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Solving the Problem of Stabilizing the Ecological State and increasing the Productivity of the Limans in the Caspian Lowland of Russia And Kazakhstan

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Abstract

The article presents the results of researches on developing the methods of stabilization of limans' ecological state in the arid steppe zone of Caspian Lowland of Kazakhstan and Russia and an increase in the productivity of perennial cereal agrocenoses cultivated thereon. The following recommendations serve as resource-saving methods on limans: on areas with normal cereal grass stand – introduction of nitrogen fertilizers in spring at a dose of N_{60}; on clogged areas - the treatment of crops with 2.4-DMA herbicide at the rate of 2 l/ha in the cereals tillering phase; and on sparse areas - double disking and sowing of cereal grass mixture (slough grass+brome+bluegrass) in autumn. With the aim of eliminating weeds and mixed grasses, the strongly sparse areas of limans must be plowed up and used for cultivation of field crops, and after 4-5 years the sowing of perennial cereal grasses and creating a new highly productive agrocenosis should be conducted.

Keywords: perennial forage cereal grasses, agrocenosis, limans, ecology, fertilizers, seeding method, herbicides, resource-saving technology, yield, steppe zone, Caspian Lowland.

INTRODUCTION

In the vast region of the arid steppe of the Caspian lowlands of Kazakhstan and Russia, the effective way of increasing the agriculture productivity is the liman irrigation that is based on the use of local flow waters for additional soil moistening. The practice proves that with proper operation in the arid steppe, the liman irrigation systems are capable of steadily providing the livestock number with the cheap and high-quality feed supplies. However, the great possibilities of liman irrigation are not fully used. Violation of the flooding regime and unsystematic use of flood waters leads to waterlogging and salinization of the productive area; the degeneration of the grass stand leads to deterioration of the ecological state of the limans, decrease in the productivity of agrocenoses, and deterioration in the quality of the feeds obtained [1, 2, 3, 4, 5, 6, 7].

To date, the scientific institutions of the region have studied in detail the formation of limans of the Caspian Lowland, their flooding regime optimization, and the meliorative state alteration [3, 4, 7, 8, 9, 10]. For the plown up limans, the selection of field crops was determined and separate methods for their cultivation were developed [11, 12, 13, 14, 15].

Currently, in order to increase the productivity of perennial cereal grasses in the limans of the Caspian Lowland and to reduce the costs in the production of feeds, further development of methods for stabilizing their ecological state and optimizing the life activity of agrophytocenosis is required, which is the reason for the urgency of the problem.

CONDITIONS, MATERIALS AND METHODS

The research was carried out in the limans of the Chizhino-Durinsky spates of the West Kazakhstan region, located on the territory of the Caspian Lowland. The climate of the zone is sharply continental. The average annual air temperature is+4.4-6.8 ° C; the amount of precipitation is low - 289-307 mm. The soils of the limans are meadow-chestnut, heavy-loamy; and the pH is close to 8. The supply of phosphorus is medium, that of potassium is high, and that of nitrogen is low.

Cultural grass stands in the limans of the Caspian Lowland began to be created in the 60-80s of the 20th century. Planning of territory, the banking of limans, preparation of soil and sowing of perennial cereal grasses - slough grass, brome, bluegrass, foxtail, meadow grass, etc., were carried out. At that time, the zone lacked the specially developed technologies for the treatment of grass stands of limans, and it lacks them even now. Every year, a limited combination of conventional traditional methods is used: spring flooding of the liman, application of fertilizers (every 2-3 years), harrowing after the water descent and drying of the soil, and harvesting the grass stand of the liman for use as hay.

The obtained data from the studies of regional scientific institutions show that at the present time there is a change in the ecological state of the limans of the Caspian Lowland. Thus, with a large water intake on the Uralo-Kushumskaya irrigation/water distribution system and in the absence of water discharge from the Saratov oblast', in the limans of the Chizhino-Dyurinsky spates of the Caspian Lowland three zones were formed:

– The zone of permanent (annual) flooding - 50-60 thousand hectares;

– The zone of periodic (once in 3 years) flooding - 70-90 thousand hectares;

– The zone not flooded with flood waters in the last 30-35 years - 150-180 thousand hectares.

The good yield of high-quality hay from the perennial forage grasses is obtained only in the limans of the annual flooding zone.

With the annual flooding of the estuaries of the Chizhino-Dyurinsky spates of the Caspian Lowland, the mineralization of groundwater is stabilized in the range of 0-3 g/l. In the absence of flooding during 3-5 years and more, the content of salts in the groundwater increases from 3 to 10-12 g/l. The absence of flooding for more than 5 years increases the salinization of groundwater above the normatives. In the absence of flooding of the liman, the water-physical and agrochemical properties of meadow soils deteriorate: the density increases, the porosity and the water content decrease. In all the years, in the flooding zone, water-physical and agrochemical indicators of the liman soils were characterized by more high-quality indicators. In the zone of permanent flooding, there is no increase in the soils salinization. In the absence of

flooding, there is an observable increase in the salinization of liman soils, an increase in the content of the absorbed sodium to 20% of the total absorbed bases. However, at the same time, studies have shown that in the zone of periodic flooding and in a non-flooded zone, the resumption of flooding even after a 30-year break leads to the restoration of fertility of the upper soil horizon.

Deterioration of the water-physical and agrochemical properties of meadow liman soils, an increase in their salinization lead to an improvement in the agro-phytocenosis of perennial grass stand and an increase in the maintenance of steppe mixed grasses. This is extremely damaging to the productivity of cultivated agrocenoses of perennial cereal grasses in the zone of periodic flooding and non-flooded zone of limans, where low yields of low-quality hay are now obtained [12, 15, 16, 17].

In the production terms, the zone of constant flooding of limans is especially important. In the absence of zonal technologies, a degeneration of grass stands, a noticeable drop in the yield and quality of hay in perennial forage grasses occur here. Due to this, further effective use of the liman lands requires the development of a set of methods for the restoration and long-term maintenance of high productivity of fodder agrocenoses of perennial cereal grasses [13, 18, 19, 20].

During 2009-2012 a field experiment was conducted according to the following scheme:

Factor A – The different percentage of perennial cereal grasses in the liman:

Scenario 1. The share of cereal grass stands was more than 70% (the first 4 years of the growth of the long-term cereal grass stand);

Scenario 2. The share of cereal grass stand was more than 50-70% (the first 5-7 years of the growth of the perennial cereal grass stand);

Scenario 3. The share of cereal grass stand was more than 30-50% (the 8-10 years of the growth of the long-term cereal grass stand).

Factor B – Methods of cultivating perennial cereal grasses:

Scenario 1. Control;

Scenario 2. Fertilizer (N_{60});

Scenario 3. Herbicide (2.4-DMA);

Scenario 4. Disking with the sowing of grass;

Scenario 5. Fertilizer (N_{60})+Herbicide (2.4-DMA);

Scenario 6. Disking with the sowing of grass+Fertilizer (N_{60});

Scenario 7. Disking with the sowing of grass+Herbicide (2.4-DMA);

Scenario 8. Disking with the sowing of grass+Fertilizer (N_{60})+Herbicide (2.4-DMA).

Disking with the sowing of perennial cereal grasses (slough grass+brome+bluegrass) was carried out at the end of summer or beginning of autumn, the introduction of mineral fertilizers - in spring after water absorbing, and treatment with 2.4-DMA herbicide - in the phase of tillering of cereals. Annually, in the first decade of April limans were flooded with a 0.4-0.5 m layer of water, with the duration of 25-30 days, in three replications. The plots were systematically located. The registration area of the plot was 100-150 m^2. Field and laboratory studies were carried out according to methods of B.A. Dospekhov [21], All-Union Research Institute of Forages n.a. V.R. Williams [22], and the Recommendations of the South-Eastern Agricultural Research Institute [23].

The density of the grass stand was determined by the number of shoots on the plots of 0.25 m^2 in three replications during harvesting; accumulation of raw above-ground biomass - by mowing the grass stand from the plots of 1 m^2 in four replications.

The yield of perennial cereal grasses was determined by mowing of 1 m^2 plots in 4 replications. The recalculation for the hay yield was determined by drying the samples to air-dry mass at a temperature of 70-75^{0}C with the conversion into a 17% moisture.

The botanical composition of the grass stand was determined by analyzing the plant samples weighing 1 kg. Biochemical feed composition of the common hay sample: nitrogen - as per GOST 13496-4-93; crude protein - as per GOST 13496-94; crude fiber - as per GOST 13496.2-91; crude fat - as per GOST 13496.15-97; crude ash - as per GOST 26226-95; carotene - as per GOST 13496.17-95; phosphorus - as per GOST 26657-97; potassium - as per GOST 30504-97; calcium - as per GOST 26570-95; fodder food value - by calculation method.

Energy and economic valuation were performed by the generally accepted calculation and regulatory method.

The experimental data were processed by the variance analysis method using the method of B.A. Dospekhov [21] and Microsoft Office Excel, 2003.

RESULTS AND DISCUSSION

The conducted researches have shown that the limans of the Caspian Lowland need a set of methods for regulating the density of the grass stand and the productivity of agrocenoses of perennial cereal grasses rather than the special agrotechnical measures.

The thickness of the stem stands has markedly changed in the scenarios with a different proportion of cereals in the agrophytocenosis. In the scenarios where the share of perennial cereal grasses in agrophytocenosis was more than 70% of the grass stand, the density of the stems of cereals was: 813 pieces per square meter on the control, 845-995 pieces per square meter in the scenarios with the use of different agricultural methods (Table 1).

Table 1 - The effect of cultivating methods on the density of the plant stand of perennial cereal grasses (average for 2010-2012)

Experiment scenarios	Number of stems at harvesting, pcs/m2		
	above 70%	50-70%	30-50%
1. Control	813	651	392
2. Fertilizer	954	715	469
3. Herbicide	845	688	413
4. Overgrassing	973	778	507
5. Fertilizer+herbicide	910	728	467
6. Overgrassing+Fertilizer	983	794	516
7. Overgrassing+Herbicide	975	782	509
8. Overgrassing+Fertilizer+Herbicide	995	804	522
	F_f	F_t	LSD_{05}
Factor A	82,571	3.17	2.3
Factor B	1,913	2.19	3.7
Combination of factors A+B	41	2.01	6.4

In the scenarios where the share of perennial cereal grasses in agrophytocenosis was more than 50-70% of the grass stand, the density of the stems of cereals was: 651 pieces per square meter on the control, 688-804 pieces per square meter in the scenarios with the use of different agricultural methods.

In the scenarios where the share of perennial cereal grasses in agrophytocenosis was more than 30-50% of the grass stand, the density of the stems of cereals was: 392 pieces per square meter on the control, 413-522 pieces per square meter in the scenarios with the use of different agricultural methods.

Similar patterns were also observed in the growth rates of plants in height and in the formation of moist above-ground biomass.

The highest indicator of the net productivity of photosynthesis (NPP) was obtained with the share of perennial cereal

grasses in agrophytocenoses of more than 70% of the grass stand on the second "fertilizer" scenario - 4.60 g/m2 per day (Table 2).

With the share of perennial cereal grasses in agrophytocenoses of 50-70% of the grass stand, the highest NPP index of perennial grasses was noted on the fifth scenario with the "fertilizer+herbicide" combination - 4.04 g/m2 per day.

Table 2 – The effect of cultivating methods on the productivity of photosynthesis of perennial cereal grasses (average for 2010-2012).

Scenarios of the experiment	NPP, g/m^2 per day		
	above 70%	50-70%	30-50%
1. Control	3.28	2.47	1.36
2. Fertilizer	4.60	3.50	2.68
3. Herbicide	3.41	2.73	1.40
4. Overgrassing	3.23	2.53	1.93
5. Fertilizer+herbicide	3.97	4.04	2.57
6. Overgrassing+Fertilizer	3.66	3.26	2.72
7. Overgrassing+Herbicide	3.69	3.14	2.07
8. Overgrassing+Fertilizer+Herbicide	3.49	3.33	3.28

In the scenarios where the share of perennial cereal grasses in agrophytocenoses covered 30-50% of the grass stand, the highest NPP index was observed when combining "overgrassing+fertilizer+herbicide" agricultural practices - 3.28 g/m^2 per day.

It was established that the highest total yield of hay in agrophytocenoses of perennial grasses had been obtained in the following cases:

– with the share of more than 70% in the second and sixth application scenarios, respectively, only "fertilizer" and the "overgrassing+fertilizer" combinations - 4.34 and 4.38 t/ha, respectively;
– with the share of 50-70% in the second and sixth application scenarios, respectively, only "fertilizer" and the "overgrassing+fertilizer" combinations - 3.70 and 3.91 t/ha, respectively;
– with the share of 30-50% in the sixth application scenario of the "overgrassing+fertilizer" combination – 3.31 t/ha (Table 3).

However, in the experiment conducted, the total yield of hay and the yield of hay of cereal grasses did not coincide according to the experiment scenarios. At the same time, the highest yield of hay of perennial cereal grasses was noted in the following cases:

– with the share of cereals above 70% in the second and eight application scenarios, only the fertilizers and the "overgrassing+fertilizer+herbicide" combination - 3.54 and 3.55 t/ha, respectively (Table 4);
– with the share of cereals above 50-70% in the sixth and eight application scenarios of "fertilizer+herbicide" and the "overgrassing+fertilizer+herbicide" combinations - 2.90 and 3.26 t/ha, respectively; and
– with the cereals share of 30-50% in the eight application scenario of the "overgrassing+fertilizer+herbicide" combination – 3.01 t/ha.

Table 3 - The effect of cultivating methods on the overall productivity of the liman cereal agrophytocenosis (average for 2010-2012), t/ha

Scenarios of the experiment	The total yield of hay with different share of cereals in the liman grass stand		
	above 70%	50-70%	30-50%
1. Control	**3.11**	**2.56**	**1.87**
2. Fertilizer	4.34	3.70	2.86
3. Herbicide	2.63	1.91	0.92
4. Overgrassing	3.25	2.89	2.46
5. Fertilizer+herbicide	3.43	3.17	1.88
6. Overgrassing+Fertilizer	4.38	3.91	3.31
7. Overgrassing+Herbicide	2.94	2.34	1.42
8. Overgrassing+Fertilizer+Herbicide	3.60	3.32	3.04
	F_f	F_t	LSD_{05}
Factor A	25,787	3.17	0.01
Factor B	12,546	2.19	0.02
Combination of factors A+B	426	2.01	0.03

This is also clearly confirmed by the data on the definition of hay class. In accordance with the requirements of GOST 4808-87, Class 1 cereal hay should have more than 35 g of digestible protein, 16 mg of carotene and above 0.50 of feed units per 1 kg. The Class 2 cereal hay should have more than 33 g of digestible protein, 15 mg of carotene and above 0.45 of feed units per 1 kg. The Class 3 cereal hay should have more than 30 g of digestible protein, 14 mg of carotene and above 0.40 of feed units per 1 kg. The hay quality data showed that depending on the proportion of cereals in the hay, the protein and feed units' content in the best scenarios, it was of Class 2, in a number of scenarios - Class 3, and on control - the non-class one (Table 5).

Table 4 – The effect of the set of techniques on the productivity of perennial cereal grasses' hay in the liman (average for 2010-2012)

Scenarios of the experiment	The yield of cereal hay (t/ha) and the share of cereals in the hay (%) with a different proportion of plants of perennial cereal grasses in the liman					
	above 70%		50-70%		30-50%	
	t/ha	%	t/ha	%	t/ha	%
1. Control	2.30	74.0	1.50	58.6	0.75	40.1
2. Fertilizer	3.54	81.6	2.62	70.8	1.82	63.6
3. Herbicide	2.58	98.1	1.87	97.9	0.87	94.6
4. Overgrassing	2.41	74.2	1.71	59.2	1.18	48.0
5. Fertilizer+herbicide	3.36	98.0	3.11	98.1	1.82	96.8
6. Overgrassing+Fertilizer	3.52	80.4	2.90	74.2	2.60	66.5
7. Overgrassing+Herbicide	2.91	99.0	2.24	95.7	1.44	94.4
8. Overgrassing+Fertilizer+Herbicide	3.55	98.6	3.26	98.2	3.51	99.0
	F_f		F_t		LSD_{05}	
Factor A	3,556		3.17		0.03	
Factor B	1,121		2.19		0.05	
Combination of factors A+B	48		2.01		0.09	

Table 5 – The effect of the set of cultivation techniques on the quality of hay of perennial cereal grasses (average for 2010-2012)

Scenarios of the experiment	The share of cereals - more than 70%			The share of cereals - 50-70%			The share of cereals - 30-50%		
	Transl. protein, g	feed units, kg.	class of hay	Transl. protein, g	feed units, kg.	class of hay	Transl. protein, g	Feed units, kg.	class of hay
1. Control	30.6	0.45	3	28.1	0.39	non-class	24.5	0.38	non-class
2. Fertilizer	33.0	0.46	2	30.2	0.44	3	30.1	0.42	3
3. Herbicide	34.2	0.48	2	33.0	0.47	2	33.5	0.47	2
4. Overgrassing	30.7	0.45	3	28.3	0.40	non-class	26.6	0.39	non-class
5. Fertilizer+herbicide	34.2	0.48	2	33.6	0.47	2	33.8	0.47	2
6. Overgrassing+Fertilizer	31.6	0.46	3	30.7	0.45	3	30.5	0.43	3
7. Overgrassing+Herbicide	34.5	0.48	2	33.2	0.47	2	33.2	0.47	2
8. Overgrassing+ Fertilizer+herbicide	34.6	0.48	2	34.3	0.48	2	34.4	0.48	2

	digestible protein			feed units		
	F_f	F_t	LSD_{05}	$F_ф$	$F_т$	LSD_{05}
Factor A	9,228	3.17	0.04	651	3.17	0.002
Factor B	16,487	2.19	0.06	841	2.19	0.003
Combination of A+B	992	2.01	0.10	67	2.01	0.005

The calculations have shown that the introduction of the developed methods of growing perennial cereal grasses on limans is characterized by high economic efficiency. At the same time, during the first 4 years of the use of fodder agrocenosis, when the share of perennial cereal grasses in the liman grass stand was more than 70%, the greatest net income was provided by the application of the "fertilizer" technological method - 16,124 rubles/ha; on the 5th-7th years of the use of fodder agrocenosis, when the share of perennial cereal grasses in the liman grass stand was 50-70%, the fertilizer+herbicide complex was the most effective - 10,109 rubles/ha; and on the 8-10th years of the use of fodder agrocenosis, when the share of perennial cereal grasses in the liman grass stand was 30-50%, the most effective was the "overgrassing+fertilizer+herbicide" complex - 8,874 rubles/ha.

The use of mineral fertilizers ensured the high energy indices on limans. On the best option, with the introduction of N_{60}, 4,824 MJ/ha of exchange energy and 10,114 MJ/ha of gross energy were obtained, and the highest agronoenergetic coefficient of 1.76 was observed.

CONCLUSION

To stabilize the ecological state of the limans and to maintain the productivity of the agrocenoses of perennial cereal grasses at a level of 3.0-4.0 t/ha of high-quality hay in the liman lands of the Caspian Lowland of Kazakhstan and Russia, the following differentiated set of technological methods is recommended:

– during the first 4 years of use, when the proportion of perennial cereal grasses in the liman grass stand is more than 70% and the density is more than 800 stems of grass per m^2, it is enough to annually introduce the 60 kg of active material of nitrogen fertilizers per hectare in the spring period after water absorption in the liman;

- on the 5th-7th years of use, when the proportion of perennial cereal grasses in the liman grass stand is 50-70% and the density is 600-800 grass stems per m^2, it is necessary to annually introduce the 60 kg of active material of nitrogen fertilizers per hectare in the spring period after water absorption in the liman and carry out the treatment of crops with 2.4-DMA herbicide at a rate of 2 l/ha in the phase of tillering of cereals;

- on the 8th-10th years of use, when the proportion of perennial cereal grasses in the liman grass stand is 30-50% and the density is 400-600 grass stems per m^2, it is required to carry out a two-fold disking and sowing the cereal grass mixture (slough grass+brome+bluegrass) in the early autumn period (at the end of the 7th year of use), to annually introduce the 60 kg of active material of nitrogen fertilizers per hectare in the spring period after water absorption in the liman, and to carry out the treatment of crops with 2.4-DMA herbicide at a rate of 2 l/ha in the phase of tillering of cereals;

– after a 10-12 year cycle of use of the liman areas with less than 30% cereal grass share and density of less than 400 grass stems per m^2, they should be plowed up, paired, used for 3-4 years for the cultivation of field crops, and then a new crop of perennial cereal grasses should be made.

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