Productivity and feed value of sparsely distributed annual crops

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Abstract. The feed value of sparsely distributed annual crops in the forest-steppe of the Krasnoyarsk territory was determined, namely: the content of feed units, feed protein units, digestible protein; the yield of green mass, the collection of dry matter, feed protein units (FPU), feed units (FU) and energy productivity. The feed value and productivity of annual grasses depended on the biological characteristics of the species and variety, the content of nutrients, the yield of green mass and the collection of dry matter. There were increases in the green mass of Echinochloa frumentacea (Roxb.) Link, Amaranthus paniculatus and Melilotus albus to control Avena sativa L. by 182 %, 148% and 145 %. The best in collecting dry matter, feed protein units, digestible protein and energy productivity were Melilotus albus and Echinochloa frumentacea (Roxb.) Link. Panicum miliaceum L. has the maximum content of feed units in the green mass 0.23 feed units/kg, Melilotus albus has 0.25 FPU/kg of feed protein units and Panicum miliaceum L. has 0.24 FPU/kg; Melilotus albus has 35 g/kg of digestible protein.

1. Introduction
The most important problems for feed production in Siberia, including the Krasnoyarsk territory, are increasing feed production and improving its quality. Extreme climatic conditions, lack of moisture in some areas and heat in other areas, low soil fertility determine the narrowness in the species composition of forage crops in the field feed production in Eastern Siberia [1, 2, 3, 4, 5].

There are few types of annual grasses in the Siberian crops. Among the annual bluegrass more and more attention is paid to forage crops Panicum miliaceum L., Setaria italic mocharium Abf., Echinochloa frumentacea (Roxb.) Link, Sorghum sudanensis (Piper), Sorghum sacchartum especially in southern regions. Sorghum sudanensis (Piper) is also grown in the northern regions of the steppe and forest-steppe zones, but it has to be sown with imported seeds of medium or even early-maturing varieties. This also applies to Echinochloa frumentacea (Roxb.) Link [6, 2, 3, 7, 8, 9, 10]. The introduction of highly productive forage crops into production in order to obtain high-quality feed for livestock has been and remains one of the main problems of agricultural production. Obtaining high-quality feed with the lowest material and labor costs, and with low cost is relevant at the present stage. At present the organization of adaptive feed production on the basis of creating highly productive agrocenoses by selecting crops and introducing new species is of great importance. Sparsely distributed
plants accumulate a large amount of organic matter and have a positive biogeocenological effect on the elements of soil fertility, have ecological efficiency [11, 8].

According to the zoning for growth of forage crops Echinochloa frumentacea (Roxb.) Link, Sorghum saccharatum and Melilotus albus are sparsely distributed on the Krasnoyarsk territory. To conduct correct crop rotations it is necessary to know the biological characteristics of crops. One of the most important reserves for increasing the feed base of livestock can be considered sorghum plants. The spread of sorghum is primarily due to its valuable qualities, such as exceptional drought and heat resistance, as well as undemanding to the soil. This crop is able to withstand high temperatures and prolonged droughts that are detrimental to other bluegrass crops, including maize [2, 12, 3].

In this regard, organization of adaptive feed production based on the creation of highly productive agrocenoses by selecting crops and introducing new species that use the zone's bioclimatic resources most fully; development of resource-saving technologies; organization of conveyor of feed production with the inclusion of non-traditional crops and taking into account environmentally friendly physical and biological factors are the most important. For the first time in the ecological conditions of the forest-steppe in the Krasnoyarsk territory we have identified sparsely distributed forage crops that provide high adaptation, productivity and nutrition in single-species crops. In the sharply continental climate of the Krasnoyarsk territory expanding the range of annual forage crops is a very urgent task for the region's livestock industry.

The purpose of the work was to determine the feed value and productivity of annual grasses when cultivated in pure form for using for fodder purposes.

Tasks set during the research:

- Evaluate annual grasses by the yield of green mass, collection of dry matter, feed protein units, digestible protein and energy productivity.
- Evaluate annual low-spread crops for the content of feed units, feed protein units and digestible protein.

2. Materials and methods

The experiments were conducted at the experimental field of the educational scientific and production complex «Borsky» in the Sukhobuzimo district of the Krasnoyarsk territory located in the forest-steppe zone in 2015-2017. The following crops and varieties were the objects of research: Avena sativa L. – «Sig»; Echinochloa frumentacea (Roxb.) Link – «Eureka»; Sorghum sudanensis (Piper) – «Novosibirskaya 84»; Panicum miliaceum L. – «Kinelskoe92» and «Rossiyanka»; Melilotus albus – «Povolzhsky»; Amaranthus paniculatus –«Kinelsky 254».

As a control we used oat a traditional forage crop for the production of green mass in Siberia. The studied forage crops in single-species crops, conditions of the region are sparsely distributed. The soil of the experimental site was luvis chernozem, medium loam in granulometric composition with the humus content in the arable layer of 5.0-6.8 %, medium-rich in the content of basic nutrition elements, pH = 6.5-6.8 [13, 14].Laying experiments and observations for plants during the growing season were carried out in accordance with the guidelines for conducting field experiments with forage crops from the All-Russian research institute of feed [15], as well as the guidelines from the Russian academy of agricultural sciences [16].Statistical processing of experimental data was carried out by the method of dispersion analysis according to B. A. Dospekhov [17], energy estimation – according to generally accepted recommendations [18].

The cultivation technology in the experiment was generally accepted, zonal for annual forage crops. The previous crop was grain crops (spring wheat, oats) in the field crop rotation. Sowing period was from 27th May to 5th June with the selection mounted pneumatic seeder (SMPS-1,6) and wheeled tractor of «Minsk tractor plant» (MTP-82). The area of the plot was 12-30 m², repeatability was four times, placement of plots was randomized. Harvesting and accounting of the green mass yield were carried out manually in 4-fold repetition, followed by weighing on electronic scales during the period of broom sweeping, the beginning of flowering for bluegrass and millet crops, Melilotus albus and Amaranthus.
panicle – during the flowering period, the beginning of fruit formation. In the forest-steppe conditions of the Krasnoyarsk territory, this period falls on 20th August – 15th September.

From the average samples of the experiment variants, plant samples were selected for zootechnical analysis. Qualitative analysis for annual forage crops was carried out in the research and testing center for quality control of agricultural raw materials and food products at the Krasnoyarsk State Agrarian University according to the generally accepted methods for animal feed analysis [19, 20].

Area of the Krasnoyarsk forest-steppe is part of the central agricultural region and located on the left bank of the river Yenisei, north of Krasnoyarsk. The climate of the zone is continental. Weather conditions during the research years differed from one another. More than the norm by 25.8-106 mm of precipitation fell during the growing season in 2015 and 2017, less than the norm – in 2016. In general, the amount of precipitation during the growing season corresponded to the average long-term value. The sum of active temperatures for vegetation in 2015-2017 was 85.0° – 111.4 °C higher than the norm. For the period of active vegetation, the hydrothermal coefficient (HC) according to long-term data from the Sukhobuzimo weather station was 1.21. In 2015 and 2017 the hydrothermal coefficient corresponded to moderate humidity (1.22 – 1.37), and in 2016 to dry conditions (0.87). In general, there was a tendency to increase the amount of active temperatures, it exceeded the norm.

3. Results and discussion
The amount of green mass yield depended on the type and variety of crops largely. Reliable increases in the yield for all studied forage crops were obtained in comparison with the control – oats. Green mass increases ranged from 9.1 t/ha for Sorghum sudanensis (Piper) to 28.0 t/ha for Echinochloa frumentacea (Roxb.) Link. The largest increases were shown by the experiment variants - Echinochloa frumentacea (Roxb.) Link, Amaranthus paniculatus, Melilotus albus up to 182.1-145.2 % in comparison with the control (Table 1).

Table 1. Influence of the annual crops type on the yield of green mass, 2015-2017.

| Variants of annual forage crops in the experiment | Yield of green mass, t/ha | Increase in control t/ha % |
|-------------------------------------------------|--------------------------|---------------------------|
| 1. Avena sativa L. – control                     | 34.1                     | -                         |
| 2. Echinochloa frumentacea (Roxb.) Link          | 62.1                     | 28.0                      | 182.1                    |
| 3. Sorghum sudanensis (Piper)                    | 43.2                     | 9.1                       | 126.7                    |
| 4. Panicum miliaceum L, Kinelskoe 92»           | 42.5                     | 8.4                       | 124.6                    |
| 5. Melilotus albus                               | 49.5                     | 15.4                      | 145.2                    |
| 6. Panicum miliaceum L, «Rossiyanka»             | 46.7                     | 12.6                      | 136.9                    |
| 7. Amaranthus paniculatus                       | 50.4                     | 16.3                      | 147.8                    |

Smallest Significant Difference

| SSD05 A | SSD05 B (year) | SSD05 A x B |
|---------|----------------|------------|
| 0.05    | 2.4            | -          |
| 6.4     | -              | -          |

It was found that all variants of the experiment exceeded the control significantly by adding green mass over the years and on average for three years of research.

The collection of dry matter of annual crops varied depending on the type and variety (in Panicum miliaceum L.), the content of dry matter in the green mass, and weather conditions. In 2015-2017 on average the highest content of dry matter was found on crops of Melilotus albus and Echinochloa.
frumentacea (Roxb.) Link up to 11.3-11.1 t/ha, the lowest was found in variants of Panicum miliaceum L (variety «Kinelskoe 92») and Sorghum sudanensis (Piper)) up to 8.7-9.9 t/ha. Maximum dry matter additions were found in Melilotus albus, Echinochloa frumentacea (Roxb.) Link, Panicum miliaceum L («Rossiyanka») and Amaranthus paniculatus crops up to 3.4-2.2 t/ha respectively. Minimum increases were found in variants with Panicum miliaceum L, «Kinelskoe 92» and Sorghum sudanensis (Piper) - 0.8-2.0 t/ha. Thus, all studied variants in the experiment exceeded the control for collecting dry matter significantly (table 2).

**Table 2. Dynamics of dry matter collection for annual forage crops, t/ha.**

| Options | 2015 | 2016 | 2017 | Average |
|---------|------|------|------|---------|
| 1. Avena sativa L. – control | 8.3  | 7.9  | 7.5  | 7.9     |
| 2. Echinochloa frumentacea (Roxb.) Link | 11.3 | 11.1 | 10.8 | 11.1    |
| 3. Sorghum sudanensis (Piper) | 9.6  | 10.3 | 9.8  | 9.9     |
| 4. Panicum miliaceum L, «Kinelskoe 92» | 7.8  | 9.1  | 9.2  | 8.7     |
| 5. Melilotus albus | 10.6 | 11.3 | 12.0 | 11.3    |
| 6. Panicum miliaceum L, «Rossiyanka» | 10.8 | 9.4  | 10.0 | 10.1    |
| 7. Amaranthus paniculatus | 9.5  | 10.7 | 10.0 | 10.1    |

Smallest Significant Difference
0.5 (crop)
SSD0.05 B (year) - - - 0.5
SSD0.05 A> B - - - 1.4

A prerequisite for an intensive feeding system for highly productive animals is to know their needs for nutrients and biologically active substances, as well as the chemical composition and nutritional qualities of feed. In production conditions the energy demand of cows, taking into account the need to increase their mass, the energy concentration in the dry matter of the feed should be 0.80 feed units/1 kg, or 9.5-10.5 MJ/kg of exchange, useful energy (EE). This energy concentration in the feed allows getting milk yield of more than 11 kg/day [6, 21, 22]. Our experiments with sparsely distributed forage crops showed high productivity, energy productivity and feed value of green mass in the forest-steppe of the Krasnoyarsk territory (table 3).

One of the most important indicators for productivity of forage crops is the collection of feed protein units (FPU) from 1 ha. So, on average during the growing season this indicator ranged from 7.5 thousand/ha for Avena sativa L. to 12.4 thousand/ha for Echinochloa frumentacea (Roxb.) Link and Melilotus albus. It was revealed that the options of experience had forage protein units in the 1.2-1.7 times higher than the control – oats feed, and these variants surpassed the control in 1.2-2.2 times by the content of digestible protein (table 3).

The maximum collection of feed protein units was provided by Melilotus albus and Echinochloa frumentacea (Roxb.) Link – 12.4 thousand/ha. The additions of these options to the control were very significant; they exceeded the control for collecting FPU by 1.7 times.

For the collection of digestible protein with the yield of natural feed (green mass) there was a trend similar to the collection of feed protein units. All studied variants in the experiment exceeded the control by 0.21-0.95 t/ha. The largest collection of digestible protein was in Melilotus albus, Echinochloa frumentacea (Roxb.) Link and Panicum miliaceum L.1.73-1.12 t/ha. The lowest content of digestible protein was found in Amaranthus paniculatus and Sorghum sudanensis (Piper) 0.96 – 0.99 t/ha.
Table 3. Energy productivity and feed value of annual grasses in the Krasnoyarsk forest-steppe, 2015-2017.

| Options in the experience                  | Collection | Energy productivity, GJ/ha | EE*, MJ/kg | Content in 1 kg of natural feed |
|--------------------------------------------|------------|----------------------------|------------|--------------------------------|
| 1. Avena sativa L. – control               | 7,9        | 79,0                       | 10,0       | 0,21 0,22 23                  |
| 2. Echinochloa frumentacea (Roxb.) Link    | 11,1       | 100,0                      | 9,0        | 0,17 0,20 22                  |
| 3. Sorghum sudanensis (Piper)              | 9,9        | 97,0                       | 9,8        | 0,21 0,22 23                  |
| 4. Panicum miliaceum, «Kinelskoe 92»       | 8,7        | 90,5                       | 10,4       | 0,23 0,24 24                  |
| 5. Melilotus albus                         | 11,3       | 122,0                      | 10,8       | 0,15 0,25 35                  |
| 6. Panicum miliaceum, «Rossiyanika»        | 10,1       | 104,0                      | 10,3       | 0,23 0,24 24                  |
| 7. Amaranthus paniculatus                  | 10,1       | 108,1                      | 10,7       | 0,16 0,18 19                  |

Note**: DM – dry matter; FPU – feed protein units, thousand/ha; DP – digestible protein, t/ha; FU – feed units; EE – exchange, useful energy.

In our research for 2015-2017 calculations to determine the energy productivity of single-species forage crops showed that the highest energy yield with the crop was obtained from the cultivation of Melilotus albus, Echinochloa frumentacea (Roxb.) Link, Amaranthus paniculatus, Panicum miliaceum L. up to 122.0-104.0 GJ/ha. Then, Sorghum sudanensis (Piper) and Panicum miliaceum, «Kinelskoe 92» showed in decreasing value 97.0 and 90.5 GJ/ha respectively. Sparsely distributed, single-species crops provided energy productivity in natural feed 90.5-122.0 GJ/ha. While control Avena sativa L provided only 79.0 GJ/ha (table 3).

Thus, with fairly average nutritional values a high collection of dry matter per unit provided higher productivity of annual crops in Melilotus albus, Echinochloa frumentacea (Roxb.) Link, Panicum miliaceum L and Amaranthus paniculatus in comparison with the control.

4. Conclusions
The nutritional value of feed based on annual, single-species crops depended on the species composition and biological characteristics of the species, including the variety. The productivity of single-species crops in annual grasses depended on the biological characteristics of the species, the yield of green and dry mass, and the content of nutrients.

Increases in the yield of green mass and the collection of dry matter of all studied annual crops were revealed in comparison with the control. In the forest-steppe conditions of the Krasnoyarsk territory Echinochloa frumentacea (Roxb.) Link, Amaranthus paniculatus and Melilotus albus had the maximum yield of green mass: 62.1 t/ha, 50.4 t/ha, 49.5 t/ha. The green mass additions to the oat control were 182.1 %, 147.8% and 145.2% respectively. The maximum collection of dry matter was provided by Melilotus albus and Echinochloa frumentacea (Roxb.) Link crops of 11.3 t/ha and 11.1 t/ha, with control increases of 34 t/ha and 3.2 t/ha.

The maximum collection of feed protein units (FPU), digestible protein and energy productivity were in Melilotus albus and Echinochloa frumentacea (Roxb.) Link. The feed protein unit collection of Melilotus albus and Echinochloa frumentacea (Roxb.) Link was 12.4 thousand/ha, the collection of DP was respectively -1.73 and 1.37 t/ha, the energy productivity was 122 GJ/ha and 100 GJ/ha. Melilotus
albus and Echinochloa frumentacea (Roxb.) Link exceeded the control by 1.7 times in the collection of feed protein units; Melilotus albus by 2.2 times and Echinochloa frumentacea (Roxb.) Link by 1.8 times in the collection of digestible protein; Echinochloa frumentacea (Roxb.) Link by 1.3 times and Melilotus albus by 1.5 times in the collection of energy productivity.

The maximum content of feed units was distinguished by Panicum miliaceum, «Kinelskoe 92» and Panicum miliaceum, «Rossiyanka» 0.23 feed units/kg, the highest content of protein units in the green mass was found in Melilotus albus 0.25 FPU/kg and Panicum miliaceum L.0.24 FPU/kg, the maximum content of digestible protein in the green mass was shown by Melilotus albus – 35 G/kg.

Recommendation for production: the named types and varieties of low-spread, high-productivity forage crops should be used for the production of green mass in the regional agricultural enterprises.

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