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IMPROVEMENT EFFECT ON THE PRODUCTIVITY OF DEGRADED GRASSLANDS

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Abstract: Following the breakup of the old USSR there has been a large-scale decline in production and increased land abandonment in Ukraine. In the long term, bringing this land into the sustainable agricultural production represents an opportunity to address the increased demand for global food production that will be needed in the forthcoming years. Any land improvement needs to be based on the scientific knowledge of best outcomes. The outcomes of our studies have resulted in different recommendations on the methods of degraded grasslands improvement. Three experiments were carried out in order to measure the effects of different improvement methods on degraded meadows situated in the lowland Ukraine. Only a very limited number of improvements, including the surface improvement by fertilizers and radical improvement by the seeding of the grass-legume mixtures are considered suitable for lowland. Detailed comparison of surface improvement using the 180^0 turning capacity plough and no-till technology on equally degraded meadows situated in the lowland highlighted the advantages of the no-till technology in the annual DM production. Significant differences in the dry-matter yield supported the hypothesis that no-till farming increased the forage resources and solved the equation of the highest possible conversion of the feeding stuff into herbage under minimal costs.
Key words: Grasslands; Fertilizer; Legume mixtures; Yield

INTRODUCTION

Grasslands play an important role in providing hay and pasture based forage for the livestock. The contribution of grasslands to the utility of multifunctional livestock systems has been recently recognized (Hopkins, A., Holz, B. 2006). With proper variety selection, favourable irrigation, fertility and harvest or grazing management, there have been obtained high yields of about 8 t ha^{-1} and even more. The improvement of degraded grassland is the key to successful forage production. The matters of finding the most suitable ways to improve the arable land or set-aside grassland are examined by many research institutions in Ukraine as well as abroad.

A lot of research findings suggest two fundamental methods of land improvement: surface cultivation using fertilizers and radical improvement by seeding the grass-legume mixtures. The reports from specialized literature suggest a range of different amounts of N fertilizer application resulting in the maximal DM yield of old grasslands (Samuil, C. 2010). One of the ways contributing to the conservation of soil's organic matter is to use a 180^0 turning capacity plough, when the roots and plant residues have important positive after-effect on the improvement of soil fertility and also on the following yields. The nutrients are better fixed in the soil when using a 180^0 turning capacity plough and this tillage provides an increase of nitrogen by 48–114 kg ha in the soil. The utilization factor of nitrogen from root and plant residues assimilates to the manure (Lyhochwor, V.V. 2002). Prof. Montgomery also estimated that each dollar invested in soil conservation would save for the society more than $5 (Montgomery D., 2007). No-till farming typically provides greater soil moisture retention and a reduction of soil erosion when compared with conventional seeding methods and, consequently, can hasten or improve its quality. Furthermore, the overseeding of legumes has the potential to increase the annual herbage production and to improve seasonal distribution of yield (Bartholomew, P.W. et al., 2011, Monacu, 2009).

These researches allow to estimate the biological potential of long-lived grasslands using differentiated fertilization systems and optimal stage of cutting; to appreciate the effectiveness of using the 180^0 turning capacity plough; to determine the expediency of using fertilizers, inoculation, growth stimulators and micronutrients under different improvement systems. There is currently little information available on the optimal methods of degraded grasslands improvement in the situations when the forage yield is very important. The objective of the present work was to select the best method of degraded meadows improvement in order to increase fodder production and conversion of feedstuff into herbage under minimal costs. We hypothesized that the no-till technology would increase the DM yield of degraded grasslands more than surface cultivation and seeding. In order to test this hypothesis, we used the surface cultivation, the seeding using a 180^0 turning capacity plough, the no-till technology and also the control variant.

MATERIAL AND METHODS

The experiments were conducted in two similar periods of time. The surface improvement by applying nitrogen fertilizer and radical improvement involving the use of a 180^0 turning capacity plough were conducted in the consecutive years 2006 (year 1), 2007 (year 2) and 2008 (year 3) on the stationary experimental field of the Institute of Agriculture in the Carpathian region of the National Academy of Agrarian Sciences of Ukraine (IACR NAAS) (Obroshyno 49°492 N 24°002 E, altitude 280–300 m). This permanent experimental field was established in 1974 on the dark grey podsolized sandy loam soils. The research including the no-tillage technology was conducted in the consecutive years 2010 (year 1), 2011 (year 2) and 2012 (year 3) on the permanent grasslands of IACR NAAS (Lishnya, 49°212 N 23°302 E, altitude 280–300 m).

The local climate is semi-continental. It has been formed by the Atlantic Ocean (a lot of precipitations and rapidly changing temperatures) and by the continental atmospheric mass. The temperature during the vegetative season was above the norm by 5.7°C in 2006, by 19.0°C in 2007, by 19.5°C in 2008, by 8.6°C in 2010, by 4.6°C in 2011, and by 12.2°C in 2012. The analysis of the monthly temperature distribution had shown a temperature below the norm only in October and September. It promoted a good regrowth of the aftergrasses.

In 2006, the stationary perennial experiment was improved by the three methods. The first one (surface) included the complete mineral fertilizer application using different amounts of nitrogen distribution for each cutting. Unfertilized control (UF) variant and phosphorus-potassium (PK) background variant were defoliated twice and the variants with nitrogen application - three times. In early spring, all the variants, except the control one, were fertilized using the mineral fertilizer according to scheme of experiment (Tab. 1).

Table 1. *Experiment's scheme of surface cultivation*

Fertilizer	Stage of cutting		
	1^{st} cycle	2^{nd} cycle	3^{rd} cycle
UF	emergence of efflorescence	in 50–55 days	
PK	emergence of efflorescence	in 50–55 days	
PK + Nud	Elongation	in 40–45 days	in 40–45 days
PK + Nuud	Elongation	in 40–45 days	in 40–45 days
PK + Nuud	emergence of efflorescence	in 40–45 days	in 40–45 days
PK + Nuud	Efflorescence	in 30–35 days	in 30–35 days

UF – unfertilized control; PK include 60 kg ha^{-1} P and 90 kg ha^{-1} K; Nud – uniform distribution per 40 kg ha^{-1} N for each cutting, Nuud – ununiformed distribution per zero-N treatment for the first cycle, per 40 kg ha^{-1} N for the second cycle and per 80 kg ha^{-1} N for the third cycle

Radical improvement was conducted using the 180^0 turning capacity plough. The roots and plant residues, which have been embedded in the soil by ploughing, were mineralized. Therefore the nutrients could be taken from the soil by the next crops. The amount of roots and plant residues was defined before the modernization of the experiment. The required quantity of nitrogen, which is necessary to obtain the planned yield, was computed using the balance calculation method (Lyhochwor, 2002). At the same time we took into consideration the soil nitrogen, the elements necessary to build a unit of grassland yield and the utilization rate of nitrogen from the soil. These results allowed asserting that the application of nitrogen fertilizer was not reasonable when using a 180^0 turning capacity plough. Therefore the nitrogen fertilizer was excluded from the research technology.

The seeding within the new experiment was done using a mixture of alsike clover (*Trifolium hybridum* L.), bird's foot trefoil (*Lotus corniculatus* L.), meadow fescue (*Festuca pratensis L.*), Timothy (*Phleum pratense* L.) and bromegrass (*Bromus inermis* Leyss). The experiment included the control variant without fertilizer, phosphorus-potassium fertilizer (PK), PK + inoculation, PK +

growth stimulator, PK + inoculation + growth stimulator, PK + inoculation + micronutrients. The lime (3 t ha^{-1}) was applied before the main tillage.

The third experiment was conducted on the degraded permanent grassland by direct overseeding of perennial legumes and grasses on unelaborated turf (no-till). The Great Plains drill 1006 NT, the legume mixture (red clover (*Trifolium pratense* L.), the alsike clover (*Trifolium hybridum* L.) and the bird's foot trefoil (*Lotus corniculatus* L.) were used for seeding. This study included the control variant without drilling and without fertilizer, another control variant without fertilizer but with drilling, drilling + PK, drilling + PK+ inoculation, drilling + PK + growth stimulator, drilling + PK + inoculation + growth stimulator, drilling + NPK + inoculation + growth stimulator. At each sampling date, for each grasslands and each subplot the sample kept from the dry matter (DM) yield measurements of the fresh harvested biomass was weighed and dried at 105^{0}C in order to determine the dry matter (DM) content comparing the difference between the fresh and dry weight. DM yield of each sampling area was calculated from the first weight of the sample, the DM content and the area that was cut (t ha^{-1} DM). The increase obtained as a result of using radical improvement on the newly-established grassland was calculated in relation to the control variant of surface improvement without fertilizer, because, from an agro-ecological viewpoint, unfertilized permanent grasslands characterize the natural fertility of meadow (Yarmolyuk, 2007).

RESULTS AND DISCUSSIONS

The surface cultivation. DM yield of the long-lived grassland significantly depends on the distribution of nitrogen fertilizer and stage of cutting as it is shown in Table 2. DM yield for the control variant (without fertilizer) was on the average 2.35 t ha^{-1} during three years. This is significantly less than for the fertilized variants. The application of PK increased the total DM yield by only 23% (Tab. 2). On the contrary, the application of 120 kg ha^{-1} N increased the DM yield by 193-232% compared with the unfertilized control variant.

Table 2. *Dry matter yield (t ha^{-1} DM) of permanent grasslands depending on the fertilizer and stage of cutting*

Fertilizer	Stage of cutting	Years			Average
		1st	2nd	3rd	
UF	A	1.49	2.05	3.5	2.35
PK	A	1.92	2.60	4.1	2.88
PK + Nud	B	7.59	6.70	9.2	7.82
PK + Nuud	B	6.47	5.25	9.0	6.90
PK + Nuud	C	5.4	6.01	9.5	6.98
PK + Nuud	D	5.76	6.72	9.1	7.2
LSD 5%		0.29	0.71	0.43	0.32

UF – unfertilized control; PK include 60 kg ha^{-1} P and 90 kg ha^{-1} K; Nud – uniform distribution per 40 kg ha^{-1} N for each cutting, Nuud – ununiformed distribution per zero-N treatment for the first cycle, per 40 kg ha^{-1} N for the second cycle and per 80 kg ha^{-1} N for the third cycle. a – first cutting at the stage of efflorescence emergence, next in 50–55 days, b – the first cutting at the stage of elongation, next every 40–45 days, c – the first cutting at the stage of efflorescence emergence, next every 40–45 days, d – the first cutting at the stage of efflorescence next every 30–35 days

DM yield was the highest in the case of uniform distribution (40 kg ha^{-1} N per each cutting), in the first cycle of cutting in stage of elongation. Total DM yield of this variant was 7.82 t ha^{-1} DM. Cutting at these stages without early spring N treatment led to DM yield decrease by 6.90 t ha^{-1} DM. A low productivity was obtained as a result of natural fertility and phosphorus-potassium fertilizer application, but the nitrogen fertilizer provided the main yield. The increase when using N treatment was within 193–232%, and it was the highest for even distribution of nitrogen where 1 kg of N provided 41 kg of DM. If N fertilizer is not applied early in spring it causes a reduction of 193%. There is a well-defined dependence between N-treatment and the date of cutting: in each subsequent stage the increment from N fertilizer increases. The increase from 1 kg of N was 29 kg of DM and 33 kg of DM for the first cutting at the stage of elongation and the first cutting at the stage of efflorescence respectively.

DM yield of long-lived grassland, which was improved by surface cultivation, increased by 23% as a result of phosphorus-potassium fertilizer application, 60 kg ha^{-1} P and 90 kg ha^{-1} K. In 2007, DM yield of unfertilized control variant and PK variant was higher than in 2006 by 35–37%. This increase in DM yield was due to the natural fertility of old grasslands, since these soils were rich in organic matter, which is one of the most important sources of nutrients' renewal (Wrage et al., 2009). Moreover the water-retaining capacity of organic matter is from five to ten times higher compared to the mineral part of the soil (Sozinov, 1993). In 2007, the weather was arid. The application of full mineral fertilization (NPK) increased the DM yield by two-three times compared to the unfertilized control variant. Similar results were obtained by others scientists (Gutmane at el., 2009). DM yield significantly depended on the date of cutting for uniform N fertilizer application and the highest DM yield was 7.20 t ha^{1} for the first cutting at the stage of efflorescence.

Therefore, the highest DM yield was 7.82 t ha^{-1} for long-lived grasslands. Such a yield was supported by full mineral fertilizer (the uniform distribution of N fertilizer) and cutting in the first cycle in the stage of elongation.

The radical improvement. Productivity of the legume-grass species depended on the fertilizer, inoculation and growth stimulator used in the new experiment (Tab. 3).

Table 3. *Dry matter yield (t ha^{-1} DM) of newly-established grasslands depending on the fertilizer, inoculation, growth stimulator and microelements*

Fertilizer	Production years			Average
	1st	2nd	3rd	
UF	2.0	4.1	3.8	3.31
PK	3.5	6.5	4.2	4.73
PK + IN	4.9	7.5	5.1	5.82
PK + GS	5.3	6.6	6.1	6.02
PK + IN + GS	5.8	8.4	6.9	7.03
PK + IN + ME	5.4	7.2	6.8	6.49
LSD 5%	0.72	0.92	0.78	0.49

UF – control (unfertilized), PK include 60 kg ha^{-1} P and 90 kg ha^{-1} K; IN – inoculation using Rizobofit, GS – spraying using the growth stimulator Gart, ME – treatment using micronutrients

The highest DM yield of legume-grass species (7.03 t ha^{-1} DM) was obtained for the variant where the phosphorus-potassium fertilizer and growth stimulator Gart were applied; the seeds were inoculated using Rizobofit. Phosphorus-potassium fertilizer application increased the yield productivity by 43%, while the application of only one of the biopreparations promoted the rise in yield by 76–82%: DM was 5.82 t ha^{-1} for inoculation and DM was 6.02 t ha^{-1} for spraying with growth stimulator. Averaged over three production years, there was 3.31 t ha^{-1} DM yield for unfertilized control variant of the newly-established grasslands, which is higher by 0.96 t ha^{-1} DM than of the unfertilized control variant of long-lived grasslands. Therefore, the radical grassland improvement that included the sowing of legume-grass mixtures and the use of the 180^{0} turning capacity plough recorded an increase of DM by 41%. The used biopreparation promoted an increase of DM yield by 11–19%. Spraying by growth stimulator Gart provided an increase of DM yield by 13%.

The application of lime and phosphorus-potassium fertilizer on the newly-established grassland resulted in an increase of 43% that is by 20% higher than in the long-lived grasslands. The difference can be explained by the presence of the legume and grass mixture, which can increase the productivity by 1.3–2 times without applying the nitrogen fertilizer (Panakhyd, 2008). The inoculation also increased the DM yield by 11% as a result of the symbiotic activity of legumes. They are fixing the atmospheric nitrogen and improving the activity of the natural nitrogen-fixing bacteria.

The highest effect of the biopreparations was obtained when they were applied together. The increase of DM yield was of 19.0% and 16.1% when inoculation was applied together with the growth stimulator and with micronutrients, respectively. A small increase was obtained as a result of using microelements (5%) and it was caused by the high concentration of soil organic matter. Thus, the 41% increase of the DM yield of the newly-established legume-grass grasslands was obtained due to the establishment of new grasslands on the long-lived ones.

The no-till technology. On average, there was obtained a yield of 2.8 t ha^{-1} DM over three productivity years under no-till technology in the absolute control variant (without overseeding and fertilizer). DM yield was higher by 4.7 t ha^{-1} than in the absolute control variant when overseeding the legume species in the degraded grasslands. In the period of three years the highest yield was obtained in the variant where the legume species were overseeded together with 60 kg ha^{-1} N, 60 kg ha^{-1} P, 90 kg ha^{-1} K, and also the inoculation and growth stimulator were applied. That allowed an increase of the yield by 56% in comparison to the absolute control variant (Tab. 4).

Table 4. *Dry matter yield (t ha^{-1} DM) of grassland when implementing the no-till technology depending on the reseeding of legume species, use of fertilizer, inoculation and growth stimulator*

Fertilizer	Production years			Average
	1st	2nd	3rd	
AC	2.7	2.5	3.2	2.8
RS	6.0	9.3	7.1	7.5
RS + PK	6.6	11.1	8.9	8.3
RS + PK + IN	6.9	11.9	9.7	9.3
RS + PK + GS	7.1	11.7	9.4	9.4
RS + PK + IN + GS	7.3	12.4	12.2	10.3
RS + NPK + IN + GS	8.8	12.6	13.7	11.7
LSD 5%	0.43	0.70	0.47	0.54

AC – absolutely control variant without reseeding and fertilizer, RS – reseeding of legume species; PK includes 60 kg ha^{-1} P and 90 kg ha^{-1} K, IN – inoculation by Rizotorfin, GS – spraying with the growth stimulator polymicsobacteryn; NPK consists of 60 kg ha^{-1} N, 60 kg ha^{-1} P and 90 kg ha^{-1} K

The application of phosphorus-potassium fertilizer over three years increased the DM yield up to 8.3 t ha^{-1} on average. The use of inoculants provided an increase of DM yield by 1.8 t ha^{-1}, and the use of spraying with the growth stimulator increased the DM by 1.9 t ha^{-1}. The combination of these both preparations increased the DM yield by 37% in comparison with the unfertilized control variant. The highest yield was obtained when using the combination of all these preparations with 60 kg ha^{-1} N.

The highest yield values were obtained as a result of the legume species overseeding (63%). The increase due to the use of phosphorus-potassium fertilizers was only 10%. As a result of using the inoculation and growth stimulator the recorded percentage increases were 11% and 12%, respectively. The combination of these both preparations provided 19% of the yield increase, and the application of N provided an increase of 12%. The yield of the grasslands cultivated with legume and grass species is due, essentially, to the presence of phosphorus-potassium fertilizers (Aloush et al., 2000; Spehlen et al., 2002). However, in our research, PK fertilizers promoted an increase of DM only by 10%. This low effect resulted from the high content of organic matter that includes a lot of phosphorus, potassium and microorganisms (Besugly, 2009). Nitrogen fertilizer was applied in each cycle by 30 kg ha^{-1} N. It did not worsen the botanical composition of grassland and did not have a negative impact on the root's symbiotic activity, therefore the increase was of 12% as a result of the N-treatment.

Considering each improvement measure separately we can conclude that the highest values of yield increase were obtained as a result of the legume species overseeding. These high rates are due to the biological characteristics of the legume and grass species, as they can provide a high yield even without using a fertilizer due to their root system, which can assimilate fertility elements from deep soil layers.

CONCLUSIONS

1. The highest yield increase of the long-lived degraded grasslands was provided by the use of nitrogen fertilizers. The highest efficiency was observed when applying even nitrogen distribution (1 kg of active ingredient of nitrogen provides 41 kg DM).

2. The yield increased by 41% in the newly-established grassland due to radical improvements which include the use of a 180^0 turning capacity plough and sowing of legume and grass mixtures. The increases are of 11% and 13% as a result of using the inoculation and growth stimulator, respectively.

3. The overseeding of perennial legume and grass species using the no-till technology gives an increase in yield of 63%. Also, there is an increase of 11%, as a result of using the inoculation, 12% as a result of using the growth stimulator and 12% as a result of using nitrogen only.

4. The comparison of surface cultivation, radical improvement and no-till technology demonstrated that the highest DM yield is provided by the legume-grass overseeding using the no-till technology.

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