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Improvement of biological productivity of saline and erosion-prone lands of Donetsk oblast by meadowing

Abstract. This study examined the soil cover and the state of the natural grass stand of saline and erosion-prone lands in the valley and gully system of the Sukhi Yaly River. Low-productive saline lands are located on the slopes and bottoms of gullies, micro-depressions of lowland and floodplain meadows. Plant groups associated with such soils are characterised by low species diversity and a lack of species valuable for fodder. The article presents the results of research on the improvement of low-productive lands on saline soils by sowing a set of forage grasses that can grow under saline soil conditions and have high fodder value. It was found that during the observation period, the yield of green mass and hay on all variants was significantly higher than the yield of natural herbage. The biochemical composition of forage grasses is characterised by an increased content of crude protein, hydrocarbons, vitamin C and essential amino acids. Data on the introduction of be herbs to improve saline fodder lands in combination with wild bee plants are presented, and their nectar content is determined. This paper presents a bio-agronomic assessment of fodder plants cultivation on black alkali soil. The authors provide recommendations for improving fodder lands on saline and alkaline soils

Keywords: low-productive and erosion-prone lands, hydromorphic meadow salt marsh, black alkali soil, fodder grasses, meadowing

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RELEVANCE

An important factor limiting the highly efficient use of soils in southern Ukraine is the significant prevalence of saline and alkaline soil types. In total, 4.7 million hectares of alkali soils were found in the steppe regions, which is 48% of arable land. Almost half of them is comprised of strong and medium alkaline soils – 2.3 million hectares (National Report on Soil Fertility, 2010).

According to the State Land Cadastre of Ukraine, saline and alkaline soils cover a total area of 2.8 million hectares (including 2.0 million hectares of arable land): saline soils are spread over 2.2 million hectares and alkaline complexes over 0.6 million hectares. The main requirement for the rational use of Ukraine's alkaline soils in modern conditions is the need for a landscape-geochemical assessment of their formation and distribution and the adaptive use of conventional and new energy-saving types of reclamation. This allows for the protection and improvement of the effective fertility of alkaline soils and the optimisation of the conditions for crops.

In the context of land reform, the system of measures for the renaturalisation of agricultural landscapes in areas of alkaline soils should in the short term provide for the withdrawal of highly saline soils and alkaline complexes with saline patches of 50% or more from arable land for the introduction of cultivated hayfields and pastures. It is recommended to use salt- and alkaline-tolerant grasses adapted to soil conditions for meadowing.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Methodological aspects of environmental sustainability of agro-landscapes in the current conditions of land relations transformation have been the subject of numerous works (Medvedev & Laktionova, 1998; Bulyghin, 2005; Bulyghin & Vitvitsky, 2018).

However, given the diversity of natural and economic conditions, it is necessary to find optimal solutions to improve erosion resistance and increase the productivity of marginal lands, considering the specifics of a given area.

Given the current shortage of resources, lack of funds, and limited state soil protection policy, the priority and mandatory measure to prevent further degradation of agricultural landscapes and soil cover is to withdraw low-productive and erosion-prone lands from cultivation and transform them into natural fodder lands (Sayka, 2000; Bulyghin & Dumin, 2001; Antypova, 2015; Antypova *et al.*, 2018; Cosgrove & Barrett, 1987; Sapck, 1998)

To improve low-productive lands on saline soils in the region, it is necessary to test a set of forage grasses that can grow in conditions of soil salinity and exhibit traits of high fodder value (Khromtsov, 2001; Patyka *et al.*, 2003; Petrychenko *et al.*, 2018; Kurhak & Tkachenko, 2016).

The purpose of the study is to examine the soil cover and the status of the natural grass stand of saline and erosion-prone lands in the valley and gully system of the Sukhi Yaly River; to conduct research on sowing a set of fodder and bee grasses to improve low-productive fodder lands; and to provide recommendations for increasing the productivity and value of fodder lands on saline and alkaline soils.

MATERIALS AND METHODS

A field experiment on the introduction of meadow-field crop rotation on saline fodder lands was established in a floodplain on the right bank of the Sukhi Yaly River. The soil type is hydromorphic meadow salt marsh. Experiments on testing bee plants were also conducted at the same site.

The plot was divided into two parts. The coastal part (water protection zone) of 25-50 m was left for control as a plot with a natural grass

stand, the yield of green mass and hay from which was compared with the yield of grasses and grass mixtures sown in five variants. The second part was used for experimental purposes. The surface was levelled and disked with disk harrows, mineral fertilisers were applied at a dose of $N_{60}P_{60}K_{60}$ per hectare, and gypsum at a dose of 2 t/ha. After applying fertiliser and gypsum, the area was ploughed to a depth of 28-30 cm.

Grasses were sown manually – *Medicago sativa* (Zaykevych variety), *Trifolium* (Skif variety) and grass mixtures: (#1) – *Medicago sativa* (Zaykevych variety) + *Medicago romanica* + *Trifolium* (Skif variety) + *Festuca gigantea* + *Festuca arundinacea* + *Elytrigia elongata* (Host) Nevski + *Phalaris arundinacea*; (No. 2) *Medicago sativa* (Zaykevych variety) + *Medicago romanica* + *Trifolium* (Skif variety) + *Festuca gigantea* + *Festuca arundinacea* + *Elytrigia elongata* (Host) Nevski + *Phalaris arundinacea* + *Isatis tinctoria* + *Bunias orientalis*. The research was conducted according to the methodology of experiments on hayfields and pastures (1969) and the methodology of perennial grasses selection (Konstantinov *et al.*, 1971).

The sowing of honey species was carried out in a wide-row method, manually. The seeding rate was calculated at 30 kg/ha of *Borago officinalis*, 4 kg/ha of *Nepeta cataria* spp. *citriodora*, 4 kg/ha of *Trifolium* and 4 kg/ha of *Melilotus officinalis* L. The nectar content of plants was determined by the method of B.I. Fesko and Ye.I. Karklyn (1967).

The experiments on the introduction of fodder plants on the black alkali soil marsh were initiated to increase the species composition of valuable fodder species and to increase the yield of low-productive fodder land.

RESULTS AND DISCUSSION

The soil profile of the salt marsh has clear signs of hydromorphism under poor drainage conditions on the floodplain terrace of the river with the close occurrence of mineralised groundwater (humus content in the Hs horizon is 3.83-5.69%). The reaction of the soil solution of the upper horizons is alkaline (pH 7.5-8.1), the lower ones are low-alkaline (pH 7.4-7.5). The content of mobile forms of phosphorus and potassium in the upper horizons is very high. However, the high concentration of salts in the soil solution significantly increases its osmotic pressure, disrupts the supply of water and plant nutrients; there is a direct toxic effect of salts on plants, which leads to their severe depression.

Structure of the profile of a hydromorphic meadow salt marsh:

Hs 0-45 cm – humus, saline, dark grey, moist, medium loamy, lumpy-grained, loose, fine-porous, salts in the form of dots and thin veins, gradual transition;

Hpsk 46-65 cm – upper transitional, saline, carbonate, dark grey, moist, medium clay, lumpy-grained, loose, porous, salts in the form of veins, gradual transition;

Phskgl 66-87 cm – lower transitional, saline, carbonate, grey, darkish dirty olive with rusty spots, moist, medium clayey, lumpy-nutty, slightly compacted, porous, gradual transition;

PksGl 88 and deeper – loess loam, carbonate, saline, heavily silty, brownish-grey with bluish tint and abundant rusty spots, damp, medium clayey, lumpy, compacted, viscous.

During the observation period, the yield of green mass and hay in all variants is significantly higher than the yield of natural grass (Table 1). On average, over three years, the yield of green mass of *Medicago sativa* was 37.3 t/ha, *Trifolium* – 37.3 t/ha, grass mixture No. 1 – 40.7 t/ha, grass mixture No. 2 – 41.7 t/ha. The yield of dry mass (hay) in the experimental variants was as follows: *Medicago sativa* – 7.73 t/ha, *Trifolium* – 7.64 t/ha, grass mixture No. 1 – 9.32 t/ha, grass mixture No. 2 – 9.70 t/ha, *Medicago sativa* + *Trifolium* – 10.74 t/ha.

Table 1. Harvest of green and dry masses of grasses and grass mixtures

Variant	Green mass over the years of vegetation, t/ha			Dry mass (hay) over the years of vegetation, t/ha		
	first	second	third	first	second	third
Control	10.1	24.5	24.6	1.14	2.73	2.75
Medicago sativa	14.2	45.2	47.1	3.28	9.69	10.22
Trifolium	19.3	47.4	45.2	3.42	10.26	9.24
Medicago sativa +*Trifolium*	22.2	52.4	32.1	4.16	14.09	13.99
Grass mixture No. 1	20.6	51.2	50.2	3.76	12.16	12.04
Grass mixture No. 2	26.4	50.3	48.3	6.76	11.54	10.82

Depending on the farming use of meadow-field crop rotations, it is necessary to consider the full development (in *Trifolium*, *Isatis tinctoria*, and *Bunias orientalis* – in the second year of vegetation, in *Medicago sativa* – in the second, third, and in cereals – in the third, fourth).

At the same time, the biochemical composition of plants under study was determined (Tables 2, 3), in phases corresponding to the pasture and haymaking stages of grasses according to the methods used in feed biochemistry.

Table 2. Biochemical composition of fodder grasses

Plant names	Nutrient content, %				Amount, % per absolutely dry matter		Content of vitamin	
	Crude protein	Crude fat	Crude fibre	Ash	Carbohydrates	Total essential amino acids g/kg	C, mg/kg	Carotene, %
Isatis tinctoria	12.03	3.47	15.53	13.65	22.21	22.19	195	2.61
Bunias orientalis	20.93	3.97	15.68	14.03	18.26	29.39	245	1.10
Trifolium pratense	10.58	4.26	33.07	10.81	18.74	21.67	100	2.12
Medicago romanica	19.96	4.42	34.5	9.62	8.18	78.73	146	2.84
Alfalfa	13.02	3.51	35.94	6.77	7.10	75.76	98	2.01
Festuca arundinacea	8.79	3.51	31.68	8.27	12.32	20.94	135	3.05
Festuca gigantea	8.53	2.68	34.01	8.11	12.04	24.11	210	2.84
Phalaris arundinacea	8.71	4.34	25.0	10.6	10.88	10.15	35	4.64
Elytrigia elongata (Host) Nevski	7.69	3.75	33.82	7.27	10.56	20.94	120	1.59
Control	13.19	3.89	27.74	8.02	9.93	50.71	128	1.24

Table 3. Nectar content and number of flowers per plant

Plant names	Nectar-forming capacity, kg/ha of sugar	Number of flowers, pcs.
Borage	776.2	3881
Nepeta cataria spp. *citriodora*	350.9	1493
Trifolium pratense	89.3	495
Melilotus albus	3280.6	18226

Bee plants form a large number of flowers (on one plant of Melilotus albus – 18226 pcs., *Borago officinalis* – 3881 pcs., *Nepeta cataria* spp. *citriodora* – 1493 pcs., *Trifolium* pratense – 495 pcs.) By improving saline fodder lands with wild honey bee plants, it is possible not only to increase the honey supply of the area, but also to preserve wild species.

Black alkali soils are found in large patches among other soil types. Profile structure of black alkali soil:

NEd 0-10 cm – humus-eluvial, dark grey, fresh, heavy loam, dusty-lumpy with a well-defined horizontal division, loose, coarsely porous, many roots, clear transition;

Eh 11-22 cm – eluvial, light grey, slightly humified, fresh, heavily loamy, lamellar, coarsely porous, many roots, sharp transition;

Ih 23-40 cm – illuvial, brownish-dark grey, fresh, medium clay, columnar-prismatic, dense, finely fissured, separate roots, gradual transition;

PIhk 41-65 cm – transitional, illuviated, light grey with a brown tint, dark brown in the lower part, light clay, nutty-prismatic, compacted, slobose, carbonates from a depth of 42 cm, some thin roots, gradual transition;

Pk(h) 66-86 cm – green-grey slightly humic clay, lumpy, compacted, slightly porous, gradual transition;

Pks 86 and deeper – greenish-grey clay, oily, from a depth of 87 cm – salts in the form of fades, from a depth of 130 cm – small gypsum druses and salt veins.

The description of the alkaline soil profile shows that it is strictly divided into eluvial (supra-salt) and illuvial (alkaline) horizons. In terms of the depth of occurrence of illuvial (alkaline) soil, it should be classified as deep.

The upper horizon is characterised by a reduced content of mobile forms of nitrogen, phosphorus, and potassium due to their leaching. The physical properties of alkali soils are unfavourable for plants. The alkaline horizon is very dense in the dry state, while in the wet state it is viscous, swells and becomes impermeable to water.

The results of phenological observations and determination of green mass productivity showed that its yield is directly dependent on the length of shoots, volume and length of root mass. Thus, in white Melilotus albus, the volume of the root system was 82 ml, the length of the root system reached 28 cm and the plant reached 100-110 cm in height (Table 4). In the year of sowing, the plants of the Psathyrostachys juncea had a root system volume of 16 ml with a length of 25 cm reaching 86 cm in height. Accordingly, the yield of the green mass of Melilotus albus was 20.5 t/ha, and of Psathyrostachys juncea – 12.8 t/ha.

Table 4. Bio-agronomic characteristics of fodder plants on black alkali soils

Plant names	Shoot length, cm		Inflorescence length, number of spikelets and whorls			Root mass*			Yield, t/ha		
	Generative	Vegetative	Inflorescence, cm	Spikelets, pcs.	Whorls, pcs	*V*, ml	*H*, cm	*L*, cm	Green mass	Dry mass	Seeds
Psathyrostachys juncea	85.75	36.73	12.6	33	-	16.2	0-25	25	12.8	3.1	0.47
Elytrigia elongata (Host) Nevski	82.65	25.6	22	14	-	5	0-18	18	10.8	3.8	1.36
Leymus racemosus	87.13	49.9	25.7	30	-	35	0-25	25	9.8	3.9	1.85
Festuca arundinacea	70.48	31.32	28.6	-	15	-	-	-	10.1	2.6	1.25
Elymus repens	56.4	19.1	10.5	13	-	3.6	3-10	14	6.1	2.7	1.09
Melilotus albus	101.6	-	-	-	-	82	3-16	28	20.5	8.6	-
Melilotus wolgicus	72.9	-	-	-	-	-	-	-	7.4	3.3	-

Notes: *V* – volume of root mass; *H* – depth of accumulation of the main body; *L* – length in the second year of vegetation

The analysis of the data on dry mass yield showed that despite the lower levels of green mass compared to the Psathyrostachys juncea, more dry mass was obtained by *Elytrigia elongata* (Host) Nevski and Leymus racemosus – 3.1 and 3.8-3.9 t/ha, respectively, and the maximum value was obtained in the variant with Melilotus albus – 8.6 t/ha.

Similar patterns are also observed for seed yields: Psathyrostachys juncea – 0.47 t/ha, *Elytrigia elongata* (Host) Nevski – 1.36 t/ha, Leymus racemosus – 1.85 t/ha.

The seed productivity of the Psathyrostachys juncea, *Elytrigia elongata* (Host) Nevski and Leymus racemosus was the highest in the third year of life, and that of the *Festuca arundinacea* in the fourth year. Optimal yields of grasses on the black alkali soil were observed in Elytrigia repens in the second and third years, Psathyrostachys juncea and *Elytrigia elongata* (Host) Nevski in the third and fourth years, in *Festuca arundinacea* in the third and fourth years, and in Leymus racemosus in the fourth and fifth years. In the following years of vegetation, the

productivity of these grasses decreases gradually and more significantly in *Festuca arundinacea*.

CONCLUSIONS

During the observation period, the yield of green mass and hay on all variants was significantly higher than the yield of natural herbage. On average, over three years, the yield of the green mass of *Medicago sativa* was 37.3 t/ha, *Trifolium* – 37.3 t/ha, grass mixture No. 1 – 40.7 t/ha, grass mixture No. 2 – 41.7 t/ha. The yield of dry mass (hay) was as follows: *Medicago sativa* – 7.73 t/ha, *Trifolium* – 7.64 t/ha, grass mixture No. 1 – 9.32 t/ha, grass mixture No. 2 – 9.70 t/ha, *Medicago sativa* + *Trifolium* – 10.74 t/ha.

In terms of crude protein content, the highest protein crops are *Bunias orientalis* and *Medicago romanica* (17-28%); medium protein crops (12-16%) are *Isatis tinctoria* and *Medicago sativa* (12-16%); all others are low protein crops (8-11%). Brassicaceae and *Trifolium* pratense have the highest content of carbohydrates and vitamin C, while *Medicago sativa* and *Medicago romanica* have the highest content of essential amino acids.

Studies of sowing bee grasses on the hygromorphic meadow salt marsh revealed that the highest nectar content was found in *Melilotus officinalis* – 3280.6 kg/ha, *Borago officinalis* – 776.2 kg/ha and *Nepeta cataria* spp. *citriodora* – 350.9 kg/ha. The yield of green mass of fodder grasses is directly related to the length of shoots, volume and length of the root mass. The yield of green mass was 12.8 t/ha for Psathyrostachys juncea, and 20.5 t/ha for Melilotus albus. For the cultivation of *Elytrigia elongata* (Host) *Nevski* and *Leymus* racemosus, a dry weight of 3.8-3.9 t/ha was obtained, and the maximum value was found in the variant with *Melilotus albus* – 8.6 t/ha. Seed yield: *Psathyrostachys juncea* – 0.47 t/ha, *Elytrigia elongata* (Host*) Nevski* – 1.36 t/ha, Leymus racemosus – 1.85 t/ha.

Given the low fertility of saline soils and their poor aeration, the arrangement of permanent hayfields and pastures on them is not rational. It is recommended to introduce meadow-field (2-3 field crops, 5-7 grass crops) crop rotations. To improve the productivity and value of fodder lands on saline soils, honey plant species should be introduced – *Borage officinalis*, *Nepeta cataria* spp. *citriodora*, *Trifolium* pratense, *Melilotus albus*.

The following should also be applied to alkali soils: *Melilotus albus*, *Melilotus wolgicus*, *Psathyrostachys juncea*, *Leymus racemosus*, *Festuca arundinacea*, *Elytrigia repens*, *Elytrigia elongata* (Host) *Nevski*, which go through a full development cycle on alkali soil algae.

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Підвищення біологічної продуктивності засолених та ерозійно небезпечних земель донецької області шляхом залуження

Анотація. Досліджено ґрунтовий покрив та стан природного травостою засолених та ерозійно небезпечних земель долинно-балкової системи р. Сухі Яли. Малопродуктивні засолені землі розташовані на схилах і днищах балок, мікрозападин низинних і заплавних лук. Рослинні угруповання, пов'язані з такими ґрунтами, характеризуються низьким видовим різноманіттям і відсутністю цінних для кормів видів. У статті представлено результати досліджень щодо поліпшення малопродуктивних земель на засолених ґрунтах шляхом посіву комплексу кормових трав, які здатні рости в умовах засолених ґрунтів і мають високу кормову цінність. Встановлено, що за період спостережень урожайність зеленої маси та сіна на всіх варіантах була значно вищою, ніж на природному травостої. Біохімічний склад кормових трав характеризується підвищеним вмістом сирого протеїну, вуглеводнів, вітаміну С та незамінних амінокислот. Наведено дані щодо інтродукції бджолоносних трав для поліпшення засолених кормових угідь у поєднанні з дикорослими бджолоносіями та визначено їх нектароносність. Наведено біолого-агрономічну оцінку вирощування кормових рослин на чорноземі вилугуваному. Надано рекомендації щодо поліпшення кормових угідь на засолених і солонцюватих ґрунтах

Ключові слова: малопродуктивні та ерозійно небезпечні землі, гідроморфне лучне солончакове болото, чорнозем солонцюватий, кормові трави, луківництво