerata* L.) is a valuable forage crop, one of the earliest, highly nutritious, widely used cereal grasses. Creating new high yielding varieties with a wide adaptive potential in changing environmental conditions is a priority for breeding programs. Due to global climate change in recent years, weather conditions have shown sharp jumps from year to year. Varieties zoned in several regions have a wider range of adaptations and higher plasticity to various environmental conditions in comparison with strictly agro-ecologically specialized varieties (Жученко, 2010). The adaptive potential of plants depends on the variability of all its structures at different levels. Cocksfoot, as a polyploid, can demonstrate a wide range of variability.

Although the role of biologically active substances for the normal functioning of organisms and improvement of the forage quality is well known, scientific studies of the content of cocksfoot plants for ascorbic acid, chlorophylls A and B, carotenes, β-carotene and carotenoids are currently scarce. There are some works on the content of carotenes, carotenoids and vitamins A and C (Woods *et al.*, 1935; Скоблин, 1983; Farshadfar, 2017). Data on the content of chlorophylls in the green mass of cocksfoot were not found in the literature. Ascorbic acid is a multi functional compound that has the ability to reversibly oxidize and regenerate, which makes it possible for it to participate in the most important energy processes of a plant cell – photosynthesis and respiration. Ascorbic acid is a powerful antioxidant. It participates in the processes of growth, flowering, vegetative and reproductive differentiation, in water metabolism, regulation of enzymatic activity, stimulation of metabolic reactions associated with nucleic acid metabolism and protein synthesis, in plant defense reactions (Чупахина, 1997). The plants contain various pigments. Green pigments are represented by chlorophylls A and B, which take part in photosynthesis processes and are contained in all assimilating organs. They are often associated with protein and are easily extracted by solutions like acetone or ether. Carotenoids are yellow fat-soluble pigments, that are tetraterpenoids and are widely distributed, as well as chlorophylls. One of the most important functions of carotenoids is additional pigments in photosynthesis. Carotenoids are widely distributed in plants and are a mixture of xanthophylls (70%) and carotenes (30%). In plants, carotenes are represented by a mixture of isomers, where the total content of the α- and β-forms reaches 98%. They have a biological activity – the ability in the organism to turn into vitamin A. The most active is β-carotene (Furr & McGrane, 2003).

Objective of the paper: to study the varieties and wild accessions of cocksfoot of different geographical origin with the identification of the most promising for breeding work in the Leningrad region, as well as for a comprehensive assessment of forage and nutritional values.

Materials and Methods

The work was carried out on the basis of the Leningrad Agricultural Scientific Research Institute 'Belogorka'. The study involved varieties and wild

accessions from the collection of the N.I. Vavilov All-Russian Institute of Plant Genetic Resources (VIR).

The nursery was founded in 2016. Scheme of experiment included two randomized replications for green yield and two replications for seed production. Square of plot was 3.5 m^2 (5 × 0.7 m), sowing continuous. Fertilizer $N_{16}P_{16}K_{16}$ was applied at the rate of 100 kg ha^{-1}.

Fifteen accessions of cocksfoot were studied: varieties, zoned in the North-West (variety 'Neva', 'Leningradskaya 853', 'Triada'), in the Northern region (variety 'Dvina'), widely zoned in Russia variety 'VIK61', and in the Volgo-Vyatka and North Caucasus regions variety 'Khlynovskaya', variety 'Tammisto' from Finland, variety 'Petrozavodskaya' from the Republic of Karelia and wild accessions from Scandinavia, North-West and Central regions of Russia. 'Neva', variety zoned in Leningrad province, was chosen as a standard for comparison. The accessions of cocksfoot under study belong to subspecies *glomerata subsp. glomerata* (2n=28).

Cutting and sampling for biochemical studies were conducted on May 28 2018 except for accession k-00001 from the Republic of Karelia (June 9 2018). Seeds were collected on July 11 2018 (from k-00001 – July 18 2018).

Material for biochemical study was processed and analyzed by methods of VIR (Ермаков *et al.*, 1987). The amount of ascorbic acid was determined by direct extraction from plants with 1% hydrochloric acid, followed by titration with 2.6-dichloroindophenol (ГОСТ 7047-55). Carotenoids and chlorophylls were extracted with acetone (ГОСТ 8756.22-80); their absorption was measured on a spectrophotometer 'Ultrospec II, LKB Biochrom' at various wave lengths, the total content of carotenes was determined by paper chromatography. Determination of crude protein was performed in a dry material using a 'Kjeltek2200' instrument.

Statistical data processing was performed using the STATISTCA 7.0 package and included the calculation of the main parameters of variation, analysis of variance and correlation analysis.

Meteorological conditions during the period of the study (2018) were distinguished by excess of heat and lack of moisture. The air temperature in May and June exceeded the average multi year by 1.6 and 1.3 °C.

The amount of precipitation in April was about twice the norm (58 mm); in May and June precipitation fell by half the norm (16 and 28 mm), in July– about two monthly norms (148 mm).

Results and Discussion

Economically valuable characters

The spring renewal of vegetation began on the 15 of April, 2018 for all accessions of cocksfoot.

Wild accessions from the Pskov region (k-38088) and Norway (k-44020) were the earliest to enter the heading phase – 15th of May. The period from the renewal of vegetation to heading was 31 days, the sum of active temperatures (more than +10 °C) over this period was 540 – 550 °C. The heading of a wild accession from the Republic of Karelia (k-00001) began on June 4 the duration of the period from the renewal of vegetation to heading – 51 days. The rest of the accessions began heading on May 18-21, 34 to 36 days passed from the renewal to heading; the amount of active temperatures was 580 – 620 °C.

The collection site of accession k-00001 (the northern coast of Onega Lake) is characterized by cold, lingering spring with recurrent frosts in May and early June (Филатов, 2004). Probably, the reaction to the length of the day, as one of the adaptations to the unfavorable conditions of the North, postpones the beginning of the generative phase to a later date, when the threat of frost has passed. Thus, the late ripeness of this cocksfoot specimen is the result of strong sensitivity to the photoperiod.

Other northern accessions from Russia, Norway and Finland in the studied set had a relatively short period from the renewal of vegetation to the beginning of the generative phase, and do not differ from the more southern accessions. This indicates the rarity of the late ripening forms in the northern cocksfoot populations. In late ripening varieties of annual cultivated cereals, such as *Avena* L. and *Triticum* L., strong sensitivity to the photoperiod was found; early ripening varieties are weakly sensitive to photoperiod (Кошкин *et al.*, 1994, 2013). Strong photoperiodic sensitivity of wheat is due to recessive genes (Keim, Welsh & McConnel, 1973). Perennial cereal grasses related to annuals, including cocksfoot, most likely have the same feature. If we consider that cocksfoot is a tetraploid (Linder, Garcia, & Velasco, 1999), the frequency of occurrence of late ripening forms will be low due to the recessivity of this trait.

The variety 'Leningradskaya 853' differed from all the others by the high intensity of spring regrowth (height on the 20th day from the renewal of vegetation). The varieties 'Khlynovskaya', 'Dvina', 'Neva' and 'Triada' had an average intensity of spring regrowth (the differences were significant). All wild accessions and varieties Tammisto and 'Petrozavodskaya' were characterized by low intensity of spring growth (Table 1).

Three groups of accessions of cocksfoot were emphasized by the height before cutting: tall – from 99 to 106.2 cm, which included most varieties and a wild accession from the Republic of Karelia (k-00001); middle – with the only accession k-44020 from Norway; low – the group of accessions (height from 76.2 to 82.8 cm), where 'Tammisto' variety

Table 1

Economic evaluation of cocksfoot, 'Belogorka', 2018

Catalogue VIR	Name	Origin	Height, cm		Hay yield, kg m^{-2}	Seed yield, g m^{-2}
			On 20th day after renewal	Before the 1st cutting		
00001	Wild	rep. Karelia	20.8 ± 1.07	100.4 ± 4.20	0.603 ± 0.107	29.5
36566	Tammisto	Finland	32.2 ± 1.93	76.2 ± 3.73	0.588 ± 0.064	32.3
36682	VIK 61	Moscow reg.	31.0 ± 1.41	99.0 ± 3.22	0.846 ± 0.266	31.4
36684	Dvina	Arkhangelsk reg.	35.6 ± 2.14	99.6 ± 3.57	0.837 ± 0.041	31.9
38088	Wild	Pskov reg.	27.0 ± 2.17	82.8 ± 2.85	0.472 ± 0.054	12.3
43142	Wild	Yaroslavl reg.	26.6 ± 1.72	81.4 ± 5.56 ±	0.735 ± 0.003	23.6
44020	Wild	Norway	32.2 ± 1.28	90.0 ± 2.61	1.032 ± 0.082	28.2
44021	Wild	Norway	30.6 ± 2.40	81.6 ± 3.97	0.659 ± 0.079	37.2
44349	Wild	Leningrad reg.	31.6 ± 1.44	81.6 ± 1.89	0.757 ± 0.073	40.7
44354	Wild	rep. Komi	30.0 ± 1.82	81.6 ± 1.63		26.7
27863	Leningradskaya 853	Leningrad reg.	40.4 ± 2.42	103.2 ± 5.09	1.165 ± 0.155	39.0
35060	Neva	Leningrad reg.	37.2 ± 2.03	99.2 ± 5.08	0.991 ± 0.009	39.7
38648	Petrozavodskaya	rep. Karelia	32.8 ± 2.33	103.4 ± 1.96	0.790 ± 0.013	36.6
45034	Khlynovskaya	Kirov reg.	34.8 ± 1.25	106.2 ± 2.96	0.875 ± 0.114	41.7
48628	Triada	Leningrad reg.	36.4 ± 2.16	102.2 ± 3.68	0.921 ± 0.212	55.6
$LSD_{0.05}$			2.67	6.97	0.109	5.42

and other wild accessions were found (Table 1) (the differences between groups were significant).

The following varieties were distinguished by hay yield: 'Leningradskaya 853', 'Neva' and 'Triada' (from the Leningrad Agricultural Scientific Research Institute 'Belogorka') and the wild accession from Norway (k-44020) (Table 1).

Varieties 'Khlynovskaya', 'Leningradskaya 853', 'Neva', 'Triada' and the wild accession k-44349 from the Leningrad region were characterized by high seed productivity.

Biochemical characters

During the work we noted significant differences in the content of nutrient and biologically active substances of cocksfoot: ascorbic acid, chlorophylls, carotenoids, carotenes, *β*-carotene and protein (Table 2).

On the basis of the research it was established that the accessions were characterized by high value and low variation of dry matter content (average value – 26.5%). The range of variability fluctuated from 24.0 to 28.8%. The highest dry matter content (more than 28%) was found in the wild accessions from the Pskov region (k-38088) and Norway (k-44020); these accessions entered the heading phase earlier than other accessions and reached the full heading phase before cutting. The accession of cocksfoot from the Republic of Karelia (k-00001) has the lowest dry matter content; the accession before the cut was still in the phase of the stem elongation.

The accumulation of protein in the studied accessions was noted at a low level: from 9.3 to 16.5% for absolute dry matter, with an average content of 11.3%. High percentage of protein (over 12.4%) in the studied accessions defined wild accessions from Norway (k-44021), the Leningrad region (k-44349) and the Republic of Karelia (k-00001) and Komi (k-44354) (Table 2).

The assimilating leaves of cocksfoot accumulated a significant amount of ascorbic acid; the average value of ascorbic acid was 40 mg 100 g^{-1}. We noted the variability in the accumulation of ascorbic acid in the green mass of various accessions ranging from 30 to 50 mg 100 g^{-1}. Three accessions were found with ascorbic acid content above 48 mg 100 g^{-1}: wild forms k-00001 (the Republic of Karelia) and k-43142 (the Yaroslavl region) and 'Neva' variety. The wild accession from the Yaroslavl region (k-43142) was characterized by both the highest content of ascorbic acid and the lowest content of pigments (Table 2).

In our experiments, the accumulation of chlorophylls A and B in plants varied greatly depending on the accession (Table 2). The total content of chlorophylls varied from 73 to 215 mg 100 g^{-1} (average content – 148 mg 100g^{-1}). We identified three accessions of cocksfoot with a high content of chlorophylls: k-44349

Table 2

Biochemical composition of cocksfoot, 'Belogorka', 2018

Catalogue VIR	Name	Dry matter, %	Ascorbic acid, mg 100 g^{-1}	Chlorophyll A, mg 100 g^{-1}	Chlorophyll B, mg 100 g^{-1}	Carotenoids, mg 100 g^{-1}	Carotenes, mg 100 g^{-1}	β-carotene, mg 100 g^{-1}	Protein, %
00001	Wild	24.0	48.96	213.77	91.33	37.72	9.87	6.212	12.44
36566	Tammisto	26.6	44.88	177.56	71.27	29.31	7.53	5.478	11.50
36682	VIK 61	25.6	40.80	222.44	96.28	32.86	10.33	7.070	9.95
36684	Dvina	26.7	39.44	209.84	91.32	36.66	10.02	6.556	9.95
38088	Wild	28.8	36.72	119.95	50.04	25.24	5.99	4.201	10.26
43142	Wild	26.4	50.32	101.88	44.25	18.44	4.91	3.437	10.26
44020	Wild	28.0	42.16	179.75	76.06	34.04	8.90	6.236	9.33
44021	Wild	26.3	32.64	215.66	99.11	33.28	11.04	7.370	16.48
44349	Wild	26.8	32.64	271.46	129.52	37.30	12.49	8.660	12.44
44354	Wild	26.0	34.00	230.52	104.73	31.53	11.36	7.437	12.44
27863	Leningradskaya 853	26.6	43.52	190.32	80.33	31.58	8.02	6.057	9.95
35060	Neva	26.0	48.96	148.82	65.18	23.18	5.59	4.668	11.81
38648	Petrozavodskaya	26.0	38.08	239.81	105.60	37.73	11.77	7.839	11.81
45034	Khlynovskaya	26.1	40.80	295.75	134.33	41.28	14.65	9.310	10.26
48628	Triada	27.0	29.92	263.89	113.12	48.76	13.25	7.938	10.88
$LSD_{0.05}$		0.58	3.53	30.02	14.50	4.13	1.59	0.911	0.98

(wild, Leningrad region), 'Khlynovskaya', 'Triada' (over 188 mg 100 g^{-1}).

The content of carotenoids in the green mass of cocksfoot (Table 2) varied from 18 to 49 mg 100 g^{-1} (average – 33 mg 100 g^{-1}). Two accessions of cocksfoot were distinguished (more than 41 mg 100 g^{-1}): 'Khlynovskaya' and 'Triada'.

There was also a strong variability in the content of carotenes in the green mass of cocksfoot. This character ranged from 4.9 to 14.6 mg 100 g^{-1} (average – 9.7 mg 100 g^{-1}). Two accessions of cocksfoot showed high rates of total carotene content (more than 13.2 mg 100 g^{-1}): 'Khlynovskaya' and 'Triada'.

The studied cocksfoot accessions contained approximately 6.6 mg 100g^{-1} of β-carotene (range of variation 3.4-9.3 mg 100 g^{-1}). It should be noted that in green mass the proportion of β-carotene composed 80 – 100% of the total amount of carotenes; in the studied accessions of cocksfoot the content of β-carotene varied from 60 to 84% (average – 69%). Four accessions with a high content of β-carotene (more than 7.8 mg 100 g^{-1}) were identified: wild k-44349 from the Leningrad region, 'Petrozavodskaya', 'Khlynovskaya' and 'Triada'.

Wild cocksfoot from the Leningrad region (k-44349) stood out according to the complex of features (high content of nutrients and biologically active substances).

Correlation structure of variation

When analyzing the system of correlations, the following results were obtained:

1. The dry matter content, protein content and foliage do not have significant correlations with other studied characteristics;
2. The yield of hay mass correlates with the height of the plants and the yield of seeds;
3. Seed productivity of accessions is also correlated with the content of pigments and plant height on the 20th day after spring regrowth and before cutting;
4. Plant height on the 20th day after regrowth and before cutting is closely correlated;
5. The content of ascorbic acid has a negative correlation with the content of all pigments;
6. The content of pigments is closely related;
7. The ratio of chlorophylls A and B negatively correlates with the content of carotenoids.

Thus, in the system of variation, two large correlation pleiads are distinguished: a) a pleiad of 'pigments', which includes the content of all pigments, and b) a pleiad of the 'plant's power', with which the height and hay mass of plants are related.

The variability of seed productivity of accessions is also associated with the first and second Pleiads.

The dependence of green yield from the content of chlorophylls, discovered previously by some authors

(Шимко *et al.*, 2009; Тютерева, Дмитриева, & Войцеховская, 2017), was not found.

Conclusions

1. Three groups of cocksfoot accessions were identified according to the degree of ripeness for economic use on green mass: a small group of early ripening (from the Pskov region and Norway k-44020) – 31 days, the group of late ripening with the single accession k-00001 from the Republic of Karelia – 51 days, large group of middle ripening with the rest of the accessions – 34-37 days. For the late ripening accession, the mechanism of regulation of the beginning of the generative phase is due to the sensitivity to the photoperiod factor.
2. The adaptive potential of cocksfoot varieties zoned in several regions is wider than that for narrowly localized. Variety 'Khlynovskaya' demonstrated a high value of main economic traits, high intensity of growth in spring, a high content of pigments under the conditions of 2018. This variety was proposed for the southern regions of Russia, and, perhaps, the productivity of the variety under the conditions of 'Belogorka' in the Leningrad region is associated with a very warm vegetative season. The variety 'Dvina' is well adapted to the conditions of the North in the Arkhangelsk region and has not shown its advantage. Variety 'Triada' surpassed in productivity and biochemical indices the other two varieties from 'Belogorka': 'Neva' and 'Leningradskaya 853'.
3. The content of pigments in the green mass of cocksfoot is closely related to each other. The system of pigments in the considered complex of features is located separately, but is positively associated with the seed productivity and negatively with the content of ascorbic acid.
4. Seed production of the studied accessions of cocksfoot is associated with both, the total content of pigments and the power of the generative shoot (length and weight). Thus, when screening cocksfoot for breeding programs, certain relationships of the listed features should be taken into account.

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