JEE Journal of Ecological Engineering

Journal of Ecological Engineering, 2025, 26(4), 220–227
https://doi.org/10.12911/22998993/200031
ISSN 2299–8993, License CC-BY 4.0

Received: 2025.01.07
Accepted: 2025.02.01
Published: 2025.02.17

The influence of fertilisation systems on the productivity and quality of different varieties of alfalfa (*Medicago sativa* L.)

Nadia Hetman[1], Uliana Karbivska[2*], Yaroslava Hryhoriv[2], Vasyl Degtyarjov[3], Mykola Marenych[4], Lesia Malynka[5], Vladymyr Kurhak[6], Antonina Golodna[6], Yurii Veklenko[7], Victoria Gniezdilova[2]

[1] Vinnytsia National Agrarian University 3 Soniachna Street, Vinnytsia, 21008, Ukraine
[2] Vasyl Stefanyk Precarpathian National University 57 Shevchenko Street, Ivano-Frankivsk, 76018, Ukraine
[3] State Biotechnological University, 44 Alchevskih Street, Kharkiv 61002, Ukraine
[4] Poltava State Agricultural University, 1/3 Skovorody Street, bldg. 1, Poltava, 36003, Ukraine
[5] Agricultural Sciences Scientific and Methodological Center of Higher and Professional Higher Education 11, Smilyanska, Kyiv, 03158, Ukraine
[6] National Scientific Centre "Institute of Agriculture of the National Academy of Agrarian Science of Ukraine", Mashynobudivnykiv Str. 2b, 08162, Chabany, Ukraine
[7] Department Institute of Feed Research and Agriculture of Podillya of the National Academy of Agrarian Sciences 16 Yunosti Ave., 21100. Vinnytsia, Ukraine
* Corresponding author's e-mail: uliana.karbivska@pnu.edu.ua

ABSTRACT

The article investigated the influence of different fertilisation systems on the productivity and quality of Medicago sativa L. of different varieties. The peculiarities of green mass formation and seed yields depending on the use of organic and mineral fertilisers were studied. Changes in quality indicators, such as protein, fibre and other nutrients in plants, were evaluated. The highest productivity of the thickness of Medicago sativa grass was achieved when mowing at the beginning of flowering. On the basis of the yield of dry matter and crude protein, the varieties were ranked in the following order: Rosana, Banat VS, Nasoloda, Unitro, Narechena Pivnochi. The maximum crude protein yield (6.98–7.31 t/ha) was observed during mowing at the early flowering phase, which exceeded the indicators at the budding stage by 0.07–0.60 t/ha. At the same time, the forage harvested at the budding phase had higher protein content, ranging from 193 to 211 g. The research results indicate a significant impact of fertilisation systems on the productivity and chemical composition of Medicago sativa, which is important for optimising agronomic practices in the cultivation of this crop. Adherence to alfalfa cultivation technologies is a key factor in ensuring high productivity of the grass thickness. On the grey forest soils of the Right-Bank Forest-Steppe, the use of alfalfa varieties of different eco-geographical origins allows for the stable production of plant raw materials for high-quality feed in the form of hay, haylage, pellets, or grass meal.

Keywords: alfalfa (*Medicago sativa* L.), varieties, height, productivity, chemical composition, feed, mineral fertilisers, organic fertilisers.

INTRODUCTION

Alfalfa (*Medicago sativa* L.) is one of the most valuable and productive forage crops, which can significantly help address the issue of plant protein deficiency in the diet of livestock in most regions. It is superior to most fodder crops in terms of protein quality and essential amino acid content (Karbivska et al., 2019; Karbivska et al., 2022; Kurhak et al., 2022; Kurhak et al., 2023). However, its cultivation faces a number of challenges: the decline of livestock farming, the use of uniform feed, soil acidification, which reduces productivity, nutritional value, and the longevity of alfalfa in thickness of grass. Additional factors include extreme climatic conditions and a lack of high-quality seeds. Therefore, improving the technology of alfalfa cultivation is an important task that will contribute not only to increasing livestock productivity, but also to enhancing soil fertility and halting its degradation (Melnyk, 2020).

Alfalfa (*Medicago sativa* L.) is a perennial forage crop grown worldwide. It is characterised by high biomass productivity and nutritional value; it also contributes to soil fertility improvement (Latrach et al., 2014; Tyshchenko et al., 2021) and protects soils from wind and water erosion (Annicchiarico et al., 2011; Vozhehova et al., 2022; Tyshchenko et al., 2022).

Moreover, due to atmospheric nitrogen fixation, alfalfa is an important precursor for other agricultural crops. It can grow under a variety of climatic conditions, from equatorial to Arctic latitudes (Bagavathiannan et al., 2009; Vozhehova et al., 2022; Tyshchenko et al., 2021). However, according to forecasts, global climate change will lead to higher temperatures, changes in precipitation patterns, and an increase in the frequency of extreme weather events, which is already noticeable in southern Ukraine (Harrison et al., 2014; Tyshchenko et al., 2020; Vozhehova et al. 2021).

Symbiotic nitrogen fixation carried out by leguminous crops helps increase yields and reduce the use of chemical fertilisers, particularly nitrogen and phosphorus fertilisers. This, in turn, contributes to strengthening food security and the development of sustainable agriculture. Research confirms that leguminous plants supply nitrogen for crop rotation systems, and its accumulation in the root zone is a key factor in providing this resource for subsequent crops (Geng et al., 2024).

Alfalfa is considered a global leader among perennial leguminous grasses in terms of the yield of digestible protein and essential amino acids per hectare of sowing (Kvitko et al., 1995; Kviтko et al., 2010). In European Union countries, large-scale production of high-quality alfalfa protein, which is cholesterol-free, is actively developing. This new protein, known as ribisco, can replace soy in various food products, such as sausages, sauces, and chocolate mousse. In terms of its properties, it is equivalent to cow's milk protein. The Swedish company "AlfaLaval" has developed a technology for extracting protein from alfalfa, and a plant in France, under the management of "France Luzerne," is already producing this product. Companies from the USA, Canada, and Saudi Arabia have also shown interest in this technology (Telekalo et al., 2017; Telekalo et al., 2019a; Telekalo et al., 2019b).

For the European Union, alfalfa protein production is particularly significant as it reduces dependence on soy imports. Additionally, this protein is safely used in livestock feed, eliminating the risk of bovine spongiform encephalopathy (mad cow disease). Alfalfa (*Medicago sativa*) shows a characteristic response to changes in temperature and day length. In September, when the duration of daylight decreases to 12.48 hours and the average daily temperature drops to the biological minimum of 5 °C, the plant stops its vegetative growth (Petrychenko et al., 2020; Kaminskyi et al., 2021).

Research has shown that for alfalfa cultivation, it is advisable to apply organic fertilisers at a rate of 20–40 t/ha for the preceding crop, as well as phosphorous-potassium fertilisers in increased doses (90–150 kg/ha P_2O_5 and 60–100 kg/ha K_2O) during ploughing. These elements are used by the cover crop and provide nutrition for the alfalfa in the following years. It is recommended to annually fertilise alfalfa with phosphorus and potassium at doses of $P_{30–60}K_{30–60}$ (Mazur et al., 2018).

During the growing season, phosphorus plays an important role, particularly in the formation of the symbiotic apparatus. Adequate phosphorus nutrition promotes an increase in the amount of leghemoglobin in the nodules, which is an indicator of nitrogen fixation activity, and also participates in the synthesis of amino acids, proteins, fats, starch, and sugars. The use of phosphorus fertilisers should not only compensate for the phosphorus losses removed with the crop, but also create a reserve of available phosphates in the soil. This ensures a long-term positive impact on crop formation and its quality (Hetman et al., 2017; Hetman et al., 2021).

Potassium plays a crucial role in the carbohydrate and protein metabolism of alfalfa. Under its influence, processes such as carbohydrate assimilation, protein synthesis, and the movement of carbohydrates from the aboveground parts of the plant to the root system are enhanced. Additionally, potassium contributes to increased drought resistance and winter hardiness of alfalfa (Shpaar, 2011).

Thus, the use of perennial leguminous grasses, particularly alfalfa, remains promising and relevant in the production of plant raw materials and the preservation of ecological balance, especially in the context of climate change. The aim of the research was to study the biological characteristics of alfalfa (*Medicago sativa* L.) and its productivity depending on varietal traits and fertilization systems.

MATERIALS AND METHODS

The research was conducted from 2016 to 2019 in the technological crop rotation of the Department of Field Forage Crops, Hayfields and Pastures of the Institute of Forage and Agriculture of Podillya, NAAS. The soil of the experimental plot is grey forest, medium loamy, on loess, typical for the Right-Bank Forest-Steppe and the Vinnytsia region.

The plow layer of the soil (0–30 cm) was characterised by the following indicators: pH (in salt) – 5.9; humus content (according to Tyurin) – 2.52%; ammonium nitrogen (according to Kornfield) – 97 mg/kg of soil; available potassium and available phosphorus (according to Chirikov) – 115 and 90 mg/kg, respectively. The hydrolytic acidity was 3.40 mg eq./kg of soil.

The hydrothermal conditions significantly differed from the long-term averages and were characterised by uneven rainfall and elevated temperatures during the growing season. In the year of sowing and formation of the grass stand (2016), the sum of active temperatures amounted to 1235 °C, exceeding the norm by 244 °C, while the amount of precipitation was 26% lower than the norm (106 mm), and the hydrothermal coefficient (HTC) was 0.86.

In the second year of vegetation, during the summer, the average daily air temperature increased to 19.1–21.4 °C, while the amount of precipitation decreased by 1.8 times compared to the long-term average. In the third and fourth years of using the alfalfa grass stand, the average daily air temperature during the period from May to September was 15.4–20.0 °C (2018) and 12.2–20.1 °C (2019), while the amount of precipitation reached 295 mm and 254 mm, respectively.

For alfalfa cultivation, the generally accepted technology was used, except for the studied factors. The experimental design included Factor A – varieties (Narechena Pivnochi, Rosana, Banat VS, Unitro, and Nasoloda) and Factor B – fertilisation (mineral and organic) (Table 1).

The experiment involved sowing high-yielding varieties of alfalfa, which differ in dormancy class and the speed of grass stand formation. It is known that the duration of the dormancy period can vary significantly both between species and among varieties of the same species. This is determined by the genetic traits of each variety and the influence of external conditions. The characteristics of the alfalfa varieties are presented in Table 2.

The sowing of alfalfa was conducted on April 29, 2016, using a bare-seed method with a seeding rate of 8.0 million viable seeds per hectare. The experiment was carried out with three replications. The accounting plot area was 25 m², and the total area was 40 m². Within the study, two fertilisation systems were investigated: organic and mineral. Organic fertilisers included poultry

Table 1. Experimental design

Factor A – varieties	Factor A – varieties
Narechena Pivnochi Rosana Banat VS Unitro Nasoloda	Mineral (phosphorus-potassium fertilizers ($P_{180}K_{180}$) Organic – poultry manure (5 t/ha)

Table 2. Classification of alfalfa varieties according to dormancy group level and climatic zone

Variety	Dormancy group and its values	Variety originator	Climatic zone
Narechena Pivnochi	2.5 (dormant)	National Scientific Center "Institute of Agriculture of NAAS"	Polissya, Ukraine
Rosana	4,0 (dormant)	Institute of Forage and Agriculture of Podillya, NAAS	Forest-Steppe, Ukraine
Banat VS	4.5 (moderately dormant)	Institute of Field and Vegetable Crops	N.S. Seme (Serbia)
Unitro	4,8 (moderately dormant)	Institute of Climate-Oriented Agriculture NAAS	Steppe, Ukraine
Nasoloda	5,0 (moderately dormant)	Breeding and Genetics Institute NAAS	Steppe, Ukraine

manure at a dose of 5 t/ha, while phosphorus-potassium fertilisers were applied at a dose of $P_{180}K_{180}$. Phenological observations and records were made according to standard methodological recommendations approved in forage production (Babich et al., 1998).

The main research material

Due to favourable hydrothermal conditions and sufficient soil nutrient supply, in the year of sowing, alfalfa (*Medicago sativa*) developed a well-established root system and a sturdy stems. The studied ecotypes provided two mowing yields: Banat VS and Rosana yielded 6.44–6.69 t/ha of dry matter, the southern varieties Unitro and Nasoloda yielded 5.38–5.71 t/ha, and Narechena Pivnochi yielded 4.80 t/ha. In the second year of vegetation, under drought conditions (hydrothermal coefficient 0.87), alfalfa productivity was limited. The plants remained stunted, reaching a height of 54–57 cm (BBCH code 50) and 55–58 cm (BBCH code 60), regardless of the nutrient background, for varieties with a dormancy group of 4.0. For varieties with a dormancy group of 4.5–5.0, the height was 52–54 cm and 54–57 cm, respectively (Fig. 1).

In the third year of vegetation, under favourable hydrothermal conditions (HTC 1.22), alfalfa of the Rosana variety reached the greatest height of 64–69 cm, while the Banat VS variety on a mineral nutrient background achieved 64–73 cm.

The lowest height indicators were observed in the Narechena Pivnochi variety (55–58 cm), as well as in the Unitro and Nasoloda varieties (60–64 cm), which belong to the dormancy group 4.8–5.0.

The formation of the grass stand and the productivity level of alfalfa largely depended on the temperature regime, rainfall amount, and fertilisation level, which resulted in differences between the varieties. The lowest dry matter yield in the second year of vegetation was shown by the Narechena Pivnochi variety – 8.05–8.25 t/ha. The Rosana variety demonstrated the highest productivity, providing 10.69–10.80 t/ha of dry matter. For varieties with a dormancy group of 4.5–5.0, productivity decreased to 9.94–10.75 t/ha, regardless of the fertilisation background.

The ecological conditions of the third year of vegetation (HTC 1.22) contributed to an increase in the gross dry matter yield during the growth and development phases. Mowing the grass stand at the bud stage and the beginning of flowering resulted in an increase in dry matter yield from 15.61–17.73 to 15.78–18.98 t/ha, depending on the variety, on the background of phosphorus-potassium fertilisation. The use of poultry manure, as a less common organic fertiliser, ensured a stable dry matter yield at a level of 15.57–18.28 t/ha, considering the varietal characteristics.

The maximum productivity of the alfalfa grass stand was achieved by mowing at the beginning of the flowering phase. In terms of dry

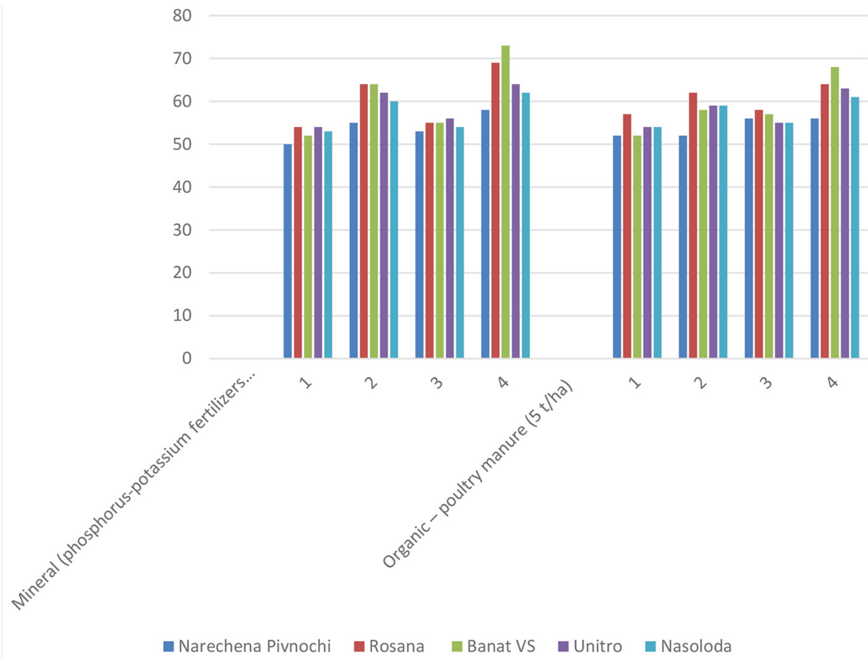

Figure 1. Changes in the height of alfalfa plants depending on the variety, fertilisation, and modes of use, cm

matter and crude protein yield, the varieties ranked as follows: Rosana, Banat VS, Nasoloda, Unitro, and Narechena Pivnochi. The highest crude protein yield (6.98–7.31 t/ha) was observed when mowing the grass stand at the beginning of the flowering phase, which exceeded the figures for mowing in the budding phase by 0.07–0.60 t/ha. At the same time, the protein content in the forage was higher at the budding phase, ranging from 193 to 211g.

The highest output of metabolisable energy was provided by the alfalfa varieties Banat VS and Rosana at the beginning of the flowering phase – 97.48 and 103.70 GJ/ha, respectively. At the budding phase, these values were also significant: 88.79 GJ/ha for the Banat VS variety and 91.30 GJ/ha for the Rosana variety. The southern ecotype varieties reached levels of 82.06–93.28 and 82.29–92.26 GJ/ha, while the lowest output was observed in the Narechena Pivnochi variety – 74.39–80.00 GJ/ha (Fig. 2).

The calculations showed that the highest energy efficiency coefficient was observed in the Rosana variety (3.24–3.62), followed by the southern ecotype varieties (2.82–2.97 and 3.24–3.30), the northern ecotype varieties (2.70–2.87), and the Banat VS variety (3.19–3.43), depending on the mode of use of the grass stand (Fig. 3). According to the research of Savchuk, Bovsunovskyi, and Vlasenko, the application of an increased fertiliser rate ($N_{40}P_{120}K_{120}$) ensured the maximum yield of both above-ground biomass and plant residues of alfalfa exclusively on sod-podzolic soils. On sod soils, a moderate fertilisation rate proved to be more effective. A similar pattern was observed regarding the accumulation of alfalfa plant residues. As a result, 296 and 278

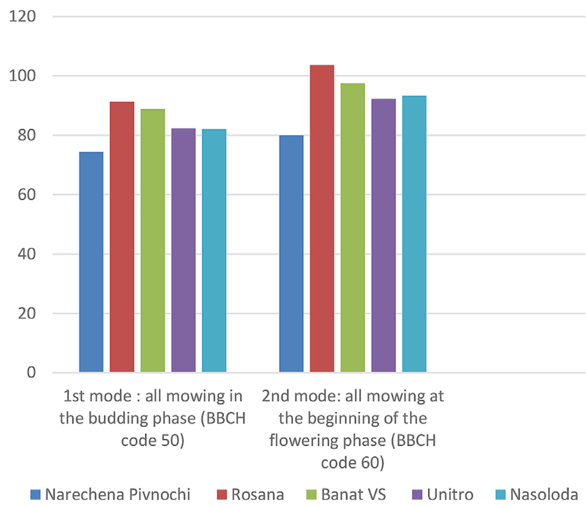

Figure 2. Metabolisable energy output of different dormancy groups of alfalfa (*Medicago sativa*) depending on variety and modes of use, GJ/ha

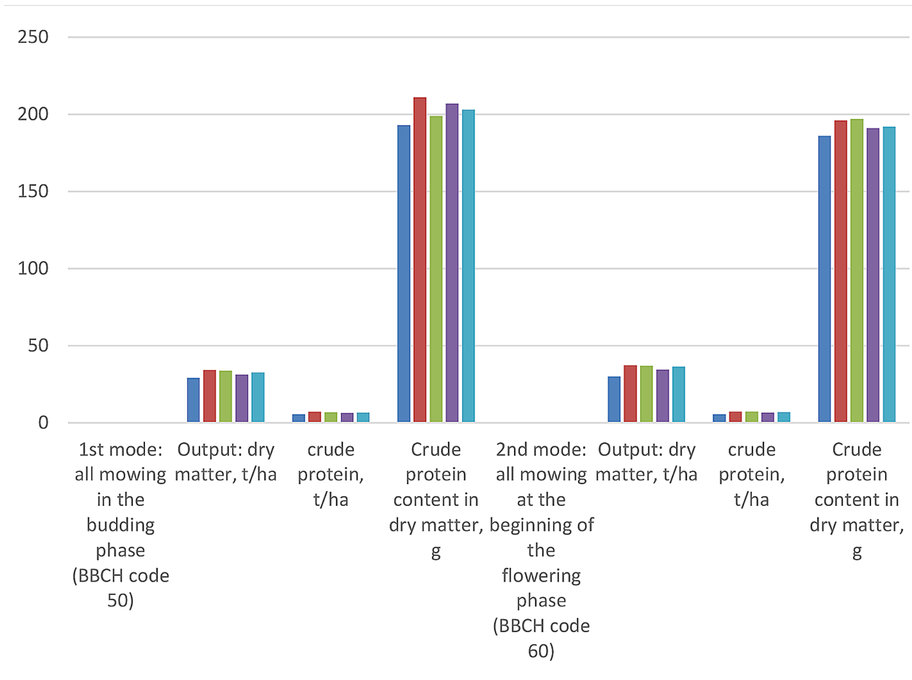

Figure 3. Forage productivity of different dormancy groups of alfalfa (*Medicago sativa*) depending on variety and modes of use

Table 3. Chemical composition of alfalfa (*Medicago sativa*) of different varieties depending on fertilisation

Variety	Fertiliser background	Indicators of nitrogen compounds, %	Crude Protein	
			Content, %	Yield, t/ha
Unitro	Phosphorus-potassium fertilizers	3,31	20,69	3,94
	Organic fertilizers	3,06	19,12	3,29
Nasoloda	Phosphorus-potassium fertilizers	3,41	21,31	3,79
	Organic fertilizers	3,23	20,19	3,61
Banat VS	Phosphorus-potassium fertilizers	3,34	20,88	3,52
	Organic fertilizers	3,13	19,56	3,98
Rosana	Phosphorus-potassium fertilizers	3,38	21,12	4,49
	Organic fertilizers	3,11	19,44	4,04
Narechena Pivnochi	Phosphorus-potassium fertilizers	3,09	19,31	3,19
	Organic fertilizers	2,82	17,62	2,89

kg/ha of nitrogen, respectively, accumulated in the soil (Savchuk et al., 2008). In the conducted research, the application of different fertilization levels contributed to a more efficient transformation of nitrogen in crop plants. The highest nitrogen content was recorded in plants of the Nasoloda variety under the variant with the application of phosphorus-potassium fertiliser, with a value of 3.41% (Table 3).

The research results showed that in all variants of the five alfalfa cultivars, the mineral fertilisation system resulted in higher levels of nitrogen compounds (ranging from 0.18–0.27%) and crude protein (ranging from 1.12–1.69%) compared to the organic fertilisation system.

According to the research results, the highest crude protein yield was observed in the Rosana variety under the mineral fertilisation system, with a value of 4.49 t/ha.

CONCLUSIONS

Among the studied alfalfa varieties, the highest forage productivity at the budding phase was observed in the Rosana variety – 34.24 t/ha, with 7.23 t/ha of crude protein, 91.3 GJ/ha of exchange energy, and a provision of 211 grams of crude protein per kilogram of dry matter.

The maximum productivity of alfalfa grass stand was achieved when mowing at the beginning of flowering in all studied varieties. On the basis of the dry matter and crude protein yield, the varieties were ranked in the following order: Rosana, Banat VS, Nasoloda, Unitro, and Narechena Pivnochi. The highest crude protein yield (6.98–7.31 t/ha) was recorded when mowing at the beginning of flowering, which exceeded the results of mowing at the budding phase by 0.07–0.60 t/ha. At the same time, a higher level of protein content in the forage was observed when mowing at the budding phase, ranging from 193 to 211 grams. Among the fertilisation systems, the best results were obtained with the application of phosphorus-potassium fertilisers at a dose of $P_{180}K_{180}$.

Adherence to technological methods of growing alfalfa (*Medicago sativa*) helps to ensure high productivity of the grass stand. On the grey forest soils of the Right-Bank Forest-Steppe, the use of alfalfa varieties of different eco-geographical origins allows for the stable production of plant raw materials for high-quality feed in the form of hay, haylage, pellets, or grass meal.

REFERENCES

1. Agroecological methods of improving the productivity of niche leguminous crops. (2019a). N. Telekalo et al. *Ukrainian Journal of Ecology*. *9*(1). 169–175.
2. Annicchiarico P., Pecetti L., Abdelguerfi A., Bouizgaren A., Carroni A.M., Hayek T. et al. (2011). Adaptation of landrace and variety germplasm and selection strategies for lucerne in the Mediterraneanbasin. *Field Crops Research. 120*, 2. 283–291. https://doi.org/10.1016/j.fcr.2010.11.003.
3. Bagavathiannan M., Van Acker R.C. (2009). The biology and ecology of feral alfalfa (*Medicago sativa* L.) and its implications for novel trait confinement in North America. *Critical Reviews in Plant Sciences.* 28. 1–2. 69–87. https://doi.org/10.1080/07352680902753613
4. Energy-economic efficiency of growth of grain-crop

cultures in conditions of Right-Bank Forest-Steppe of Ukraine. (2018). V. Mazur et al. *Ukrainian Journal of Ecology*. *8*(4). 26–33.

5. Geng S., Li L., Miao Y., Zhang Y., Yu X., Zhang D., Yang Q., Zhang X., Wang, Y. (2024). Nitrogen rhizodeposition from corn and soybean, and its contribution to the subsequent wheat crops. *J. Integr. Agric.* 23, 2446–2457. [CrossRef]
6. Harrison M.T., Tardieu F., Dong Z., Messina C.D. & Hammer G.L. (2014). Characterizing drought stress and trait influence on maize yield under current and future conditions. *Glob. Change Biol.* 20. 3. 867–878. https://doi.org/10.1111/gcb.12381
7. Kaminskyi V., Kolomiiets L., Bulgakov V., Olt J. (2021). An investigation into the state of agricultural lands under water erosion conditions. *Agronomy Research. 19*(2), 458–471. https://doi.org/10.15159/AR.21.029
8. Karbivska U.M., Butenko A.O., Masyk I.M. et al. 2019. Influence of agrotechnical measures on the quality of feed of legume-grass mixtures. *Ukrainian Journal of Ecology*. *9*(4). 547–551. https://doi.org/10.15421/2019_788.
9. Karbivska U.M., Kovalenko I.M., Onychko T.O., Radchenko M.V., Pshychenko O.I., Tykhonova O.M., Vereshchahin I.V., Bordun R.M., Tymchuk D.S. 2022. Economic and energy efficiency of growing legume grasses. *Modern Phytomorphology 16*, 21–26. https://doi.org/https://doi.org/10.5281/zen
10. Kvitko G.P., Lipkan M.V., Shtoyko O.P. (1995). ProduktivnIst lyutserni v zalezhnostI vid sposobiv viroschuvannya i rezhimiv vikoristannya travostoyu. UkraYina v svitovih zemelnih, prodovolchih, kormovih resursah i ekonomichnih vidnosinah*: materiali Mizhnar. konf. Vinnitsya*, 379–380. (in Ukrainian).
11. Latrach L., Farissi M., Mouradi M., Makoudi B., Bouizgaren A., Ghoulam C. 2014. Growth and nodulation of alfalfa-rhizobia symbiosis under salinity: electrolyte leakage, stomatal conductance, and chlorophyll fluorescence. *Turkish Journal* of *Agriculture and Forestry*. 38, 320–326. doi: 10.3906/ tar-1305-52
12. Savchuk O.I., Bovsunovskiy A.M., Vlasenko O.O. 2008. EfektivnIst viroschuvannya lyutserni zalezhno vid rivnya udobrennya na riznih tipah Gruntiv. *Kormi ta kormovirobnitstvo*. 61. 55–60. (in Ukrainian).
13. Tucak M., Ravlić M., Horvat D., Čupić T. 2021. Improvement of Forage Nutritive Quality of Alfalfa and Red Clover through Plant Breeding. *Agronomy* J. 11. 2176. doi: 10.3390/agronomy11112176
14. Tyshchenko A.V., Tyshchenko O.D., Kuts G.M., Piliarska O.O., Galchenko N.M. 2021. Anti-pest protection of two-year old alfalfa grown for seeds. *Breeding and seed production.* 119. 170–180.
15. Tyshchenko O., Tyshchenko A., Piliarska O., Kuts H., Lykhovyd P. 2020. Evaluation of drought tolerance in alfalfa (Medicago sativa) genotypes in the conditions of osmotic stress. *AgroLife Scientific Journal*. 9. 2. 353–358.
16. Vozhehova R.A., Tyshchenko A.V., Tyshchenko O.D., Dymov O.M., Piliarska O.O. 2021. Otsinjuvannia posuhostijkosty selektsijnogo materialu ljutserny za pokaznykamy vodnogo rezhymu v umovah Pivdnia Ukrainy. *Plant Varieties Studying and protection.* 17,1. 21–29. https://doi.org/10.21498/2518-1017.17.1.2021.228204
17. Vozhehova R.A., Tyshchenko A.V., Tyshchenko O.D., Piliarska O.O., Galchenko N.M. 2022a. Otsinka posuhostijkosty populiatsij ljutserny kormovogo vykorystannia v rik sivby za matematychnymy ingeksamy. *Agrarni innovatsii*. 13. 190–198. DOI https://doi. org/10.32848/agrar.innov.2022a.13.28 (in Ukrainian).
18. Vozhehova R.A., Tyshchenko A.V., Tyshchenko O.D., Piliarska O.O., Fundyrat K.S., Galchenko N. M. 2022b. Otsinka posuhostijkosty populiatsij ljutserny za nasinnevogo vykorystannia v rik sivby. *Agrarni innovatsii*. 15. 89–96. DOI https://doi.org/10.32848/ agrar.innov.2022b.15.14 (in Ukrainian).
19. Hetman N., Veklenko Yu., Tkachuk R. 2017. Formuvannia ekologichno stijkyh agrofitotsenoziv ljutserny posivnoi zalezhno vid umov vuroshchuvannia. *Kormy i kormovyrobnytstvo*. 84. 70–74. (in Ukrainian).
20. Hetman N.Ya., Kvitko M.G., Tsyganskii V.I. 2021. Ljutserna posivna: monografia. Vinnytsia, TVORY. 428. (in Ukrainian).
21. Demydas G.I., Kvitko M.G. 2019. Vplyv norm vysivu ta shyryny mizriaddia na vysotu ljutserny posivnoi. *Kormy i kormovyrobnytstvo*. 88. 37–43. (in Ukrainian).
22. Kvitko G.P., Mazur V.A., Davymoka O.V., Lomachevskii S.M., Tkachuk O.P., Samiliak M.V. 2010. Adaptyvni energooshchadni tehnologii vyroshchuvannia bagatorichnyh bobovyh trav na korm v umovah Lisostepu pravoberezhnogo. *Kormy i kormovyrobnytstvo*. 66. 78–82. (in Ukrainian).
23. Kurgak V.G., Degodjuk E.G., Gavrysh Ya.V. 2022. Kormova produktyvnist lutserno-zlakovyh agrotsenoziv z riznymy zlakovymy komponentamy. *Visnyk agrarnoi nauky.* 3 (828). 28–36. (in Ukrainian).
24. Kurgak V.G., Slusar S.M., Krasiuk L.M., Gavrysh Ya.V. 2023. Dynamika produktyvnosti luchnyh agrofitotsenoziv za uchasti ljutserny posivnoi pry formuvanni pershogo ukosu. *Visnyk agrarnoi nauky.* 10 (847). 19–27. (in Ukrainian).
25. Melnyk M.V. 2020. Ekonomichna efectyvnist vyroshchuvannia ljutserny posivnoi. *Tavriiskii naukovyi visnyk.* 112. 122–129. (in Ukrainian).
26. Metodyka provedennia doslidzhen u kormovyrobnytstvi i godivli tvaryn. 1998. A.O. Babych ta in. Kyiv. *Agrarian science*, 80. (in Ukrainian).

27. Petrychenko V.F., Hetman N.Ya., Veklenko Yu.A. 2020. Obgruntuvannia produktyvnosti ljutserny posivnoi za tryvalogo vykorystannia travostou v umovah zminy klimatu. *Visnyk agrarnoi nauky*. 3. 20–26. (in Ukrainian).
28. Telekalo N., Blah M. 2017. Vplyv elementiv tehnologii vyroshchuvannia na produktyvnist ljutserny posivnoi v umovah Lisostepu pravoberezhnogo. *Silske gospodarstvo ta lisivnytstvo: zbirnyk naukovyh prats Vinnytskogo natsionalnogo agrarnogo universytetu.* 6. 2. 35–43. (in Ukrainian).
29. Telekalo N., Melnyk M. 2019b. Shliahy pidvyshchennia produktyvnosti ljutserny posivnoi na nasinnia. *Silske gospodarstvo ta lisivnytstvo: zbirnyk naukovyh prats Vinnytskogo natsionalnogo agrarnogo universytetu.* 15. 56–63. (in Ukrainian).
30. Tyshchenko A.V., Tyshchenko O.D., Kuts G.M., Piliarska O.O., Konovalova V.M. 2022. Nasinnieva produktyvnist ljutserny pershogo roku zhyttia zalezhno vid zastosuvannia gerbitsydiv. *Agrarni innovatsii.* 11. 92–102. DOI https://doi.org/10.32848/agrar. innov.2022.11.12 (in Ukrainian).
31. Tyshchenko A.V., Tyshchenko O.D., Luta Yu.O., Piliarska O.O. 2021. Osoblyvosti rozvytku populiatsii ljutserny za riznyh umov vyroshchuvannia. *Naukovi dopovidi NUBiP Ukrainy*, 4(92), 1–16. (In Ukrainian).
32. Shpaar D. 2011. Ljutserna – koroleva kormovyh kultur. *Agroexpert.* 4. 52–56. (In Ukrainian).