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PECULIARITIES OF GROWTH AND DEVELOPMENT OF LEGUMINOUS FODDER GRASSES IN THE SOUTH OF UKRAINE

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Abstract

In recent decades, the intensity of chemical use in agriculture has increased significantly, which threatens food security, contributes to the accumulation of toxic chemicals in the environment, leading to the destruction of beneficial organisms (entomophages) and soil microflora, and thus disrupting the balance of the ecosystem. Agroecology and organic farming have become priority topics integrated into the scientific and technological approach to sustainable agriculture. The inclusion of legumes in crop rotation can contribute to the restoration of soil fertility and phyto-improvement of saline soils in the southern region of Ukraine, desalination being possible due to natural drainage and carbonic acid root secretion. In addition, the root system of these plant species enriches the soil with nitrogen and improves its structure. This article presents the results obtained in a field experiment with 3 species of perennial and biennial forage legumes, under different technological conditions with the aim of: i) evaluating the phenological evolution and biological characteristics of the growth and development of the studied plants; ii) investigating the impact of their cultivation on the ecological state of the soil and iii) determining the optimal parameters regarding the production obtained under different cultivation conditions.

***Key words**: fodder leguminous grasses, soil fertility restoration, agroecology, crop rotation.*

INTRODUCTION

Scientists have found that the increased use of arable land over the last century has led to a total decrease in soil fertility on the planet. (Nyfeler, 2009; Clayton et al., 2004; Meyer, 1984; Armin, 2011; Parrish, 2005; Özköse & 2016). This problem is extremely relevant for Ukraine. Since plants and microorganisms are the mandatory and most active participants in soil formation processes, the issue of soil fertility formation should quite rightly be considered as largely biological. However, the biological state of many soils in the country today should be recognized as degraded. Dehumification processes in the soils are activated due to the absence of organic matter and unbalanced use of mineral fertilizers, ignoring crop rotation, minimizing the areas under legumes crops, and burning straw (Antonova et al., 2019; Gibson et al., 2006).

The composition of soil biocenoses is significantly impoverished as there is a reduction to a minimum and even a loss of certain species, some of them being beneficial organisms. Besides, many agrocenoses have turned into reservoirs of pathogens (Vozhehova et al., 2020; Vlashchuk et al., 2015). The magnitude of such phenomena causes serious concerns and there is an urgent need for improvement measures, adopted at the state level, in order to optimize the state of agrocenoses in general and soil-forming processes in particular (Rajput et al., 2008; Tristram, 2013).

Among the biological measures for the conservation and increase of soil fertility, the cultivation of plant species (e.g. fodder legumes) that are capable of having beneficial effects on the soil at the physical, chemical and biological levels is one of the most effective measures from an agro-ecological and economic point of view (for example, it is 5-10 times cheaper than chemical improvement). In addition, in today's conditions, it is also possible to solve the problem of vegetal protein deficiency by increasing the sown area, expanding the range and increasing the yield of perennial and annual fodder legumes. This also contributes to the natural restoration of soil fertility due to the plants' nitrogen-fixing ability, which is especially relevant today because of the increase in the mineral and organic fertilizers cost (Vozhehova et al., 2020; Rigal M. et al., 2016; Demydas' G. I. et al., 2017; Harker et al., 2012; Babich et al., 2000).

In general, legumes are some of the best preceding plants in crop rotation and also, they are effective soil improvers. They enrich the soil with nitrogen and improve its structure, which contributes to the growth of agricultural crops. Legume fodder grasses act also as improvers for saline soils that is the case of the southern region of Ukraine not only due to drainage, but also due to the root release of carbonic acid, which triggers the chemical process of desalination. So, these crops are able to provide soil reclamation (Wolf, 2004; Vozhehova et al., 2020; Zinchenko et al., 2003).

The South of Ukraine belongs to the risky agriculture zone, therefore, the cultivation of drought-resistant agricultural crops, capable of forming stable yields of high-quality seeds in extreme conditions, is of exceptional importance in the region (Bezugliy et al., 2012; Tsandur, 2006; Zinchenko et al., 2003; Denisow B., 2016).

Therefore, our project envisages conducting research to establish the characteristics of growth processes and productivity of perennial forage legumes, as well as studying their impact on the ecological state of the soil in the southern steppe zone of Ukraine. The research is relevant because it addresses the issues of improving agrocenoses in organic farming rotations through the use of environmentally safe perennial forage legumes, which will contribute to improving and restoring the ecological state of the soil and increasing the yield of agricultural crops within the rotation.

The aim of the research was to determine the optimal parameters that would ensure the best phenological indicators of plants and maximum productivity of perennial and biennial forage legume seeds under irrigated and non-irrigated conditions, as well as to investigate the impact of cultivating these species on the ecological status and soil restoration.

MATERIALS AND METHODS

The influence of the main tillage methods and irrigation on the peculiarities of growth processes and the formation of fodder legumes grasses seed productivity and the influence of their cultivation on the content of exchangeable cations in the soil were studied. The experimental part was carried out in the conditions of the experimental field of the Institute of Climate Smart Agriculture of the National Academy of Agrarian Sciences (NAAS), located in the south of Ukraine during 2022-2024.

The climate of the research area is continental with insufficient precipitation and its extremely uneven distribution throughout the year, low relative humidity, warm autumn and winter, and a long frost-free period. The region is also characterized by the greatest aridity and the greatest thermal resources (Figure 1).

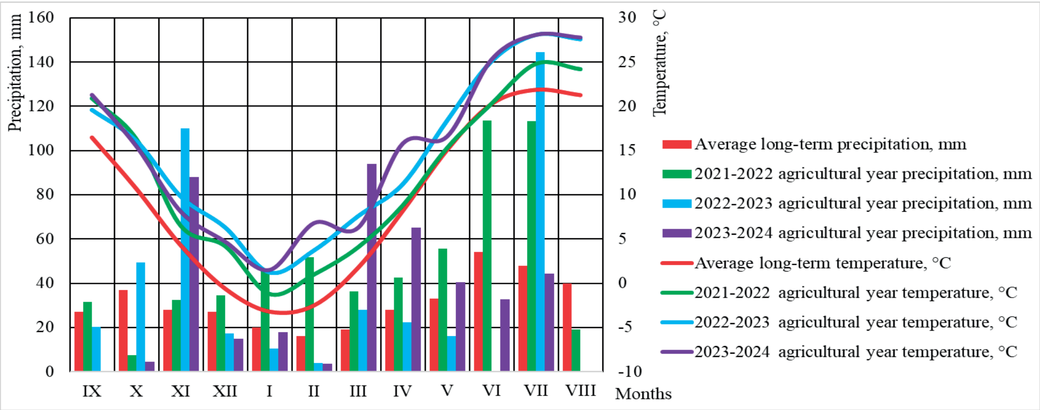

Figure. 1. Monitoring of weather conditions over the research years

Almost every year there are periods with strong winds, dust storms, and dry winds, which cause great damage for agriculture (Babich, A.O. et al., 2000; Tsandur, 2006). Thus, the soil and climatic conditions of southern of Ukraine are favorable for the formation of a high and stable harvest of fodder leguminous grasses seeds, but due to insufficient rainfall and to high temperatures, the potential of crops is not always able to be realized. In this regard, it is necessary to constantly improve the elements of cultivation technology.

The experiment was set up in randomized plots with using the split-plot method, with four replications. The experiment followed the single logical difference principle and the range of factors' gradations, which allows determining the optimal parameters of the action of each factor. The research was carried out sequentially, and the obtained data were systematized. The experiment was a three-factor experiment: Factor A was the presence of irrigation (without irrigation; irrigation), Factor B was the method of main tillage (plowing to a depth of 27-30 cm; chiseling to a depth of 22-44 cm; disking to a depth of 15-17 cm), Factor C was the fodder leguminous grasses (*Medicago sativa* L.; *Onobrychis viciifolia* Scop.; *Melilotus albus* Medik.). The generally accepted field experiment methods and methodological recommendations were used (Vozhehova et al., 2014; Ushkarenko et al., 2014).

The results of the harvest accounting were processed by methods of variance, correlation and regression analyses using the software and information complex "AGROSTAT" (Software Product Developer Institute of climate smart agriculture of the National Academy of Agrarian Sciences of Ukraine).

RESULTS AND DISCUSSIONS

Plant height

The influence of the studied factors on the dynamics of the height of leguminous forage crops was established. The results of observations indicate that the growth rates of plants in height are directly dependent on the growing conditions (Table 1).

The growth and development of plants is influenced by a significant number of factors, the main of which in the arid conditions of the Southern Steppe of Ukraine are the availability of irrigation and the main tillage method.

Table 1. Dynamics of plant height of fodder leguminous grasses depending on the studied factors, cm (average for 2022-2024)

Factor A, irrigation	Factor B, main tillage method	Factor C, fodder leguminous grasses	Phenological phases			Average by factor B		
			branching	budding	flowering	branching	budding	flowering
Without irrigation	plowing (27-30 cm)	*Medicago sativa* L.	18,1	45,6	58,7	17,9	55,2	81,7
		Onobrychis viciifolia Scop.	18,0	41,3	56,4			
		Melilotus albus Medik.	17,2	69,2	110,5			
	chiseling (22-24 cm)	*Medicago sativa* L.	17,9	48,5	56,6	17,8	54,8	79,1
		Onobrychis viciifolia Scop.	17,7	40,1	55,8			
		Melilotus albus Medik.	17,0	68,4	105,8			
	disking (15-17 cm)	*Medicago sativa* L.	17,6	40,0	54,7	17,5	51,7	75,9
		Onobrychis viciifolia Scop.	17,4	39,8	53,9			
		Melilotus albus Medik.	16,8	64,3	98,5			
Average by factor A			17,5	50,8	72,3	Average by factor C		
Irrigation	plowing (27-30 cm)	*Medicago sativa* L.	18,7	50,7	69,4	18,1	47,4	61,9
		Onobrychis viciifolia Scop.	18,4	49,5	66,8	18,0	44,5	60,5
		Melilotus albus Medik.	17,3	74,8	128,2	17,1	69,8	114,2
	chiseling (22-24 cm)	*Medicago sativa* L.	18,5	50,1	67,3			
		Onobrychis viciifolia Scop.	18,7	49,0	65,9			
		Melilotus albus Medik.	17,2	72,6	123,1			
	disking (15-17 cm)	*Medicago sativa* L.	18,0	49,2	64,9			
		Onobrychis viciifolia Scop.	17,9	47,4	64,0			
		Melilotus albus Medik.	17,0	69,5	119,2			
Average by factor A			17,9	56,9	85,4			
Assessment of the materiality of partial differences		LSD_{05}, cm	A=0,16 B=0,10 C=3,26	A=0,11 B=0,14 C=3,26	A=0,20 B=0,13 C=3,26			
Assessment of the significance of average (main) effects		LSD_{05}, cm	A=0,05 B=0,04 C=0,05	A=0,04 B=0,06 C=0,05	A=0,07 B=0,05 C=0,04			

Over the years of research, extreme weather conditions with rather high values of average daily temperatures and lack of precipitation did not allow fodder leguminous grasses plants to fully realize their biological potential, which usually affected the height of the plants.
According to Factor B (the main tillage method), in non-irrigated conditions, the best results were shown by plowing to a depth of 27-30 cm. In this variant, plants of *Medicago sativa* L. in the flowering phase had a height of 58.7 cm, which was per 3.65% higher than by chiseling to a depth of 22-44 cm and was per 6.81% higher than by disking to a depth of 15-17 cm. The plants of *Onobrychis viciifolia* Scop. in similar conditions had a height of 56.4 cm, which was per 1.07% higher than by chiseling to a depth of 22-44 cm and 4.46% higher than by disking to a depth of 15-17 cm. Plants of *Melilotus albus* Medik. in such conditions reached a height of 110.5 cm, which was per 4.25% higher than by chiseling to a depth of 22-44 cm and was per 10.86% higher than by disking to a depth of 15-17 cm.
Irrigation (Factor A) had a positive effect on the growth and development of fodder leguminous grasses' plants and contributed to an increase in the height of these plants' species by an average of 16.58-18.5%, depending on the crop and the main tillage method. At the same time, the trend in the response of plants to the influence of the main tillage system was maintained. Thus, the best results in irrigated conditions were shown by the use of plowing to a depth of 27-30 cm. In these conditions, the plants of *Medicago sativa* L. in the flowering phase had a height of 69.4 cm, which was per 3.02% higher than by chiseling to a depth of 22-44 cm and was per 6.48% higher than by disking to a depth of 15-17 cm. The plants of *Onobrychis viciifolia* Scop. in the flowering phase iv similar conditions reached a height of 66.8 cm, which was per 1.35% higher than by chiseling to a depth of 22-44 cm and was per 4.19% higher than by disking to a depth of 15-17 cm. The height of *Melilotus albus* Medik. plants in these conditions reached of 128.2 cm, which exceeded per 3.98% the variant with chiseling to a depth of 22-44 cm and exceeded per 8.97% the variant with disking to a depth of 15-17 cm. On average, the use of irrigation allowed to increase the height of plants of *Medicago sativa* L. per 18.23-18.91%, the height of plants of *Onobrychis viciifolia* Scop. per 18.10-18.74% and the height of *Melilotus albus* Medik. plants per 16.02-17.37%, depending on the main tillage method.

Seed productivity

Depending on the main tillage method in irrigated and non-irrigated conditions, fodder leguminous grasses' plants formed different seed productivity (Table 2).
During the research period, the maximum seed productivity (0.89 $t \cdot ha^{-1}$) was obtained by sowing of *Onobrychis viciifolia* Scop. and using plowing to a depth of 27-30 cm in irrigation conditions.
When combining these elements of agricultural technology (plowing and irrigation), *Medicago sativa* L. and *Melilotus albus* Medik. also formed the highest seed productivity (0.46 and 0.74 $t \cdot ha^{-1}$, respectively).
In general, irrigation (Factor A) contributed to an increase in the average seed productivity of fodder leguminous grasses to 0.63 $t \cdot ha^{-1}$. The values of the same indicator in the variants without irrigation were lower by 0.15 $t \cdot ha^{-1}$, or per 23.78% (LSD_{05} A - 0.014 $t \cdot ha^{-1}$, B - 0.017 $t \cdot ha^{-1}$, C - 0.033 $t \cdot ha^{-1}$).
The method of main tillage (Factor B) also affected the formation of the average seed productivity index of fodder leguminous grasses. For plowing to a depth of 27-30 cm it was obtained the highest average seed productivity (0.61 $t \cdot ha^{-1}$). With other methods of main tillage (chiseling to a depth of 22-44 cm and disking to a depth of 15-17 cm), the values of this indicator were lower.
The seed productivity of various fodder leguminous grasses depends more on their biological potential. According to the Factor C (fodder leguminous grasses), the average maximum seed productivity (0.74 $t \cdot ha^{-1}$) was obtained by sowing *Onobrychis viciifolia* Scop.
As a result of variance analysis, the share of influence of factors on the growth, development and formation of seed productivity of fodder leguminous grasses was determined (Figure 2).
All factors and their interaction were significant in this experiment. It was established that the studied factors to the greatest extent (72.4%) depended on the biological characteristics of the fodder leguminous grass (Factor C).

Table 2. Seed productivity of fodder leguminous grasses depending on the studied factors, $t \cdot ha^{-1}$ (average for 2022-2024)

Factor A, irrigation	Factor B, main tillage method	Factor C, fodder leguminous grasses	Average seed productivity	Average by factor A	Average by factor B	Average by factor C
Without irrigation	plowing (27-30 cm)	*Medicago sativa* L.	0,46	0,48	0,61	0,34
		Onobrychis viciifolia Scop.	0,89			0,74
		Melilotus albus Medik.	0,74			0,59
	chiseling (22-24 cm)	*Medicago sativa* L.	0,39		0,55	
		Onobrychis viciifolia Scop.	0,82			
		Melilotus albus Medik.	0,67			
	disking (15-17 cm)	*Medicago sativa* L.	0,34		0,51	
		Onobrychis viciifolia Scop.	0,78			
		Melilotus albus Medik.	0,59			
Irrigation	plowing (27-30 cm)	*Medicago sativa* L.	0,31	0,63		
		Onobrychis viciifolia Scop.	0,69			
		Melilotus albus Medik.	0,58			
	chiseling (22-24 cm)	*Medicago sativa* L.	0,27			
		Onobrychis viciifolia Scop.	0,64			
		Melilotus albus Medik.	0,51			
	disking (15-17 cm)	*Medicago sativa* L.	0,25			
		Onobrychis viciifolia Scop.	0,61			
		Melilotus albus Medik.	0,47			
Assessment of the materiality of partial differences						
LSD_{05}, $t \cdot ha^{-1}$		A =	0,014			
		B =	0,017			
		C =	0,033			
Assessment of the significance of average (main) effects						
LSD_{05}, $t \cdot ha^{-1}$		A =	0,050			
		B =	0,060			
		C =	0,050			

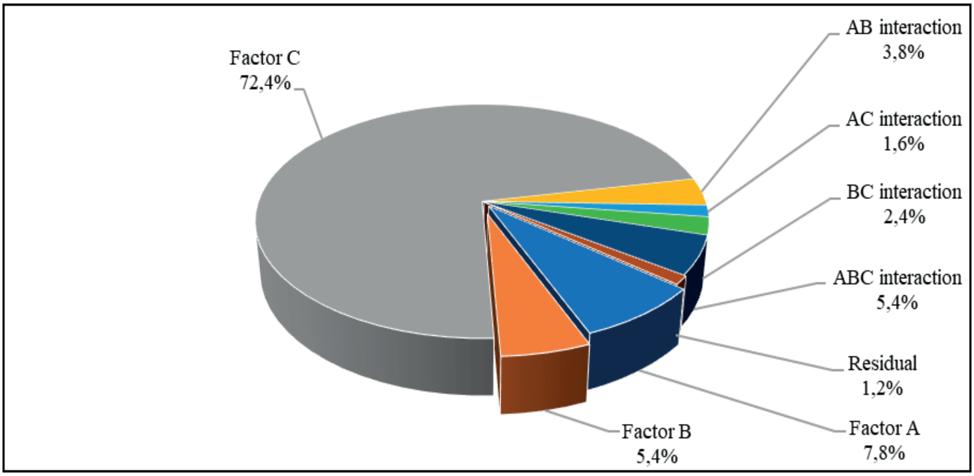

Figure 2. The share of the influence of factors and their interaction on the formation of the height of fodder leguminous grasses' plants and their seed productivity (average for 2022-2024); Factor A - irrigation; Factor B - main tillage method; Factor C - fodder leguminous grass

The presence of irrigation (Factor A) provided a share of influence of 7.8%. The method of main tillage (Factor B) provided a share of influence on the studied plant indicators of 5.4%.

Correlation between the height and seed productivity

It has been established that there is a certain correlation between the height of fodder leguminous grass plants and seed productivity (Figure 3).

For all studied fodder leguminous grasses, the correlation coefficients (r) between seed productivity and plant height in all variants of the experiment have a positive value and are within 0.907-0.993.

This indicates a strong positive correlation between these indicators.

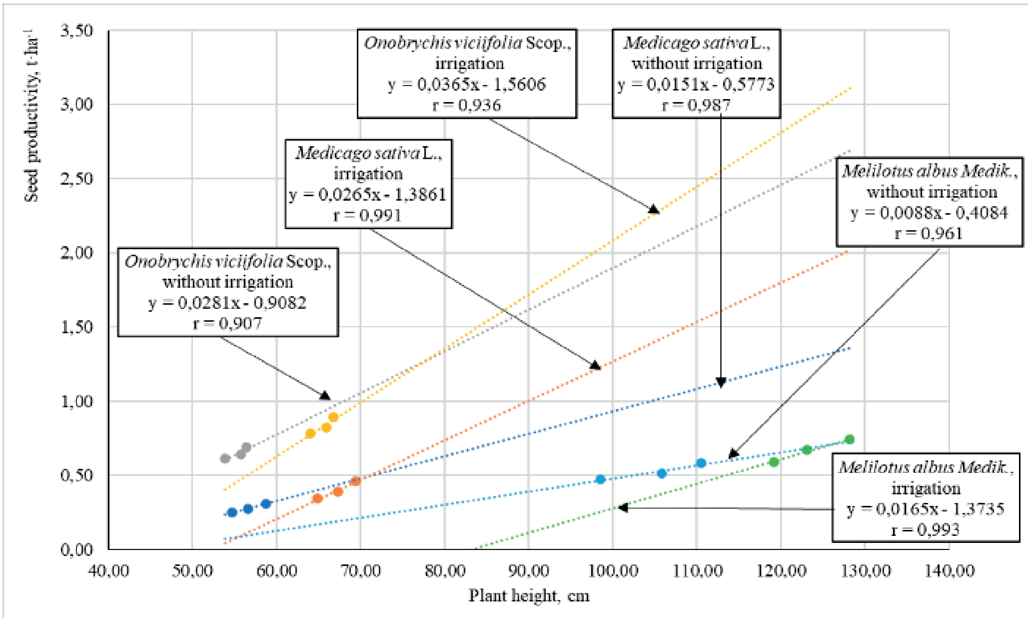

Figure 3. Correlation-regression models of the dependence of fodder leguminous grasses' seed productivity on plant height (average for 2022-2024)

At the same time, higher values of correlation coefficients (r) for the studied crops were established in variants where irrigation was used. The highest value of the correlation coefficient (r=0.993) was established for *Melilotus albus* Medik., during the cultivation of which irrigation was used. The lowest value of correlation coefficient (r=0.906) was established for *Onobrychis viciifolia* Scop. in non-irrigated conditions, which indicates the possibility of increasing the seed productivity of the studied crops by implementing optimal agrotechnical solutions that will contribute to increasing the height of these plants. The obtained regression equations have a linear relationship, which indicates that with an increase in the height of the plants, their seed productivity will increase within the biological potential of the crops. This confirms the possibility of increasing the seed productivity of these crops by choosing an appropriate main tillage system and introducing irrigation.

A feature of fodder leguminous grasses is that root secretions in a certain way affect the content of exchangeable cations in the soil. In the study, the dynamics of the content of exchangeable cations in the soil were studied during the growing of *Medicago sativa* L., *Onobrychis viciifolia* Scop., *Melilotus albus* Medik.

Changes in the content of exchangeable cations in the soil

Table 3 shows the content of exchangeable cations in the soil layer of 0.40 cm before sowing fodder leguminous grasses.

According to the experimental variants before sowing, no significant fluctuations in the content of exchangeable cations in the soil were found, therefore the average values of the indicators are given.

At the end of the growing season of crops, the content of exchangeable cations underwent changes in all experimental variants depending on the studied factors (Table 4).

It was found that in irrigation conditions, the total content of exchangeable cations was slightly higher (17.95-18.23 meq·100 g^{-1}) than without irrigation (17.86-18.08 meq·100 g^{-1}).

Table 3. Content of exchangeable cations in the soil before sowing of fodder leguminous grasses, meq·100 g^{-1} (average for 2022-2024)

Content of exchangeable cations			TCEC*)	Percentage of the cations sum, %		
Na^{+}	Mg^{+2}	Ca^{+2}		Na^{+}	Mg^{+2}	Ca^{+2}
0,56	5,6	12,7	19,1	3,9	30,2	65,9

*) TCEC: Total content of exchangeable cations

This trend indicates a slight increase in the content of exchangeable cations during irrigation due to irrigation water. But this increase is insignificant, within 0.25 meq·100 g^{-1}, which gives grounds to conclude that the use of fodder leguminous grasses helps to control the number of exchangeable cations that cause increased soil salinization.

Table 4. Content of exchangeable cation in soil before harvesting of fodder leguminous grasses, meq·100 g^{-1} (average for 2022-2024)

Factor A, irrigation	Factor B, main tillage method	Factor C, fodder leguminous grasses	Content of exchangeable cations			TCEC
			Na^{+}	Mg^{+2}	Ca^{+2}	
Without irrigation	plowing (27-30 cm)	*Medicago sativa* L.	0,56	5,4	11,6	18,04
		Onobrychis viciifolia Scop.	0,58	5,5	11,7	18,08
		Melilotus albus Medik.	0,55	5,3	11,5	18,01
	chiseling (22-24 cm)	*Medicago sativa* L.	0,55	5,2	11,7	17,94
		Onobrychis viciifolia Scop.	0,57	5,4	11,8	18,00
		Melilotus albus Medik.	0,53	5,2	11,7	17,93
	disking (15-17 cm)	*Medicago sativa* L.	0,53	5,2	11,9	17,87
		Onobrychis viciifolia Scop.	0,55	5,3	11,9	17,91
		Melilotus albus Medik.	0,52	5,1	11,8	17,86
Irrigation	plowing (27-30 cm)	*Medicago sativa* L.	0,60	5,7	12,0	18,14
		Onobrychis viciifolia Scop.	0,63	5,8	12,1	18,23
		Melilotus albus Medik.	0,59	5,6	12,0	18,09
	chiseling (22-24 cm)	*Medicago sativa* L.	0,57	5,6	12,0	18,10
		Onobrychis viciifolia Scop.	0,60	5,7	12,0	18,19
		Melilotus albus Medik.	0,57	5,6	12,0	18,04
	disking (15-17 cm)	*Medicago sativa* L.	0,56	5,4	12,0	18,03
		Onobrychis viciifolia Scop.	0,58	5,5	12,0	18,09
		Melilotus albus Medik.	0,53	5,3	12,0	17,95

CONCLUSIONS

Fodder leguminous grasses, such as *Medicago sativa* L., *Onobrychis viciifolia* Scop., *Melilotus albus* Medik., due to their biological characteristics can be successfully introduced into crop rotations in arid conditions of Southern Step of Ukraine. The influence of the main tillage methods on the growth and development and formation of seed productivity of these crops in irrigated and non-irrigated conditions, and influence of fodder leguminous grasses on the change in the ecological and reclamation state of chestnut soils, namely content of exchangeable cations, has been established.

It was found that according to Factor B (main tillage method), plants grew and developed best by plowing to a depth of 27-30 cm. On average, this main tillage method provided an increase in the height of plants in the experiment per 1.07-10.86%. At the same time, this main tillage method contributed most to the growth of *Melilotus albus* Medik. plants. The best response to irrigation (Factor A) was shown by *Medicago sativa* L., increasing the height of plants an average per 18.5%. *Onobrychis viciifolia* Scop. increased the height of plants an average per 18.43% and *Melilotus albus* Medik. increased the height of plants an average per 16.58%.

Studies have shown that the fodder leguminous grasses' seed productivity depended on the use of irrigation, main tillage method, and plant species. It was found that the use of optimal values of all studied factors contributed to obtaining maximum seed productivity of fodder leguminous grasses.

By Factor A (irrigation), the highest average seed productivity of fodder leguminous grasses (0.63 t·ha^{-1}) was obtained by using irrigation. By Factor B (main tillage method), the highest average seed productivity (0.61 t·ha^{-1}) was obtained by plowing (factor B). By Factor C (fodder leguminous grasses), the maximum seed productivity (0.74 t·ha^{-1}) was obtained by sowing *Onobrychis viciifolia* Scop.

The use of irrigation contributed to an increase in the fodder leguminous grasses' seed productivity by an average per 23.78%. The most sensitive to irrigation was *Medicago sativa* L., which showed the greatest increase in seed productivity per 32.61%. The least sensitive to irrigation was *Melilotus albus* Medik. with a maximum seed productivity increase per 21.62%. *Onobrychis viciifolia* Scop. showed intermediate results with a maximum seed productivity increase per 22.47%.

Observations of the dynamics of exchangeable cations in the soil indicate that growing of fodder leguminous grasses helps to control the number of cations that cause increased soil salinization.

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