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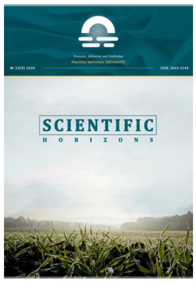

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BIOLOGICAL FEATURES OF THE DISTRIBUTION OF ROOT SYSTEMS OF PERENNIAL LEGUME GRASSES IN THE CONTEXT OF CLIMATE CHANGE

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Abstract. The key factor in the choice of perennial legume grasses in the face of climate change is their drought resistance, because the development of roots directly affects this property, as well as determines their fertility. The purpose of the study was to establish what morphological and biological characteristics of grass roots ensure economic characteristics in the context of climate change. Methods of observation, comparison, and field experiment were used. The study found that the roots of alfalfa have the greatest depth in the soil, spread in the horizontal direction, the thickness of the root neck and lateral roots, which ensures plasticity, durability, and productivity of its crops. The roots of white melilot have the greatest depth in the soil, the thickness of the root neck, central root and lateral roots, their spread in the horizontal direction, which affects the drought and frost resistance of crops. The roots of birdsfoot trefoil are distinguished by the greatest number of renewal buds on the root neck, the smallest depth, and the thickness of the root neck, which affects productive longevity and the possibility of growth in poor and acidic soils. The roots of eastern galega have the greatest depth of the main plant, distribution in the horizontal direction, the thickness of the central root, which affects productive longevity and high biological plasticity. The roots of Hungarian sainfoin are distinguished by the greatest distribution in the horizontal direction and the deepest placement of the main branching, which affects high biological resistance to adverse growing conditions. It was also found out that the roots of meadow clover have the smallest spread radius in the horizontal plane, the thickness of the central and lateral roots, which determines the possibility of its cultivation in the field crop rotation. These findings would facilitate the selection of perennial legume grasses to achieve their full potential in the face of climate change

Keywords: plants, roots, underground development, morphology, years of vegetation

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INTRODUCTION

One of the key factors when choosing perennial legume grasses in the face of climate change is their adaptability to periodic lack of moisture during the growing season, which depends on the development of the root system of grasses. At the same time, placing crops of perennial legume grasses on poor and acidic soils limits the growth of their roots and reduces drought resistance [1]. It is known that the processes that occur in the vegetative organs of plants have a direct connection with the function of their underground part. The larger the volume and length of the root system, the greater the aboveground mass of the plant. A well-developed root system contributes to the efficient use of nutrients and moisture from the soil [2].

In arid conditions, in the year of sowing with clean cultivation, the roots of alfalfa penetrate to a depth of 120-140 cm. With sufficient moisture supply, the root system does not need to penetrate deeply. In general, the root of alfalfa penetrates to a depth of 10 m or more [3]. The root system of meadow clover penetrates the soil from 20 cm per year of sowing and up to 150-200 cm in general. Hungarian sainfoin has a well-developed root system that penetrates up to 150-200 cm [4]. Birdsfoot trefoil is less resistant to drought than alfalfa. Its root system is well branched and penetrates up to 1.5 m deep and is well adapted to acidic and poor soils [5]. Eastern galega is also drought-resistant but develops well in soils with high water retention capacity [1]. White melilot has a well-developed root system, which determines its drought resistance. In white melilot, the root is thickened in the upper part, with well-developed lateral roots, penetrates deeply into the soil, reaching the subsoil [6].

The issue of the distribution of root systems of traditional perennial legume grasses in the context of climate change has been studied in the works of many scientists. In particular, G.P. Kvitko investigated the influence of the development of root systems on soil fertility indicators [5]; P.S. Makarenko studied the distribution of plant roots in grass mixtures [6]; O.L. Kirilesko considered the development of root systems of perennial legume grasses on sloping lands [7]; I. Zabarna examined the morphology of meadow clover roots [8]. K. Schnidtke, R. Rauber analysed the influence of root development on the intensity of their absorption of heavy metals from the soil [9]; P.K. Ghosh and T.K. Maiti studied the relationship between the root systems of perennial legumes and their nodule bacteria [10]; M. Marczak, A. Mazur, P. Koper, K. Zebracki and A. Skorupska investigated the symbiotic productivity of grass roots [11]; G.G. Stevens, M.A. Perez-Fernandez, R.J.L. Morcillo, A. Kleinert, P. Hills, D.J. Brand, E.T. Steenkamp and A.J. Valentine studied the peculiarities of growth and development of the roots of perennial legume grasses in conditions of nutrient deficiency in the soil [12]; T. Suzaki, N. Takeda, H. Nishida, M. Hoshino, M. Ito, F. Misawa, Y. Handa, K. Miura and M. Kawaguchi studied the development of root systems of perennial legume grasses in the absence of symbiotic bacteria in the soil [13]; C. Jacob, B. Carrasco, A.R. Schwember analysed the achievements of selection and biotechnology of perennial legumes [14]; M.A. Adams, N. Buchmann, J.I. Sprent, T.N. Bucley and T.L. Turnbull examined the effects of moisture and nitrogen on the spread of root systems of grass [15]. For the most part, they indicate a powerful development of the root system. At the same time, the influence of climate change conditions on the morphobiological features of the root systems of perennial legumes and their adaptation to adverse environmental conditions has been rather neglected.

Alfalfa is a traditional forest-steppe crop, has been grown in this region for a long time, is well adapted to the soil and climatic factors and changes in growing conditions, and characterised by plasticity and durability. However, the use of other types of perennial legume grasses should be complementary to alfalfa, using their biological and economic advantages in local soil and climatic conditions. Thus, Hungarian sainfoin is characterised by high biological resistance to adverse growing conditions; white melilot has good drought and winter hardiness. Birdsfoot trefoil is characterised by productive longevity and the ability to grow on poor and acidic soils. Eastern galega is characterised by productive longevity and high biological plasticity [16].

Therefore, the *purpose* of this study was to establish what morphological and biological characteristics of the root systems of perennial legume grasses ensure their ecological and economic features in the context of climate change.

MATERIALS AND METHODS

Field research was conducted during 2013-2017 at the research farm "Agronomichne" of the Vinnytsia National Agrarian University. The experimental site was located on gray podzolic medium loamy soil. Agrochemical composition of the soil: humus content – 2.0%, hydrolysed nitrogen (according to Kornfield) – 133 mg/kg of soil, mobile phosphorus (according to Chirikov) – 390 mg/kg of soil, mobile potassium (according to Chirikov) – 64 mg/kg of soil, hydrolytic acidity – 2.53 mg-EQ/100 g of soil, reaction of pH salt of soil solution – 6.0.

Studies were conducted with the following types of perennial legume grasses: alfalfa (*Medicago sativa* L.), red clover (*Trifolium pratense* L.), Hungarian sainfoin (*Onobrychis arenaria* Kit.), white melilot (*Melilotus albus* L.), birdsfoot trefoil (*Lotus corniculatus* L.) and eastern galega (*Galega orientalis* Lam.). Grasses were sown in early spring using a clean cultivation way using a post-emergence herbicide. The green mass was harvested at the beginning of the flowering phase. Determination of the distribution features of the roots of perennial legume grasses in the soil was carried out by dry excavation [17; 18]. Quantitative parameters of root systems were determined using a measuring tape and caliper in four repetitions.

During the 2013 calendar year, 652 mm of precipitation fell, which is 18 mm more than the long-term average (634 mm), with an average annual temperature of 9.0°C, which is 2.0°C more than normal (7.0°C). The growing season began in the first ten days of April and lasted until the end of the second ten days of November. During the growing season, the amount of precipitation was 429 mm. In 2014, precipitation was 550 mm, which was 87% of the long-term average. The average annual temperature was 8.6°C, which is 1.6°C higher than normal. The growing season began in the first ten days of March and lasted until the end of the first ten days of November. During the growing season, the amount of precipitation was 442 mm.

In 2015, 368 mm of precipitation fell, which was 58% of the long-term average. The average annual temperature was 9.3°C, which is 2.3°C higher than normal. The growing season began in the end of March and lasted until the second ten days of November. During the growing season, 235 mm of precipitation fell. In 2016, the average annual temperature was 9.0°C, which is 2°C higher than normal. The amount of precipitation during the year was 469 mm, which was 26% less than normal. The growing season began in early April and lasted until the end of September. 2017 was characterised by an average annual temperature of 9.1°C, which was 2.1°C higher than normal. The amount of precipitation for the year was 503 mm, which corresponds to 80% of the long-term norm.

Thus, the most favourable growing conditions, taking into account the temperature regime and humidity level, were in 2014, which corresponds to the second year of vegetation of perennial legume grasses. The least favourable growing conditions were typical observed in 2016, when the grasses were growing for the fourth year.

RESULTS AND DISCUSSION

Features of initial aboveground and underground growth of perennial legume grasses

Observations of the germination of root systems of perennial legume grasses have shown that the roots of alfalfa and white melilot begin to germinate most quickly – on the 2nd-3rd day after sowing, later – red clover, Hungarian sainfoin, and at the latest – birdsfoot trefoil (Table 1).

Table 1. *Dynamics of early growth of underground and aboveground parts of perennial legume grasses, M±m*

Perennial legume grasses	Height, cm depending on the day after sowing				
	5	10		15	
	underground growth	aboveground growth	underground growth	aboveground growth	underground growth
Alfalfa	2.1±0.2	0.6±0.2	2.5±0.2	1.1±0.2	4.2±1.0
Red clover	2.2±0.1	0.2±0.1	2.6±0.2	0.6±0.1	2.9±0.4
Hungarian sainfoin	2.7±0.3	0.5±0.2	3.7±0.3	3.5±0.3	7.1±2.1
White melilot	1.7±0.2	0.3±0.1	2.2±0.2	0.8±0.1	3.3±0.9
Birdsfoot trefoil	0.3±0.1	0.1±0.05	0.8±0.1	0.4±0.1	2.5±1.0
Eastern galega	0.6±0.1	0.2±0.05	1.3±0.2	1.5±0.2	4.7±1.6

Source*: compiled based on the author's own research*

The results of studies showed that on the fifth day after sowing, the length of the roots of perennial legume grasses was 0.3-2.7 cm. Hungarian sainfoin had the greatest root length, which was 89% longer than birdsfoot trefoil, which crops had the smallest root length.

On the 10th day after sowing, the root length of perennial legume grasses was 0.8-3.7 cm. It remained the largest in plants of Hungarian sainfoin, which was 78.4% more than in plants of birdsfoot trefoil, which had the smallest root length. Starting from the 10th day, the growth of aboveground parts of legumes and perennial grasses begins. The ratio between the length of roots and aboveground seedlings in most plants was 6.5-8.0, in alfalfa – 4.2, and in red clover – 13.0 with a predominance of underground parts.

15 days after sowing, the length of the roots was 2.5-7.1 cm, and aboveground seedlings – 0.4-3.5 cm. In all indicators, Hungarian sainfoin plants prevailed. The ratio between the length of the underground and aboveground parts of plants decreased to 2.0-6.3. At this time, the root system grew more intensively in comparison with the aboveground part in red clover, birdsfoot trefoil and white melilot, and the aboveground part – in Hungarian sainfoin, eastern galega and alfalfa. The growth rate of the roots of perennial legume grasses for the first 5 days was highest in Hungarian sainfoin – 0.54 cm/day, while in birdsfoot trefoil – 0.06 cm/day.

During the second five-day period, the rate of root growth was 0.08-0.20 cm/day. It was the highest in the Hungarian sainfoin plants, and the smallest – in alfalfa and red clover. During this period, the intensity of root growth decreases in all types of legume grasses, with the exception of birdsfoot trefoil and eastern galega. The greatest decrease in growth was observed in alfalfa and Meadow Clover – by 5.5-5.3 times, compared to the first five-day period. This is conditioned by the beginning of aboveground growth. Plants of birdsfoot trefoil and eastern galega increased the average daily growth, compared to the first period, by 1.7 and 1.2 times – up to 0.14-0.10 cm/day and had, respectively, the smallest growth of the aboveground part of the plant, compared to other plants.

In the third observation period, the average daily growth of root systems of plants was 0.22-0.68 cm/day, except for red clover, where this indicator was 0.06 cm/day. The largest gains were observed in Hungarian sainfoin and eastern galega. The intensity of root growth at this time increased by 2.2-4.9 times compared to the second five-day period, especially in the eastern galega.

The highest average daily root growth in the third observation period was noted in eastern galega, birdsfoot trefoil and Hungarian sainfoin. The intensity of their growth in the eastern galega and birdsfoot trefoil increased from the first to the third periods, while in the Hungarian sainfoin it decreased in the second period compared to the first. Alfalfa, red clover and white melilot had the greatest root gains in the first observation period.

Morphological and biological features of root system development

The intensity of growth and development of root systems of perennial legume grasses depends on the value of symbiotic nitrogen fixation of nodule bacteria, the intensity of absorption of nutrients and water from the soil, the size of the formed aboveground crop. From an agroecological standpoint, the size of the root system determines the amount of organic matter that will return to the soil and replenish the supply of nutrients, and it also affects the agroecological resistance of the agrocenosis of legumes to unfavorable abiotic and biotic factors. The complex of morphological features of the distribution of plant root systems includes such parameters as the spread of roots in depth, the horizontal radius of root growth from the stem, and the depth of the main mass of branching of the plant root system.

The greatest depth of penetration of the root system into the soil thickness in the first year of vegetation was reached by alfalfa and white melilot, respectively, 83 and 82 cm, while the root system of birdsfoot trefoil reached a depth of 44 cm. The radius of horizontal root distribution, relative to the central root, was the largest in alfalfa plants – 25 cm, and the smallest – in red clover – 9 cm. The biggest depth of the main mass of branching of the root system was in eastern galega plants – 28 cm and Hungarian sainfoin – 23 cm, and the smallest – in alfalfa – 15 cm. A special feature of the root system of white melilot is its extremely high fragility, which may determine the biennial nature of the plant (Fig. 1).

Eastern galega, in addition to the root system itself, which is characterised by strong fibrousity, which determines its durability, also has root shoots, which are autonomous centres of emergence of individual plants. At the end of the first year of vegetation, the eastern galega plant forms up to 7-9 shoots. The maximum radius of their penetration from the central root is 25 cm, and the thickness is 3 mm. On such a shoot there can be up to 7 buds.

A) B) C) D)

***Figure 1**. Root system of eastern galega (A), white melilot (B), alfalfa (C), Hungarian sainfoin (D) on the first year of growth*

The main organ for restoring the vegetation of legume grasses and accumulating spare nutrients is the root neck. The productivity and durability of the herbage depends on the features of its development. The greatest thickness of the root neck in the year of sowing was observed in white melilot – 12 mm and alfalfa – 11 mm, and the smallest – in eastern galega – 5 mm and red clover – 6 mm (Table 2).

Table 2. *Morphology of root systems of perennial legumes depending on the growing season, M±m*

Perennial legume grasses	Years of growth	Depth of root penetration, cm	Root system radius, cm	Depth of the main mass of branching, cm	Thickness, mm			Number of buds on the root neck, pcs.
					root neck	central root	side roots	
Alfalfa	1	83±3	25±3	15±1	11±1	4±1	1.5±0.2	12±3
	2	258±9*	28±3	26±2	18±2	5±1	2.0±0.2	25±4
	3	432±4*	37±2	34±2	25±3	7±2	2.1±0.2	34±3
	4	813±15*	42±3	40±3	33±3	9±2	2.3±0.2	41±4
Red clover	1	51±2	9±1	18±1	6±2	2±1	0,8±0,2	14±2
	2	167±7	20±2	24±2	9±2	4±1	0.9±0.2	28±3
Hungarian sainfoin	1	65±3	15±2	23±2	8±2	4±1	1.0±0.2	13±2
	2	178±6	23±3	35±2	15±2	7±2	1.3±0.2	26±3
	3	269±5*	34±3	39±3	22±3	10±2	1.4±0.2	35±3
	4	311±9*	39±3	47±3	29±3	14±2	1.6±0.2	42±4
White melilot	1	82±4	20±2	18±1	12±2	6±1	3.0±0.2	6±1
	2	260±7*	30±3	31±2	17±2	6±1	3.0±0.2	6±1
Birdsfoot trefoil	1	44±3	18±2	21±2	7±1	3±1	1.1±0.2	33±3
	2	87±6	21±2	25±2	7±1	3±1	1.2±0.2	51±4
	3	101±8	22±2	27±2	11±2	4±1	1.2±0.2	70±4
	4	129±8	24±2	29±2	13±2	5±1	1.4±0.2	89±4
Eastern galega	1	52±4	16±1	28±3	5±2	4±1	1.0±0.2	8±2
	2	108±8	27±2	32±3	11±2	5±1	1.0±0.2	12±2
	3	119±7	31±3	37±3	17±2	9±1	1.1±0.2	16±3
	4	122±8	31±3	42±3	23±3	14±2	1.3±0.2	20±3

****Note**: reference data established in accordance with the literature sources listed below*
***Source**: compiled based on the author's own research and [5-7]*

An important indicator of the root neck is the number of buds on it, which are able to form a vegetative shoot next year. The largest number of them at the end of the growing season of the first year was observed in the birdsfoot trefoil – 33 pcs., which determines its intensive regrowth and three mowings during the first year of growth. The smallest number of buds was observed on the root neck of white melilot – 6 pcs., which, accordingly, determines its biennial nature and unsatisfactory regrowth with low mowing.

The greatest thickness of the middle part of the central root in the year of sowing was: in white melilot – 6 mm; and the smallest – 2 mm – in red clover. The average thickness of the lateral roots was also the largest in white melilot – 3.0 mm, and the smallest – 0.8 mm – in red clover.

Summing up the findings on the development of root systems of perennial legume grasses in the first year of vegetation, it should be noted: the greatest depth of root penetration into the soil and its greatest horizontal branching relative to the central root was observed in alfalfa and white melilot. However, the depth of the main mass of root branching in these crops was the smallest; the relatively shallow root system of eastern galega, Hungarian sainfoin, birdsfoot trefoil, and red clover in the year of sowing is compensated by an increase in the depth of the main mass of its branching. In plants of birdsfoot trefoil – also partially by a large radius of horizontal root spread relative to the central root. The greatest thickness of the root neck, central root, and side roots are noted in those types of perennial legumes in which the root system penetrates deeper.

At the end of the second year of vegetation of grasses, the depth of penetration of their roots increased significantly. The root system of white melilot and alfalfa was most deeply penetrated into the soil – up to 260-258 cm. The root system of birdsfoot trefoil was the least deep in the soil – up to 87 cm, which is 3 times less than that of white melilot and alfalfa. There was a similar tendency of root penetration into the soil of these species of leguminous grasses in depth with the first year of research on grasses that have the largest and smallest depth of penetration into the soil.

The radius of horizontal distribution of root systems of legumes in the second year of vegetation also increased. It was the largest in the plants of white melilot – 30 cm and eastern galega – 27 cm. The lowest horizontal root distribution was observed in red clover and birdsfoot trefoil – 20-21 cm, which is 1.5 times less than in white melilot. Compared to the first year of study, the horizontal distribution of eastern galega roots has significantly increased.

The greatest depth of the main mass of branching of the root system was characteristic of plants of Hungarian sainfoin – 35 cm and eastern galega – 32 cm. The lowest depth of distribution of the main mass of roots was observed in red clover, birdsfoot trefoil and alfalfa – 24-26 cm, which is 1.4 times less than in Hungarian sainfoin.

The thickness of the root neck of perennial legume grasses in the second year of vegetation was 7-18 mm. The thickest root neck was characteristic of alfalfa and white melilot, and the thinnest – for birdsfoot trefoil. The number of buds on the root neck of plants was 6-51 pcs. and it did not depend on the thickness of the root neck. Most of the buds were on the neck of the birdsfoot trefoil, which had the thinnest root neck, and the least – on the root neck of the white melilot, which had the thickest root neck.

The thickness of the central root of legume grasses was 3-7 mm. It was thickest in the Hungarian sainfoin and white melilot, and the thinnest – in the birdsfoot trefoil. To a large extent, the thickness of the central part of the main root was directly proportional to the thickness of the root neck. The thickness of the lateral roots of legume grasses in the second year of vegetation increased slightly and amounted to 0.9–3.0 mm. The thickest were the lateral roots of white melilot plants, and the thinnest were those of red clover.

In the third year of vegetation of perennial legumes, the depth of penetration of their roots into the soil continued to increase and amounted to 100-432 cm. The roots of alfalfa were most deeply penetrated into the soil, and the roots of birdsfoot trefoil were the least deep. The radius of horizontal distribution of the root system of legume grasses was 22-37 cm. It was the largest in alfalfa plants, and the smallest – in birdsfoot trefoil. Compared to previous years of observation, the radius of the root system of alfalfa increases significantly.

The depth of the main mass of branching of the root system of legumes was 27-39 cm at the end of the third year of vegetation. It was largest in the Hungarian sainfoin and eastern galega, and the smallest – in the birdsfoot trefoil. The thickness of the root neck of legume grasses at the end of the third year of vegetation was 11-25 mm. It was the largest in alfalfa plants, and the smallest – in birdsfoot trefoil. The number of buds on the root neck continued to grow and amounted to 16-70 pcs. Most of them were in the birdsfoot trefoil, and the least – in the eastern galega.

The thickness of the central root of legume grasses was 4-10 mm. It was the largest in the plants of Hungarian sainfoin, and the smallest – in birdsfoot trefoil. The thickness of the lateral roots of legume grasses was 1.1–2.1 mm. It was the largest in alfalfa plants, and the smallest – in eastern galega.

In the fourth year of vegetation of perennial grasses, the depth of penetration of their roots was 122-813 cm. The root system of alfalfa was the deepest, and the least deep – in the eastern galega and birdsfoot trefoil. Compared to the previous year, the depth of penetration into the soil of the roots of the birdsfoot trefoil increased and the eastern galega – decreases.

The radius of horizontal distribution of the root system of legume grasses was 22-37 cm. It was the largest in alfalfa plants, and the smallest – in birdsfoot trefoil plants. The depth of the main mass of branching of the root systems of perennial grasses was 29-47 cm. It was the largest in the plants of Hungarian sainfoin, and the smallest – in birdsfoot trefoil.

The thickness of the root neck of plants in the fourth year of vegetation was 13-33 cm. It was the largest in alfalfa plants, and the smallest – in birdsfoot trefoil. The number of renewal buds on the root neck of plants was 20-89 pcs. Most of them were in the birdsfoot trefoil, and the least – in the eastern galega.

The thickness of the central root of legume grasses was 5-14 mm. The thickest root was observed in the plants of Hungarian sainfoin and eastern galega, and the thinnest – in birdsfoot trefoil. Compared to the previous year, the thickness of the central root in eastern galega has significantly increased. The thickness of the lateral roots of plants was 1.3-2.3 mm. It was the thickest in alfalfa plants, and the thinnest – in birdsfoot trefoil and easterm galega.

Dynamics of root system growth and development over all years of study

Analysing the change in the depth of root distribution of perennial legume grasses during all growing years, it was found that during the first two years, the depth of root distribution in all plants was similar. Starting from the third year, there was an intensive growth of alfalfa roots and a slowdown in the root growth of birdsfoot trefoil and eastern galega.

In the second year of vegetation, the depth of penetration of alfalfa roots increased 3.1 times, in the third year – 1.7 times, and in the fourth – 1.9 times. The depth of white melilot roots in the second year increased 3.3 times. The depth of red clover roots in the second year increased by 3.3 times, but their distribution in depth was much less than that of white melilot and alfalfa plants. The roots of Hungarian sainfoin developed similar to the deepening of red clover roots. Their depth in the second year increased by 2.7 times, in the third –1.5 times, and in the fourth – 1.2 times. The roots of birdsfoot trefoil and eastern galega were least widespread in depth: in the second year, their depth increased by 2.0-2.1 times, in the third year – 1.1-1.2 times, in the fourth – 1.0-1.3 times.

The dynamics of changes in the radius of horizontal distribution of grass roots during all the years of vegetation was more uniform. A significant increase in this indicator was typical for all types of perennial grasses during the first year of vegetation.

A significant increase in the root distribution radius in alfalfa plants occurred in the third year of vegetation – 1.3 times; Hungarian sainfoin plants – in the second and third years of vegetation – 1.5 times each; eastern galega plants – in the second year of vegetation – 1.7 times. A significant increase in the root distribution radius of red clover and white melilot was observed in the second year of vegetation – 1.5 times. The root radius of birdsfoot trefoil plants grew evenly throughout all the years.

The depth of distribution of the main mass of roots in alfalfa plants increased most rapidly: in the second year of vegetation – by 1.7 times, in the third year – by 1.3 times, in the fourth – by 1.2 times. Intensive growth of the depth of the main mass of Hungarian sainfoin roots was observed in the second year of vegetation – 1.5 times and in the fourth year – 1.2 times. The depth of the main mass of white melilot roots in the second year of vegetation increased 1.7 times. The remaining herbs changed the depth of the main mass of roots evenly.

The number of renewal buds on the root neck of perennial legume grasses increased evenly during the growing season. The most intensive increase in their number was characteristic of birdsfoot trefoil: in the second year of vegetation – 1.6 times, in the third year – 1.4 times, in the fourth – 1.3 times. In Hungarian sainfoin and alfalfa plants, the number of buds was similar over the years and increased by 2.1 times in the second year, by 1.4 times in the third year, and by 1.2 times in the fourth year. The number of buds on the root neck of red clover in the second year of vegetation increased by 2 times, and in white melilot, during the two years of vegetation, no changes were observed. The number of buds in eastern galega plants increased 1.3-1.5 times each year.

CONCLUSIONS

Based on the conducted studies and comparisons of biometric indicators of root systems of various types of perennial legumes, the following conclusions can be made:

– the root system of alfalfa is characterised by the largest: penetration into the soil, spread of the roots in a horizontal direction; thickness of the root neck during all the years of vegetation, thickness of the lateral roots during the third or fourth years of vegetation, but the smallest distribution in the soil of the main mass of root branching in the year of sowing and the following year of vegetation. Such features of the root system development ensure the plasticity, durability, and productivity of alfalfa;

– the root system of white melilot is characterised by the largest: penetration into the soil, thickness of the root neck, central root and lateral roots during all the years of vegetation, horizontal spread of roots in the second year of vegetation, but the smallest number of renewal buds on the root neck during all the years of vegetation. These features determine the high drought and frost resistance of white melilot;

– the root system of the birdsfoot trefoil has the largest number of renewal buds on the root neck during all the years of vegetation. However, the plant had the smallest penetration into the soil, thickness of the root neck and the central root during all the years, radius of horizontal root spread and the depth of the main mass of root branching in the second or fourth years of vegetation, which determines its productive longevity and ability to grow on low-productive and acidic soils;

– the root system of eastern galega iss characterised by the largest: depth of the main mass of roots in the soil in all years, the horizontal spread of roots in the second year of vegetation, the thickness of the central root in the fourth year, but the smallest: depth of roots in the soil in the fourth year, thickness of the root neck during the first year and thickness of the side roots during the second, third, and fourth years of vegetation, the number of renewal buds on the root neck during the third and fourth years of vegetation. Such characteristics determine the productive longevity and high biological plasticity of eastern galega;

– the root system of Hungarian sainfoin was characterised by the greatest: horizontal spread of roots and the deepest placement of the main mass of root branching in the third or fourth years of vegetation; thickness of the central root during the second to fourth years. Thus, Hungarian sainfoin plants form a powerful root system in the third and fourth year of vegetation, which determines high biological resistance to adverse growing conditions;

– the root system of red clover has the smallest radius of horizontal root distribution, the thickness of the central root and the thickness of the lateral roots during all the growing years, which affects the possibility of its cultivation in the field crop rotation.

Expanding knowledge about the biological and morphological features of the distribution of root systems of perennial legume grasses during the growing season and in comparison with each other would allow the researchers to understand the processes occurring in plants, as well as select the optimal types of legumes for certain purposes in the context of climate change.

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БІОЛОГІЧНІ ОСОБЛИВОСТІ ПОШИРЕННЯ КОРЕНЕВИХ СИСТЕМ БОБОВИХ БАГАТОРІЧНИХ ТРАВ В УМОВАХ ЗМІНИ КЛІМАТУ

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Анотація. Визначальним чинником при виборі бобових багаторічних трав за умов змін клімату є їх посухостійкість, адже розвиток коренів прямо впливає на цю властивість, а також визначає їх продуктивність. Метою досліджень було встановити, за рахунок яких морфологічно-біологічних характеристик коренів трав забезпечуються господарські особливості в умовах змін клімату. Застосовували методи спостереження, порівняння, польового досліду. З'ясовано, що корені люцерни посівної мають найбільше заглиблення у ґрунт, поширення у горизонтальному напрямі, товщину кореневої шийки та бічних корінців, що забезпечує пластичність, довговічність і продуктивність її посівів. Встановлено, що корені буркуну білого мають найбільше заглиблення у ґрунт, товщину кореневої шийки, центрального кореня і бічних корінців, їх поширення у горизонтальному напрямі, що впливає на посухо- і морозостійкість рослин. Обґрунтовано, що корені лядвенцю рогатого відзначаються найбільшою кількістю бруньок відновлення на кореневій шийці, найменшим заглибленням, товщиною кореневої шийки, що впливає на продуктивне довголіття та можливість росту на бідних і кислих ґрунтах. Виявлено, що корені козлятнику східного мали найбільше заглиблення основної маси, поширення у горизонтальному напрямі, товщину центрального кореня, що впливає на продуктивне довголіття і високу біологічну пластичність. Встановлено, що корені еспарцету піщаного відзначались найбільшим поширенням у горизонтальному напрямі та найглибшим розміщенням основної маси розгалужень, що впливає на високу біологічну стійкість до несприятливих умов вирощування. З'ясовано, що корені конюшини лучної мали найменший радіус поширення у горизонтальній площині, товщину центрального і бічних корінців, що визначає можливість її вирощування у польовій сівозміні. Зазначені наукові знання дозволять підібрати види бобових багаторічних трав для повної реалізації їх потенціалу за умов зміни клімату

Ключові слова: рослини, корені, підземний розвиток, морфологія, роки вегетації