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Influence of Sowing Time on Chemical Composition and Nutritional Value of Annual Herbs in Mixed Crops

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Abstract

The sowing period significantly affects organic matter accumulation in the green mass of the studied plant: peas, spring barley, and oats. Experiments were carried out in the agricultural artel (collective farm) "Zarya" of the Kemerovo region-Kuzbass in 2019-2020. The article presents the results of comparing different sowing dates obtained by cultivation of mixed crops and single crops of annual forage crops. Despite the insignificant differences in growing conditions, the experiment established a pattern that characterizes the reaction of the studied plants to the sowing period. The analysis of the nutritional value of haylage obtained from mixed crops has been carried out. The article presents the feed organoleptic assessment (color, odor), active acidity, biochemical assessment (mass fraction of dry matter; crude protein; crude fat; crude fiber; content of lactic, acetic, and butyric acids), calculated feed units, metabolic energy, and nitrogen-free extractive substances. As a result of the research, links between the sowing period and such quality indicators as the content of crude fat, protein, fiber, and ash were revealed.

Keywords: Haylage, Active acidity, Carbohydrates, Crude protein

Introduction

Stagnari *et al*. and Kulkarni *et al*. say that legumes can be a source of increased vegetable protein production in farm animals' feeding. Plants from the Fabaceae family synthesize about 1.5-3 times more protein than Poaceae (Stagnari *et al*., 2017; Kulkarni *et al*., 2018).

According to VM Kosolapov, an increase in the share of cultivated plants from the Fabaceae family will reduce the protein deficiency by 8%, and an increase in the share of the cereal component will provide the crude protein content in the dry matter of feed to 14-15% (Kosolapov, 2008; Baigonussova *et al*., 2021).

The development of animal husbandry in the risky farming zone of Western Siberia is impossible without creating a solid forage base. According to Bents, the protein feed imbalance is one of the reasons for the decline in livestock production in Russia (Bents, 1999).

By discussing the development of animal husbandry in Siberia, Koshevarov *et al*. conducted an extensive scientific study. They found that an increase in the productivity of farm animals is constrained by the imbalance of feed-in protein and sugar, which is the reason for significant overspending of feed (Koshevarov & Vyazovsky, 2010).

Salnikova believes that this problem should be solved by cultivating mixed agrocenoses of legumes and cereals, which make it possible to obtain not only high and stable yields but also to increase the quality indicators of green mass, and to obtain unleaded grass stand and create favorable conditions for subsequent crops of crop rotation (Salnikova, 2020).

Many scientists note that there is not a single country in the world in which agriculture would not use mixed crops (Wang-nian *et al*., 2019).

In 2010, Merzlikina *et al*. and Artemiev *et al*., and later in 2019, Khramoy *et al*. showed that multi-species cenoses are more productive and more stable than single-species ones provide a well-balanced nutritious food (Artemiev, 2010; Merzlikina, 2010; Khramoj *et al*., 2019).

Mironova *et al*. believe that a limiting factor in increasing animal productivity is decreased production and quality of green feed (Mironova *et al*., 2019).

The nutritional value of haylage obtained from the green mass of grain and legumes is very high. Other researchers confirm this. For example, S. Karamaev *et al*. Confirm the advantage of haylage in animal feeding (Karamaev *et al*., 2019).

According to A. Kapsamun *et al*., silage rations will solve the problem of vitamin nutrition of animals and obtain high-quality products (Kapsamun *et al*., 2019).

Ovtov *et al*. believe that one of the solutions to obtain high-quality, balanced feed is the cultivation of mixed crops of *Fabaceae* and *Poaceae* crops (Ovtov & Ovtova, 2020).

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Jensen *et al*. are of particular relevance to studies devoted to studying the technology of cultivation of mixed crops of legumes and cereals (Jensen *et al*., 2020).

According to Eichler-Löbermann *et al*., mixed sowing of *Fabaceae* and *Poaceae* crops will increase yields and obtain high-quality animal feed (Eichler-Löbermann *et al*., 2020).

The research aims to study and assess the sowing period's influence on the nutritional value of annual grasses in multi-species crops grown for haylage.

Materials and Methods

The object of research was the annual crops - *AvenasativaL*. varieties Rovesnik, *Hordeum L.* - variety Biome and *Pisumsativum L.* no-grade. The studies were carried out on the agricultural artel (collective farm) "Zarya" of the Kemerovo region, located in the south-east of Western Siberia, in 2019-2020. A sharply continental climate characterizes climatic conditions. In this territory, the limiting factor for the growth and development of plants and the creation of yield is moisture, which falls in the form of precipitation, which causes significant fluctuations in yield and quality of the products obtained from year to year.

The soil of the experimental plot of the subboreal type is leached podzolized heavy loamy chernozem. The agrochemical parameters of the soil varied over the years within the following limits: pHsol 5.7-6.5, the humus content in the plow horizon 6-10% (according to Tyurin). The provision with exchangeable potassium (according to Kirsanov) was 33 mg/100g, mobile phosphorus - high 13 mg/100g of air-dry soil.

The quality of haylage obtained from peas, oats, and spring barley was assessed when cultivating these crops in mixed crops at different sowing dates. In the experiment, three sowing dates were studied: the first - upon reaching the physical ripeness of the soil from April 30 to May 5; the second - with the onset of biological maturity of the soil from May 5 to May 10; the third from May 10 to May 15. The predecessor in the experiments was oats. The repetition is fourfold. The accounting area was 100 m^2. Sowing was carried out with a Kuzbass sowing complex at a seeding rate of peas of 0.8 centners of germinating seeds per hectare, oats, and barley - 2.4 c/ha in three sowing periods. Harvesting was carried out in the milky-wax ripeness of grain crops, peas in the phase of fruit formation.

Fertilizers were not applied before sowing; pre-sowing treatment of seeds with fungicides was not carried out. The crops were not treated with herbicides against weeds. The dry matter content was determined according to GOST 31640-2012, crude protein according to GOST 13496.4-93, crude fiber according to GOST 31675-2012, carotene according to GOST 13496.17-95, butyric acid according to GOST 23637-90, calcium according to GOST 26570-95, phosphorus following GOST 26657-97 in the laboratory of the quality of feed and food products of the Novosibirsk State Agrarian University, the calculation of feed units and exchange energy was carried out for cattle according to the guidelines for assessing the quality and nutritional value of feed approved by the Ministry of Agriculture of the Russian Federation dated 06.17.02, organoleptic assessment (color, smell, consistency) was carried out in accordance with GOST 55452-2013.

The meteorological conditions during the years of the experiments did not differ very much among themselves. 2019-2020 were comparatively favorable for the growth and development of oats, peas, and spring barley plants. Mathematical processing was carried out according to the method of Dospekhov (Dospekhov, 2011).

Results and Discussion

Haylage is a type of concentrated feed. This is a green mass of plants, dried to a 40-45% moisture content and preserved under anaerobic conditions. The highest yield of green mass was obtained in clean crops for oats 35.3 t/ha and peas 25.4 t/ha **(Table 1)**. The average yield of absolutely dry matter in fodder oats of the Rovesnik variety was 11, 9 c/ha, barley of the Biom variety - 7.9 c/ha, and non-grade peas - 8.5 c/ha.

Table 1. The Yield of Green Mass in Single-species and Mixed Crops, Average Values for 2019-2020

Type of crop	Green mass, c/ha	Deviation from mixed crops, %	Component ratio, %	
			legumes	cereals
Oats	35.3	39.3	-	100
Barley	20.1	65.5	-	100
Peas	25.4	56.4	100	-
Barley + oats + peas	58.2	-	10	90
HCP_{05}	2.3			

It was revealed that the average yield of green mass in single-species crops was lower in oats by 39.3%, barley by 65.5%, peas by 56.4% than in mixed crops. Three-component mixtures, consisting of barley, oats, and peas, had an advantage in the yield of green mass. They formed an average green mass yield of 58.2 c/ha over two years.

It was established that the total productivity of mixed crops is less affected by the meteorological conditions of individual years than single-species crops. This is indicated by the low coefficient of variation V = 8.9%. The yield of grain crops of oats, barley, and peas in single-species crops varied greatly and ranged from V = 40.9% to V = 53.4%.

Thus, two-year scientific research has shown that for the formation of green mass for haylage production, three-component mixtures of plants have been most productive and stable over the years: barley, peas, and oats (58.2 c/ha). This can be explained by the ability of oat, barley, and pea plants in mixed crops to more fully use solar energy, soil fertility, and all life factors due to the layered arrangement of the aboveground mass and root system. Such

mixtures more fully assimilate the nutrients and moisture present in the soil, form a more powerful photosynthetic apparatus, and, as a result, high productivity.

Of all the diversity of the weed component in clean crops of oats, barley, and peas, annual weeds predominated, among which the most widespread were chicken millet (*Echinochloacrusgalli*), white moth (*Chenopodium album*), odorless chamomile (*Matricaria perforata*). Among perennial weeds, the field thistle (*Cirsiumarvense*), field bindweed (*Convolvulusarvensis*), and field thistle (*Sonchusarvensis*) were rare.

A reliable regularity was established for the absence of varietal characteristics' effect on the weediness of crops at the initial stages of growth and development. Still, a decrease in the weediness of mixed crops was revealed. The sowing time influenced the weediness. At an early stage, it was minimal and did not exceed 9 pcs/m^2, and at an average and late sowing time, the infestation increased to 12 pcs/m^2. In the variant of mixed sowing, there were 2-3 pcs/m^2. Their growth and development were suppressed due to an increase in the seeding density. Thus, mixed crops lead to a decrease in weed infestation by 16.7%, compared to the option of clean crops.

Then, the quality of haylage obtained from bluegrass - barley and oats and the legume component of peas was studied. The chemical composition and nutritional value of the green mass of the three-component mixture, depending on the sowing time, is given in **Table 2**.

According to organoleptic and chemical indicators, the haylage quality assessment was carried out: smell, color, moisture, mass fraction in absolutely dry matter of protein, fiber, carotene, butyric acid, acetic, and lactic acid. Our research showed that the timing of sowing crops that makeup haylage did not affect organoleptic characteristics. There were no deviations from the normative documents for these indicators. An organoleptic evaluation showed that the haylage was free of musty, herring, and acetic acid odors. The haylage had a fragrant (fruity) smell. Color varied from yellow-green to greenish-brown. The consistency is not smeared, without slackness. Thus, the haylage was of high quality at all sowing times and was assigned to the 1st class in terms of organoleptic characteristics.

Leafiness is an indirect indicator of nutritional value - this is the mass of leaves from the total mass of plants. The number of leaves was 18%, and the inedible part was 12%.

One of the most important tasks in cultivating legumes and grain crops in mixed crops is the enrichment of haylage with crude protein by increasing the crude protein content in the haylage of cereals with legumes, the protein content of the forage increases. We have studied the mass fraction of crude protein. This is one of the most important indicators of feed quality. Protein deficiency leads to a decrease in milk productivity of farm animals since protein is the only source of essential amino acids for the synthesis of proteins in farm animals.

In our studies, the varieties of bluegrass crops and the legume component in haylage showed low protein. Depending on the sowing time in haylage, the mass fraction of protein varied from 8.8% to 10.6% and changed slightly in the years under study (V=16.9%). It was revealed that during the first sowing period, the plants of annual grasses accumulated the greatest amount of crude protein; it was 1.2 times higher than in the third period. The mass fraction of crude protein at the first sowing period in haylage was 10.6%; at the third, it was 8.8%, which is 1.8% lower **(Table 2)**.

Table 2. The Influence of Sowing Time on the Nutritional Value of Haylage from Annual Grasses (Average Values for 2019-2020)

Exchange energy, per 1 kg of dry matter, MJ	Feed units, natural moisture, g	Absolut dry matter, per 1 kg of haylage, %			Nitrogen-free extractive substances, per 1 kg, natural moisture, g
		crude protein	crude fat	crude fiber	
1 sowing period (early)					
7.5	0.24	10.6	2.6	31.8	29.8
2 sowing period (middle)					
6.3	0.10	9.3	2.9	30.5	26.4
3 sowing period (late)					
7.1	0.22	8.8	3.5	29.8	27.4

It can be seen from the results of our scientific research that one fodder unit of haylage from cereal crops of crude protein accounts for 80.8-106.0 g/kg, which is within the zootechnical norm. The maximum feed unit with crude protein provision was found in haylage at an early sowing period of annual crops.

Lack of fat in the diet reduces the absorption of fat-soluble vitamins A, D, E, and K. In addition, unsaturated fatty acids are supplied with lipids contained in the plants that make up the hay. These fatty carboxylic acids are not synthesized in the body of animals and must be supplied with food. These are oleic C18:1, linoleic C18:2, linolenic C18:3 and arachidonic C20:4 acids.

Our studies found that the sowing time affects the synthesis of fat in the studied plants. At the third stage of sowing, fat accumulation was 1.4 times higher than at first.

One of the important indicators of the quality of the obtained silage is the content of crude fiber and ash. In the rumen of ruminants, fiber plays a very important role in the nutrition of the cellulose-degrading microflora. At the same time, a large amount of energy is released, and volatile fatty acids (lactic, acetic, propionic) are formed, which are considered precursors of the formation of milk fat. With a lack of fiber in animals, the microflora of the proventriculus activity is disrupted, the development of the digestive organs in young animals is delayed, and their motor function is inhibited.

The study of the crude fiber content in haylage showed that during the first sowing period, this organic matter is synthesized in plants in 1.1 times more than at the third. It was found that the fiber content during the years of research varied from 29.8 g/kg of haylage to 31.8g/kg. However, the variability for this trait was insignificant. The coefficient of variation in terms of sowing was V = 6.3%. In our studies, for all three sowing dates, crude fiber content decreases in the third sowing period from 31.8% to 29.8%.

Nitrogen-free Extractive Substances (NFES) are easily digestible carbohydrates and provide all body cells with energy. This group includes starch, sugars, and pentosans. BEV activates the activity of microorganisms synthesizing B vitamins, fatty acids, and microbial protein.

In the conducted experiments, the maximum accumulation of NFES was revealed during the first and second sowing periods. The difference with the second term was 3.3 g/kg feed. This indicator of the qualitative assessment of haylage varied on average depending on the sowing time at natural moisture content from 26.4 g/kg to 29.8 g/kg. The variation coefficient was V=11.4%.

The beneficial effect of feed is determined by the indicators of energy and total nutritional value of haylage, expressed in terms of metabolic energy (for cattle) and feed units, which allows predicting the efficiency of its use. Natural moisture silage obtained in the experiment contained 0.19-0.33 feed units per 1 kg and 5.5-7.13 MJ/kg of metabolizable energy in dry matter, which indicates a good quality feed. Consequently, the conducted scientific research allows us to assert the feasibility of laying haylage from the green mass of joint crops of legumes and grain crops in the territory of this region.

Mineral substances do not have an energetic effect. Still, their role in the nutrition of farm animals is extremely large since they are a necessary basis for building a skeleton, are part of all cells, tissues, organs, and fluids. They also participate in biochemical processes, regulate metabolism, as they are in the composition of enzymes and vitamins.

The conditions of mineral nutrition of animals are one of the factors that determine the usefulness of feeding farm animals. Vital elements include macronutrients: calcium, phosphorus, sodium, chlorine, magnesium, potassium.

The content of crude ash and main macronutrients in haylage, depending on the timing of sowing peas, oats, and barley grown in mixed crops, is shown in **Figure 1**.

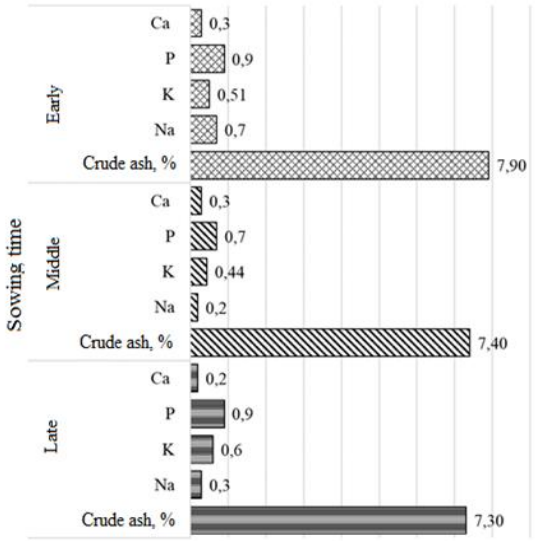

Figure 1. Influence of the Timing of Sowing Bluegrass and Legumes in Mixed Crops on the Content of Crude Ash and Macronutrients (%) in Haylage, Average Values for 2019-2020

The content of macronutrients in haylage changed depending on the sowing time, the content of crude ash also changed. The content of calcium, phosphorus, potassium, and sodium varied within wide limits. In terms of calcium and sodium accumulation, the plants that make up the haylage showed the greatest variability. The coefficient of variation depending on the sowing time of bluegrass and legume components was V = 33%, V = 22%, V = 16%, V = 40%, respectively. The crude ash content, on average, over the sowing time ranged from 7.3% to 7. 9%, with a coefficient of variation V = 7.59%.

The content of carotene, nitrates, and nitrites is shown in **Figure 2**.

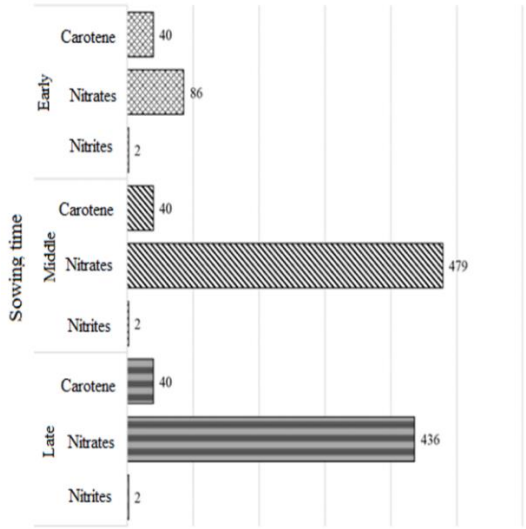

Figure 2. Influence of Sowing Time of Bluegrass and Legumes on the Content of Nitrates, Nitrites, Carotene in Dry Matter of Haylage, mg/kg, Average Values for 2019-2020

According to the obtained research results, the timing of sowing annual crops did not affect the content of carotene and nitrates. Their content in haylage in all variants of the experiment was 40 mg/kg and 2 mg/kg haylage, respectively.

It was found that the sowing time strongly affects the accumulation of nitrates in the green mass. According to this indicator, we observe great variability and a large accumulation of them. The nitrate content varied greatly in sowing from 86 mg/kg (1 sowing period) to 479 mg/kg (2 sowing period), with a coefficient of V=82%. Such a high variation in this indicator can be explained by an uneven thermal regime during the growing season of plants, especially by an increase in temperature in combination with a shortage of water. Low illumination associated with the density of plants in mixed crops also contributes to the increased accumulation of nitrates.

The pH value serves as an indicator of the quality of the finished silage. In our studies, the active acidity of haylage was pH=4.38 (1 sowing period); pH = 4.10 (2 sowing period) and pH = 4.35 (3 sowing time), i.e., it did not exceed the norm (pH norm = 4.7-5.6). The sowing period did not affect this indicator, only on the microbiological activity of microorganisms, which leads to the accumulation of lactic and other acids. It was revealed that the higher the level of lactic acid content, the lower the active acidity of the environment.

An important indicator of haylage quality is the ratio of organic acids: acetic, lactic, and butyric **(Table 3)**. Lactic acid does not have a pronounced odor; therefore, well-prepared feeds with a predominance of lactic acid do not smell or have a slightly sour smell with hints of fermented milk products. The often encountered pronounced sour smell of silage indicates the presence of acetic acid in it. It demonstrates that uncontrolled fermentation occurred in the feed, characterized by significant losses of dry matter and energy.

Table 3. Low Molecular Organic Acids of Haylage from the Green Mass of Cereals and Leguminous in Single-species and Mixed Crops

Sowing time	pH	Low-molecular organic acids, %			Total amount	Acid ratio, %		
		lactic	acetic	butyric		acetic	lactic	butyric
Early	4.40	0.96	0.32	0.12	1.40	45.5	48.8	5.70
Middle	4.10	1.45	0.13	0.08	1.63	42.46	54.36	3.18
Late	4.35	1.25	0.19	0.00	1,44	13.04	84.56	2.40

It was revealed that lactic acid is the most widespread acid in haylage obtained during fermentation of green mass. Acetic acid is also present in haylage but lesser amounts. During fermentation, most of the acetic acid is converted to lactic acid.

When evaluating haylage, the ratio of lactic acid to acetic acid is important: the higher it is, the higher the feed value. Our studies have shown that this ratio is 3 for an early sowing period, 11.5 for an average, and 1.3 for a late one.

Butyric acid may be present and has been found in harvested silage but very small quantities. Its content at the early and middle stages was 0.08 and 0.12%. And at a later date, butyric acid was absent in the haylage. For all sowing periods, the lactic acid concentration does not exceed the standard 0.5% in absolutely dry matter.

Conclusion

1. In the conditions of the forest-steppe of Western Siberia, the maximum collection of green mass is provided by a three-component mixture of barley 20% + peas 10% + oats 70% - 58.2 c/ha.
2. In terms of the yield of green mass, mixed crops exceed single-species crops by 39.3-65.5%.
3. The laying of haylage from the green mass of plants of the bluegrass family with a legume component makes it possible to obtain high-quality haylage of 2-3 class according to GOST R 55452-2013, with a content of 0.1-0.24 feed units per 1 kg of feed or 6.28-7.53 MJ of volumetric energy.
4. The influence of the sowing time on the accumulation of organic matter in the green mass of the studied plants of peas, spring barley, and oats has been established. Early sowing increases the content of crude fat, protein, fiber, and ash.

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