Scientific Justification of the Scheme of the Green (Raw Material) Conveyor for the Conditions of Sakhalin Island

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Abstract: The article identifies the main reasons for the insufficient provision of feed for highly productive livestock in the island region (Sakhalin island). The ways of transition to a new level of development of adaptive feed production are proposed on the basis of the available scientific developments in the Sakhalin Research Institute of Agriculture – the results of agroecological testing of various types and varieties of forage crops with different maturation periods, improved technological methods of cultivation of the most promising phytocenoses in pure form and grass mixtures in the main, intermediate and postcut crops. For the first time in a monsoon climate, a technological scheme has been developed for the uninterrupted supply of feed mass of annual and perennial phytocenoses for the organization of a green (raw material) conveyor during the summer and autumn period for the sustainable production of high-quality bulky feed. The complex of forage crops proposed for cultivation is characterized not only by a variety of uses and high productivity (20-60 t/ha of green mass, 4-12 t/ha of dry matter), but also by the ability to extend the period of functioning of the green (raw material) conveyor to an average of 120-125 days. Improving the structure of the mowed areas of forage crops guarantees the production of high-quality feed with a nutrient content of 1 kg of dry matter not lower than 9-10 MJ of exchange energy and a crude protein content of 13-14%.

1 INTRODUCTION

For the stabilization and further development of animal husbandry in modern household, economic and changing climatic conditions, the creation of a forage base remains, as before, a priority, but has its own characteristics (Kosolapov, Chernyavskikh, 2022;Trofimov, Trofimova, Yakovleva, 2022).

In the Sakhalin region, one of the directions of agricultural production is dairy cattle breeding, for the accelerated and stable development of which the organization of adaptive feed production becomes important (Chuvilina, 2016).

When creating a stable forage base, it is necessary to use not only the traditional set of zoned forage crops, but also to expand the range by introducing new species and varieties capable of using the bioclimatic potential of the territory with maximum efficiency (Kosolapov, Chernyavskikh, Kostenko, 2021; Rud, Kosolapov, Hogland, 2022; Cherniavskih, Dumacheva, Lisetskii, 2020).

An integral part is also the development of resource-saving technologies for promising phytocenoses that ensure guaranteed production of high-quality feed with an exchange energy of 9-10 MJ/kg of dry matter and a crude protein content of 13-14% (Kutuzova, Shpakov, Kosolapov, 2021; Reheul, Cougnon, Kayser, 2017; Kutuzova, Teberdiev, Kosolapov, 2021).

An important way to improve the provision of livestock with high-quality feed, reduce costs, reduce the cost of products is the continuous improvement of the structure of sown areas (Kosolapov, Cherniavskih, Zarudny, 2022), the introduction of crop rotations with high saturation with perennial and annual grasses (Subbotin, Narushev, Solodovnikov, 2019; Duborezov, Duborezov, Andreev, 2018;

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Cherniavskih, Dumacheva, Borodaeva, 2019), increasing the specific weight of the legume component as the lowest-cost in crop production (Vagunin, Ivanova, Anciferova, 2021; Dumacheva, Cherniavskih, Gorbacheva, 2018)**,** the cultivation of highly productive phytocenoses in pure form and as part of herbal mixtures (Ashirbekov, Shayakhmetova, Savenkova, 2022; Wiering, Ehlke, Catalano, 2021; Manni, Lötjönen, Huuskonen, 2021)**.**

Another way to improve the forage base is the intensive use of the fodder area by cultivating the widest possible set of forage crops in the system of technological conveyors (green and raw materials) (Pavlyuchik, Kapsamun, Degtyarev, 2016; Duborezov, Vinogradov, Duborezov, 2017). Despite certain differences in the purpose of use, both conveyors are united by the continuity of the supply of feed mass: in the first case – for the preparation of feed, in the second – for feeding animals with green mass. Continuity is achieved by carrying out sequential harvesting of various types and varieties of forage crops grown in main, intermediate and postcut crops (Andreeva, Pilipenko, Sidorova, 2018; Artemyev, Gur'yanov, Kapitanov, 2018).

For the uninterrupted organization of the feed supply in the difficult conditions of the monsoon climate of Sakhalin Island is affected not only by modern economic problems related to the availability of arable land, machinery, fertilizers, seeds, labor resources, but also by the limited species composition of forage crops, low natural fertility of soils with heavy mechanical composition, heterogeneous relief, short growing season, lack of heat, sudden changes in night and day temperatures, excessive moisture and others (Kosolapov, Chernyavskikh, Kostenko, 2021).

In this regard, studies have been conducted at the Sakhalin Research Institute of Agriculture, the results of which are the basis for creating the necessary conveyor continuous supply of forage mass of perennial and annual phytocenoses from mid-June to mid-November (Chuvilina, 2017). These are the results of agroecological testing of various types and varieties of forage crops with different maturation periods (Taranich, Chuvilina, 2015; Chuvilina, 2012), technological methods of cultivation of the most promising phytocenoses in pure form and grass mixtures (Chuvilina, 2017; Reshetnikova, 2012).

The purpose of the research is to develop a technological scheme for the uninterrupted supply of forage mass of annual and perennial phytocenoses for the organization of a green (raw material) conveyor during the summer - autumn period in the conditions of the monsoon climate of Sakhalin Island.

2 CONDITIONS, MATERIALS AND METHODS

The development of a technological scheme of a green (raw material) conveyor of annual and perennial grasses in the conditions of the island region (Sakhalin Island) is based on the results of a series of experiments conducted with annual and perennial crops in the main, intermediate and postcut crops in mono- and poly-species phytocenoses. Experimental studies were carried out on the lands of the Sakhalin Research Institute of Agriculture according to generally accepted methods (B. A. Dospekhov Methodology of field experience (with the basics of statistical processing of research results). M.: Agropromizdat. 1985. 352 p.; Methodological guidelines for conducting field experiments with forage crops. Moscow: VNIIK. 1983. 197 p.).

The soil under the experiments is meadow-gley old-arable with a heterogeneous granulometric composition (medium and heavy loamy) and a supply of nutrients. Agrochemical indicators depended on the location of experiments, precursor crops, and the year of research, but were generally characterized by an acidic reaction of the medium, high hydrolytic acidity, low content of mineral forms of nitrogen, high phosphorus and potassium.

The methods of cultivation of forage crops corresponded to the technologies developed in the Sakhalin Research Institute of Agriculture (the System of Agriculture of the Sakhalin region. Voronezh: Kovcheg. 2017. 396 p.). The main tillage included chilling, spring plowing, fertilization, pre-sowing cultivation, rolling. Before sowing, complex mineral fertilizers (diammophoska) were applied with a total background in the amount of 300 kg/ha. On the crops of perennial grasses, fertilizing was carried out annually in the spring with the same dose of mineral fertilizers.

The island region belongs to the southern taiga vegetation zone. Climatic conditions are formed under the influence of the monsoon of temperate latitudes. Summers are cool and relatively short with significant clouds and frequent fogs. The duration of the sunshine is 30% of the possible. The amount of precipitation in the warm period increases from 300 mm in the north to 800 mm in the south, while 60-80% falls from April to November, in summer – in July-September. Relative humidity often reaches 90-100%. The warmest month is August with an average daily temperature from +10 °C in the northeast to +18 °C in the southwest of the island; the sum of effective temperatures (above +10 °C) ranges from 1110 to 1830 °C. Spring is long, cold, windy with long-term

preservation of snow cover. The climatic characteristics of the research area are described on the basis of the reference book (Agro-climatic resources of the Sakhalin region. L.: Hydrometeoizdat. 1973. 104 p.).

Nevertheless, in general, the hydrothermal conditions of the growing seasons were favorable for the growth and development of the studied phytocenoses and contributed to the formation of a high and high-quality crop of forage mass.

3 RESULTS AND DISCUSSION

As a result of the research, it was revealed that when growing the main forage crops, it is possible to organize a green (raw material) conveyor in two ways. The first is the sowing of the same crop or grass mixture at different times at certain intervals. As a one-component phytocenosis, it can be the use of traditional oats, annual ryegrass, spring rapeseed, annual lupine, having a short period from sowing to the phase of mowing ripeness – 50-70 days. As a mixed phytocenosis, various combinations with oats and barley can be used, using components such as peas, vetch, rapeseed, amaranth, annual lupin. The period before the phase of mowing ripeness will depend on the purpose of use and on the quality of the feed mass (for protein production – emphasis on the protein component, for dry matter and sugars – on the cereal component).

Such an organization of the conveyor is possible, however, it is ineffective in terms of arable land productivity, the use of the growing season and heat, and the timing of the receipt of green mass (Chuvilina, 2017). In single-crop cultivation of annual grasses, as a rule, no more than 50% of the growing season and the sum of active temperatures are used. Moreover, the losses are not the same depending on the timing of sowing (Table 1).

Table 1: Use of the growing season depending on the sowing period of the oat-pea mixture.

Sowing period	Number of days			Harvest from 1 ha, t/ha		
	not used before sowing	used to form the crop, % of the	not used until the end of the growing season	green mass	dry mass	digestible protein
		total *				
May 10	4-5	42-48	92-83	25.2	3.9	0.43
May 20	13-15	40-44	88-81	24.6	3.8	0.38
June 1	26-28	36-41	81-73	23.0	4.2	0.45
June 10	35-37	34-38	76-68	21.9	4.3	0.45
June 20	45-47	33-38	67-58	24.7	4.3	0.42
July 1	55-57	34-40	56-45	27.0	3.9	0.43
Note * The first digit – when harvesting in the phase of the beginning of earing, the second – in the phase of full earing of oats						

The onset of the optimal harvesting period of the oat-vetch mixture will be about a week later than the oat-pea mixture (if you focus on the bean component). If we take oats in its pure form, then the share of the use of the growing season will be even less than in grass mixtures. Unfortunately, peas, vetch, even rapeseed and oats do not give a full-fledged aftermath, which will eventually lead to a shortage of the maximum possible yield of feed mass per unit area.

The duration of the growing season of spring rapeseed according to the phases of growth and development, depending on the sowing period, corresponds to: sowing-budding – from 43 to 65 days, sowing-flowering – from 52 to 66 days (mass flowering occurs on average 10 days after budding), sowing-fruiting – from 61 to 86 days. That is, the period occupied by the main crop lasts 60-90 days, the rest of the growing season remains inactive. Table 2 also shows the productivity of spring rapeseed depending on the timing of sowing (Chuvilina, 2012).

Table 2: The effect of sowing and harvesting periods on the duration of the growing season and the productivity of spring rapeseed, t/ha.

Harvest period (development phase)	Sowing period (decade, month)						
	II. V	III. V	II. VI	I.VII	II.VII	III. VII	II.VIII
Duration of the growing season							
Sowing-budding	53	50	46	43	43	50	65
Sowing-flowering	64	59	56	52	53	66	-
Sowing-fruit formation	86	81	85	85	61	-	-

Green weight							
Budding	26.4	29.9	38.3	34.0	33.4	40.5	20.5
Flowering	34.1	38.2	44.8	39.1	37.6	42.6	-
Fruit formation	41.6	42.2	49,4	41.3	38.5	-	-
Dry matter							
Budding	3.3	3.6	5.0	3.1	3.3	4.4	2.6
Flowering	4.1	4.3	5.6	4.5	4.1	6.6	-
Fruit formation	7.5	8.5	8.5	6.7	7.5	-	-
LSD_{05}: budding – 0.3; flowering – 0.5; fruit formation – 0.7 t/ha							
Forage units							
Budding	3.4	3.6	4.9	2.9	3.2	4.4	2.5
Flowering	4.2	4.2	5.4	4.3	4.0	6.7	-
Fruit formation	7.5	8.4	8.3	6.6	7.7	-	-
Raw protein							
Budding	0.68	0.75	1.15	0.73	0.77	0.93	0.58
Flowering	0.80	0.92	0.98	0.95	0.81	1.25	-
Fruit formation	0.96	1.20	1.24	0.99	1.20	-	-

As a result, this is an inefficient use of the growing season, a hectare of arable land, as well as in the conditions of late cold spring, early sowing dates are shifted, and productivity from May-June crops is almost the same and suitable at the same time. This creates a certain arrhythmicity of the forage mass intake.

The second way of organizing the raw material conveyor when sowing the main crops is to select components of phytocenoses from both annual and perennial grasses that are different in maturity.

An example of a green (raw material) conveyor from annual forage crops can be phytocenoses of oats or barley with a bean, cabbage or amaranth component, or spring rapeseed with a cereal and legume component (oats, barley, vetch, peas, amaranth, etc.) (Chuvilina, 2017; Chuvilina, 2012).

Table 3: Forage productivity of the first mowing of annual forage crops in pure and mixed crops (during the earing of bluegrass, flowering of legumes and cabbage).

Crop	Growing season	Productivity, t/ha			
		green mass	dry matter	forage unit	raw protein
Oats	62	24.5	4.3	3.6	0.60
Barley	57	22.4	5.2	4.8	0.71
Peas	60	21.9	3.8	3.4	0.68
Rapeseed	63	36.2	5.3	5.1	0.98
Oats+peas	60	28.4	5.0	4.4	0.79
Oats+vetch	65	22.2	4.8	4.4	0.75
Oats+rapeseed	63	30.6	5.3	4.8	0.74
Barley+rapeseed	63	29.1	5.1	4.8	0.83
Peas+rapeseed	63	34.6	5.0	4.6	0.94
Oats+peas+rapeseed	63	37.9	6.0	5.5	1.10
Paiza	80	28.5	5.3	4.5	0.80
Sudan grass	70	39.0	7.8	5.3	0.86
Corn	90	51.3	8.9	7.4	0.67
LSD_{05}	-	-	1.3	-	-

When using this approach to the organization of a green (raw material) conveyor from annual grasses, the forage mass is received more evenly than in the first variant. However, the productivity of arable land and the use of the growing season in this case are also not very effective due to the weak aftermathability of annual forage crops.

An example of a conveyor made of perennial grasses can serve as phytocenoses of eastern galega (Reshetnikova, 2012), meadow clover or alfalfa with a cereal component (cocksfoot, smooth brome, meadow or reed fescue, reed canary grass, common timothy) (Table 4). Perennial grasse s give a full-fledged aftermath, which in some years may be at the level of the first mowing, but, as a rule, is 1.2-1.5 times lower.

Table 4: Productivity and nutritional value of eastern galega with bluegrass grasses (average for 5 years) in total for 2 mowing, t/ha.

Component	Green weight	Dry weight	Raw protein	Forage units	Exchange energy, GJ/ha
	t/ha				
Eastern galega	68.5	14.8	2.51	13.8	164
Eastern galega + reed canary grass	82.3	17.7	2.86	16.1	188
Eastern galega + smooth brome	74.4	16.2	2.58	14.8	172
Eastern galega + fescue	94.1	19.9	2.93	18.3	206
Eastern galega + cocksfoot	78.1	16.2	2.52	14.8	172
Eastern galega + timothy	78.8	17.2	2.63	15.7	180
LSD_{05}	1.4	-	-	-	-

When cultivating and using perennial grasses and their mixtures in the green (raw material) conveyor system, it is necessary to take into account their basic biological features, such as earliness of ripening, aftermathability, loss of productivity, energy and protein nutrition in later phases of growth and development.

The early-maturing ones include the cocksfoot, meadow foxtail, reed canary grass, creeping clover; the middle-maturing ones are the smooth brome, meadow fescue, reed fescue, double-cut red clover, alfalfa, eastern galega, birdsfoot trefoil; the late-maturing ones are common timothy, white bentgrass, single-cut red clover, alsike clover.

For each type of grass, the optimal harvesting time is relatively short: for cereals – 7-15 days (from the tubulation phase to earing), including for reed canary grass and cocksfoot – 7-10 days, for timothy, fescue, and smooth brome –10-15 days); from earing to flowering – this is another 10-15 days and significant losses of nutrients substances and energy. In legumes, the period of budding-beginning of flowering on average ranges from 8 to 12 days, and before mass flowering – from 15 to 20 days, depending on the type, variety and weather conditions. However, during the full flowering phase, the fiber content increases sharply, the protein for most legumes decreases gradually.

The high-aftermathable crops include the cocksfoot, reed fescue, yellow alfalfa; medium-aftermathable – smooth brome, meadow fescue, reed canary grass, double-cut red clover, alfalfa, eastern galega; low-aftermathable – common timothy, alsike clover, single-cut red clover.

Cereal grasses (cocksfoot, fescue, timothy and reed canary grass) have significant differences, both in productivity and in the quality of the forage mass, depending on the phase of vegetation and the duration of use of the herbage (Table 5).

Table 5: Comparative forage productivity of perennial bluegrass grasses in the conditions of Sakhalin Island, t/ha.

Crop	Total harvest for 2 mowing			
	green mass	dry matter	raw protein	forage units
Reed canary grass	46.8	11.4	1.8	8.2
Cocksfoot	46.5	9.5	1.6	7.7
Smooth brome	39.0	9.0	1.5	7.5
Common timothy	38.6	8.9	1.3	7.9
Meadow fescue	30.6	8.7	1.4	6.7
LSD_{05}	-	0.3	-	-

When the cocksfoot is included in the green (raw) conveyor, the optimal time for its mowing is the phase of entering the tube, then the fiber content increases sharply, there is a loss of protein and energy. The same pattern is observed in the reed canary grass. The quality of common timothy is preserved for a longer time. In leguminous grasses – meadow clover and creeping clover – the fiber content increases sharply from the budding phase. At the same time, it should be noted that with the aging of plants, according to this indicator, leguminous grasses are approaching the cocksfoot.

With double-cut use, first of all, the cocksfoot is mowed down, then the smooth brome, meadow fescue, early-ripening red clover, reed canary grass and grass mixtures with them. The first mowing of grasses ends with the use of common timothy, alsike and single-cut clover and grass mixtures with them. These features should be taken into account when placing crops, when creating a green (raw material) conveyor from different types and varieties of herbs, observing the order of their harvesting and thereby prolonging the period of forage harvesting.

To increase the efficiency of the use of arable land, an important role belongs to intermediate crops of forage crops. And this is another important technique in the organization of a green (raw material) conveyor in the feed production of the island region. The purpose of intermediate crops is to obtain an additional crop of fodder mass due to unused soil and climatic resources by the main crops

from the same area. This is the most important reserve for increasing feed without expanding the area of arable land for forage crops.

The figure shows the classification scheme and the main types of intermediate forage crops in relation to the conditions of Sakhalin.

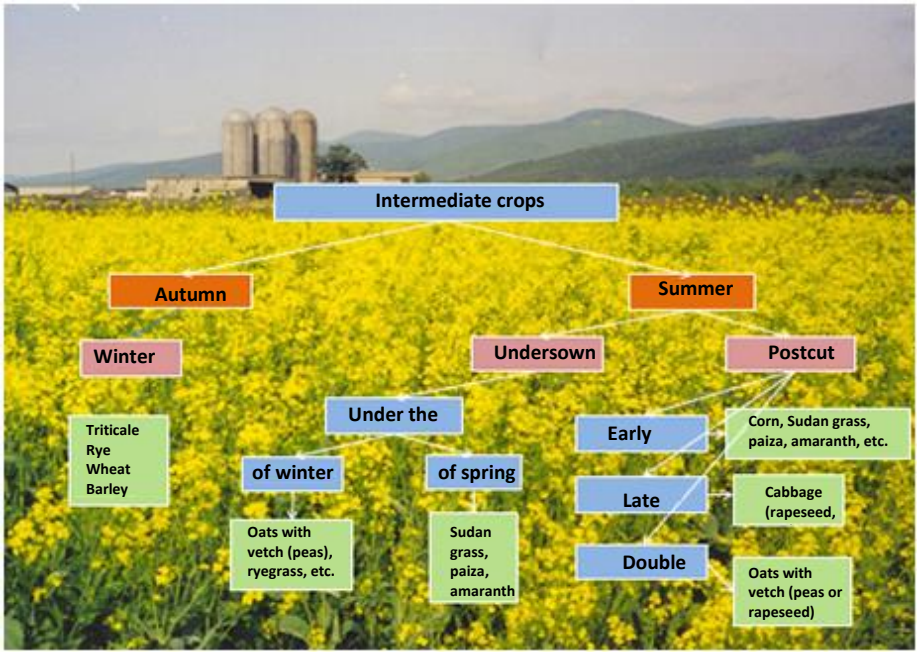

Figure 1: Classification scheme of intermediate fodder crops for Sakhalin conditions.

Of all intermediate crops, winter crops (rye, triticale, wheat, barley) yield the highest and most stable yields. The value of these crops for Sakhalin is that they form a harvest early, regardless of significant temperature fluctuations in May-June (Chuvilina, 2017). It is necessary to mow winter rye before flowering (it is possible in the early stages – June 10-20 in the tubulation phase, optimal – June 20-25 in the earing phase and late dates – June 25-July 5 in the full-end earing phase). The formation of winter triticale feed mass occurs 1.5-2 weeks later than winter rye. Further use of arable land can go in three ways: 1) getting the aftermath; 2) sowing the main postcut crop (any with a short growing season, and with early harvesting – you can even sow thermophilic corn, Sudan grass, barnyard grass as green fodder); 3) you can undersow annuals in stubble with rye aftermath or triticale.

When selecting the main postcut crops for sowing after intermediate winter crops, the principle should be clearly observed: the earlier the winter crops are mowed, the more thermophilic and late-ripening crops are more appropriate to sow (for example, Sudan grass, barnyard grass, corn, cereal-bean mixtures). And, conversely, with later mowing, the best results are obtained when sowing early-ripening and cold-resistant crops (for example, cabbage - rapeseed, oilseed radish, winter cress, white mustard, rapeseed-oat-bean mixtures, annual ryegrass) (Chuvilina, 2012).

An example of increasing the productivity of arable land can be the use of oat-pea mixture and winter rye as the main and intermediate crops, respectively, and spring rapeseed as a postcut crop (Table 6).

Table 6: Productivity of a hectare of arable land when sowing fodder crops with one and two harvests during the growing season using spring rapeseed.

Main and postcut forage crops	Harvest from 1 ha, t			
	green mass	dry matter	forage units	raw protein
Winter rye	34.9	7.0	6.2	0.99
Oats+peas	28.0	5.0	4.6	0.94
Winter rye + spring rapeseed (postcut)	73.5	12.0	11.2	1.86
Oatmeal pea mixture + spring rapeseed (postcut)	60.4	8.3	8.0	1.76

Spring rapeseed (mowing + aftermath)	46.0	5.2	5.4	1.03
LSD_{05}	-	1.3	-	-

The types of forage crops in repeated crops are practically the same, with the exception of heat-loving ones. The main thing here is that re-sowing in a monsoon climate of Sakhalin Island should be carried out by August 1. Accordingly, the harvesting of the first – the main crop or mixed phytocenosis should be carried out at an early date and in a short time (July 15-25). The technology of cultivation of double crops practically does not differ from the technology of the first crop.

Thus, based on the available numerous scientific studies conducted at the Sakhalin Research Institute of Agriculture, it is possible to draw up a technological scheme of a green (raw material) conveyor from intermediate, main and postcut perennial and annual forage crops for the conditions of the monsoon climate of the island region (Table 7).

Table 7: Technological scheme of the green (raw material) conveyor of annual and perennial phytocenoses in the conditions of Sakhalin Island.

Agrocenosis (in pure and mixed form)	Period of onset of mowing ripeness	Harvest from 1 ha, t	
		green mass	dry matter
Winter rye	10.06-30.06	32.0-35.5	4.1-8.6
Winter triticale	20.06-10.07	34.3-37.8	5.6-9.2
Eastern galega + cocksfoot (1st cut)	30.06-10.07	47.0	9.7
Eastern galega + smooth brome (1st cut)	05.07-15.07	44.2	9.4
Ryegrass (1st seeding period)	05.07-20.07	23.2	4.5
Clover + smooth brome (1st cut)	10.07-20.07	29.0	6.3
Alfalfa + fescue + timothy (1st cut)	15.07-20.07	28.5	6.4
Eastern galega + timothy (1st cut)	15.07-25.07	48.5	10.3
Oats+peas (vetch) (1st sowing period)	15.07-25.07	28.4	5.0
Oats+peas (vetch)+rapeseed (1st sowing period)	20.07-30.07	37.9	6.0
Eastern galega + cocksfoot (aftermath)	10.08-20.08	31.2	6.5
Eastern galega + smooth brome (aftermath)	15.08-25.08	30.3	6.8
Ryegrass (aftermath)	15.08-30.08	20.1	4.0
Clover + smooth brome (aftermath)	15.08-30.08	25.6	5.7
Alfalfa + fescue + timothy (aftermath)	20.08-30.08	23.5	5.9
Sudan grass (postcut)	20.08-10.09	30.3-33.1	5.9-6.8
Eastern galega + timothy (aftermath)	25.08-05.09	30.3	6.9
Corn	25.08-30.09	52.3-61.1	8.9-12.0
Paiza	10.09-20.09	28.5	5.3
Oats+ rapeseed (postcut or repeatedly)	10.09-10.10	30.6	5.3
Spring rapeseed (postcut)	10.09-10.10	36.2	5.3
Oats +peas (vetch) (postcut or repeatedly)	25.09-15.10	28.4	5.0

5 CONCLUSIONS

Improvement of the structure of the mowed areas of forage crops in the form of a developed green (raw material) conveyor in the island region (Sakhalin Island) is a priority direction for the development of field adaptive feed production both at the present stage and in the future; it serves as the basis for stabilizing the forage base for highly productive dairy livestock.

The value of phytocenoses of forage crops offered for cultivation in difficult soil and climatic conditions of Sakhalin is determined not only by their high productivity (20-60 t/ha of green mass, 4-12 t/ha of dry matter) and nutritional value (dry matter not lower than 9-10 MJ of exchange energy, 13-14% of crude protein), variety of use, but also by the fact that they allow to extend the period of functioning of the green (raw material) conveyor to an average of 120-125 days.

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