BIOPRODUCTIVITY OF ONE-YEAR FODDER CROPS ON GREEN CRYOFEED IN CONDITIONS OF CRYOLITHOZONE

DOI:10.24411/2588-0209-2019-10042

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The article presents the results of field studies on the biological production of fodder crops in cryolithozone conditions for the production of green frozen food. The purpose of the research is to study the yield, nutritional value and productivity of oats, and its mixtures with peas, rapeseed and barley at different sowing times for cryofeed. Field experiments were conducted on permafrost floodplain sod-gley soils of the Oymyakonsky District (Cold Pole) of the Republic of Sakha (Yakutia). Laboratory studies were performed on the basis of the laboratory of biochemistry and mass analysis (GOST-26205-86). In Oymyakon, the duration of the period with an average daily temperature above 10 degrees is equal to 73 days on average. The transition of the average daily air temperature through + 10 degrees occurs in August, after + 5 - in September, the sum of active temperatures above +10 degrees is 913 degrees Celsius, which allows cultivation of cold-resistant feed crops for cryofeed. The highest crop of forage crops in an average of 3 years of research was obtained by the second term of sowing. Oats provided the maximum yield of green mass - 10.6 t/ha. The yield of the green mass of the oatmeal mixture was 10.2 t/ha, the oats + barley provided 9.5 t/ha of the green mass. The oatmeal mixture has the lowest yield of green mass - 6.4 t/ha, which is explained by the biological features of the plants. In terms of productivity, the highest rates were noted for oats - the gross energy collection for the second term was 48.4 GJ/ha, the exchange energy was 28.2 GJ/ha, and the digestible protein was 0.36 t/ha. The oat-pea mixture provided the maximum yield of feed-protein units for the second sowing period — 0.64 t/ha, while the gross energy was 46.5 GJ/ha, the exchange energy was 25.0 GJ/ha, and the digestible protein was 0.49 t/ha, dry weight yield was 2.7 t/ha. A distinctive feature of the production of cryofeed is that the sowing of forage crops is carried out not in spring, but in mid-July (the second term of sowing), with the calculation of the remaining amount of active temperatures 650-700 degrees Celsius sufficient for the accumulation of high yield of green mass (6.4-10.6 t/ha) by the time of transition of average daily air temperature through +5 degrees to minus. The production of frozen by natural cold green fodder based on the late date of sowing annual forage crops in permafrost conditions will provide for the need of feed protein and animal vitamins of the North in the winter-spring period.

Keywords: *cryofeed, forage crops, oats, pea-oat mixture, rapeseed, barley, sowing time, yield, permafrost soil, cryolithozone, bioproductivity, nutritional value, carotene.*

Introduction

Major factors affecting crop productivity under "Cold pole" Oimyakon conditions are heat and moisture. Nominal sums of heat and humidity are profusely and efficiently used by annual plants for its green mass accumulation. Hence, the knowledge about bioclimatic factors and biological needs for growth and development of annual plants gives an opportunity for the correct choice of forage crops and its cultivation for green food in cryolithozone conditions.

Deficiency of available nutrients in winter and spring, low protein in reindeer moss, minerals and vitamins content, significant expenditure of accumulated through summer animals' energy during cold seasons- these factors all-together lead to the number of unpleasant consequences: decrease of living mass, increased morbidity, mass death of reindeer during hostile years due to depletion [1].

To eliminate factors preventing the productivity increase and improvement of production quality, it was previously suggested to produce food stock and enrich reindeer and horses winter diet with green frozen food. Green winter food of reindeers is composed of plants that are partially or fully preserved under the snow in its green attire. Likewise, browned plants are also included in the winter foods list. In winter, reindeer struggle to survive without snow preserved green plants, even in reindeer moss enriched grasslands [2]. Reindeer's winter diet on average by all periods comprises 52.2% of green plants [3].

Technological production of green cryofeed under natural cold increases carotene amount at each hectare. Green cryofeed harvesting method is based on sowing forage crops at later periods with further harvesting in a gradual manner accordingly to specified sub-zero temperature terms. By simple words, green cryofeed is the green food frozen naturally and further compressed in small-sized bales.

Despite the latest achievements and discoveries in science and applications, there are no synthesized food alternatives that would outstand green plants by its wholeness and low-cost. The absence of sowed pasturelands, rotational grazing, regulated herding, the low yield of natural pastures and other reasons would contribute to the shortage of summer plant resources usage duration for the green conveyor. The prominent example of green frozen food (green cryofeed) utilization can be natural winter grazing behavior observed in reindeer and Yakut horse. Animals would clean up snow layer in order to get the small autumn crop sprout frozen under natural conditions and containing the complete set of nutrients and vitamins essential for animal's vivacity during the long winter. Food shortage and its low quality, high cost and imbalanced nutrients diet during long cold periods are major constraining factors for livestock development in Republic Sakha (Yakutia).

Cattle provision with green food in winter have great potential to increase meat and milk production via eradicating lack of vitamins and nutrients. Pressing green cryofeed into bales and rolls allows to preserve its quality as well as to transport to any desired location. Green cryofeed may be used as supplementary food for main diet. In order to resolve the issue with proteins and vitamins supply in a winter-spring period, we studied annual forage crops cultivation agro-technique for production of green foods with further preservation by the natural cold.

In Yakutia common water content in the root layer (30cm) during the first half of summer does not exceed 100-120mm, depth of soil melting is 0.5-1.0m. These are nominal living conditions for plants provided by northern nature. Lack of soil warmth is one of the major factors limiting normal plants growth and development.

Average air temperature transition through dates are 12th of May in spring and 23rd of September in September. Ambient vegetation period duration is 133 days. The transition of daily air temperature trough +5^{o}C in mountainous taiga territory was observed from 21st to 30th of May. It is the beginning of vegetation period. Duration of vegetation period with air temperature above 5^{o}C is 99-110 days. Oymyakon daily air temperature above +10^{o}C in average lasts for 73 days. Autumn air temperature decreases up to +10^{o}C occurs in August, to under +5^{o}C- in September. Due to the low precipitation rate, Oymyakon-Verkhoyansk zone "North pole" can be described as "aridity pole" among circumpolar districts. According to available long-term data, annual precipitation rate is 134 mm. In June-August, vegetative periods, precipitation rate is only 60-90 mm. Due to the low precipitation, this zone was included in the arid desert zone. Maximal air temperature (July) goes up to +31-37^{o}C, daily maximums (June-August) often exceeds 30^{o}C with wind absence. By the mid-July, available water for plants at all-terrain points is 10-12% [4].

To summarize above-mentioned, Oymyakon basin, where this study was held, is characterized by extreme continentality of climate.

Methods

Experimental works on bio-productivity of forage crops and seeding timings were carried out in pilot production facility "Yuchyigei" of Oymyakon district from 1996 to 1998.

The main goal of this study was to investigate production, nutrient composition and efficiency of oats and its mix with pea, rapeseed, and barley under alternative seeding dates aimed for the cryofood.

Soils described as frozen floodplain sod-podzolic of intermontane through. The top layer at the beginning of experiments contained 7.51-7.88% of humus in topsoil (0-20cm); pH was 5.87-5.95; salinity level was decreased; nitric nitrogen was concentrate on major layer 0-10cm 0.91-1.05g per 100g of soil. The mechanical composition was comprised of light-, medium-, heavy clay seals covering sand and gravel. Study area's soils are potentially fertile but are not sufficiently supplied with nutrients for plants.

The study was carried out according to the approved methods in field practice [5], cultivation agro-technique of forage crops was done following to recommendations from Yakut Scientific Research Institute of Agriculture [6], laboratory experiments were carried out by biochemistry and mass analysis methods (GOST- 26205-86), mathematical processing was carried by B.N. Dospekhov and statistical analysis was done on *Stalislibra-6*. Bioenergy value was calculated by the method offered by All-Russian National Scientific Institute of Foods [7].

Variants of seedings were sorted by following variants: 1- oat; 2- oat+pea; 3- oat+rapeseed; 4- oat+barley. Seeding dates variants were- in the 1st term 25th of June, the 2nd term- 5th of July; 3rd term- 15th of July. Sowing standards of oat and barley were 200kg/ha, oat-pea mix 150kg/ha and oat+rapeseed- 150kg/ha, 6kg/ha of rapeseed. Plot area was 18 m2. Record plot area was 10 m2. The experiment was replicated 4 times. Fertilizers background were $(NPK)_{60}$.

Major field processing was carried out according to the type of plowed field in the autumn. Pre-seeding soil processing was done via disking LDG-10 in 2-3 tracks or KPS-4 in the hitch with spike-tooth harrow lengthwise and crosswise the field and soil rolling by smooth water-filled roller before and after seeding.

Results

In 1996, the weather during the vegetative period was relatively dry. Spring was in particular prolonged and cold. In 1997 no satisfactory conditions for proper crops growth and development were met. Main factors were low soil moisture and high air dryness. Accumulation of green mass continued until III decade of August. Spring 1998 started at the later time and was cold wither. Average monthly temperature in May was -0.3˚C, lower than the long-term average. In general, by meteorological characteristics, 1998 was characterized as warm and rainy. Precipitation rate from May to September was 198mm which is 1.32 times higher than the average (150 mm). June-July were warm with average monthly temperature 16.3˚C.

Throughout years of study the average air temperature at the beginning of the vegetative period was 1.9 ˚C, in the period of major vegetation- 15.2 ˚C, and in the end (August)- 11.2 ˚C. Precipitation during vegetative periods in study years was corresponding to the long-term norm- 152 mm. The sum of active temperature higher +10 ˚C in agricultural areas of Central Yakutia was 1400-1600, which is enough for the cultivation of such crops as rapeseed, oat, winter barley, legumes and perennial plants [8]. Sum of active temperature in Oymyakon district higher than +10 ˚C was 913C allowing cultivation of cold tolerating forage crops. Date of temperature transition through +10 ˚C was noted in 10th of June and 16th of August (Tab.1).

The green food quality improvement and its storage by preservation via natural coldness can be achieved by late seeding of annular forage crops when heat supply from the rest of vegetative period is 690- 745°C and its cleaning begins with low air temperature. Green cryofeed preparation technology allows to conserve vitamins and nutrients in food, improve its quality under the natural coldness (fig.1).

Table 1

Meteorological data from Oymyakon station (1996-1998 гг.)

Observation periods	Month					
	May	June	July	August	September	October
Air temperature, °C						
I decade	-2,8	13.1	16.2	14.0	6.9	-5.8
II decade	2,0	16.6	14.9	11.1	2.8	-14.0
III decade	6,3	15.9	14.3	8.4	-2.1	-17.9
Month	1,9	15.2	15.1	11.2	2.4	-12.6
Precipitation rate, mm						
I decade	2	0	15	8	14	6
II decade	3	5	31	14	13	1
III decade	5	7	16	15	4	8
Month	10	12	62	37	31	15
Top soil layer temperature °C (long-term average)						
Month	3	15	18	14	3	-17
Dates of temperature transitions, °C through: (long-term average)						
	0		+5		+10	
Spring	10.V		25.V		10.VI	
Autumn	19.IX		9.IX		16.VIII	
Temperature sums, °C, above (long-term average)						
0		+5			+10	
1248		1185			913	

Fig.1 Oat-rapeseed mix seedings in blooming phase

The combination of heat and cold available “resources” found in northern nature allows producing the green cryofeed as vitamin-rich, ecological and cheap product. Seedlings of annular forage crops for green food are produced in order to remove high-quality green mass yield with the beginning of early frosts (Fig.2).

Fig.2 Green Cryofeed in rolls

To increase the productivity and appearance of potential possibilities of forage crops, the rational usage on the basis of plants’ biological characteristic take an important role. Herewith, studies on productivity, dry-resistance, salt-resistance and nutrition value of particular breeds and species are essential.

Oat *(Avena sative L.)* and barley (*Hordeum L.*) are forage crops having the least requirement to heat and resistant to dryness. Vegetative period for green food crops lasts for 45-55 days. Rapeseed (*Brassica napus L.*) is cold-resistant long-day plant. Sprouts can tolerate frost up to -5°C. Vegetative period for green mass is 55-65 days [9]. Pea (*Pisum sativum L.*) sprouts grow at +4- +5°C and can tolerate temperature outdrop till -8°C. Vegetative period is 54-70 days.

Crops seeding in Oymyakon district were carried in three distinct periods- I term- 3rd decade of June; II term- I decade of July; III term- 2 decade of July.

The highest forage crop yield obtained among 3 years was obtained by II term of seeding in general. Oats maximum green mass yield was 10.6t/ha. Oat and pea mix yiled was 10.2t/ha and oat+barley mix green mass was 9.5t/ha. The oatmeal mixture has the lowest yield of green mass - 6.4 t/ha, which is explained by the biological features of the plants. (Tab.2).

Table 2

Forage crops yield depending on seeding terms, t/ha
(average 1996-1998., Oymyakon)

Crop	Seeding terms (timing)		
	I term	II term	III term
Oat	10.1	10.6	9.5
Oat+pea	8.8	10.2	8.0
Oat+rapeseed	6.6	6.4	6.5
Oat+barley	8.1	9.5	7.5

LSD_{05} by factor A – 0.90
LSD_{05} by factor B – 0.72

All crops at varied seeding terms are characterized by high nutritional values and contain optimal or high carotene. Maximal carotene content of 138.06-181.67mg/kg was detected in oats, oat+pea, oat+barley variants seeded at II and III terms. Nitrate content in forage crops was observed at normal levels: 79.4-478.6 mg/kg (Tab.3).

Gross and metabolic energy, feeding unit and digestible protein per 1kg of dry forage crops material are not significantly different by crop types and seeding timings.

The highest productivity values were noted in oats- the gross energy sum by II term was 48.4GJ/Ha, metabolic energy 28.2GJ/Ha and digestible protein content was 0.36 tons.

Table 3

Nutritive value of forage crops depending from seeding terms
(average 1996-1998, Oymyakon)

Crop	Seeding term	Dry component, %	Per 1kg of mass				Provision of 1 feeding unit of digestible protein (g)	Carotene, Mg/kg	Nitrates N-NO_3 Mg/kg
			Gross energy, MJ	Feeding unit	Digestible protein, g	Metabolic energy, MJ			
Oat	I	25	17.63	0.84	146.7	10.17	171.9	59.93	147.8
	II	25	17.94	0.88	133.7	10.43	149.7	110.65	324.8
	III	25	17.98	0.84	157.0	10.16	188.5	138.44	478.6
Oat+pea	I	25	17.80	0.82	154.4	10.09	224.8	112.88	134.9
	II	25	17.90	0.76	189.0	9.62	245.4	138.06	79.4
	III	25	17.47	0.79	168.8	9.86	196.9	99.14	426.6
Oat+rapeseed	I	20	17.30	0.70	100.9	9.09	144.1	44.97	416.9
	II	20	17.17	0.70	160.3	9.28	229.0	95.68	151.4
	III	20	17.12	0.73	173.6	9.50	237.8	102.11	445.7
Oat+barley	I	25	17.64	0.83	152.3	10.12	177.4	97.89	338.8
	II	25	17.46	0.87	155.4	10.38	177.0	127.87	93.3
	III	25	17.34	0.82	159.9	10.01	198.9	181.67	346.7

Oat-pea mix had the largest output of protein feeding units, by II seeding term- 0.64t/Ha, with gross energy 46.5GJ/ha, metabolic rate 25.0Gj/ha, digestible protein 0.49t/ha, dry mass yield 2.7t/ha. Highest characteristics for oat+rapeseed mix were obtained at III seeding term. Gross energy- 29.1GJ/ha, metabolic energy 16.2GJ/ha, digestible protein outflux 0.40t/ha, protein feeding protein units mass was 0.40t/ha. In oat+barley variant, the best values were obtained via II seeding terms with gross energy outflux 24.9GJ/ha, feeding protein units 0.42t/ha, digestible protein 2.09t/ha, dry mass 2.4t/ha (Tab.4).

Cold-resistant annual crops (oat, rapeseed), that were not able to complete the whole growth cycle under late seeding timings, started the process of toughening toward low temperature similarly to the type of toughening to a low temperature by perennial plants. During the early winter, green parts of these plants contain nutritious and biologically active compounds if preserved under freezing conditions. It is very likely due to the linking complexes of organic-mineral compounds with water. Later sown oats overcame strong freezers and low temperature by the end of September remain young with resilient leaves and high water content (cryofeed).

By these means, cryolithozone conditions are beneficial for plants to toughen against cold weather from the end of August. The high amount of warm sunny days contribute to the accumulation of stock compounds, especially sugars. Cold nights, on the other hand, inhibit its loss of breathing and growth processes.

Various methods for food productions possess diverse general nutritive components loss rates: field drying lead to up to 45% of loss, siloing 35%, senagation- 20% and for natural preservation (cryofeed)- only 5%.

Quick transition from autumn to winter under Yakutia conditions without long thawing episodes allows saving green cryofood under natural conditions without

loss of nutritional values of green mass in bale, roll, and stack forms throughout the whole stack period.

Table 4

Forage crops productivity depending from seeding terms, t/ha

(average 1996-1998, Oymyakon)

Crop	Seeding terms	Green mass	Dry mass	Feeding units	Digestible protein	Feeding protein units	Metabolic energy, GJ/ha	Gross energy, GJ/ha
Oat	I	10.1	2.5	2.10	0.37	0.43	25.4	44.1
	II	10.7	2.7	2.38	0.36	0.40	28.2	48.4
	III	9.5	2.3	1.93	0.36	0.43	23.4	41.4
Oat+pea	I	8.9	2.2	1.80	0.34	0.49	22.2	39.2
	II	10.2	2.6	2.00	0.49	0.64	25.0	46.5
	III	8.1	2.0	1.60	0.27	0.32	19.7	34.9
Oat+rapeseed	I	6.7	1.7	1.19	0.17	0.24	15.5	29.4
	II	6.4	1.6	1.12	0.26	0.37	14.8	27.5
	III	6.6	1.7	1.24	0.30	0.40	16.2	29.1
Oat+barley	I	8.2	2.1	1.74	0,32	0.37	21.3	37.0
	II	9.5	2.4	2.09	0.37	0.42	24.9	41.9
	III	7.6	1.9	1.56	0.30	0.38	19.0	32.9

Conclusion

To summarize, green cryofood unique parameters are characterized by summer seedings with calculated active temperature 650-700 Celsius degrees that are sufficient for the collection of high green mass yield (6.4-10.6t/ha), before the daily average air temperature drops from +5 to negative degrees. Under these conditions, oat and its mixed crops provide high quality green cryofood meeting northern animals' needs for feeding protein and vitamins during the winter-spring seasons.

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