Bulgarian Journal of Agricultural Science, 29 (No 5) 2023, 917–924

Methods to improve degraded grass stands of crested wheatgrass (*Agropyron pectiniforme*) in northern-eastern steppe zone of Kazakhstan

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Abstract

Kukusheva, A., Kakezhanova, Z, Uakhitov, Zh., Sarbasov, A. & Nasiyev, B. (2023). Methods to improve degraded grass stands of crested wheatgrass (*Agropyron pectiniforme*) in northern-eastern steppe zone of Kazakhstan. *Bulg. J. Agric. Sc., 29*(5), 917–924

The article provides information on the study of the impact of surface treatment with mechanized tools on degraded grass stands of crested wheatgrass *(Agropyron pectiniforme*) in the arid climate of Northeast Kazakhstan. Due to the extensive root system, wheatgrass, in a short time, forms a solid sod layer; at the same time, from year to year, grass density increases several times, reducing the feeding area of wheatgrass to a minimum and, as a consequence, the fresh yield decreases. Grass stand of wheatgrass can remain in one locality for more than 10-20 years. The longevity of the wheatgrass is explained by its high drought and winter hardiness and good vegetative and seed regeneration of the herbage. Moreover, the stubble residues of perennial wheatgrass greatly enrich the soil with humus. According to the data obtained, mechanized tillage reduced soil density, improving its water permeability and increasing the productive moisture reserves in the soil (by 5.6-18.6 mm). As well as, mechanized tillage influenced the nutrient and air regimes by destroying the dense sod layer, loosening the soil, and creating an optimal feeding area for plants, increasing, in their turn, the yearly grass density by 12-37 pcs/m^2. These methods had a positive impact not only on soil indicators but also on the fresh yield of wheatgrass: when using soil spiker and disc harrow, it averaged for two years 1.76 and 1.85 t/ha, respectively; when using heavy disc harrow – 2.81 t/ha and 2.59 t/ha, compared with the control – 0.82 t/ha.

Keywords: crested wheatgrass (*Agropyron pectiniforme*)*;* tillage; degraded crops; soil fertility; fresh yield and hay yield

Introduction

According to the FAO synthesis report on the state of the world's land and water resources, 35% (1660 million ha) of all agricultural land in the world shows signs of anthropogenic degradation (FAO, 2021). At the same time, the restoration of these lands and improvement of their productivity are limited by erosion processes, reduction of soil carbon, nutrients and diversity of soil organisms. The report also indicates that from 2000 to 2019, there was a significant reduction in rangeland worldwide by 191 million hectares, of which 13% is caused by human-induced degradation and 34% by overgrazing, which negatively affects vegetation cover and physical soil properties, as also confirmed by other researchers (Akiyama & Kawamura, 2007; Han et al., 2008; Gang et al., 2014).

The issue of grassland degradation is also relevant for Kazakhstan since the main branch of agriculture in the country is cattle breeding (horse breeding, sheep breeding). According to the Ministry of Agriculture of Kazakhstan, as of November 1, 2021, 83.5% (178816.6 thousand ha) of all agricultural land in the country falls on the rangelands (Ministry of Agriculture of the Republic of Kazakhstan, 2021). Assessment of rangelands in 2021 revealed several causes of degradation: overgrowth with shrubs (10.6%) and forest (1.8%), overgrowth with feather grass (*Stipa capillata* L.) (4.3%), presence of mounds (0.9%) and stones (2.6%) and run-down of grasslands (15.1%). Moderate to severe run-down grassland accounts for 27.1 million hectares. Rangeland degradation occurs when high-value fodder grass stand is replaced by low-yield, non-edible, and annual plant species, which is caused by climate change leading to aridity and irrational human economic activity. Such a change in the vegetation cover of rangelands leads to a reduction in their productivity and to a narrow seasonal focus of their use, which in turn leads to a decrease in the number of animals in the wild and overgrazing on the remaining rangelands.

It is believed that the natural restoration of rangelands, provided moderate grazing is observed, is more cost-effective than the artificial creation of rangelands by sowing forage grasses. An important ecological role of improving natural grass stands in arid climates is that natural steppe vegetation maintains rangeland biodiversity and reduces soil erosion (Asefa et al., 2003). In addition, carbon sequestration in seeded fodder plants, which is higher in at-ground biomass and less in underground, is still lower than in natural steppe vegetation (Strategic measures to combat desertification in the Republic of Kazakhstan until 2025, 2015).

Grasslands are good for fixing and accumulating carbon in the soil, and further effective increase is possible through rangeland management (e.g., control over grazing intensity, increasing productivity, etc.) and restoration of degraded rangelands (O'Mara, 2012).

Intensive grazing on the semi-arid sandy Horkin rangelands in northern China led to the desertification of the area, which was reflected in a decrease in vegetation cover and plant litter accumulation, in deterioration of soil properties, and development of wind erosion, in reduction of carbon and nitrogen content, and microbiological activity of soils (Su et al., 2005).

In the territory of Western Kazakhstan in the semi-desert zone, researchers noted that under intensive grazing, there is a reduction in vegetation cover of valuable fodder grasses by 35% and a decrease in rangeland productivity by 72.1%, a decrease of humus reserves by 17.78%, an increase in soil density by 13.11% (Nasiyev et al., 2020). The moderate grazing technology proposed by the authors implies using only 65-75% of the plants in the grazing season, which will allow the grasses to recover their vitality after grazing without a significant decrease in yields year by year (Nasiyev et al., 2020). This method increases humus content by 0.41%, available phosphorus by 46.15%, structures the soil and reduces soil density by 11.29% (Nasiyev et al., 2022).

Under the conditions of the North-West Caspian area, restoration of degraded rangelands was studied by the method of phytocenotic supplementation, which consists in identifying and selecting the necessary phytomeliorants absent in the studied agrophytocenosis, able to withstand salinization and lack of moisture in the soil, and also suitable for feeding to animals. Ameliorative forage plantations of young shrubs and sub-shrubs (winterfat *(Krascheninnikovia ceratoides)*, wormwood (*Artemísia),* camphorosma (*Camphorosma*) and others) increase rangeland productivity by 7-8 times (Voronina & Vlasenko, 2011).

Under the conditions of the northern Far East, to improve low-yielding meadow agrophytocenoses, we used a bio-technological method that includes the application of necessary doses of mineral fertilizers, lime, grass seeding, and mechanized tillage of old-age meadows (discing, harrowing) in order to restore valuable species of local grasses due to their high responsiveness to the agronomic practices (Ivanova, 2015).

Since the Northeast of Kazakhstan (Pavlodar region) features massive forage lands, many of which are more than 20-25 years old, the rangeland restoration is of crucial importance. Today, due to the lack of maintenance of crops, as well as annual intensive use (haymaking, rangeland), these agricultural lands are severely degraded. According to its economic properties, the main crop for the steppe areas of Pavlodar region both for hay-making and cattle grazing is crested wheatgrass *(Agropyron pectiniforme).* Its clean and strip sowing in fallow fields was one of the elements of soil protection from wind erosion, especially in dry years.

Wheatgrass is a perennial herbaceous plant that belongs to the *Gramineae luss* grass family, *Agropyron Gaerth* genus, *Eu-agroyron Nevski* subgenus. In the wild, this subgenus is represented by relatively low diversity and amount (Velichko, 2006).

Grass stand of wheatgrass can remain in one locality for more than 10-20 years. The longevity of the wheatgrass is explained by its high drought and winter hardiness and good vegetative and seed regeneration of the herbage. Moreover, the stubble residues of perennial wheatgrass greatly enrich the soil with humus.

Wheatgrass has high fodder value. The wheatgrass hay has a high nutritional value: 1.9 kg of wheatgrass hay is equal in nutritional value to 1 kg of oat grain. The wheatgrass hay is high in protein, minerals (especially calcium and silicon), and vitamins (Ostrikova, 2021).

Thus, the sowing of perennial wheatgrass is very valuable in terms of the ecological aspect of the Pavlodar arid region, as it solves the problems of preventing soil degradation to the greatest extent in connection with providing fuller compliance with agro-ecological requirements of crops and their environment-forming influence (Irmulatov et al., 2016).

Due to the extensive root system, wheatgrass, in a short time, forms a solid sod layer; at the same time, from year to year, grass density increases several times, reducing the feeding area of wheatgrass to a minimum and, as a consequence, the fresh yield decreases.

Therefore, splitting this root mass into small pieces with tillage tools will enable the new root systems of the wheatgrass to form young root hairs that will produce new shoots.

Materials and Methods

The use of science-based methods and techniques to improve grass stands will help to restore and recover degraded rangelands.

In this regard, the purpose of this research is to study the effect of different methods of surface improvement on degraded wheatgrass crops to restore them and increase their productivity.

The objects of the experiment were degraded areas with dense planted wheatgrass of Karabalyk 202. The research was conducted in 2021-2022 on the territory of Zamandas farm in the Irtysh district of Pavlodar region (Northeast Kazakhstan).

The soils of the experimental plot are southern carbonate chernozems. According to the precipitation ratio of the study area, the zone is characterized as very arid, i.e., the main limiting factor for yields is the lack of moisture. The climate is sharply continental. Springs and falls are short, with extremely erratic temperatures, with sharp fluctuations from warm to cold and often from hot to freezing. Summers are hot and dry and winters are cold and snowy. The annual precipitation is 250-310 mm. Maximum precipitation falls in the second half of summer.

Experimental design

Option 1 – No tillage (control);

Option 2 – Tillage with a tooth harrow (tool brand Zig-Zag);

Option 3 – Tillage with a soil spiker (tool brand BIG-3A);

Option 4 – Tillage with a disc harrow (tool brand LDG-10);

Option 5 – Tillage with a heavy disc harrow (tool brand BD-5);

Option 6 – Tillage with a disc harrow (high-speed harrow).

All tillage methods on degraded wheatgrass lands were carried out on the same day (June 12, 2021).

When working with a tooth harrow on degraded wheatgrass lands, it was noted that every 10-15 m the tool was clogged with dead plant residues and required constant cleaning, increasing the labor intensity of such tillage. In addition, on bumpy surfaces, the harrow only glides on the surface, not going deep into the surface soil layer, or on compacted areas, loosens the soil to a depth of only 3-5 cm, also the harrow tines pull out most of the living plants, cut and break off some surface roots of the mother plants.

The soil spiker was used in the «active» mode, each needle entering the soil to a depth of 7-10 cm and not only loosening the soil, but also breaking the root system of wheatgrass. After the tillage, the field was partially black, and a week later there were strong sprouts of wheatgrass.

The use of a disc harrow showed that they undercut part of the stems and surface roots, but even changing the angle of attack by 25% does not lead to a significant improvement or better loosening; discs undercut only part of the plants.

The purpose of using heavy disc harrows was to create better conditions for the young roots to grow and to better aerate the soil for optimum air access when cutting vertically the old roots of the wheatgrass. The tillage stages showed that after the heavy discs the field became black. Approximately 10 days after the tillage, individual sprouts of wheatgrass began to appear over some of the field.

As the practice of degraded wheatgrass tillage showed, the disc harrow perfectly works on sodded grasslands. Due to the double-row arrangement of the spherical discs with a certain angle, as well as the high-speed movement of the discs, dense bushes (clones) of wheatgrass are well broken into separate parts, especially last year's bushes. In about 10-12 days, the first sprouts of wheatgrass were observed.

Counts and observations of plants in the crop rotation were carried out following the field experiment method by B.A. Dospekhov (Dospekhov, 1985). The experiment was conducted in triplicate. The area of the record plot is 100 m^2.

To determine the soil density, samples were taken at the beginning of wheatgrass regrowth in the 0-30 cm layer, in layers every 10 cm.

Soil density (d) was determined with the help of a structural sampling tube. Under field conditions, undisturbed soil samples were taken in metal cylinders, which allows us to determine the density of the soil in natural composite.

Density of the soil (d, g/cm^3) is calculated by formula (1):

$$d = (SM * C_h) / V \quad (1)$$

where d – is the soil density, g/cm^3; SM – is the soil mass, g; C_h – is the hygroscopic coefficient; V – is the cylinder volume, cm^3.

The soil samples were taken, and productive moisture reserves were assessed in the 0-100 cm layer during the beginning of the wheatgrass regrowth.

Calculation of productive moisture reserves (PMR) in the soil was carried out in millimeters per hectare according to formula (2):

$$PMR = 0.1 * h * d * (FSM – WM) \quad (2)$$

where d – soil density, g/cm^3; h – thickness of soil layer, cm; FSM – field soil moisture, %; WM – wilting moisture, %.

The yield structure was established by weight method before mowing the wheatgrass. The weight of stems, leaves, and inflorescences was determined, then the percentage of each fraction was calculated. The number of bushes per 1 m^2 in the period after mechanized grass stand tillage and at the end of vegetation in discontiguous replications in 2021-2022 was determined for the different options.

Soil samples were taken in the 0-30 cm layer for humus and nutrient content during full regrowth of the wheatgrass. Samples were analyzed in the laboratory of the Republican Scientific and Methodological Center of Agrochemical Service (Pavlodar): humus content by the method of I. V. Tyurin, mobile alkaline-hydrolysable nitrogen by the method of A. H. Kornfield, mobile phosphorus by the method of B. P. Machigin.

The fresh yield of the wheatgrass by options was determined in flowering period by the method of continuous accounting of fresh grass from the record plot of all replications. The hay yield was determined by weighing after drying the plants on plots till the moisture was 17%.

Correlation coefficients were calculated using Microsoft Excel 2010 to assess the significance of the relations between the indicators. The differences were considered statistically significant at $p < 0.05$.

Results and Discussions

The impact of the improvements primarily affected the density of the soil. The effective density of the topsoil for sowing wheatgrass is important for farming purposes. Plants tend to come into great contact with soil particles and develop a strong root system to the detriment of the aboveground vegetative mass due to extensively loose soil. On the contrary, the wheatgrass root system in too dense soil of the upper horizons, which very often dries out and plants do not get enough moisture. Only the optimal composition of the plow layer develops a normal root system that can take the nutrition from the upper and the moisture from the lower horizons.

The data presented in Table 1 shows when the topsoil stays intact the density of the soil on average in the layer 0-30 cm is 1.33 g/cm^3 which according to the scale of assessing the density of soils corresponds to a highly compacted soil. When the topsoil tilled with spike and tooth harrow the density decreases by 0.05 g/cm^3 (3.8%) in comparison with control, other options also decrease the soil density by 0.07-0.09 g/cm^3 (5.3-6.8%) according to the grading scale the soils in these options are compacted.

The uneven distribution of precipitation, typical for the north-east Kazakhstan climate determines the relatively often sharp aridity of spring and the first half of summer. Insufficient soil moisture, active eolation and low relative humidity during these periods inhibit plant growth and development. May and the first half of June are most often dry. This makes the growth and development of wheatgrass plants strongly dependent on the amount of accumulated moisture in the soil before sowing.

There is a gradual decrease in the content of productive moisture in the soil in spring, according to the data of I. L. Didenko and S. G. Chekalin. This is primarily due to the fact that the continued absence of deep tillage in the grass crops contributes to making the agrophysical processes of the soil direction towards its natural composition. Self-consolidation of the soil is combined with an increase in its density, hence with a decrease in water permeability. The more compact soil is not able to filter the existing moisture into the soil under short snowmelt conditions (Didenko & Chekalin, 2011).

Table 1. Soil density and productive moisture reserves depending on the methods of cultivation of degraded wheatgrass stands (second third of April – beginning of wheatgrass regrowth), average for 2021-2022).

Option	Soil density (in a layer of 0-30 cm), g/cm^3	Reserves of productive moisture (in a layer of 0-100 cm), mm
No tillage (control)	1.33	109.1
Tillage with a tooth harrow	1.28	114.7
Tillage with a soil spiker	1.28	119.9
Tillage with a disc harrow	1.26	117.2
Tillage with a heavy disc harrow	1.24	125.2
Tillage with a disc harrow	1.25	127.7

On average, two-year increases in productive moisture reserves by 5.6-18.6 mm were observed in all options with the tillage of degraded wheatgrass crops compared to the control (no tillage). More moisture was accumulated under tillage with disc harrow (by 14.8%) and high-speed disk harrow (by 17%) than in the control. This is due to the fact that the tillage with these tools not only loosens the soil, but also breaks the dense sod, thereby increasing its water permeability and reducing moisture evaporation from the soil surface. Moisture reserves evaluation in the one-meter layer shows that in the control and tillage with a tooth harrow the reserves are poor, in all other options the reserves are satisfactory. Thus, the moisture content rate will define the further growth of the crop and the formation of fresh yield.

The vegetation was disturbed grass regrowth was slow due to damage to the root systems because of first year of mechanized tillage (in 2021).

Wheatgrass roots are 0.3-1.0 mm diameter and thiner. Degraded crops of wheatgrass on the experimental site have shown, the abundant number of roots covers the upper soil horizons so completely that there is no free space (volume), not penetrated with it. The root mass of wheatgrass in the 0-20 cm horizon in the second year of wheatgrass life as follows (kg/ha air-dry weight): according to Krasnokutsk experimental station – 835, Saratov experimental station of animal husbandry – 1122, Kazakh Research Institute of Agriculture – 1050 (Velichko, 2006). Naturally, as plants age, root mass increases.

Evaluation of grass stand density (number of bushes per 1 m^2) showed that all types of mechanized tillage of degraded wheatgrass crops resulted in increase in the bushes per unit area in the improvement year (Table 2). Thus, by the end of the crop vegetation, there is a significant increase in the number of bushes of wheatgrass during the tillage with a high-speed disk harrow – 82.3%, which is explained by the increased feeding area of plants when cutting sod with discs, when part of the old wheatgrass bushes divided into parts and partially dies, while in their place young shoots begin to grow due to improvement of water and air regimes of the soil. In other options, the crop density increased not so significantly: by 40% in the tillage with a heavy disc harrow, in other options by 14.3-25.0%.

Increase in the number of bushes per unit area by 12-37 pcs/m^2 was observed in all options by the end of vegetation in the second year of research (2022). When comparing the grass stand density by years, a significant increase in 2022 of the number of bushes in options with the heavy disc harrow and high-speed disk harrow tillage was observed more than twice, the percentage of the grass stand density increase in these options was 119.3-123.8%, exceeding the control by almost 77.9-82.4%. The remaining options also show an increase in the bushes, compared with the option without tillage, by 41.9-54.7%.

Wheatgrass has a highly developed root system, penetrating the soil for the depth 2 m, in two years of vegetation can accumulate in the arable soil layer to 21 tons of root residues per hectare.

Extended grassing with perennial grasses increases the flow of fresh organic matter into the soil, thereby replenishing the soil with nutrients and carbon.

When assessing the humus content there was a variation by options from 3.51% (disc harrow tillage) to 3.89% (soil spiker tillage), while the percentage humus content of the control was 3.74%. Low humus content was observed in all options according to the humus content assessment scale. Ural Agricultural Experimental Station research showed that the growth of wheatgrass on the emergency field of the farming rotation increased the humus content in the 0-20 cm soil layer to 3.07%, and in the 20-40 cm layer to 2.7%. The humus content in the soil of the grain and fallow farming rotation was 2.5% in the 0-20 cm layer and 2.16% in the 20-40 cm layer (Chekalin, 2009).

Table 2. Grass stand density (number of bushes per 1 m^2) of wheatgrass depending on the methods of tillage of degraded crops (for 2021, 2022)

Option	Herbage density, pcs/m^2			Increasing the density of the grass stand of the granary, %	
	after processing (2021)	the end of the growing season of the granary (1st decade of October)			
		2021	2022	2021	2022
No tillage (control)	29	29	41	–	41.4
Tillage with a tooth harrow	21	26	51	23.8	96.1
Tillage with a soil spiker	20	25	48	25.0	92.0
Tillage with a disc harrow	21	24	44	14.3	83.3
Tillage with a heavy disc harrow	15	21	47	40.0	123.8
Tillage with a disc harrow	17	31	68	82.3	119.3

The majority of the perennial grass yield in modern agriculture forms at the account of previously accumulated nutrients and mobilization of soil fertility without sufficient compensation for the nutrients brought out with the crop. Nitrogen content analysis indicated low nitrogen content in all options of the experiment, however, there was a slight increase compared to the control in options with tooth and needle harrow tillage by 7-8%, in options with disc harrow and disk harrow by 10-15% respectively (Table 3).

The content of mobile phosphorus varied and was very low in all test options from 6.06 to 7.29 mg/kg, with its greatest amount noted in the control option. Plant phosphorus absorption directly depends on the moisture in the soil, because plants only obtain phosphorus in dissolved form from the soil solution that washes around the root hairs.

Table 3. Nutrient content in the 0–30 cm soil layer based on tillage methods for degraded wheatgrass crops (second third of May 2022)

Option	N, mg/kg	P_2O_5, mg/kg
No tillage (control)	120.4	7.29
Tillage with a tooth harrow	128.8	7.05
Tillage with a soil spiker	130.2	6.06
Tillage with a disc harrow	121.8	6.93
Tillage with a heavy disc harrow	133.0	6.06
Tillage with a disc harrow	138.6	6.30

According to our data on the control option moisture reserves were poor due to absence of tillage on the control, soil density was higher compared with other options, which negatively affected plant growth and accumulation of green mass. For example, the height of plants in 2022 was 12.8 cm during the full growth of wheatgrass and by the blooming phase it reached only 15 cm, indicating a low growth rate of plants. We believe that due to the low yield of the crop (0.88 t/ha) in the option without tillage during the vegetation phase, removal of nutrients from the green mass was small and the reserves of phosphorus in the soil consumed little, which explains the slight excess of its content in the control compared with other options.

Percentage analysis of harvest structure elements before mowing (blooming phase) in 2022 shows that most of the weight of the plant is on stems – 45.4-75.1% and on inflorescences – 9.6-42.2%. Leaf coverage of the plant was not high, the lowest in the control. In the option with heavy harrow tillage the percentage of leaves increases almost 4 times – 12.4%, and the maximum leaf coverage on the plants was in the option with high-speed disk harrow tillage – 20.1% (Figure 1).

As we can see from the data in Table 4, the wheatgrass fresh yield in 2021 was low – 0.68-1.31 t/ha, which is associated with slow regrowth of grass after mechanized tillage according to the experimental scheme.

Fresh yield in 2022 in all options with tillage higher than control (no tillage): with the tooth harrow by 0.52 t/ha, with the soil spiker by 1.69 t/ha, with the disc harrow by 2.01 t/ha, with the heavy disc harrow by 3.85 t/ha and with the high-speed disk harrow by 2.98 t/ha.

Analysis of hay yield of wheatgrass by years showed that in 2021 by options exceeded control insignificantly – by 0.04-0.33 t/ha, but in the second year there is a more significant increase in yield by options – by 0.34-1.78 t/ha higher than the control. The highest mass of hay per hectare were

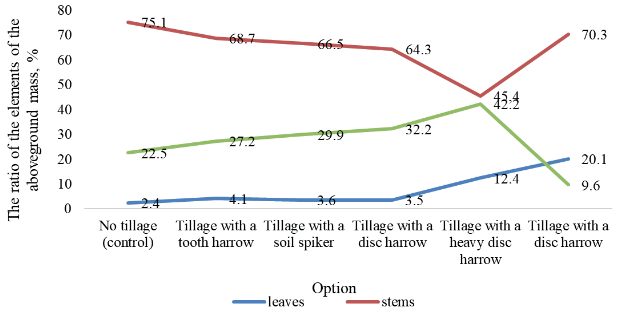

Fig. 1. Grass stand wheatgrass structure based on tillage methods (second third of June, 2022)

Table 4. Green and dry mass yields of wheatgrass based on tillage methods (for 2021, 2022)

Option	Yield of green mass, t/ha			Yield of dry weight, t/ha		
	2021	2022	on average for 2021–2022	2021	2022	on average for 2021–2022
No tillage (control)	0.76	0.88	0.82	0.44	0.69	0.57
Tillage with a tooth harrow	0.68	1.40	1.04	0.39	1.03	0.71
Tillage with a soil spiker	0.94	2.57	1.76	0.56	1.34	0.95
Tillage with a disc harrow	0.82	2.89	1.85	0.48	1.47	0.97
Tillage with a heavy disc harrow	0.89	4.73	2.81	0.53	2.47	1.50
Tillage with a disc harrow	1.31	3.86	2.59	0.77	1.95	1.36

obtained in options with the high-speed disk harrow tillage and heavy disc harrow – 1.95 and 2.47 t/ha, respectively.

Evaluation of the impact of mechanical tillage of sodded wheatgrass crops on the fresh yield in 2022 reveals a significant correlation in some experimental options of its level with soil parameters and foliage of the grass stand.

Thus, the correlation between the wheatgrass fresh yield and soil density shows that in the options with heavy disc harrow tillage (r = – 0.91 ± 0.16), high-speed disc harrow tillage (r = – 0.96 ± 0.12), disk harrow (r = – 0.98 ± 0.09) There is a significant correlation between these indicators, and in the option with a tooth harrow, the correlation is moderate (r = – 0.56 ± 0.4), which indicates an insignificant influence of this method on soil opening. Soil opening and sod layer breaking improved its water permeability, so the fresh yield was in direct correlation with the productive moisture reserves. Thus, in the high-speed disk harrow tillage version the correlation coefficient was r = 0.92 ± 0.19, with the disc harrow – r = 0.91 ± 0.16. The correlation between the fresh yield and leaf coverage revealed a strong direct correlation, thus in the option with the high-speed disk harrow tillage – r = 0.98 ± 0.09. Close correlation between these indicators was also noted for the other tillage options. These correlations are statistically significant ($p < 0.05$), as the significance criteria of correlation coefficients exceed the values of the t-test of Student.

Conclusions

Hence, mechanized tillage of degraded crops reduces soil density, improving its water permeability, nutrient and air regimes, due to destruction of sod turf, loosening the soil and creating an optimal feeding area for plants, grass density increases from year to year. These methods had a positive impact not only on soil indicators but also on the fresh yield of wheatgrass: when using soil spiker and disc harrow, it averaged for two years 1.76 and 1.85 t/ha, respectively; when using heavy disc harrow – 2.81 t/ha and 2.59 t/ha, compared with the control – 0.82 t/ha.

Source of funding

This research has been funded by the Ministry of Agriculture of the Republic of Kazakhstan BR10764915 "Development of new technologies for restoration and rational use of pastures (use of pasture resources)".

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Received: **February, 12, 2023**; *Approved*: **June, 29, 2023;** *Published:* **October, 2023**