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Formation of meadow phytocenoses under different restoration methods, fertilization systems, and utilization regimes

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ABSTRACT

The aim of the study was to identify the specific features of meadow sward formation under different restoration methods on arable lands of the Right-Bank Forest-Steppe of Ukraine, considering species composition, life span, family structure, fertilization systems, and mowing regimes. Field studies were conducted on gray forest soils in the northern Forest-Steppe of Ukraine (Chabany, Kyiv region). A long-term field experiment compared spontaneous fallow restoration, improved fallow with overseeding of seven native grass species collected from a virgin meadow, and restoration of degraded old-sown grasslands by overseeding a grass mixture (smooth brome *Bromopsis inermis* + meadow fescue *Festuca pratensis*) or four legume-grass mixtures including alfalfa (*Medicago sativa*), red clover (*Trifolium pratense*), white clover (*Trifolium repens*), or Ukrainian bird's-foot trefoil (*Lotus ucrainicus*). Treatments were evaluated under three fertilization backgrounds and two mowing regimes. Species composition was assessed using geobotanical surveys. In the ninth year of succession, fallow phytocenoses were dominated by perennial non-sown grasses, accounting for 59–82% of the vegetation, while forbs represented 18–38%. Wood small-reed (*Calamagrostis epigeios*) was the dominant wild grass species. Spontaneous fallow supported up to 37 herbaceous species, whereas overseeding native grasses increased diversity to 45 species. The occurrence of species such as *Festuca valesiaca* reflected the increasing contribution of characteristic meadow species to the developing phytocenosisIn the phytocenosis of improved fallow. Nitrogen fertilization (N_{140}) or complete mineral fertilization ($N_{140}P_{60}K_{120}$) increased the proportion of grasses by 10–14%. Restoration through overseeding cultivated grasses and legumes reduced the number of wild species to 21–31 but rapidly improved forage quality. During the first three years, the swards were dominated by the introduced cultivated species. Overseeding smooth brome and meadow fescue resulted in a smooth brome-dominated community by the third year. In legume–grass mixtures, legumes acted as codominants with the grasses. Alfalfa and Ukrainian bird's-foot trefoil remained stable in the swards, maintaining a 33–50% share for three years, whereas red and white clovers persisted only during the first two years with a 36–53% share. These results demonstrate that native-species restoration promotes biodiversity and ecological stability, while cultivated grass–legume mixtures provide rapid establishment of productive forage swards.

Keywords: perennial legumes and grasses, species composition, meadow phytocenosis, forbs, plant families, floristic richness.

INTRODUCTION

As a result of the long-term progressive development of agricultural practices, different types of agricultural land have formed over time within agricultural landscapes, including meadow (natural forage) lands. Meadow lands in the agrolandscape are considered by us as specific complex integral self-regulating thermodynamic open ecological systems—biogeocenoses, in which all components, abiotic (soil and subsoil) and biotic (phytocenosis, zoocenosis, and microbiocenosis), form an interpenetrating internally contradictory unity and closely interact with each other. The main supplier of energy in meadow biogeocenoses is the phytocenosis (Polishchuk, 1984; Merezhko, 1985; Kurhak, 2023).

Meadow ecosystems, compared with field agrophytocenoses, involve mineral and organic substances in the biological cycle to a much greater extent, reliably retain them within the cycle and thus prevent their loss beyond the boundaries of these ecosystems. Due to the dense sward, they constitute a reliable barrier to the surface migration of silty soil particles and agrochemicals from arable land, which often occurs during heavy rains (Petrychenko et al., 2013; Kurhak, 2023).

The plant cover of meadow lands, like other perennial vegetation, significantly improves soil. As a result of the accumulation of root residues and the increase in the number of earthworms in the soil, the humus content increases, its biological activity and structure improve, and erosion is prevented. The zone where meadows are located is a relatively environmentally safe territory where, during their management, the use of chemical plant protection products against pests and diseases is almost completely excluded. Therefore, their location near settlements contributes to improving the environmental living conditions of people, and near livestock farms reduces the costs of their management (Bogovin et al., 2017; Crews et al., 2018; Goreth et al., 2021; Kiss et al., 2022; Kurhak, 2023).

In relation to aquatic ecosystems, the condition of which is an indicator of ecological balance within river basins, meadow biogeocenoses purify spring runoff during floods, protect river channels, and regulate the water level in rivers. During the flood period, the meadow floodplain receives silt and bottom sediments from the river channel, intensively processes them, forms biomass yield, and thus carries out energy exchange between the river and the floodplain (Bogovin et al., 2017, 2020).

In combination with warming processes and the pressure of chemicalization, not only do rivers become silted, lands are repeatedly flooded, and water sources and drinking water become polluted, but the south of Ukraine is also undergoing desertification, which negatively affects human health and quality of life (Petrychenko et al., 2013; Kurhak et al., 2019).

The unsystematic gradual plowing of meadow lands for the cultivation of intensive row crops (in some places up to 80% or more) has led to the deterioration of the forage base of livestock production and the development of soil erosion (4.5 million ha of arable land are affected by erosion). As a result, 30% of arable land in Ukraine has become degraded, and in some basins of small rivers this figure reaches 60–70%; more than half of the small rivers and a quarter of other water bodies have become silted. All this, combined with the constant pressure of chemicalization, leads not only to the pollution of water sources, including drinking water, but also to a decline in species biodiversity, in particular the disappearance of valuable plant species and an increase in annual greenhouse gas emissions attributable to agriculture (Petrychenko et al., 2013; Kurhak et al., 2019; FAO, 2020; Cadastre, 2022).

At the same time, it is known that meadow lands, as nature conservation objects, reliably protect soils from erosion even on steep slopes and, together with forests and shrubs, protect rivers and other water bodies from silting and pollution. Perennial herbaceous phytocenoses (natural meadow forage lands, grass, legume–grass, and legume herbaceous agrophytocenoses) most reliably protect soils from the effects of water erosion. Their anti-erosion resistance on slopes with a steepness of 7–9° is 76–91%, whereas that of winter and spring cereals and annual grasses is 40–69%, and that of row crops and bare fallow is 0–26%. Among natural forage lands, hayfields are characterized by higher anti-erosion resistance than pastures, and among perennial grasses, grass and legume–grass swards are more resistant than pure legume stands. A similar pattern was observed on slopes with lower steepness, although with a lower level of erosion processes (Scientific Foundations, 2025).

Significant volumes of grain production in Ukraine have been achieved due to the high proportion of plowed land and the natural fertility of chernozems, the country's greatest national wealth. These soils were formed as a result of the long-term influence of perennial herbaceous vegetation of meadows and steppes which, as nature conservation objects, reliably protect soils from erosion even on steep slopes and protect rivers and other water bodies from silting and pollution (Kurhak et al., 2019).

The area of meadows in Ukraine amounts to about 6.6 million hectares. Based on the ecological minimum, taking into account grassing of protective zones along rivers and erosion-prone slopes, as well as the cultivation of perennial grain, grain-legume, oilseed and other crops, the area of undisturbed (untouched) land should amount to 50%. In particular, the share of territory occupied by perennial herbaceous vegetation (meadows + perennial herbaceous non-forage crops) should be 30%, while afforestation should account for 20%, which corresponds to the principles of the European Green Deal (Petrychenko et al., 2013; Crews et al., 2018; FAO, 2020).

The main methods of meadow restoration are as follows: restoration through grassing with the creation of sown swards, primarily legume–grass swards with the participation of cultivated species and varieties of perennial grasses; restoration through spontaneous natural overgrowth with the formation of swards on fallow land; restoration through spontaneous overgrowth combined with overseeding of seeds of wild grass species collected from reference virgin sites (Scientific Foundations, 2025). One of the effective ways of developing grassland management, including organic systems, is the efficient use of perennial legumes as an inexpensive source of symbiotic nitrogen. Legumes can accumulate 200 kg/ha or more of nitrogen (Demydas et al., 2018, 2019; Olifirovych, 2018; Prorochenko, 2018; Karbivska et al., 2019; Kurhak, 2023).

The use of legumes through the creation of legume–grass mixtures with an increased proportion of legumes, according to the UNESCO International Biological Programme, is considered one of the most promising and cost-effective directions for intensifying not only organic grassland management but also organic forage production worldwide. The production of mineral nitrogen is ten times more expensive than symbiotic nitrogen, which is fixed naturally and can be considered a "gift of nature." There is no alternative to the wider use of perennial legumes in organic grassland management (Petrychenko et al., 2013; Dziubailo et al., 2020; Kovtun et al., 2020; Karbivska et al., 2019a, 2019b).

Innovative measures aimed at increasing the stability of legume components and the productivity of legume–grass agrocenoses are based on the following principles: the selection of high-yielding legume species and varieties for mixed cropping systems, together with the most suitable cereal components for them; sowing mixtures at the most optimal time (early spring) with separate row and narrow-strip (up to 30 cm) placement of legume and grass components; the application of a dynamic system of organic fertilization with an effective combination of symbiotic nitrogen from legumes and nitrogen from organic fertilizers; replacement of the legume component during the years of use of the legume–grass agrophytocenosis by overseeding into the sod another legume species different from the one originally sown, which prevents "legume fatigue" (confirmed by patent); and rational use of the cenoses according to the biological requirements of legumes and the forage purpose of the biomass (Method, 2002, 2003; Petrychenko et al., 2013; Kovtun et al., 2017; Kurhak, 2023). Under conditions of sufficient resource availability, the restoration of meadow lands is carried out through grassing with the establishment of sown grass swards involving cultivated species and varieties of perennial grasses and their mixtures, where the main factor of intensification is the application of mineral nitrogen fertilizers (Kotiash et al., 2019; Martsinko, 2020, 2023). However, until now, the specific features of the formation of different types of meadow swards depending on the methods of their restoration on arable lands, the species composition of legume–grass agrophytocenoses, and fertilization have not been sufficiently clarified.

The aim of our study was to identify the specific features of the formation of different types of meadow swards with the restoration of species composition and their distribution according to family composition and life span under different methods of restoration (through spontaneous natural overgrowth and grassing with cultivated species of perennial grasses) and fertilization systems on arable lands with gray forest soils of the Right-Bank Forest-Steppe of Ukraine.

MATERIALS AND METHODS

Field studies aimed at investigating the specific features of meadow phytocenosis formation under different methods of meadow restoration were conducted on gray forest soils of the northern part of the Forest-Steppe of Ukraine (Chabany, Kyiv region). The coordinates of the experimental site are 50.346085, 30.412631, within the Kyiv agro-soil district. The terrain is flat and characterized by relatively low absolute elevations not exceeding 180–190 m above sea level.

According to geobotanical zoning, the experimental site is located within the Starokostiantyniv–Bila Tserkva geobotanical district of steppe-like meadows and meadow steppes, as well as oak and hornbeam–oak forests (Geobotanical Zoning of the Ukrainian SSR, 1977). This territory is situated in the northern part of the Right-Bank Forest-Steppe. In the composition of the grass cover before the plowing of the steppes, associations of bentgrass–fescue groups were present. Characteristic species for steppe-like meadows include red fescue, narrow-leaved bluegrass, quaking grass, and Syreyshchykov's bentgrass.

A characteristic feature of the climate in this district is relatively high moisture availability and moderate temperatures. The average annual precipitation amounts to about 600 mm in the west and 500 mm in the east, while during the growing season it reaches 350–450 mm. The growing season lasts 200–205 days. The moisture coefficient ranges from 1.8 to 1.4. The average annual air temperature varies between 6.6 and 7.0 °C. Weather conditions during the years of the study were favorable for the growth and development of perennial grasses in the experiments. Precipitation was generally close to the long-term average (norm), while the air temperature exceeded the norm by 1–1.5 °C.

The morphological structure of the soil profile of the experimental site by horizons is characterized as follows:

- HE – 0–39 (39 cm), humus–eluvial horizon, brownish-black, fresh, granular–crumb structure, dense, coarse silty light loam, presence of roots of herbaceous plants (biological mass – normal), gradual transition;
- HI – 40–78 (38 cm), humus–illuvial horizon, dark brown, fresh, nutty–granular structure, dense, coarse silty light loam, presence of roots of herbaceous plants (biological mass – sparse), presence of humus tongues, gradual transition;
- I – 79–140 (61 cm), illuvial horizon, brown, moist, fine columnar–nutty structure, compacted, coarse silty light loam, presence of roots of herbaceous plants (biological mass – very sparse), presence of weakly humified spots, gradual transition;
- I_{rk} – 141–170 (29 cm), transitional illuvial horizon to the parent material, light brown, moist, columnar–fine crumb structure, dense, coarse silty light loam, presence of carbonates indicated by strong effervescence, gradual transition;
- P_k – 171 cm and deeper, parent material, light brownish-yellow with a faint orange tint, moist, columnar–crumb structure, dense, sandy light loam, presence of carbonates.

The main morphological feature of the described soil profile horizons under an eight-year-old hayfield is their darker coloration and gradual transition compared with the soil profile of adjacent arable land. Due to the predominance of coarse silt in the granulometric composition (55%), the plow layer of the soil is structureless, which causes surface sealing, the formation of a strong crust after rainfall, and a coarse cloddy surface after tillage. In the 0–20 cm soil layer, the humus content was 1.90%, alkaline hydrolyzable nitrogen – 86.8 mg/kg, available phosphorus – 182.5 mg/kg, and available potassium – 86.2 mg/kg of soil, with a pH of 5.5.

Thus, according to agrochemical indicators, the soil is generally favorable for the normal growth and development of meadow grasses. It is well supplied with phosphorus and potassium and has a slightly acidic soil reaction. Nitrogen can be replenished through the application of mineral nitrogen fertilizers to grass swards or through the use of symbiotically fixed nitrogen by perennial legumes as components of meadow phytocenoses, while soil acidity can be reduced through chemical amelioration by liming.

A field experiment on the formation of different types of swards was established in 2020 by overseeding seeds of a grass mixture and four legume–grass mixtures composed of cultivated grass species into an old-sown grass sward that had been established in 2013. The research was conducted in comparison with fallow plots, which were also established in 2013, specifically Fallow 1, formed through spontaneous natural revegetation, and Improved Fallow 2, established by overseeding a mixture of seeds from seven wild grass species manually collected from a virgin plot located under soil and climatic conditions similar to those of the field experiment. The results are presented for the period 2021–2023. The stated objective was addressed in a field experiment established according to the following design:

Experimental design (type of sward, grass species and seeding rates, kg/ha – factor A):

1. Fallow 1 (spontaneous natural overgrowth).
2. Fallow 2 (overseeding of seeds of wild grass species collected from virgin land: fescue (*Festuca valesiaca* Gaud.), colonial bentgrass (*Agrostis tenuis* Sibth.), loose silky-bent (*Apera spica-venti* L.), narrow-leaved bluegrass (*Poa angustifolia* L.), tufted vetch (*Vicia cracca* L.), yarrow (*Achillea submillefolium* Klok. et Krytzka), hedge bedstraw (*Galium mollugo* L.)).
3. Sown grass sward (smooth brome *Bromopsis inermis* (Leyss.) Holub – 12 kg/ha, meadow fescue *Festuca pratensis* Huds. – 10 kg/ha).
4. Alfalfa–grass sward (the same grasses + alfalfa *Medicago sativa* L. – 10 kg/ha).
5. Red clover–grass sward (the same grasses + red clover *Trifolium pratense* L. – 10 kg/ha).
6. White clover–grass sward (the same grasses + white clover *Trifolium repens* L. – 6 kg/ha).
7. Bird's-foot trefoil–grass sward (the same grasses + Ukrainian bird's-foot trefoil *Lotus ucrainicus* Klok. – 8 kg/ha).

The experiment was conducted under three fertilization backgrounds – factor B (1 – no fertilizers, 2 – N140, and 3 – N140P60K120) and two utilization regimes – factor C (1 – two-cut – with the first mowing at the beginning of flowering of the dominant grass and legume components and the next after 50–55 days; 2 – four-cut – with the first mowing at the end of stem elongation–beginning of heading of grasses and budding of legumes, with subsequent mowings after 30–35 days).

In the mixtures, regionalized varieties of legume and grass species were overseeded into the old-sown grass sward: meadow fescue Evola, smooth brome Vyshhorodskyi, alfalfa Olha, red clover Polianka, white clover Danaia, and Ukrainian bird's-foot trefoil Ant.

Phosphorus and potassium fertilizers were applied in spring at one time. Nitrogen fertilizers were applied in equal portions before each cut: N70 under the two-cut regime and N35 under the four-cut regime of utilization.

To reduce soil acidity, the experimental plot was limed in autumn 2013 by surface application of defecate at a rate of 5 t/ha. The size of the sown plots was (2.5 × 4.0 m) 10 m² and the accounting plots (2.0 × 4 m) 8 m². The experiment was conducted with four replications to determine productivity and in a single replicate to assess the botanical and species composition of the phytocenoses.

The research was carried out according to generally accepted methods in forage production and grassland management (Babich, 1994). The statistical analysis of the botanical composition data was performed using the method of variation statistics, with years considered as replicates. Botanical and species composition of meadow phytocenoses at the experimental site was determined by geobotanical description of the swards before yield assessment according to DSTU 4687:2007 (DSTU, 2007). The names of species and families of meadow plants and their life span were determined according to the modern taxonomic nomenclature (Determiner, 1987).

The botanical composition of all studied variants of the field experiment was assessed annually (in 2021, 2022, and 2023) before harvesting the biomass of the first cut, based on the proportion of the following economically and botanically defined groups in the herbaceous phytocenoses: sown and wild grasses, legumes, and forbs.

The species composition of wild (non-sown) species occurring in the studied phytocenoses was determined in the first cut under the unfertilized treatment in the final (third) year of use (cutting), i.e., in 2023.

RESULTS AND DISCUSSION

The duration of the stabilization process of fallow and sown swards differs, which is caused by the initial composition of the swards and their adaptation to existing ecological conditions, as well as the presence of seeds in the soil. The onset of the intermediate fallow stage, as well as the final stage of stabilization of a meadow community or the formation of a virgin-like state, can be accelerated by enriching the regenerating cenosis with seeds of rhizomatous grasses collected under natural conditions (Bogovin et al., 2017, 2020).

In sown swards, the undesirable initial stage of domination by annual and biennial weeds, which occurs during spontaneous overgrowth and leads to a significant decrease in yield and forage quality, can be avoided. During this period, the sown species dominate here—initially legumes, then loosely and densely tufted grasses, tall or low-growing depending on the utilization regime, and ultimately rhizomatous sown and non-sown grasses with the dominance of couch grass (*Elytrigia repens*). Further transformation proceeds in the same direction as during spontaneous overgrowth (Petrychenko et al., 2013; Kurhak, 2023). With the increase over the years in the proportion of forbs in an artificially created agrophytocenosis, its forage value is often lost due to reduced productivity and deterioration of forage quality. At the same time, there is an opinion that the significant biodiversity of natural meadow–pasture lands forms the basis of their stability and resistance to changing environmental conditions, as well as a guarantee of obtaining high-quality grass forage.

Our studies showed that the proportion of wild species on fallows 1 and 2 and cultivated species in artificially created grass and legume–grass phytocenoses with different legume components depended on the method of their formation, fertilization system, and mowing regime (Table 1). On both fallows, on average over the years of research, non-sown grasses predominated in the swards, their proportion under both studied utilization regimes ranging from 59 to 82%. The proportion of forbs was 19–38%, while non-sown legumes accounted for 0–5%. Moreover, under the non-nitrogen fertilization background on improved fallow 2 with overseeding of wild grasses from virgin land, the proportion of grasses was 8% higher and the proportion of forbs 10% lower than on fallow 1 with spontaneous overgrowth.

The application of N_{140} or $N_{140}P_{60}K_{120}$, on average over the years of research, increased the proportion of grasses in the cenoses of fallows by about 10%, while $N_{140}P_{60}K_{120}$ increased it by 12–14%. Under the four-cut regime, on average over the years of research, the proportion of non-sown grasses on fallows was 1–5% higher and the proportion of forbs 1–5% lower than under the two-cut regime. In contrast to the variants with nitrogen application, where legumes were absent, a small proportion (3–5%) of wild legumes was present in the fallow swards on the non-nitrogen background (no fertilizer treatment).

On the sown grass sward under the non-nitrogen background, the proportion of grasses was 81% under the two-cut regime and 86% under the four-cut regime. The application of nitrogen fertilizers increased the proportion of grasses to 89–90% under the two-cut regime and to 90–91% under the four-cut regime. In the grass sward on the control under the two-cut regime, sown grasses occupied the dominant position with a share of 55%, while under the four-cut regime their share reached 62%. On average over the years of research, under different fertilization backgrounds among the sown grasses included in the grass mixture, the share of meadow fescue (*Festuca pratensis* Huds.) ranged from 15 to 23%, smooth brome (*Bromopsis inermis* (Leyss.) Holub) from 35 to 49%, wild (non-sown) grasses from 24 to 27%, and forbs from 9 to 19%.

In the sown grass sward, compared with fallows, according to averaged data, the proportion of forbs on the non-nitrogen background was 1.5–2.0 times lower under the two-cut regime and 1.8–2.4 times lower under the four-cut regime, with shares of 19% and 14%, respectively. In the sown legume–grass swards, on average over the years of research, the sown grass and legume species dominated. The proportion of grasses under the two-cut regime across different fertilization backgrounds ranged from 49 to 72%, and under the four-cut regime from 46 to 71%. The share of non-sown grasses ranged from 11 to 14%. As in the grass sward, among the sown grass species the proportion of smooth brome was approximately twice as high as that of meadow fescue.

The share of legume components in legume–grass agrophytocenoses under the two-cut regime ranged from 22 to 46%, while under the four-cut regime it ranged from 23 to 50%. The proportion of alfalfa (*Medicago sativa* L.) and Ukrainian bird's-foot trefoil (*Lotus ucrainicus* Klok.) was 5–10% higher than that of red clover (*Trifolium pratense* L.) and white clover (*Trifolium repens* L.). The proportion of legumes was also 10–15% higher under the non-fertilized background compared with the application of N_{140} or $N_{140}P_{60}K_{120}$. Alfalfa (*Medicago sativa* L.) and red clover (*Trifolium pratense* L.) were preserved somewhat better in the treatment without fertilizers under the two-cut regime than under the four-cut regime, whereas white clover (*Trifolium repens* L.), on the contrary, persisted better under the four-cut regime than under the two-cut regime across all fertilization backgrounds.

Significant changes in the botanical–economic composition and species structure of the swards were also observed over the years of the study (Figures 1 and 2). In the swards of both fallows, non-sown grasses dominated under all fertilization backgrounds. Their proportion increased to a greater or lesser extent under both utilization regimes during the period from the first to the third year of the study, while the proportion of forbs

Table 1. Botanical composition of meadow swards depending on fertilization and utilization regimes, average for 2021–2023, %

Sward type	Fertilization	Utilization regimes											
		2 cuts						4 cuts					
		Grasses				Sown legumes*	Forbs	Grasses				Sown legumes*	Forbs
		Total	including					Total	including				
			Festuka pratensis Huds.	*Bromopsis* inermis (Leyss.) Holub	wild grasses				*Festuka pratensis* Huds.	*Bromopsis* inermis (Leyss.) Holub	wild grasses		
Fallow 1	No fertilizers	59	–	–	59±6	3±1	38 ±4	64	–	–	64±6	3±1	33±4
	N_{140}	69	–	–	69±7	–	31±4	70	–	–	70±7	–	30±4
	$N_{140}P_{60}K_{120}$	71	–	–	71±7	–	29±4	69	–	–	69±7	–	31±4
Fallow 2	No fertilizers	67	–	–	67±6	5±1	28±6	71	–	–	71±6	4±1	25±5
	N_{140}	77	–	–	77±7	–	23±5	79	–	–	79±7	–	21±4
	$N_{140}P_{60}K_{120}$	81	–	–	81±8	–	19±4	82	–	–	82±7	–	18±4
Sown grass	No fertilizers	81	20±4	35±4	26±5	–	19±3	86	19±4	43±4	24±4	–	14±3
	N_{140}	89	21±5	41±5	27±4	–	11±2	90	15±5	49±5	26±3	–	10±2
	$N_{140}P_{60}K_{120}$	90	23±5	43±5	24±4	–	10±2	91	18±5	48±5	25±3	–	9±2
Alfalfa–grass	No fertilizers	49	11±3	25±4	13±2	46±3	5±1	56±	11±3	32±4	13±2	39±2	5±1
	N_{140}	70	18±4	38±5	14±2	25±4	5±1	69	14±4	42±5	13±2	24±4	7±1
	$N_{140}P_{60}K_{120}$	69	19±4	37±5	13±2	27±4	4±1	71	16±3	44±5	11±2	23±4	6±1
Red clover–grass	No fertilizers	56	12±3	32±5	12±2	36±9	8±2	62	12±3	37±4	13±2	33±8	5±1
	N_{140}	70	17±3	39±5	14±2	22±8	8±2	67	14±4	41±5	12±2	25±9	8±2
	$N_{140}P_{60}K_{120}$	71	17±4	42±5	12±2	22±8	7±1	71	15±4	43±5	13±2	24±9	5±1
White clover–grass	No fertilizers	63	13±3	37±4	13±2	30±9	7±1	57	9±2	39±4	9±2	38±7	5±1
	N_{140}	70	16±4	42±5	12±2	23±8	7±1	68	16±3	42±4	10±2	25±8	7±1
	$N_{140}P_{60}K_{120}$	72	17±4	44±5	11±2	22±8	6±1	68	13±4	46±5	9±2	26±8	6±1
Bird's-foot trefoil–grass	No fertilizers	51	11±3	30±4	10±2	45±3	4±1	46	9±3	30±4	7±2	50±3	4±1
	N_{140}	58	11±4	36±5	11±2	36±4	6±1	61	9±4	40±5	12±2	33±4	6±1
	$N_{140}P_{60}K_{120}$	60	9±4	41±5	10±2	35±4	5±1	63	11±4	42±5	10±2	33±4	4±1

Note: *For both fallows, the proportion of non-sown legume species is presented.

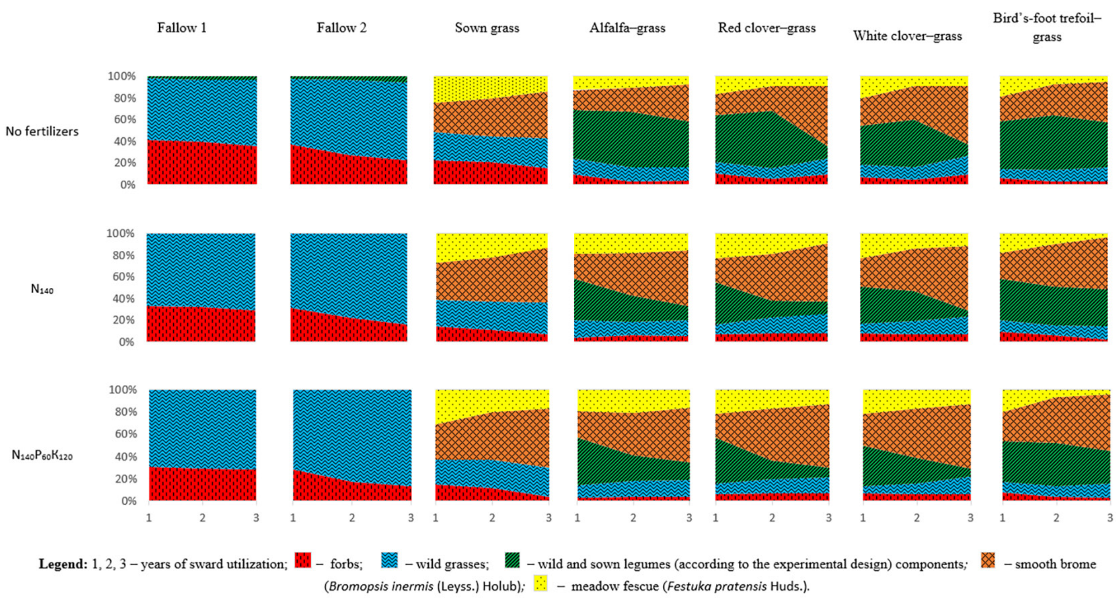

Figure 1. Dynamics of the botanical composition of different types of meadow swards over the years under the two-cut utilization regime depending on fertilization, 2021–2023, %

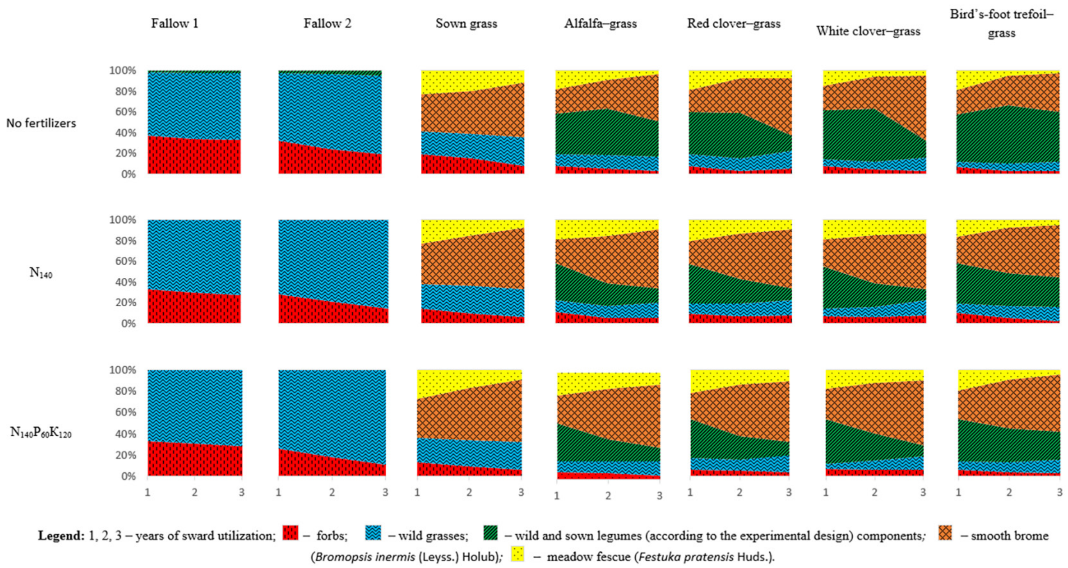

Figure 2. Dynamics of the botanical composition of different types of meadow swards over the years under the four-cut utilization regime depending on fertilization, 2021–2023, %

decreased by 3–15%. These changes were more pronounced on fallow 2 than on fallow 1 and were also more evident under mineral fertilization than without fertilizers. The greatest changes were observed on fallow 2 with the application of N140P60K120, while the smallest changes occurred on fallow 1 without fertilization.

Regardless of the utilization regime, in the sown grass sward the proportion of sown species increased from the first to the third year, particularly that of smooth brome (*Bromopsis inermis* (Leyss.) Holub) by 13–22%, while the share of non-sown grasses and forbs decreased by 7–11%. This process occurred more rapidly under fertilization. Under the application of N140P60K120, by the third year the forbs had almost completely disappeared from the sward. At the same time, the proportion of sown grasses increased to 78–80%. In particular, the share of smooth brome (*Bromopsis inermis* (Leyss.) Holub) increased to 53–59%, whereas the share of meadow fescue (*Festuca pratensis* Huds.) decreased to 11–17%.

In the legume–grass agrophytocenoses, along with the sown grasses, the total proportion of which over the years under different experimental treatments ranged from 40 to 70%, a significant share was occupied by legume components with a proportion ranging from 12 to 53%. The patterns of change over the years regarding the grass components in the legume–grass swards were similar to those observed in the grass sward, but occurred at a lower level of their content in the agrophytocenoses.

Changes over the years with respect to individual legume components were different. Alfalfa (*Medicago sativa* L.) remained stable for three years of utilization in the treatment without fertilization, with a proportion of 42–51% under the two-cut regime and 34–45% under the four-cut regime. In the third year, the proportion of alfalfa was 6–8% lower under the four-cut regime than under the two-cut regime, indicating that it responds negatively to increased mowing frequency. With the application of nitrogen fertilizers at a rate of N140, regardless of the mowing regime, the proportion of alfalfa decreased during the period from the first to the third year of utilization to 9–13%, or by 22–27%.

Red clover (*Trifolium pratense* L.) and white clover (*Trifolium repens* L.) remained stable in the agrophytocenoses under both utilization regimes only during the first two years at a level of 36–53% in the treatment without fertilization. In these years, the proportion of red clover was 4–8% higher under the two-cut regime, while that of white clover was higher under the four-cut regime. In the third year, even in the treatment without fertilizers, the proportion of both species sharply decreased to 9–11%, which is explained by their biological characteristics and relatively short life span. With the application of nitrogen fertilizers at a rate of N140, the persistence of both clover species in the agrophytocenoses sharply decreased. Already in the first year of utilization, their proportion decreased to 34–39%, in the second year to 16–28%, and in the third year to 6–9%.

Ukrainian bird's-foot trefoil (*Lotus ucrainicus* Klok.) remained relatively stable in the agrophytocenoses over three years of utilization under different fertilization systems and utilization regimes. Its proportion over the years (from the first to the third year) did not change in the treatment without fertilizers, whereas with the application of nitrogen fertilizers at a rate of N140 it decreased only by 4–11%. This decrease was somewhat greater under the four-cut regime than under the two-cut regime.

The results of the study on the floristic richness of non-sown species in different types of meadow phytocenoses restored by various methods in the third year of utilization are presented in Table 2. Their analysis showed that in the phytocenosis of fallow 1 with spontaneous overgrowth, in the treatment without fertilizers in the ninth year of utilization and the third year of our research, 37 wild species of meadow plants were recorded under different mowing regimes. Among them, grasses accounted for 11 species, legumes for 3 species, and forbs for 25 species. In this fallow, both under the two-cut and four-cut regimes, the most widespread grasses with a share from 2 to 26% were wood small-reed (*Calamagrostis epigeios* L.), orchard grass (*Dactylis glomerata* L.), eastern fescue (*Festuca orientalis* Hack.), red fescue (*Festuca rubra* L.), couch grass (*Elytrigia repens* (L.) Nevski), and Kentucky bluegrass (*Poa pratensis* L.), while among the forbs the most common were shepherd's purse (*Capsella bursa-pastoris* (L.) Medik.), Canadian fleabane (*Erigeron canadensis* L.), common dandelion (*Taraxacum officinale* Webb. ex Wigg.), scentless chamomile (*Matricaria perforata* Merat), field horsetail (*Equisetum arvense* L.), and mouse-ear hawkweed (*Hieracium pilosella* L.). The proportion of other wild species, mainly belonging to the group of annual and biennial plants (lamb's quarters (*Chenopodium album* L.), wild carrot (*Daucus carota* L.), scentless chamomile (*Matricaria perforata* Merat), common chickweed (*Stellaria media* (L.) Vill.), small mallow (*Malva pusilla* Smith), corn cockle (*Agrostemma githago* L.), field pansy (*Viola arvensis* Murr.), round-leaved chickweed (*Cerastium rotundatum* Schur), annual fleabane (*Stenactis annua* Nees), etc.) was considerably lower. On fallow 1, the dominant species in the phytocenosis was wood small-reed with a share of 26%.

On the improved fallow 2, 45 species were recorded, including 14 grass species, 4 legume species, and 27 forb species. In addition to the species present on fallow 1, the sward also included *Festuca valesiaca* Gaud., *Agrostis tenuis* Sibth., *Apera spica-venti* L., *Poa angustifolia* L., *Vicia cracca* L., *Achillea submillefolium* Klok. et Krytzka, and *Galium mollugo* L., with a total share of about 20–25%, which appeared as a result of overseeding seeds collected from virgin land. On fallow 2, along with wood small-reed with a share of 17%, the codominants were the overseeded species collected from virgin land, *Festuca valesiaca* and *Poa angustifolia*, each with a share of 8–10%.

In phytocenoses formed by overseeding mixtures of cultivated grass and legume species into an old-sown grass sward, the number of wild species in the third year of utilization ranged from 18 to 39 species. Among them, grasses accounted for 8–10 species, legumes for 0–3 species, and forbs for 11–28 species. The largest number of wild grass species occurred in legume–grass swards with the participation of red or white clover, where these species had significantly thinned by the third year and their place was occupied by representatives of wild plant species. In general, however, the share of each wild species in the swards formed by overseeding cultivated perennial grasses was low, and therefore they did not play a significant role in the formation of biomass yield. The exception was wild orchard grass (*Dactylis glomerata* L.) and red fescue (*Festuca rubra* L.), whose share in different treatments was 6–11% and 2–7%, respectively.

Analysis of the distribution of the species composition of non-sown components of meadow swards by life span showed that perennials predominated in all experimental treatments, with the number of species ranging from 19 to 33 and their share in the total yield biomass from 10 to 93% (Table 3). A greater number of perennial species occurred on fallow 2, as well as generally 1–5 more species under the two-cut regime than under the four-cut regime. In all experimental treatments, the smallest number of species belonged to the group of annuals (1–4 species). Among the swards formed from cultivated grass species, in the third year the largest number of annuals appeared in clover–grass swards due to the significant thinning of the legume components. However, it should be noted that even in the third year the share of non-sown species in the total biomass yield of swards formed from cultivated grasses, unlike fallows, did not exceed 43%. The

Table 2. Proportion of non-sown grass species in different types of meadow agrophytocenoses under different utilization regimes in the third year and under the no-fertilizer background, 2023, % of total yield biomass

Species	Fallow 1		Fallow 2		Sown grass		Alfalfa–grass		Red clover–grass		White clover–grass		Bird's-foot trefoil–grass	
	Cuts													
	2	4	2	4	2	4	2	4	2	4	2	4	2	4
Grasses (*Poaceae*)														
Bromus hordeaceus L.	9	11	10	10	4	8	4	7	+	7	+	6	+	4
Dactylis glomerata L.	6	3	6	3	11	2	6	2	9	4	10	2	9	+
Festuka valesiaca Gaud.*	-	-	8	10	+	-	+	-	+	-	+	-	+	-
Festuca pratensis Huds.	+	+	+	+	-	-	-	-	-	-	-	-	-	-
Festuca orientalis Hack.	7	7	5	6	7	5	+	-	+	+	+	+	+	+
Festuca rubra L.	4	11	5	11	2	8	2	5	6	6	7	5	4	5
Calamagrostis epigeios L.	26	19	17	11	4	+	+	+	+	+	+	+	-	-
Agrostis tenuis Sibth.*	+	+	3	3	-	-	-	+	-	-	-	-	-	-
Apera spica-venti L.*	-	-	+	+	-	-	-	-	-	-	-	-	-	-
Elytrigia repens (L.) Nevski	3	4	1	3	+	+	+	+	+	+	+	+	+	+
Echinochloa crusgalli L.	-	-	+	-	-	-	-	-	-	-	+	+	-	-
Bromopsis inermis Leyss.	+	-	+	+	-	-	-	-	-	-	-	-	-	-
*Poa angustifolia L.**	+	+	10	12	+	+	+	+	+	+	+	+	+	+
Poa pratensis L.	6	9	7	7	+	4	+	+	+	+	+	+	+	+
Total grasses, %	**61**	**64**	**72**	**76**	**28**	**27**	**12**	**14**	**15**	**17**	**17**	**13**	**13**	**9**
Total grasses, number of species	**11**	**10**	**14**	**13**	**9**	**8**	**9**	**8**	**9**	**8**	**10**	**9**	**8**	**7**
Legumes (*Fabaceae*)														
Vicia cracca L.*	-	-	1	+	-	-	-	-	+	-	+	+	-	-
Trifolium pratense L.	+	-	+	-	-	-	-	-	-	-	-	-	-	-
Trifolium repens L.	-	+	+	+	-	-	-	-	-	-	-	-	-	-
Medicago saniva L.	+	-	-	-	-	-	-	-	+	-	-	-	-	-
Lotus ucrainicus Klok.	4	3	5	5	-	-	+	-	+	-	+	+	-	-
Total legumes, %	**4**	**3**	**6**	**5**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Total legumes, number of species	**3**	**2**	**4**	**3**	**0**	**0**	**1**	**0**	**3**	**0**	**2**	**2**	**0**	**0**
Forbs														
Convolvulus arvensis L.	+	+	+	-	+	-	+	-	+	-	+	+	+	-
Hyoscyamus albus L.	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Capsella bursa-pastoris (L.) Medik.	6	5	2	3	-	+	-	-	+	-	+	+	-	-
Achillea submillefolium Klok. et Krytzka*	+	+	6	6	3	2	+	+	1	+	1	+	1	+
Senecio vulgaris L.	+	+	+	+	+	-	-	-	-	-	-	+	+	-
Senecio jacobaea L.	+	+	+	+	+	+	+	-	+	-	+	+	+	-
Stellaria media (L.) Vill.	1	+	+	+	-	-	-	-	+	-	+	+	-	-
Erigeron canadensis	1	3	+	+	-	+	+	+	+	+	+	+	+	+
Malva pusilla Smith	-	+	+	-	-	-	-	-	-	+	+	+	-	-
Tragopogon pratensis L.	1	1	2	+	1	+	+	-	1	+	2	+	+	-
Agrostemma githago L.	-	-	-	-	-	-	-	-	-	-	-	+	-	-

Table 2. Cont. Proportion of non-sown grass species in different types of meadow agrophytocenoses under different utilization regimes in the third year and under the no-fertilizer background, 2023, % of total yield biomass

Melandrium album (Mill.) Garcke	-	-	+	-	-	-	-	-	-	-	-	+	-	-
Taraxacum officinale Webb. esWigg.	11	10	3	3	3	2	2	1	3	3	3	1	1	2
Lactuca serriola Torner	+	+	+	-	-	-	-	-	-	-	-	+	-	-
Chenopodium album L.	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Linaria vulgaris Mill.	+	+	+	+	+	+	+	-	+	+	+	+	+	-
Euphorbia virgultosa Klok.	+	-	+	-	+	-	-	-	+	+	+	+	-	-
Daukus carota L.	+	+	+	+	-	-	+	-	-	+	+	+	+	-
Hieracium pilosella L.	4	6	3	2	3	2	+	2	+	2	+	2	+	1
Cirsium arvense (L.) Scop.	-	+	-	+	-	+	-	+	+	+	-	+	-	+
Potentila argentea L.	2	4	1	3	1	1	1	-	2	-	1	-	1	-
Galium mollugo L.*	-	-	+	+	+	-	-	-	-	-	+	-	-	-
Plantago lanceolata L.	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Artemsia absinthium L.	+	1	+	+	+	+	+	+	+	+	+	+	+	+
Artemsia vulgaris L.	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Gerastium rotundatum Schur	-	+	-	+	-	-	-	-	-	+	-	+	-	-
Matricaria perforate Merat	1	1	+	+	-	-	-	-	+	+	1	+	-	-
Echium vulgare L.	+	-	-	-	-	-	-	-	-	-	+	-	-	-
Viscaria vulgaris (Moench) Garcke	2	1	1	1	+	+	-	+	-	+	-	+	-	+
Stenactis annus Nees	5	+	3	+	3	+	+	+	+	+	+	+	+	+
Viola arvensis Murr.	-	+	-	-	-	-	-	-	-	+	-	+	-	-
Equisetum arvense L.	1	1	1	1	1	1	1	+	2	+	1	+	+	+
Rumex acetosella L.	-	-	+	+	-	-	-	-	-	-	-	-	-	-
Rumex confertus Willd	-	-	+	+	-	-	-	-	-	+	-	-	-	-
Forbs, %	**35**	**33**	**22**	**19**	**15**	**8**	**4**	**3**	**9**	**5**	**9**	**3**	**3**	**3**
Total forbs, number of species	**23**	**25**	**27**	**24**	**17**	**16**	**15**	**11**	**19**	**20**	**21**	**28**	**16**	**11**
Total wild species, %	**100**	**100**	**100**	**100**	**43**	**35**	**16**	**17**	**24**	**22**	**26**	**16**	**16**	**12**
Total wild species, number of species	37	37	45	40	26	24	25	19	31	28	33	39	24	18
Total sown grass species, %	-	-	-	-	57	65	42	49	65	63	63	68	43	40
Total sown legume species, %	-	-	-	-	-	-	42	34	11	15	11	16	41	48
Total sown species, %	**-**	**-**	**-**	**-**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Note: * – grass species whose seeds were collected from a reference virgin site and overseeded on fallow 2. – species absent; + – species occurring singly.

most resistant to the invasion of non-sown species were the bird's-foot trefoil–grass phytocenosis under both utilization regimes and the alfalfa–grass phytocenosis under the two-cut regime. The distribution of components by plant families in different types of meadow swards formed by various restoration methods under different mowing regimes is presented in Table 4.

The analysis of the results showed that, across the different experimental treatments, 53 wild species of meadow plants belonging to 19 families participated in the formation of the agrophytocenoses. Species contributing to the formation of meadow sward biomass belonged to the following families: grasses (*Poaceae*), asters (*Asteraceae*), legumes (*Fabaceae*), pinks (*Caryophyllaceae*), knotweeds

Table 3. Distribution of the species composition of non-sown components of meadow swards by life span under different utilization regimes on the no-fertilizer background, 2023

Sward type	Number of cuts	Number of species, units			Share in total yield biomass, %		
		0	Θ	Y	0	Θ	Y
Fallow 1	2	2	8	27	6	17	77
	4	4	8	25	5	11	84
Fallow 2	2	4	8	33	2	10	88
	4	3	6	31	3	4	93
Sown grass	2	1	2	23	-	7	36
	4	1	3	20	-	6	29
Alfalfa–grass	2	1	3	21	-	4	12
	4	1	3	20	-	6	29
Red clover–grass	2	2	4	25	-	-	24
	4	3	5	20	-	4	18
White clover–grass	2	4	6	24	-	1	25
	4	4	9	23	-	6	10
Bird's-foot trefoil–grass	2	2	3	19	-	-	16
	4	2	3	19	-	-	16

Note: 0 – annuals; Θ – biennials; Y – perennials.

Table 4. Distribution of wild species in different types of swards by plant families under different utilization regimes in the third year and under the no-fertilizer background, 2023, number of species

Families	Fallow 1		Fallow 2		Sown grass		Alfalfa–grass		Red clover–grass		White clover–grass		Bird's-foot trefoil–grass	
	Number of cuts													
	2	4	2	4	2	4	2	4	2	4	2	4	2	4
Poaceae	11	10	14	13	9	8	9	8	9	8	10	9	8	7
Fabaceae	3	2	4	5	0	0	1	0	3	0	2	2	0	0
Asteraceae	12	13	12	12	9	10	9	8	11	10	10	13	10	8
Apiaceae	1	1	1	1	0	0	1	0	0	1	1	1	1	0
Caryophyllaceae	2	3	3	3	1	1	0	1	1	2	1	5	0	1
Chenopodiacea	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polygonaceae	0	0	2	2	0	0	0	0	0	1	0	0	0	0
Brassicaceae (Cruciferae)	1	1	1	1	0	1	0	0	1	0	1	1	0	0
Malvaceae	0	1	1	0	0	0	0	0	0	1	1	1	0	0
Euphorbiaceae	1	0	1	0	1	0	0	0	1	1	1	1	0	0
Solanaceae	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Scrophulariaceae	1	1	1	1	1	1	1	0	1	1	1	1	1	0
Plantaginaceae	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Rosaceae	1	1	1	1	1	1	1	0	1	0	1	0	1	0
Convolvulaceae	1	1	1	0	1	0	1	0	1	0	1	1	1	0
Boraginaceae	1	0	0	0	0	0	0	0	0	0	1	0	0	0
Rubiaceae	0	0	1	1	1	0	0	0	0	0	1	0	0	0
Violaceae	0	1	0	0	0	0	0	0	0	1	0	1	0	0
Equisetaceae	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total families, number of families	13	13	15	12	10	8	9	5	11	11	15	14	8	5

(*Polygonaceae*), umbels (*Apiaceae*), figworts (*Scrophulariaceae*), plantains (*Plantaginaceae*), roses (*Rosaceae*), horsetails (*Equisetaceae*), mustards (*Brassicaceae* (*Cruciferae*)), and others. The largest number of species across the different experimental treatments belonged to the families *Poaceae* and *Asteraceae* (7–14 species each). Five species each belonged to the families *Fabaceae* and *Caryophyllaceae*. The remaining families were represented by a single species. The greatest number of families (11–15) in the third year was recorded on both fallows and in the clover–grass swards, whereas the smallest number occurred in the alfalfa–grass and bird's-foot trefoil–grass swards. In most cases, 1–5 more families were represented under the two-cut regime than under the four-cut regime.

CONCLUSIONS

The study presents the specific features of the formation of different types of meadow swards with restoration of species composition and their distribution by family composition and life span under different methods of meadow restoration on arable lands (formation of fallows through spontaneous natural overgrowth and the combination of spontaneous overgrowth with overseeding of seeds of wild grass species collected from virgin land, as well as through overseeding with grass and legume–grass mixtures of cultivated perennial grasses), fertilization systems, and utilization regimes on gray forest arable soils of the Right-Bank Forest-Steppe of Ukraine.

In the ninth year of utilization, phytocenoses dominated by perennial non-sown (wild) grasses with a share of 59–82% are formed on fallows, with the highest proportion of wood small-reed (*Calamagrostis epigeios* L.) (13–28%). The proportion of forbs ranged from 18 to 38%. On fallow under spontaneous overgrowth, phytocenoses involving up to 37 species of herbaceous plants are formed under different restoration methods, fertilization, and utilization regimes, whereas on improved fallow with overseeding of seeds of wild grasses from virgin land up to 45 species occur. In the phytocenosis of improved fallow with overseeding of wild grasses from virgin land, additional overseeded wild species are also present, in particular *Festuca valesiaca* Gaud., *Agrostis tenuis* Sibth., *Poa angustifolia* L., *Vicia cracca* L., *Achillea submillefolium* Klok. et Krytzka, and occasionally *Galium mollugo* L. and *Apera spica-venti* L., the seeds of which were collected from virgin land. The occurrence of these species indicates the establishment of a more diverse species composition characteristic of meadow phytocenoses in the study region. The application of N_{140} increases the proportion of grasses by 10–14%.

During the formation of grass and legume–grass swards through overseeding with cultivated grass species, the total number of wild species, compared with fallows, decreases to 21–31 species. When perennial grasses and legumes are overseeded into a degraded old-sown grass sward, cenoses dominated by overseeded cultivated grass species valuable for forage are formed already within the first three years of utilization. When a grass mixture of smooth brome (*Bromopsis inermis* (Leyss.) Holub) and meadow fescue (*Festuca pratensis* Huds.) is overseeded, a smooth brome-dominated community is formed by the third year. When legume–grass mixtures are overseeded, phytocenoses are formed in which legume components act as codominants alongside the sown grasses. Alfalfa (*Medicago sativa* L.) and Ukrainian bird's-foot trefoil (*Lotus ucrainicus* Klok.) remain well preserved in the swards with a share of 33–50% during the first three years of utilization. Red clover (*Trifolium pratense* L.) and white clover (*Trifolium repens* L.) persist well in the phytocenoses only during the first two years of utilization with a share of 36–53%, whereas in the third year their proportion decreases to 5–7%.

Under different methods of meadow restoration, phytocenoses are formed in which perennial species predominate among the non-sown (wild) plants, ranging from 19 to 33 species and accounting for 10–93% of the total yield biomass. The number of annual species does not exceed four and that of biennial species does not exceed nine, while their share in the total yield biomass does not exceed 9% and 17%, respectively. Both in terms of species number and their share in the total yield biomass, the highest proportion of perennials is preserved in the phytocenosis of the fallow formed through the combination of spontaneous natural overgrowth and overseeding of seeds of wild grass species collected from virgin land. Among swards formed from cultivated grass species, in the third year the largest proportion of non-sown annual species (up to 43%) appears in legume–grass phytocenoses with the participation of red clover (*Trifolium pratense* L.) or white clover (*Trifolium repens* L.) due to the significant thinning of these legume components. The most resistant to the invasion of non-sown species are the bird's-foot trefoil–grass phytocenosis under both utilization regimes and the alfalfa–grass phytocenosis under the two-cut utilization regime.

A total of 53 wild species of meadow plants belonging to 19 families participate in the formation of all phytocenoses: grasses (*Poaceae*), asters (*Asteraceae*), legumes (*Fabaceae*), pinks (*Caryophyllaceae*), knotweeds (*Polygonaceae*), umbels (*Apiaceae*), figworts (*Scrophulariaceae*), plantains (*Plantaginaceae*), roses (*Rosaceae*), horsetails (*Equisetaceae*), mustards (*Brassicaceae* (*Cruciferae*)), and others. The largest number of species across the experimental treatments belonged to the families *Poaceae* and *Asteraceae* (7–14 species each). Five species each were recorded for the families *Fabaceae* and *Caryophyllaceae*, while the remaining families were represented by a single species. The highest number of families (11–15) in the third year was recorded in the phytocenoses of fallows and in clover–grass swards, whereas the lowest number (5–9 families) occurred in alfalfa–grass and bird's-foot trefoil–grass swards. In most cases, 1–5 more families were represented under the two-cut regime than under the four-cut utilization regime.

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