IMPACT OF THE METHODS OF SURFACE IMPROVEMENT ON THE PRODUCTIVITY AND NUTRITIONAL QUALITY OF THE PASTURE GRASS IN THE STEPPE ZONE OF THE AKMOLA REGION

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Abstract

The paper presents the effect of different improvement methods on the productivity and herbage quality of degraded pastures in the Akmola Region, Kazahstan. The experiment was conducted during the 2014–2015 period, including 12 variants in three replications. The essence of the research consisted in studying the composition of plant communities, the formation of green mass and dry matter yields, the changes in the chemical composition of the soil under the influence of tillage by disk and drag harrow and application of mineral fertilizers, as well as analysis of the changes in the chemical composition of the herbage. The results showed that the methods usedfor surface improvement had positive effectson the level of available nutrients in the soil. Green mass and dry matter yields as well as herbage quality increased significantly after tillage and mineral fertilizing.

Key words: grasslands, fertilization, herbage quality, productivity, tillage.

INTRODUCTION

The total area of the Republic of Kazakhstan is 2,724,900 km^2 where as meadows and pastures occupy approximately 188.7 million hectares and their share of the agricultural land exceeds 7.5 times that of arable land. There are approximately 6.5 million hectares of pastures in the Akmola region. Most of these existing pastures have no access to water due to their locations thus significantly reducing the possibilities for cattle breeding. Only around 30% of all pastures are used for grazing as the other areas are completely dry (Filatova et al., 2014). As a result of this, these pastures are highly degraded because of the overgrazing that affects adversely the regeneration capacity of phytocenosis, and the upper soil layer is compacted, especially in the spring and in the autumn when the soil is temporarily in a state of water logging (Mojaev and Serekpaev, 2014).

In this regard, there is a need to increase the productivity of natural grasslands and also to use different techniques to maintain their long term productivity. All of these applied to grasslands are commonly referred to as “improvement” (Rusanov, 2015). The most important factor that affect yield and quality of pastures is fertilizing because of positive change of soil agrochemical characteristics (Ciobanu et al., 2012; Chinea and Arévalo, 2014; Hejduc, 2015).

The development of evidence-based methods to improve grasslands is possible with integrated observations, assessment and prediction of degradation processes occurring in the pastures of different soil-climatic zones of the country, in other words – using agro-ecological monitoring of natural pastures.

MATERIALS AND METHODS

The experiments were conducted in “Baimyrza Agro” LLP (village of Birsuat), which is in the Enbekshilder district of Akmola region in the period 2014–2015. Subjects of study were natural pastureson dark brown soil, located 5 km away from the village. Different types of mineral fertilizers and tillage was carried out using modern and traditional equipment in the spring of the first year of studies. The fertilizers were applied by grain stubble seeder (SZS-2,1), equipped with a sharpened iron pipe on paw planter in order not to damage the pasture sod. The area of the experimental plot was 126 m^2. The experiment was in three replications.

Experiment included the following 12 variants: 1) Control (without tillage and fertilizers); 2) Tillage by disk harrow; 3) Tillage by drag harrow; 4) No till + N; 5) Tillage by disk harrow + N; 6) Tillage by drag harrow +N; 7) No till + P; 8) Tillage by disk harrow + P; 9) Tillage by drag harrow + P; 10) No till + N + P; 11) Tillage by disk harrow + N + P; 12) Tillage by drag harrow + N + P.

For the experimental purposes John Deere 2600 disk harrow and drag harrow BIG-3A were used. The 45 kg/ha nitrogen and 150 kg/ha phosphorus was applied using nitrogen-containing (NH_4NO_3) and phosphorus-containing ($Ca(H_2PO_4)2{\cdot}H_2O+2CaSO_4$) fertilizers.

The essence of the research consisted in studying the composition of plant communities, the formation of grass productivity on the grasslands, the changes to the chemical composition of the soil under the influence of different methods of treatment of the sod and import of mineral fertilizers, as well as analysis of the changes in the chemical composition of the herbage.

Work was carried out in accordance with the methods for experimentation on grasslands and pastures (Ramensky, 1997). The doses of imported mineral fertilizers were calculated on the basis of actual and optimal nutrient content of the soil (Chernenok, 2009). Fertilizers were importing using SZT-3.6 grain/herb planter. The count of plants, the determination of the level of ground phytomass and the collection of plant samples for chemical analysis were carried out on sections of 1 m x 1 m. A special tool was used for the chemical analysis of the soil taking a compound sample of 1 kg consisting of five samples taken from the same section. Nitrate nitrogen content of the soil was determined according to Sdobnikova's method; the concentration of mobile mineral phosphorus and potassium was determined according to Machigin's method as modified by CINAO, and the humus content was determined according to Tyurin's method according on theoxidationof organic matter.

Statistical calculations were performed using Excel 2010, Statistica.

RESULTS AND DISCUSSION

The weather conditions for the growth of perennial grasses on natural pastures (weather station of Stepnyak) were different in the studied period.

In 2014, the average daily air temperature during the winter months (January, February) were lower (-16.4 °C and -18.0 °C) compared to the average annual rates (-2.1 °C and -6.2 °C).

The relatively low temperatures persisted in March and April with -5.2 °C and +6.4 °C (as compared to annual average values -3.5 °C and +9.3 °C). In May, the temperature slightly exceeded (+14.0 °C) the annual average value (+13.1 °C) with daytime temperature of +15.2 °C falling to -1.5 °C during the night that affected negatively the growth of perennial grass on natural pastures. Low daily average temperatures with sudden changes between daytime (+14.2 °C) and nighttime (+1.7 °C) continued through the first ten days of June, but during the following three weeks they exceeded the average long-term values and that subsequently had a positive impact on the growth and development of perennial grass. In July, the daily averages by ten-day periods were lower than the annual average with +9 °C (+16.4 °C and +25.4 °C annual average).

Over the whole period precipitations were unevenly distributed. During the winter months (January, February) of 2014, the precipitations exceeded the annual averages by 1.5 to 2 times (in January with 30.3 mm compared to annual average of 19.0 mm, and in February with 29.0 mm compared to 14.0 mm annual average). In March and in May, the precipitations reached the annual average level (17.7 mm and 30 mm respectively) while in April they exceeded by 1.7 times (34.7 mm compared to annual average of 20.0 mm). In June there were 29.8 mm of rain (annual average 41.0 mm) and July fell 80 mm, 28 mm more than the annual average value.

To the difference of 2014, in 2015 there was no significant difference in comparison with the annual average precipitations. The daily average temperatures during the winter months were at the level of the annual average values with 14.7 °C in January and 11.4 °C in February. In April the daily average temperature was +3.9 °C whereas the annual average value for this month is +9.3 °C. The temperature remained stable in May with +13.6 °C. The situation was similar in June: with annual average temperature of +19.4 °C in 2014 it was +19.6 °C. Slightly cooler was July with an average of +17.8 °C (annual average +25.4 °C).

While in 2014 the second half of the grass vegetation period happened to be rainy, with some dry conditions in July, in 2015, starting from April through July there was enough rain although in August it decreased. In January, February, March and April precipitation levels hardly differed from the annual average values: 24, 9.9, 15 and 15 mm respectively. In May there was 32 mm more rain than the annual average (63 mm). In June, the precipitations exceeded the multiannual average by 17 mm (58 mm) and in July by 14 mm (66 mm).

These better moisture conditions later played a positive role in the formation of perennial grass productivity.

The discussions in the article are connected with the results forplant and soil resources after applying different rates of N and P and carrying out two types of surface treatment of the upper soil layer in the spring of 2014.

Initially, the chemical analysis of the soil from the studied section of the pasture showed low content of available nutrients (tabl. 1).

Table 1. Content of available nutrients in the soil of the experimental fields

№	Variants	Nutrients				
		$N\text{-}NO_3$ mg/kg	P_2O_5 mg/kg	K_2O mg/kg	Humus, %	pH
May 2014						
1.	Control	> 4	10,01	410	2,7	8,67
May 2015						
1.	Control	<4	9,95	525	4,3	7,05
2.	Tillage by disk harrow	<4	9,69	524	3,9	7,12
3.	Tillage by drag harrow	<4	9,07	438	3,5	7,14
4.	No till + N	8,5	9,47	355	3,4	7,19
5.	Tillage by disk harrow + N	9,8	8,94	314	3,3	7,20
6.	Tillage by drag harrow + N	9,3	9,46	534	3,4	7,23
7.	No till + P_2O_5	9,9	10,07	386	3,5	7,20
8.	Tillage by disk harrow + P_2O_5	5,4	10,19	402	3,8	7,19
9.	Tillage by drag harrow + P_2O_5	13,1	13,92	551	3,7	7,21
10.	No till + N + P_2O_5	10,4	10,39	403	3,7	7,19
11.	Tillage by disk harrow + N + P_2O_5	16,9	11,95	477	3,2	7,22
12.	Tillage by drag harrow + N + P_2O_5	14,4	14,66	456	3,5	7,20

Chemical analysis of the soil showed that in terms of nitrate nitrogen content in the 0-40 cm layer the studied soils would be classified as very poor, and poor in terms of mobile phosphorus and humus content, but rich in exchangeable potassium. In terms of acidity, that soil is medium alkaline.

Reanalysis one year after mineral fertilizing showed positive dynamics in the content of available nutrients in the soil. It appeared that in variants without import of fertilizers the nitrate nitrogen content of the soil had not increased at all (< 4 mg per kg of soil) while with import of N it had increased by 8.5 to 9.8 mg/kg (medium provision), and in variants with P application the level of nitrate nitrogen in the soil had also increased from low to medium, i.e. from 5.4 to 13.1 mg per kg of soil. The highest increase in the nitrate nitrogen content of the soil in the positive direction was observed in variants with N+P application: between 10.4 and 16.9 mg/kg. In terms of phosphorus availability, the values vary in a wide range between 8.94 and 14.66 mg/kg. Increased content of mobile phosphorus characterizes the variants with import of mixed nitrogen and phosphorus containing fertilizers: between 10.39 and 14.66 mg/kg. Lowest phosphorus content in the soil was observed in the variant with tillage using John Deere and introduction of nitrogen. Although potassium containing fertilizers were not used, the potassium content of the soil slightly increased from 410 mg/kg in 2014 to 441 mg/kg in 2015. Humus content also increased from 2.7% to 3.6%.These results were according to (Hejduc, 2015) found significant differences between some agrochemical soil characteristicsafter application of mineral fertilizers in pastures.

The observation of the plant at the first stage of study revealed that crested wheatgrass (*A. cristatum)* was the most frequently found in all variants because of its best adaptation to dry rangeland conditions. In all variants the crested wheatgrass was presented with high numbers with an average of 58 plants per m² but in terms of chemical composition the quality of these plants was not high (fig. 1).

The monitoring of changes in the number of plants on different variants, depending on the introduction of different mineral fertilizers and on the use of different types of sod treatment in 2015, showed that the number of crested wheatgrass plants had grown already during the first year of study compared to the values of the control spring selection of plant samples in average from 58 to 77 plants per m². The highest number of crested wheatgrass was found in the variant with use of P without sod tillage (120 per m²) but this is not always corresponded with pasture productivity because different methods of improvement affect not only the number of plants but stimulate plant tillering, too.

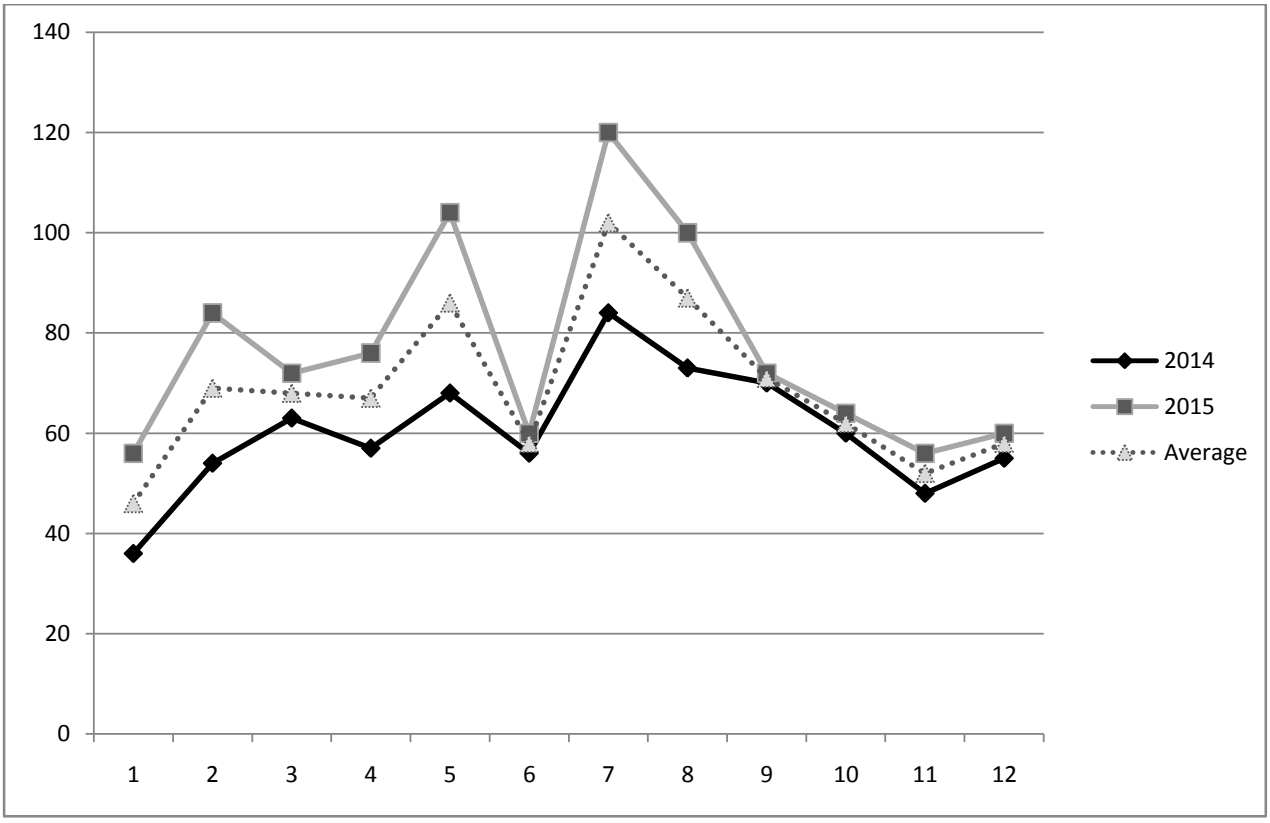

Fig. 1. *Number of Agropyron cristatum* L. *Gaertn.* plants/m^2

During the studied period the fertilizers and tillage had apositive effect on the green mass and dry matter yield (tabl. 2 and tabl. 3). The productivity of the grass pastures varied among the variants and years. In 2014, the green mass yieldsvaried from 1810 kg/ha (control) to 2310 kg/ha (no till+N). The green mass yield observed in all variants were above the control with statistically significant differences. In 2015, the maximum green weight mass was observed in the variants with tillage (by disk harrow and drag harrow) and application of N+P (2370 kg/ha and 2520 kg/ha, respectively; high values were also observed in the variants with application of phosphorus containing fertilizers. The green mass weight was lowest in the variant without fertilizers and without tillage (1820 kg/ha).

The same tendency was observed in dry matter yields. Tillage and mineral fertilization increased dry matter yield significantly during the studied period. The average dry matter yield increased from 536 kg/ha (control) to 649 kg/ha (notill+N+P).

The results showed that tillage combined with mineral fertilization leads to improved yields of degraded pastures may be due to improved soil texture and characteristics.

The dates about chemical composition of the herbage are presented in table 4. The results showed that the tillage combined with fertilization had positive effect on herbage quality (protein, fiber, fat and etc.). Comparative analysis of the chemical composition of herbage from different variants showed the immediate effect of mineral fertilizers. Compared to the control for all indicators positive dynamics was observed: protein content increased from 2.9 to 7.5% (treatment by disk harrow with application of N) fat - from 1.1 to 1.7%, and feed units - from 0.19 to 0.23 (tillage by disk harrow + N + P_2O_5).

The cellulose content of the plants decreased from 21.8% (control) to 13.9 (treatment using John Deere disk harrow and nitrogen containing fertilizers). However, the large amount of fibers reduces the nutritional value of feed. The younger the plant, the lower the fiber content, which leads to the conclusion that the studied methods of pasture improving have rejuvenation effect on the plants (compared with the control one).

Table 2. Green mass yield (kg/ha)

№	Variants	2014		2015		Average	
		Green mass yield		Green mass yield		Green mass yield	
		Kg/ha	%	Kg/ha	%	Kg/ha	%
1.	Control (without tillage and fertilization)	1810	100	1830	100	1820	100
2.	Tillage by disk harrow	2000	110	2250	122	2125	116
3.	Tillage by drag harrow	2100	116	2300	126	2200	121
4.	No till + N	2310	128	2490	136	2400	132
5.	Tillage by disk harrow + N	1900	105	1930	105	1915	105
6.	Tillage by drag harrow + N	1880	104	2260	123	2070	114
7.	No till + P_2O_5	2050	113	2560	140	2505	126.5
8.	Tillage by disk harrow + P_2O_5	1870	103	2490	136	2180	119.5
9.	Tillage by drag harrow + P_2O_5	2230	123	2410	132	2320	127.5
10.	No till + N + P_2O_5	2200	121	2430	133	2315	127
11.	Tillage by disk harrow+ N + P_2O_5	2070	114	2370	129	2220	121.5
12.	Tillage by drag harrow + N + P_2O_5	2150	119	2520	137	2335	128
	LSD – 5%	**40**		**56**		**48**	

Table 3. Dry matter yield (kg/ha)

№	Variants	2014		2015		Average	
		Dry matter yield		Dry matter yield		Dry matter yield	
		Kg/ha	%	Kg/ha	%	Kg/ha	%
1.	Control (without tillage and fertilization)	479	100	593	100	536	100
2.	Tillage by disk harrow	500	104	681	115	590	110
3.	Tillage by drag harrow	500	104	675	114	588	109
4.	No till + N	566	113	597	101	582	107
5.	Tillage by disk harrow + N	550	115	650	110	600	112.5
6.	Tillage by drag harrow + N	580	121	682	115	631	118
7.	No till + P_2O_5	532	111	641	108	587	109.5
8.	Tillage by disk harrow + P_2O_5	567	118	684	115	626	116.5
9.	Tillage by drag harrow + P_2O_5	565	118	659	111	612	114.5
10.	No till + N + P_2O_5	551	115	747	126	649	120.5
11.	Tillage by disk harrow + N + P_2O_5	490	102	690	116	590	109
12.	Tillage by drag harrow + N + P_2O_5	504	105	648	109	576	107
	LSD – 5%	**19**		**14**		**17**	

Table 4. Chemical composition of the herbage

№	Variants	Protein, %	Fat, %	Fiber, %	Feed unit
1.	Control	2,9	1,1	21,8	0,19
2.	Tillage by disk harrow	3,2	1,3	14,5	0,19
3.	Tillage by drag harrow	5,0	1,3	20,9	0,21
4.	No till + N	4,9	1,3	20,6	0,20
5.	Tillage by disk harrow + N	3,8	1,4	13,9	0,18
6.	Tillage by drag harrow + N	7,5	1,3	21,8	0,20
7.	No till + P_2O_5	4,2	1,1	16,3	0,16
8.	Tillage by disk harrow + P_2O_5	4,1	1,3	15,9	0,17
9.	Tillage by drag harrow + P_2O_5	5,4	1,4	18,2	0,20
10.	No till + N + P_2O_5	4,9	1,4	19,7	0,20
11.	Tillage by disk harrow + N + P_2O_5	5,5	1,7	21,3	0,23
12.	Tillage by drag harrow + N + P_2O_5	4,9	1,5	18,2	0,21

CONCLUSIONS

1. The use of methods for surface improvement such as tillage and application of mineral fertilizers shows positive trends for the level of available nutrients in the soil. The nitrate nitrogen content after application of mixed nitrogen and phosphorus containing fertilizers has increased from 4 to 10.9 mg/kg (maximum 16.9 mg/kg with tillage by disk harrow combined with N+P fertilizing). The available phosphorus content increased slightly, in average by 10.01 mg/kg to 10.65 mg/kg of soil (up to 14.66 mg/kg of soil after introduction of nitrogen and phosphorus containing fertilizers).

2. During the second year of study, the number of crested wheatgrass plant increased (to the difference of 2014) from 58 to 77 per m² (maximum observed in the variants with introduction of phosphorus containing fertilizers).

3. Green mass and dry matter yields increased significantly after tillage and mineral fertilizing.

4. A positive trend was also observed in the chemical composition of the herbage: protein content increased from 2.9% (control) to 7.5% (tillage by disk harrow + N); fat content increased from 1.1% (control to 1.7% (tillage by disk harrow + N + P_2O_5) and cellulose content dropped from 21.8% (control) to 13.9% (tillage by disk harrow + N).

5. Kazakhstan resources showed high values that allow fullest use of the potential of hayfields and pastures. The improvement of natural grasslands will provide the opportunity to produce sufficient quantities of cheap, high-quality roughage, which in turn will accelerate the development of stock-breeding and improve its profitability.

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