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The Influence of Elements of Technology and Soil-Climatic Factors on the Agrobiological Properties of *Onobrychis Viciifolia*

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ABSTRACT

The significance of this study stems from the imperative to justify and advance agrobiological foundations aimed at enhancing the cultivation practices of *Onobrychis viciifolia*. There exists a compelling necessity to refine agronomic methodologies and streamline their comprehensive efficacy within the technological phases of cultivation. This study is aim to provide a critical analysis of scientific problem of substantiation of biological and organic foundations of the technology of *Onobrychis viciifolia* growing. Innovative technological interventions were formulated by extrapolating discerned patterns of influence pertaining to climatic and meteorological factors. Patterns governing the growth, development, and productivity formation of *Onobrychis viciifolia* were identified, and both the theoretical and practical principles of contemporary methods for cultivating perennial legumes were established. The chemical compound of aboveground biomass of *Onobrychis viciifolia* is varied depending on researched factors. Fertilization practically did not increase the productivity of *Onobrychis viciifolia*. The natural fertility of low-humus chernozem soil ensures the formation of a high, stable yield without fertilizing. This is the evidence that *Onobrychis viciifolia* compares favorably with other perennial legumes. Due to its biological characteristics, it is much more effective, especially in leveraging natural factors for the yield formation, i.e., it plays a significant role in the biologization of plant production, and in obtaining the most environmentally friendly, high–quality, yet cheap feed. The outcomes derived from the conducted research indicate that, under uniform soil conditions and varying fertilizer levels, the mowing height emerges as the predominant factor. The highest concentrations of nutrients within the overground biomass of *Onobrychis viciifolia* were noted at a cutting altitude of 11 centimeters. Concurrently, an elevation in crude protein and ash content was observed, accompanied by a concomitant reduction in the index of crude fiber.

Keywords: *Onobrychis viciifolia*, ecological biomass, yield formation, fertilization, mowing height, yield, phenological phases, ecological and biological crop production.

INTRODUCTION

Onobrychis viciifolia contains high–quality protein with a high content of valuable amino acids and can serve as a source of nectar for honey production (up to 200 kg ha^{-1}). *Onobrychis viciifolia* taproot morphologically similar to alfalfa and clover, and can branch up to 70 cm [Borreani et al., 2003; Demydas' et al., 2013]. This ability allows for the efficient uptake of nutrients from deep soil layers in sufficient quantities [Bulyhin and Tonkha, 2018; Chwietczuk, 2021; Kovalenko et al., 2022]. The distribution of *Onobrychis viciifolia* is primarily determined by the structural characteristics of its root system and its heightened demand for calcium. It is predominantly sown on slopes and poorly productive soils in Forest-steppe and Steppe regions, where the upper soil layer contains an adequate calcium content [Borreani et al., 2003; Liu, 2008]. High productivity of *Onobrychis viciifolia* is achieved even in conditions where sufficient moisture is present only in deep soil layers. *Onobrychis viciifolia* grows well in calcareous soils and has a taproot that provides a high level of drought tolerance [Liu, 2008].

Onobrychis viciifolia is a perennial legume that has been an important component of the cropping system in many parts of Europe for the past four centuries. As a legume, it biologically fixes atmospheric nitrogen (N), which allows it to be successfully grown without N fertilization [Hartwig and Nosberger, 1996; Delgano, 2008; Tufenkci, 2008; Chwietczuk, 2021]. Nodule bacteria in the rhizosphere of *Onobrychis viciifolia* are capable of fixing 100–200 kilograms of nitrogen per hectare in the soil annually, which significantly exceeds the values of free–living diazotrophs in the rhizosphere of other crops [Mazurenko et al., 2020; Honchar et al., 2020]. A new root system grows annually on the taproot, similar to the aboveground mass, and the last year one is mineralized, improve the availability of soil nutrients and soil carbon content [Demydas′ et al., 2013].

Sainfoin seeds require absorbing moisture equivalent to approximately 150% of their own weight to initiate germination. The minimum germination temperature is 3–5 °C, but for uniform emergence, the soil temperature should be around 10 °C in the 0–4 cm layer, allowing for emergence within 7–10 days after sowing. The resilience of *Onobrychis viciifolia* to drought stress is primarily influenced by meadow clover and specific varieties of alfalfa. Additionally, it exhibits a considerable level of winter hardiness, with the exception of the Transcaucasian variety [Schweizer, 2006; Kokovikhin et al., 2020; Kovalenko et al., 2021a]. The productivity of *Onobrychis viciifolia* depends on the genetic potential and cultivation technology of the crop [Dalzell and Shelton, 2002].

The introduction of 90 kg ha^{-1} of phosphorus fertilizer at the beginning of flowering increased productivity and improved the quality of *Onobrychis viciifolia* herbage. Phosphorus supplementation improve the dry mass accumulation and the chemical compound of legumes [Comakli and Tas, 1996; Türk et al., 2007; Shalyuta and Kostitskaya, 2018; Sikora et al., 2020; Sobko et al., 2023] showed that fertilization with P increased the dry matter yield, the content of P, Ca, and Mg in the products, and the amino acid composition. The nutrient content is not necessarily the only criterion for assessing plant nutritional value [Thomson, 1982; Witek et al., 2016; Khmelovskyi et al., 2019; Szparaga et al., 2019]. The paramount factor influencing the chemical composition and digestibility of feed is the growth stage. In most plants, the nutrient content is reduced before maturation [Borreani et al., 2003; Szelag-Sikora et al., 2019; Gugała et al., 2019a; Gugała et al., 2019b; Krawczuk et al., 2021; Karpenko et al., 2022] proved that sainfoin has a positive response to organic fertilizers, phosphorus and potassium fertilizers on calcareous soils; Lorenz [2010] noted that *Onobrychis viciifolia* requires more phosphorus and nitrogen than *Medicago sativa*, but less potassium and calcium.

Sainfoin responds well to the application of 60 kg ha^{-1} of nitrogen on frozen soil before the onset of vegetative growth, or they are mixed by cultivators to a depth of 10–12 cm. In general, as it is known, applying a nitrate form of nitrogen reduces the rate of nitrogen fixation of legumes [Chwietczuk, 2021; Radchenko et al., 2023]. However, a low level of inorganic nitrogen stimulates nitrogen fixation in *Onobrychis viciifolia*, with a subsequent increase in plant biomass by 20–30% [Liu, 2008; Voitovyk et al., 2024]. However, no dependence of the direct yield on the level of soil fertility and the provision of crops with nitrogen was found. Shan [1991] proved a decrease in the productivity of *Onobrychis viciifolia* by 4% after the application of 90 kg ha^{-1} nitrogen. Several other studies have shown that low nitrogen rates increased productivity and crop quality [Heckendorn et al., 2006; Kovalenko, 2015; Voloshun and Avetisyan, 2017; Hryhoriv et al., 2022]. The studies of Voloshun and Avetisyan [2017] proved that the application of a minimum ($N_{20}P_{30}K_{20}$) or average ($N_{40}P_{60}K_{40}$) dose of fertilizers with a sowing rate of 2.500.000 germinating seeds per hectare of the crop, using standard agromethods, increased the nutrient content of nitrogen *Onobrychis viciifolia* plants by 0.15–0.67%, phosphorus – by 0.04–0.16 mm% and potassium – by 0.44–0.87%, contributed to the economical use of water by plants and an increase in yield by 47–55% compared to non-fertilized options. The productivity potential of *Onobrychis viciifolia* can reach 50 tons/ha of green mass (or 4 tons/ha of hay equivalent). [Tonkha et al., 2021; Karbivska et al., 2023]. In light of the aforementioned, the authors posit that studying the agrotechnical principles governing optimal *Onobrychis viciifolia* yields is essential, contingent upon factors such as fertilization and cutting altitude.

Considering the information presented above, the study aimed to theoretically justify and advance the agrobiological foundations for intensifying *Onobrychis viciifolia* cultivation. This involved establishing quantitative parameters for the formation and operation of stable production zones, as well as determining the level of realization dependent on weather conditions and agrotechnical factors. Additionally, the focus was on optimizing crop placement and developing and implementing competitive technologies for growing perennial legumes. These technologies aim for high energy recovery and adaptability to environmental conditions by enhancing and integrating fundamental agronomic techniques within a comprehensive technological cycle.

To achieve the defined goal and solve the existing problems, the following tasks were set:

- to determine the parameters of action and feasibility of mineral fertilizers and integrated protection application in the system of factors of intensification in the studied crops growing,
- to establish the features of the influence of fertilizers, the intensity of the assimilation surface functioning and the forage productivity formation of *Onobrychis viciifolia*.

MATERIAL AND METHODS

The studies were carried out in the stationary experiment in the local office of National University of Life and Environmental Sciences of Ukraine, "Agronomic Experimental Station" in Vasylkiv district (Kyiv region) in the period 2013–2018. On typical large–sawed medium loamy chernozem soil on loess. The effect of four fertilization options was investigated: 1. Without fertilizers (control); 2. $P_{60}K_{60}$; 3. $N_{30}P_{60}K_{60}$; 4. $N_{30}P_{60}K_{60}$ and 2 mowing heights of 6 and 11 cm.

The sowing area was 90 m^2, and the accounting area – 50 m^2. To achieve the purposes of research it program included the following observations and analyzes according to generally accepted methods: "raw" ash, using dry ashing (DSTU 26226-84), "raw" protein by Kjeldahl method (DSTU 13496.4-84), "raw" fat by Rushkovskyi method (DSTU 13496.15-85), total phosphorus after ashing by photocolorimetric method according to Denizhe method in Levytskyi modification (GOST 26657-85); total potassium after ashing, using a flame photometer of calcium trilonometric method (DSTU 26570-85), moisture content by weight was determined by gravimetric method (DSTU ISO 11465-2001). The statistical analysis of the experimental data was carried out according to the method of Dospekhov [1985] using the mathematical apparatus of Microsoft Excel; the typicality of weather conditions was determined according to the method of Manko [2007] taking into account the indicator of the coefficient of efficiency of deviation Ki. Accounting for the biological yield of sainfoin was carried out manually in three replications. To date, there have not been conducted or there are technologically obsolete research on optimization of technologies of *Onobrychis viciifolia* cultivation, in particular, such agricultural measures: fertilizer rates, number of mowing, mowing height, which confirms the relevance of research on these factors.

RESULTS AND DISCUSSION

Examining the dynamics of phenological processes holds paramount significance in comprehending the influence of both natural and agrotechnical factors on plants, the establishment of quantitative and qualitative parameters within agrophytocenoses and plant's productivity. Impact of fertilization and parameters of mowing are shown in Tables 1 and 2. Research findings indicate that both the fertilization regimen and the height of cutting have significant effects on the development of common *Onobrychis viciifolia* herbage. The application of fertilizers notably accelerated the regrowth of the grass stand during spring. When comparing herbage development at various mowing heights, it's noteworthy that growth was more vigorous when cutting at an altitude of 11 centimeters. At this specific height, the development phases commenced earlier.

This occurrence can be ascribed to the circumstance wherein, at elevated cutting altitudes, the grass stand preserves a greater reservoir of pliable nutrient reserves. Consequently, the herbage tends to grow earlier, leading to earlier phases of development and creating optimal conditions

Table 1. Phenological observations of the development of common sainfoin (Onobrychis viciifolia) depending on fertilizers and cutting height (average for 2013–2015)

Fertilizers rates	Development phase				
	Regrowth	Shooting	Budding	Beginning of flowering	Mass flowering
Cutting height 6 cm					
Without fertilizers (control)	7.04	2.05	13.05	24.05	29.05
$P_{60}K_{60}$	7.04	2.05	13.05	24.05	29.05
$N_{30}P_{60}K_{60}$	6.04	1.05	13.05	23.05	29.05
$N_{45}P_{60}K_{60}$	6.04	1.05	13.05	23.05	19.05
CV, %	8.8	37.2	0	2.5	18.8
Cutting height 11 cm					
Without fertilizers (control)	5.04	30.04	10.05	19.05	25.05
$P_{60}K_{60}$	5.04	30.04	10.05	18.05	25.05
$N_{30}P_{60}K_{60}$	5.04	29.04	9.05	18.05	24.05
$N_{45}P_{60}K_{60}$	5.04	29.04	9.05	18.05	25.05
CV, %	0	2.0	6.0	2.7	2.3

Table 2. Phenological observations for the development of common sainfoin (Onobrychis viciifolia) depending on fertilizers and cutting height (average for 2016–2018)

Fertilizers rates	Development phase				
	Regrowth	Shooting	Budding	Beginning of flowering	Mass flowering
Cutting height 6 cm					
Without fertilizers (control)	4.04	29.04	10.05	19.05	26.05
$P_{60}K_{60}$	4.04	29.04	9.05	19.05	25.05
$N_{30}P_{60}K_{60}$	4.04	28.04	9.05	18.05	25.05
$N_{45}P_{60}K_{60}$	4.04	28.04	9.05	18.05	25.05
CV, %	0	2.1	5.4	3.1	2.0
Cutting height 11 cm					
Without fertilizers (control)	2.04	27.04	7.05	16.05	2.04
$P_{60}K_{60}$	2.04	26.04	7.05	15.05	2.04
$N_{30}P_{60}K_{60}$	2.04	26.04	7.05	15.05	2.04
$N_{45}P_{60}K_{60}$	2.04	26.04	7.05	15.05	2.04
CV, %	0	1.9	0	3.3	0

for achieving high yields. This underscores the significance of mowing height as an influential factor, even under conditions of equal growth and mineral nutrition. Optimal circumstances for the thriving and maturation appear to be established at a cutting altitude of 11 centimeters.

ANOVA revealed significant fluctuations in phenological observations and indicators of common sainfoin development, influenced by both fertilizer application and cutting altitude. The variability among the observed parameters was reflected in a coefficient of variation spanning from 0 to 37.2%. The crop yield is contingent upon a composite of factors, encompassing crucial elements such as altitude, leaf area, and the density of the grass stand. Consequently, the experiments demonstrated how grass height fluctuates depending on fertilizer application and mowing height. The prediction of overground biomass, developmental conditions, and yield projections can be inferred from the plants' height and the rate of their linear growth. It's been determined that stand height is a multifaceted indicator influenced by numerous factors, and there's a linear relationship between plant height and herbage yield. Research findings indicate variations in grass height along different slopes. Precisely, the elevation of the grass stand on the initial slope surpassed that observed on the subsequent slope. This disparity can be attributed to favorable growth and development conditions, utilization of reserve nutrients retained in the plants after winter, and the existence of significant soil moisture reserves amassed throughout the fall-winter interval. Furthermore, the moisture accessibility during the development of the second cut was suboptimal in contrast to the initial cut. Irregular precipitation patterns, coupled with elevated temperatures, resulted in inefficient moisture loss through soil evaporation and transpiration, as outlined in Table 3. The yield and nutritional quality of the grass stand are significantly influenced by its structure. Leaves and inflorescence, as plant organs, predominantly dictate the chemical composition and fodder value of the herbage. Additionally, the size of the assimilative surface area and the energy converted into chemical bonds in organic compounds depend on the quantity and total area of leaves. Leaves typically contain a protein content 2–3 times greater than stems, along with reduced fiber content, and are rich in various vitamins and other compounds beneficial for health. Variation coefficients, ranging between 3.8% and 4.7%, indicate a moderate level of variability and consistency in the parameters of common sainfoin herbage height, influenced by fertilizer application and cutting altitude.

The proportion of leaf mass in the total biomass depended on the growing conditions. Adjusting the leaf-to-stem ratio can be achieved through agronomic practices, considering economic feasibility. Increasing the leaf proportion leads to improved feed properties and the plant's assimilation capacity (Table 4). The cutting altitude emerged as the primary determinant of the observed ratio, as per the research results. Cutting at a height of 11 cm resulted in a higher proportion of leaves and a lower proportion of stems. The increase in leaf mass can be attributed to the fact that cutting at an altitude of 11 centimeters promoted greater stem reproduction, subsequently leading to more leaf growth.

Table 3. Height of common sainfoin (Onobrychis viciifolia) grass stand depending on fertilizer and cutting height under conditions, cm (average for 2013–2018)

Fertilizers norm	Cutting height			
	6 cm		11 cm	
	The first cut	The second cut	The first cut	The second cut
Without fertilizers (control)	77.5	44.0	79.5	47.0
$P_{60}K_{60}$	83.0	47.0	87.0	50.0
$N_{30}P_{60}K_{60}$	84.5	47.5	88.0	50.0
$N_{45}P_{60}K_{60}$	84.5	48.0	87.5	51.5
CV, %	4.0	3.9	4.7	3.8

Table 4. The ratio of stems and leaves of common sainfoin (Onobrychis viciifolia) depending on fertilizer and cutting height under conditions, % (average for 2013–2018)

Fertilizers norm	Cutting/development phase			
	The first cutting		The second cutting	
	Stems	Leaves	Stems	Leaves
Cutting height 6 cm				
Without fertilizers (control)	51.9	48.1	48.8	51.2
$P_{60}K_{60}$	52.0	48.0	48.2	51.8
$N_{30}P_{60}K_{60}$	51.8	48.2	48.6	51.4
$N_{45}P_{60}K_{60}$	52.1	47.9	48.8	51.2
Cutting height 11 cm				
Without fertilizers (control)	50.3	49.7	47.7	52.3
$P_{60}K_{60}$	49.6	50.4	47.7	52.3
$N_{30}P_{60}K_{60}$	49.5	50.5	47.6	52.4
$N_{45}P_{60}K_{60}$	49.2	50.8	47.3	52.7

Observations and measurements indicated that under conditions of higher cutting, percolation processes were intensified, leading to the formation of a denser grass stand. The heightened growth of shoots was attributed to the activation of axillary buds on the stems and the emergence of buds at the root collar. The considerable increase in the number of leaves, a consequence of elevated cutting heights, exerted an influence on the chemical composition indicators. Leaves, serving as the primary organ for protein synthesis within the plant, demonstrated the highest protein content when the cutting altitude was set at 11 centimeters. In contrast, at a cutting altitude of 6 centimeters, stems dominated the composition of the crop, thereby impacting the chemical makeup of the grass stand. At this specific height, there was a reduction in protein and ash content, coupled with an elevation in fiber content.

Cutting altitude is a critical factor that positively influencing the stem-to-leaf ratio in *Onobrychis viciifolia*. Opting for a higher cutting altitude, such as 11 cm, fosters more robust leaf formation, which not only enhances yield but also improves the nutritional value of feed. The production of each crop and the storage of nutrients predominantly take place in the vegetative parts of plants. Hence, the robust growth of vegetative mass is crucial and acts as a prerequisite for the establishment of high yields. Crop yield is contingent upon various indicators of vegetative mass, including height, density, stand, and leaf area.

Plant density serves as a crucial indicator impacting the efficient utilization of reserve nutrients, moisture, overground spatial availability, solar irradiance, and, ultimately, crop yield. As per the information, the use of fertilizers had a minimal impact on the density of the *Onobrychis viciifolia* stand. Whether with or without fertilization, the planting density remained nearly the same. Instead, the cutting height of the grass stand had a more pronounced influence on stand density, with thicker grass stands observed at a cutting altitude of 11 centimeters. The structural organization of sowing and the ability to develop an active photosynthetic apparatus are key factors in maximizing solar energy utilization. The growth of vegetative mass, influenced by leaf area, offers a quantitative evaluation of conducive conditions for growth and the establishment of yield. The significance of the leaf surface is paramount in the generation of both yield and feed quality, as leaves serve as the primary organs responsible for the plant's photosynthetic activity. The conducted researches revealed variations in leaf surface size, with cutting height exerting the most significant influence on its formation, as outlined in Table 5.

Under a cutting altitude of 11 centimeters, there was a conspicuous increase in leaf area compared to grass stands cut at 6 centimeters. It was noted that the higher cutting height (11 centimeters) promoted robust growth of the vegetative mass, leading to earlier maturity of the grass stand. Notably, when mowed at 11 cm, the grass stand not only developed a larger surface area but also produced larger leaves, resulting in greater specific gravity and denser seeding. These observations indicate that when the cutting altitude is set at 11 centimeters, the plant retains a higher amount of residual flexible substances, promoting the intensive formation of axillary buds responsible for shoot and leaf surface growth.

Leaf surface area indicators of common *Onobrychis viciifolia*, influenced by both fertilizer application and cutting height, exhibit minimum values ranging from 1.4% to 3.1%. The production of green biomass and feed unit's generation, coupled with the collection of protein, the

Table 5. Leaf surface area of common sainfoin (Onobrychis viciifolia) depending on fertilizer and cutting height under conditions, thousand m² ha-1 (average for 2013–2018)

Fertilizers norm	Cutting			
	The first cutting		The second cutting	
	Cutting height		Cutting height	
	6 cm	11 cm	6 cm	11 cm
Without fertilizers (control)	49.1	50.3	29.7	32.6
$P_{60} K_{60}$	50.4	50.9	31.0	32.4
$N_{30} P_{60} K_{60}$	51.2	52.3	31.1	32.0
$N_{45} P_{60} K_{60}$	50.7	51.8	29.2	32.2
V, %	1.8	1.7	3.1	0.8

harvesting stage of *Onobrychis viciifolia* profoundly affects the yield of green mass. As previously highlighted, in the realm of plant cultivation, identifying the ideal timing for harvesting *Onobrychis viciifolia* entails not only striving for maximal yield but also optimizing the retrieval of nutrients, particularly protein, from a given area. The amount of obtained mass is intricately tied to the developmental stage of *Onobrychis viciifolia*. Harvesting at either an excessively early or belated developmental stage may lead to deficiencies in both yield and nutrients, including protein.

It is particularly undesirable to utilize the grass stand during later phases of sainfoin development. The decline in protein content and other nutrients during these later stages is attributed not only to plant aging but also to a significant decrease in the specific gravity of the slope mass, especially in its most valuable and nutrient-rich part -the foliage. Given the significance of foliage, the conducted studies elucidated the alterations in leaf surface area contingent upon the developmental phase of the plant, as outlined in Table 6. The largest leaf area is attained at a cutting altitude of 11 centimeters at the initiation of the flowering phase, ranging from 50 300 to 52 300 m² ha^{-1}. However, as mass flowering progresses, the leaf surface diminishes to 46 700 to 47 630 m² ha^{-1}. This reduction is attributed to the gradual and subsequently intensified yellowing observed during the mass flowering phase of sainfoin. In the end, the lower leaves of the stem start to fall off. This shedding of leaves leads to a significant decrease in the quality of feed, particularly in terms of protein content.

Hence, it is advisable to start collecting sainfoin at the beginning of flowering and to complete it as soon as possible. Harvesting towards the conclusion of the flowering phase results in a reduction in both yield and the quantity of valuable feed substance – protein and other important nutritional parameters of feed. Variation analysis corroborated the consistency of common *Onobrychis viciifolia* leaf surface area indicators, contingent on fertilizer application and cutting altitude across various developmental phases during the first cutting. The least variability, indicated by coefficients spanning from 0.8% to 1.0%, was noticed when the cutting altitude was set at 11 centimeters during the stages of mass flowering, budding, and the initial flowering phase. A marginal inclination towards an elevation, reaching 1.7% to 1.8%, was observed at the commencement of flowering, regardless of the chosen cutting altitude. Throughout the study, the impact of fertilizer application and cutting altitude on *Onobrychis viciifolia* yield was investigated, with the research findings presented in Table 7. According to the results obtained, the herbage of *Onobrychis viciifolia* hardly reacted to fertilization, and the yield practically did not increase under their influence. This indicates that *Onobrychis viciifolia* differs from other crops; It can achieve high yields under natural soil conditions with optimal conditions.

The yield plays a pivotal role in establishing the economic value of the *Onobrychis*

Table 6. Leaf surface area of common sainfoin (Onobrychis viciifolia) depending on fertilizers and cutting height in various development phases (first cutting), thousand m² ha-1 (average for 2013–2018)

Fertilizers rates	Development phase (calendar dates)			
	Shooting (5.05)	Budding (15.05)	Beginning of flowering (26.05)	Mass flowering (1.06)
Cutting height 6 cm				
Without fertilizers (control)	29.0	42.3	49.1	44.9
$P_{60}K_{60}$	29.7	43.0	50.4	45.8
$N_{30}P_{60}K_{60}$	29.4	43.4	51.2	46.1
$N_{45}P_{60}K_{60}$	30.2	43.6	50.7	46.2
CV, %	1.7	1.3	1.8	1.3
Cutting height 11 cm				
Without fertilizers (control)	30.6	44.3	50.3	46.7
$P_{60}K_{60}$	31.2	44.6	50.9	47.2
$N_{30}P_{60}K_{60}$	30.9	45.3	52.3	46.9
$N_{45}P_{60}K_{60}$	31.4	44.9	51.8	47.6
CV, %	1.1	1.0	1.7	0.8

Table 7. Common sainfoin (Onobrychis viciifolia) productivity depending on fertilizer (factor A) and cutting height (factor B), t ha-1

Fertilizers rates	Average for 2013–2018			
	Green mass		Dry mass	
	Cutting height		Cutting height	
	6 cm	11 cm	6 cm	11 cm
Without fertilizers (control)	36.87	39.41	7.47	7.99
$P_{60}K_{60}$	37.57	40.50	7.61	8.23
$N_{30}P_{60}K_{60}$	37.47	40.53	7.59	8.25
$N_{45}P_{60}K_{60}$	37.28	40.29	7.54	8.14
LSD_{05}, t ha^{-1}	A – 1.05; B – 1.23		A – 0.27; B – 0.34	

viciifolia crop. Various indicators determine the nutritional value of plant feed, with the most crucial ones being crude protein, ash, calcium, fiber, phosphorus, fat, and nitrogen-free extractive substances (NFE). Information regarding the chemical composition of the green mass is presented in Table 8. Based on this data, the influence of fertilizers and cutting altitude appeared to have marginal effects on the majority of chemical composition indicators. Nevertheless, the content of crude protein displayed the most notable variability. *Onobrychis viciifolia* herbage treated with fertilizers demonstrated elevated protein levels in comparison to those cultivated without fertilizers. Furthermore, regardless of mineral nutrition conditions, *Onobrychis viciifolia* mass contained more crude protein when cut at an altitude of 11 centimeters. This suggests that herbage cut at this height consistently produced larger leaf surfaces, with leaves being the most valuable and nutritious parts storing higher protein levels.

The potassium content demonstrated marginal fluctuation based on both fertilizer application and cutting altitude, indicating a probable sufficiency of potassium supply within the soil. Additionally, the deep penetration of the *Onobrychis viciifolia* root system allows the crop to absorb this element as required, even without additional fertilization. According to zootechnical standards, the quantities of potassium present in *Onobrychis viciifolia* herbage were deemed sufficient and safe.

As shown by the studies presented in [Giner-Chaver et al., 1997; Cassida et al., 2000; Gebrehiwot et al., 2002; Albayrak et al., 2009; Tonkha et al., 2018; Bobos et al., 2019] grass productivity stands as a crucial indicator, albeit not the exclusive one, in the selection of *Onobrychis viciifolia*. The primary measure of winter hardiness effectiveness includes improvements in crop yield,

Table 8. Common sainfoin (Onobrychis viciifolia) green mass chemical composition depending on fertilizers and cutting height, % of dry mass (average for 2013–2018)

Fertilizers rates	Crude protein	Crude fiber	Fat	Ash	Calcium	Phosphorus	Potassium
Cutting height 6 cm							
Without fertilizers (control)	15.9	25.8	1.7	9.4	1.73	0.59	2.1
P_{60} K_{60}	16.1	25.2	1.8	10.1	1.81	0.64	2.4
N_{30} P_{60} K_{60}	16.4	25.4	1.7	9.7	1.79	0.62	2.2
N_{45} P_{60} K_{60}	16.6	25.1	1.6	9.5	1.75	0.63	2.3
Cutting height 11 cm							
Without fertilizers (control)	16.5	24.6	1.6	9.3	1.71	0.61	2.0
P_{60} K_{60}	16.7	24.4	1.7	10.9	1.76	0.63	2.2
N_{30} P_{60} K_{60}	17.9	24.2	1.8	10.6	1.74	0.64	2.4
N_{45} P_{60} K_{60}	18.1	24.3	1.7	10.7	1.75	0.60	2.1

production efficiency, overall costs, net income, and levels of profitability. The economic indicators' value, beyond quantitative aspects, is significantly impacted by qualitative factors such as feed balance and digestibility. These qualitative aspects play a crucial role as they directly influence the efficiency of livestock production.

Any approach used to improve the yield of common *Onobrychis viciifolia* is considered acceptable only if it results in economic gains. This entails that the expenses associated with implementing the technique should yield supplementary products, the value of which exceeds the production costs. Only under such circumstances can the technique be deemed cost–effective and profitable, i.e., economically viable. Expenditures that do not contribute to an economic advantage not only escalate production costs but also impede the momentum of expanded reproduction. Hence, the economic evaluation assumes a pivotal role in discerning the practical feasibility of the examined factor [Haring et al., 2009; Luescher et al., 2014; Kovalenko and Kovalenko, 2018; Havrylianchyk et al., 2020; Kovalenko et al., 2020; Kovalenko et al., 2021a].

Considering that a minimum of 50% of the total production costs in livestock products comprises at least half of all production expenses, the primary focus lies in the advancement and application of highly efficient agrotechnical approaches to augment common *Onobrychis viciifolia* yield. This emphasis aims to establish a robust forage foundation, enhance livestock efficiency, and diminish production costs [Rebole et al., 2004; Paolini et al., 2005; Türk and Çelik, 2006; Tonkha et al., 2020; Tryhuba et al., 2020; Lutsiak et al., 2021; Kovalenko et al., 2021b]. Our research proves that the cutting altitude is an important element for production conditions in the technology of growing *Onobrychis viciifolia*. The formation of high yields at the mentioned height occurs due to enhanced growth processes, an increase in the mass and number of shoots, leaf surface area, the most complete use of reserve nutrients, aboveground space, solar radiation, moisture, and other factors.

CONCLUSIONS

Based on the results generalization of research on establishing the patterns of formation of production processes of *Onobrychis viciifolia*, as well as economic and energy efficiency of the developed agricultural measures of intensive technology for its cultivation to obtain sustainable plant productivity, we recommend:

1. The height of mowing is an important element in the technology of *Onobrychis viciifolia* growing. Under equal growing conditions, higher yields were provided by a mowing height of 11 cm. Chemical compound of *Onobrychis viciifolia* aboveground biomass varied depending on the studied factors. Under uniform soil conditions and varying fertilizer levels, the height of mowing emerged as the most influential factor. Higher chemical composition values were observed when mowing at a height of 11 centimeters. Specifically, there was an increase in crude protein and ash content, accompanied by a reduction in crude fiber content.
2. To ensure maximum productivity of *Onobrychis viciifolia*, apply mineral fertilizers at the dose $P_{60}K_{90}$ and mow at a cutting altitude of 11 centimeters. The development of increased crop yields at the mentioned cutting height is due to enhanced growth processes, increasing the mass and number of shoots, leaf surface area, the efficient utilization of reserve nutrients, moisture, overground spatial availability, solar irradiance and other factors. The use of *Onobrychis viciifolia* at a cutting altitude of 11 centimeters allows to increase the production of highly nutritious balanced feed with a lower unit cost. This allows to increase the competitiveness of *Onobrychis viciifolia* production, its profitability and efficiency of management in general.

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